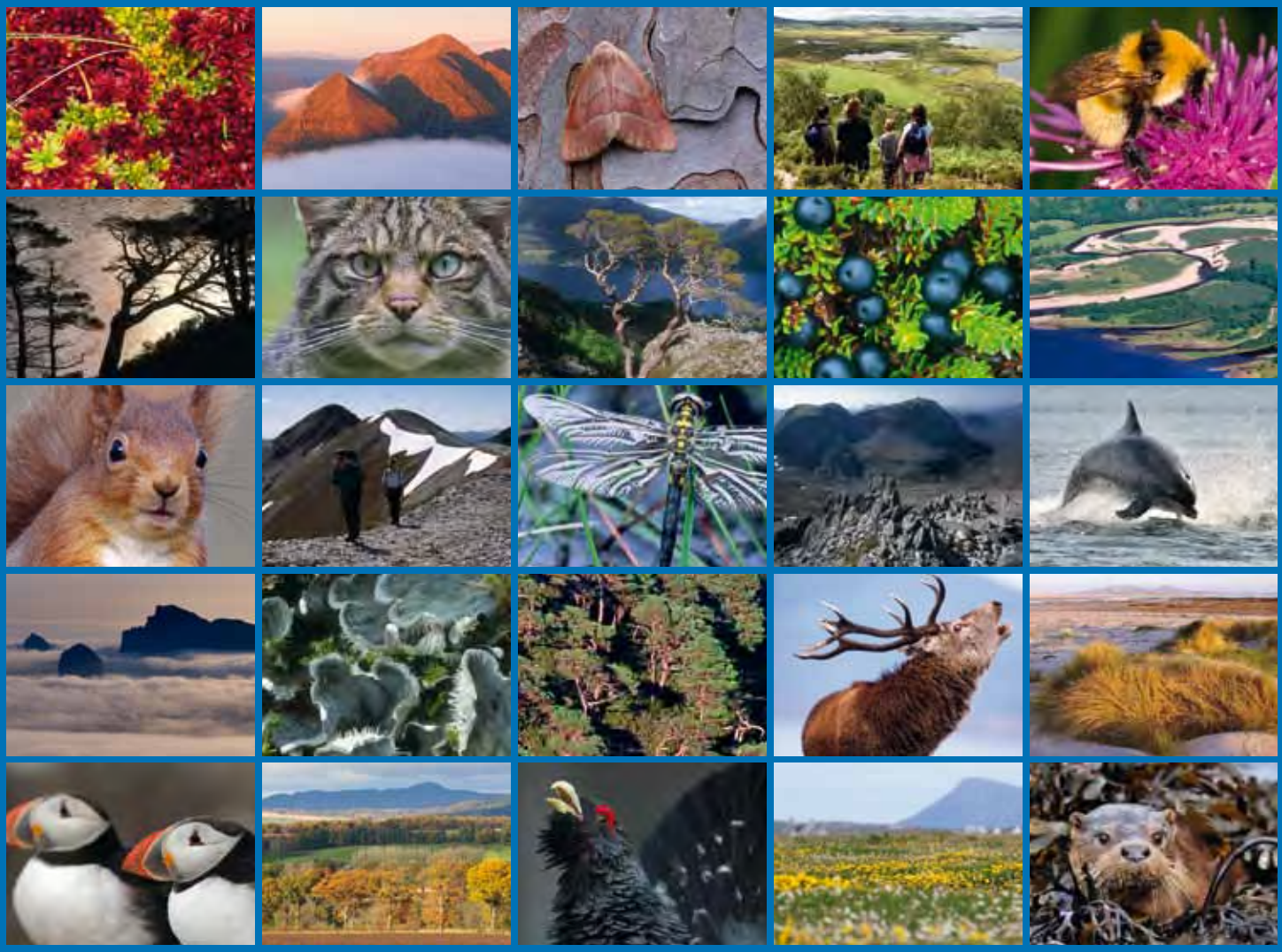
Scottish Natural Heritage
Commissioned Report No. 488

An assesment of the impacts of climate change on Scottish landscapes and their contribution to quality of life: Final report



Scottish Natural Heritage
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COMMISSIONED REPORT

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An assessment of the impacts of climate change on Scottish landscapes and their contribution to quality of life: Final report

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Preface

Note on the status of this report

This report supersedes the Phase 1 Interim Report. It updates the findings of the Interim Report to take account of the UKCP09 climate change projections. The symbol 09 has been used to indicate where the Interim Report findings have been modified to reflect the UKCP09 projections. Sections 2 and 3, and Appendix 11 of this report provide a detailed analysis of the implications of the UKCP09 projections for the study findings. These find that under UKCP09 and for Scotland, one variable – winter precipitation – is likely to be significantly different in terms of scale and spatial distribution, when compared to the relevant UKCIP02 projections.

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BACKGROUND

Climate change will have implications for Scottish landscapes and the social, economic and environmental benefits they provide. Bringing together current research on the effects of climate change across a range of sectors, including forestry, agriculture, ecology and the built environment, this study explores how these changes could interact and alter Scottish landscapes and townscapes, and their benefits to people. This study represents Phase 1 of a two stage research process. The second stage will explore ways of communicating the key messages, thereby influencing climate change policy and practice so that it takes account of landscape and quality of life concerns.

MAIN FINDINGS

- There is uncertainty associated with climate change information, and the potential landscape impacts, and therefore the research has focused on potential scenarios and overall directions of change rather than predictions.
- Landscape change will result from the direct impacts of a changing climate as well as from indirect impacts of human attempts to slow climate change (mitigation) and the way that we respond to a changing climate (adaptation). Overall, mitigation and adaptation measures are likely to have a more significant influence on landscape character than the direct effects of climate change, i.e. analysis of UKCP09 probabilistic projections suggests that changes associated with temperature are, all other things being equal, more likely to occur thanthose associated with rainfall.
- The combined influence of these direct, mitigation and adaptation effects are likely to be greatest in lowland and coastal landscapes reflecting the dominance of land management, settlement and land use in shaping landscape character, and the likely impacts of changing sea levels. In the uplands landform is a more dominant factor. Here, with the exception of developments such as windfarms and related infrastructure, change may be gradual and subtle.
- Using the framework of ecosystem services at a local level, the study revealed a mixed pattern of effects on quality of life, broadly reflecting the pattern of landscape change, although cultural heritage values were affected across the local study area.

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GLOSSARY

Adaptation	The Intergovernmental Panel on Climate Change (IPCC) defines climate change adaptation as "*adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.*"[1].
	Adaptation can be planned or unplanned.
Confidence	The degree of certainty that a given climate or landscape change may occur.
Designated sites	Sites protected by local or national designation as defined by local or national policy.
Historic Designed Landscape	Grounds in which, either singly or in combination, flowers, fruits, vegetables, trees and shrubs are consciously laid out for artistic effect, to create a beautiful prospect, or for public resort.
Direct impact	The direct results of changes in climate, e.g. tree death as a result of drought stress, migration of species in relation to a warmer climate, erosion resulting from sea-level rise.
Ecosystem services	The benefits that people obtain from ecosystems. These include provisioning, regulating and cultural services that directly affect people and the supporting services provided by the environment to maintain other services.
Green and blue infrastructure	Includes open spaces for outdoor recreation and aspects of the marine and water environment.
Historic Land Use Assessment (HLA)	HLA is a GIS-based mapping project that shows the historic origin of land-use patterns, describing them by period, form and function. The HLA has identified some 55 individual historic land-use types, which can be grouped under 14 thematic headings (or categories) to simplify the data. It also depicts relict land-use, including relict archaeological landscapes greater than 1 hectare in area.[2]
Isostatic rebound	The rebound of the earth's surface following the release of a heavy load such as the melting of the glaciers following the last ice age.
Landscape character	The pattern that arises from the way that different components of the environment including natural (the influences of geology, soils, climate, flora and fauna) and cultural (the historical and current impact of land

[1] IPCC Fourth Assessment Report, see http://www.ipcc.ch/ipccreports/ar4-syr.htm
[2] www.historic-scotland.gov.uk

	use, settlement, enclosure and other human interventions) aspects and how they interact together and are perceived.[3]
Landscape character area	Unique areas that are the discrete geographical areas of a particular landscape type (see landscape character type definition below).
Landscape character assessment	The characterisation of landscapes involving identifying, mapping, classifying and describing landscape character, and the process of making judgements based on landscape character to inform a range of different decisions.[4]
Landscape character type	These are distinct types of landscape that are relatively homogeneous in character. They are generic in nature in that they may occur in different areas in different parts of the country, but wherever they occur they share broadly similar combinations of geology, topography, drainage patterns, vegetation and historical land use and settlement pattern.
Miscanthus	A perennial grass originating from south east Asia and grown as a biomass crop in the UK, reaching typical heights of 4m.
Mitigation	An human intervention to reduce the sources or enhance the sinks of greenhouse gases.[4]
Muirburn	The controlled burning of moorland is a traditional management tool used to help regenerate heather, and in turn benefit livestock and wildlife.
Natural Heritage Futures	The SNH Natural Heritage Futures initiative promotes integrated management of the natural heritage and is based on three main outputs. National documents consider the natural heritage across 6 themes. Local documents consider the natural heritage in 21 areas each of which has its own distinctive identity resulting from the interaction of geology, landforms, landscapes, wildlife and land use. These are underpinned by the supporting reference documents - National Assessments - which provide data and information about the natural heritage, presented both at the national level and within each of the 21 areas.
Natural Heritage Zones	21 areas covering Scotland defined by SNH as part of the Natural Heritage Futures programme which represent areas with similar natural heritage characteristics which contribute a distinctive identity resulting from the interaction of geology, landforms,

[3] The Countryside Agency Scottish Natural Heritage (2002) Landscape Character Assessment: Guidance for England and Scotland
[4] IPCC (2001) Climate Change 2001: Synthesis Report Annexes

	landscapes, wildlife and land use.
Peri-urban	Areas of land in close proximity to urban areas.
Pluvial flooding	Flooding resulting directly from overland flow of rainfall before the water enters drainage systems.
Quality of life	There is no one definition, but it is taken here to mean the degree of satisfaction of the physical needs of the residents of an area (e.g. food and health), together with enriching cultural, environmental and intellectual stimuli.
Regional character area	Areas recognisable as distinct landscape regions at a broad scale, based upon general characteristics such as landform, geology, soils, land use, ecological associations, historical associations and urban and industrial activity.
Socio-economic scenarios	UKCIP has recognised the importance of uncertainties about the adaptation and mitigation responses of humans, particularly over the medium to longer terms, and has developed four alternative socio-economic scenarios to illustrate the different directions in which society might develop.
Short rotation coppice	An energy crop which usually consists of densely planted, high-yielding varieties of poplar or willow, harvested on a 3-5 year rotation.
Surge risk	Coastal flood risk during a storm surge event which occurs when low pressure and high winds raise the water level above mean levels.
Sustainable Urban Drainage Systems (SUDS)	Sustainable Urban Drainage Systems are a sequence of water management practices and facilities designed to drain surface water in a manner that will provide a more sustainable approach than the practice of routing run-off through a pipe to a watercourse, controlling water retention in the system and reducing flood risk.
UKCIP02	The United Kingdom Climate Impacts Programme 2002 (UKCIP02) climate change scenarios provide four alternative descriptions of how the climate of the UK might evolve over the course of this century. The alternatives result from uncertainty about future trends and behaviour and how these might influence future global emissions of greenhouse gases. To address this emissions uncertainty, the UKCIP02 scenarios describe future climate change under four alternative futures, ranging from rapid economic growth with intensive use of fossil fuels (High Emissions) to increased economic, social and environmental sustainability with cleaner energy technologies (Low Emissions). Each of the four UKCIP02 scenarios, changes are described for three

	future thirty-year time-slices: 2011 to 2040 (the 2020s), 2041 to 2070 (the 2050s) and 2071 to 2100 (the 2080s). All changes in climate are given relative to the baseline period of 1961 to 1990. The information is displayed on a grid of 50km squares which cover the whole of the UK.
UKCP09	More up to date and detailed projections than UKCIP02. See http://ukcp09.defra.gov.uk/.
Urban heat island effect	The increased temperature of urban air compared to its rural surroundings, caused by the storage of solar energy in the urban fabric during the day and release of this energy into the atmosphere at night.
Wave fetch	The distance over which wind blows from a constant direction, which has a direct influence on wave height.
Wild land	Uninhabited and often relatively inaccessible countryside where the influence of human activity on the character and quality of the environment is, or appears to be, minimal.

ABBREVIATIONS

Abbreviation	Explanation
CLIO	Climate Impacts and Options
CMP	Catchment Management Plan
CP	Coastal Processes and Climate Change Predictions in the Coastal Study Areas
CRU Scoping	Climate change: Scottish Implications Scoping Study (1999)
FCS	Forestry Commission Scotland
FF	Farming Futures (topic pages)
IFS	Indicative Forestry Strategies
LCA	Landscape Character Assessment
LFA	Less Favoured Areas
NIWT	National Inventory of Woodlands and Trees
OS	Ordnance Survey
RBMP	River Basin Management Plans
RSPB	Royal Society for the Protection of Birds
SCAPE	Scottish Coastal Archaeology and the Problem of Erosion
SCCIP	Scottish Climate Change Impacts Partnership
SEERAD	Scottish Executive Environment and Rural Affairs Department
SEPA	Scottish Environment Protection Agency
SNH CC AP	SNH Climate Change Action Plan
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research
SRC	Short Rotation Coppice
SRDP	Scottish Rural Development Programme
SRNLS	Scottish Road Network Landslides Study
SUDS	Sustainable Urban Drainage Systems
TCPA	Town and Country Planning Association
TS	Transport Scotland
UDG	Urban Design Group

EXECUTIVE SUMMARY

E1.1 Climate change is widely accepted as one of the greatest challenges facing us over the coming decades. Changes will result from the direct impacts of changing temperatures, patterns of precipitation, weather events and sea level change. Changes will also result from human attempts to slow climate change by developing renewable energy or increasing the amount of carbon locked up in soils and vegetation, and the way that we adapt to the changing climate in planned and unplanned ways.

E1.2 Many of these changes have implications for Scottish landscapes. While the landscapes we see today are in part a product of a constantly changing climate, the speed and range of changes we are now experiencing, and are likely to experience in the future, are very different. These changes could alter the character of the landscape, the way in which it is perceived and enjoyed, and the way in which it contributes to our quality of life.

E1.3 A range of studies and strategies have considered climate change in Scotland, though most focus on specific land uses or sectors such as agriculture or transport. Until now, there has been no attempt to see how these changes could combine to affect the landscape. This study therefore draws this knowledge together to provide an initial analysis of how climate change could affect landscapes at national, regional and more local scales over the next 40 or 50 years.

E1.4 This objective must be set against the recognition that there are significant uncertainties about future patterns of climate change, the effects on natural systems and the way that society will respond in the form of mitigation and adaptation measures. The study does not include primary research but draws upon existing published material, much of which will have dealt with these uncertainties in different ways. Consequently, the landscape changes described in the report should be regarded as potential scenarios illustrating the possible type and direction of change. A further complication is the non-climate related changes which could in any case affect the landscape over the next 50 years. To help address this area of uncertainty, the research has used four socio-economic scenarios to test out the implications of different socio-economic and political pathways, focusing at the local level.

1.1.1 Key findings

E1.5 The research distinguishes between landscape changes that could result from climate change itself (direct effects) and from mitigation and adaptation measures.

E1.6 The most significant **direct changes** could include an increase in coastal flooding and erosion, including loss of low lying areas of land to the sea as a consequence of sea level rise, larger waves and storm surges. There is also likely to be an increase in river flooding, erosion and slope instability. Semi-natural habitats are likely to change as species' climate space moves north. This could have particular implications for heather moorland, peat bogs, native woodlands and montane plant communities. There are also likely to be direct effects on trees and forests more widely, resulting from changing patterns of rainfall, increases in storm damage and a potential increase in pests and disease. This could be most evident in agricultural areas, woodlands, designed landscapes and settlements. The pattern of snowfall and snow lie is also likely to change. In areas such as more vulnerable sections of coast, or in catchments where flooding or land stability are already issues, these occurrences could result in quite dramatic changes in landscape character. However, for the most part these changes will cause more gradual and subtle changes which may modify rather than transform landscape character.

E1.7 Measures designed to **mitigate climate change** are already influencing landscape change. The development of windfarms is introducing large modern structures into many upland landscapes. This trend is likely to continue alongside the upgrading and expansion of the national grid, and the growth of offshore wind energy, particularly along the east coast, Solway Firth, the coast of Argyll, Islay and Tiree. Other forms of renewable energy technologies are likely to include the cultivation and processing of biomass in the form of short rotation coppice and energy crops. There could also be development of tidal and marine based renewables, and the wider take up of small scale or micro-renewables such as solar panels on buildings. Some of these developments could have a significant effect on landscape character, particularly where several windfarms are located in a relatively small area, or where there is extensive cultivation of biomass crops.

E1.8 Climate change mitigation will also include measures designed to increase carbon storage. There is already an objective to increase the total area under woodland and forests, meaning that many parts of Scotland are likely to see an expansion of productive and native or semi-natural woodland. Depending on where such expansion takes place, and how new woodlands are designed, this could either reinforce or change existing landscape character. Other measures could include the restoration of natural upland habitats, for example by reversing drainage of peat bogs, where these contribute to carbon storage. These changes are likely to reinforce and restore landscape character.

E1.9 **Planned and unplanned adaptation** to climate change is also likely to result in a range of landscape changes. Planned adaptation is likely to include a range of responses to the increased risk of riparian and coastal flooding. Catchment wide measures could include the restoration of natural floodplains and the expansion of woodland to intercept rainfall and slow the speed of run-off. There may also be a requirement for engineered flood defences, particularly where settlements, historic properties, infrastructure or more productive farmland are at risk. Similar responses are likely along the coast, including estuaries and sea lochs. Some managed realignment schemes may result in the loss of land to the sea but the retention of valued coastal habitats and landscapes. Elsewhere, coastal flood defences may be strengthened resulting in the loss of inter-tidal landscapes. Other measures could include the upgrading of infrastructure to make it better able to deal with higher rainfall.

E1.10 Other planned adaptation responses are likely to include changes in the way that forests and woodlands are managed. Changing rainfall patterns, temperatures and storminess are likely to be reflected in the use of different tree species, restructuring to avoid higher and more exposed locations and, where opportunities exist, a move towards continuous cover forestry techniques in preference to clear fell. Timing of forestry activity may also change reflecting the impact of wetter winters. The need to help species adapt to climate change is already leading to the development of habitat networks, including new woodlands, and this could result in a noticeable increase in woodland cover, particularly in more intensively settled and farmed landscapes where there has been significant habitat loss in the past.

E1.11 Unplanned adaptation responses could result in significant landscape changes in some parts of Scotland. The agricultural sector is likely to respond to the opportunities presented by a warmer climate and to a growing competitive advantage over other areas where the impacts of climate change are more severe. Adaptation could take the form of the intensification of existing production in existing core areas, the introduction of different crops and expansion into currently more marginal areas where soil quality allows. This could result in trends such as field enlargement, the requirement for improved farm buildings and the need for on farm water storage and

irrigation. The need for shelter and shade could be reflected in the creation of shelter belts, while increased stress, allied to field enlargement could result in the loss of field boundary trees and hedges, together with features such as drystone dykes. Higher winter rainfall in some areas[1] could influence the timing of sowing and other operations and could result in a range of detailed measures to reduce the risk of soil erosion and damage.

E1.12 Finally, the changing climate is likely to have an impact on patterns of tourism and recreation, as people adapt to warmer and drier summers. Scotland could see an expansion in recreation activity, particularly in more accessible areas around settlements and in protected landscapes. Conversely, an increase in winter rainfall and reduction in snow lie could have an impact on winter recreation, reinforcing existing patterns of seasonality. These changes could result in pressure on accessible recreation facilities during the summer, with possible increases in erosion and fire risk, and pressure for tourism related development. There are also likely to be changes in people's outdoor experience reflecting the changing climate, increases in tourist numbers during the summer, and of course, the landscape and visual effects of all the other forms of climate related landscape change.

E1.13 All these changes could have an influence on the character of the landscape and, importantly, the ways in which it contributes to our quality of life. The research examines this contribution in terms of 'ecosystem services' using the following headings:

- inspiration and enrichment;
- health and wellbeing;
- aesthetic values;
- cultural heritage values;
- recreation and tourism.

E1.14 Although also relevant to national and regional levels, this part of the research looks at the local level where the landscape's contribution to quality of life, and the implications of climate change, can be more easily analysed and described.

1.1.2 National analysis

E1.15 The national analysis includes a spatial analysis of those features which may be affected by climate change. Key findings include:

- **Woodland and forests** could be affected by a number of changes. Native woodlands in areas such as Argyll and the Cairngorms could be colonised by other species and damaged by storms. However, the area of woodland is likely to expand in order to contribute to carbon sequestration and flood management strategies. These changes are likely to affect upland glens and, perhaps, some current agricultural areas. Productive forests are likely to experience changes in species composition, especially in the east where some existing species such as Sitka Spruce will be less viable, and management, with increased use of continuous cover cultivation and a move away from higher and more exposed

[1] The research has been reviewed to take account of the UKCP09 climate change projections which were published after the work was carried out. The symbol has been used to indicate where the original findings have been modified to reflect the new projections. Section 2 and Appendix 11 of the report provide a detailed analysis of the implications of UKCP09 projections for the study findings.

slopes. Within more agricultural landscapes there could be a change in the pattern of woodland, with an increase in the development of woodland networks and shelterbelts, but a possible loss of individual trees.

- **Freshwater systems**, including rivers, burns and lochs are likely to be affected by changes in patterns of rainfall and possible increases in the intensity of rainfall events. This is likely to result in changing patterns of erosion and deposition, alterations in river courses and more frequent flood events and land slides. Human responses to these changes may have even more profound implications on the landscape. River catchments are likely to see measures to slow the speed of run-off with woodland expansion and the restoration of natural floodplains and upland peatbogs evident in areas upstream of settlements and other areas vulnerable to flooding. In some cases responses will take the form of engineered flood defences to protect towns and villages. While some of the largest increases in winter precipitation are projected for the east and west coasts, the Hebrides and Northern Isles, these changes are likely to be most evident in settlements located on rivers with large catchments such as the Tay and the Tweed.

- Changing **sea levels** and the increased risk of storm surges are likely to result in an increased risk of flooding in low lying coastal and firth locations. The changes could be compounded by human responses either in the form of managed realignment or the upgrading of coastal defences. The analysis showed that areas most likely to experience these changes were the Firths of Forth and Tay, the Moray Firth, parts of the inner Firth of Clyde and the coast of Argyll, and the Solway Firth.

- Climate change could affect **settlements** in a range of ways. In addition to the potential requirement for upgraded riparian flood defences, there is likely to be a need for wider use of sustainable drainage systems and the development of habitat networks to help plant and animal species adapt to climate change and the effects of habitat fragmentation. Open space is likely to come under greater demand for recreation activity, while urban trees and other vegetation may suffer stress from summer drought and winter water logging. Building designs, materials and techniques may change to include energy efficiency measures, micro-renewables and features such as green roofs and walls. These effects are likely to be most pronounced in the south and eastern parts of the central belt.

- Warmer and drier summers are likely to result in an increase in **recreation and tourism activity**, particularly in more accessible areas around settlements and key transport corridors. This is likely to result in pressure for additional recreation and tourism infrastructure in these areas. In the winter, reductions in snowfall and an increase in rainfall could result in a decrease in recreation activity, and the further diversification of areas currently specialising in winter sports.

- **Infrastructure** is likely to be affected by changing patterns of energy production, including further development of renewable sources such as wind, tidal, wave and biomass energy. Transport infrastructure may be upgraded to cope with higher winter rainfall and, in specific locations, an increased risk of landslides and slope instability. Increasing demand for water elsewhere in the UK could result in the development of reservoirs and aqueducts in southern Scotland.

- The changing climate is also likely to affect **natural and semi-natural habitats**, though published information on the broad patterns of change is currently limited. Changing rainfall could have mixed effects on peat bogs. Where winter rainfall increases the rate of peat formation could accelerate, but there could also be an

elevated risk of bog-bursts and erosion. Summer drought could also have a negative impact on peat bogs. Heather moorlands may also change, partly in direct response to climate changes, and partly in response to the way they are managed.

- **Agriculture** could experience a range of changes, many of which would be influenced by wider economic forces. It is likely that Scotland will increase its competitive advantage over areas where the effects of climate change are more severe. Agriculture is likely to become more intensive in areas that are currently most productive - particularly along the east coast. In these areas there may be changes in crops, the need for new farm buildings, loss of traditional landscape features including field boundaries and trees, and more evident use of irrigation infrastructure and on-farm water storage. Elsewhere, it is possible that arable cultivation may expand into lowland pastoral areas, and into the more fertile lower parts of the Highland glens. Dairying, cattle and sheep could move into currently marginal areas. There is likely to be some trade-off between a re-invigorated agricultural sector and measures to increase woodland cover.

- All these changes will have implications for the wider **historic environment** which is evident within the landscape. Specific effects could include the deterioration of historic gardens and designed landscapes, the loss of veteran and landmark trees and the impact on the landscape setting of key historic sites. Mitigation and adaptation measures including the expansion of woodland and changing patterns of cultivation could also have implications for archaeology above and below the ground, as well as at the coast.

1.1.3 Regional analysis

E1.16 The regional analysis focuses on Tayside to explore how these changes could affect specific landscapes. The analysis concludes that, within the uplands, the most significant landscape changes would probably be associated with the further development of renewable energy projects, including windfarms and, at lower altitudes, biomass. Expansion of woodlands and changes in moorland management, together with the temporal effect of reduced snow lie would have a more extensive, though more gradual effect. In the lowlands, there could be more extensive changes, reflecting the need to adapt to rising sea levels and surge tides along the coast, and the likely changes and intensification of farming within some of Scotland's most productive agricultural areas. The latter could accelerate past trends of landscape change, but could be tempered by measures to create habitat networks and shelterbelts.

1.1.4 Local analysis

E1.17 The local analysis focuses on four locations within Tayside to explore and illustrate possible local landscape effects of climate change. Photomontages are used to show the kinds of changes that could take place, though these are necessarily speculative in terms of the combinations and scale of landscape change. They also do not illustrate non-visual, seasonal or very localised changes.

Killiecrankie

Figure 1: Illustration of possible climate related landscape changes at Killiecrankie

E1.18 In the area around **Killiecrankie** (within the Loch Tummel National Scenic Area) the most significant climate related landscape changes are likely to be associated with changes in the extent and types of woodland (expansion of native woodlands and the creation of habitat links through remaining areas of improved farmland) and the gradual retreat of heather moorlands as a result of grassland colonisation. More dramatic changes, most notably the development of windfarms, are considered unlikely to occur, reflecting the national importance of this upland landscape.

E1.19 These changes would have a relatively limited impact on the landscape's contribution to **quality of life**. The landscape would still be distinctive and inspirational even though the pattern of landcover and land use would have changed.

Strathmore

Figure 2: Illustration of possible climate related landscape changes in Strathmore

E1.20 Within the agricultural landscape of **Strathmore** the most significant climate related landscape changes are likely to be those associated with the intensification of agricultural activity in response to improved climatic conditions and the advantage the region would have over other agricultural areas. Changes could include the accelerated loss of the distinctive structure of field boundaries and field boundary trees, the introduction of new crops, the development of new agricultural buildings, and the wider use of irrigation equipment. The development of renewable energy, including medium or small scale windfarms, electricity infrastructure and, at a more local level, biomass production, processing and use, could also have an effect on the rural character of this landscape.

E1.21 These changes would have a negative effect on the landscape's contribution to **quality of life** by reducing the aesthetic and inspirational value of the landscape and weakening the currently distinctive sense of place. The historic character of the landscape would also be weakened.

Firth of Tay

Figure 3: Illustration of possible climate related landscape changes along the Firth of Tay

E1.22 Within the **Firth of Tay** the most significant climate related changes are likely to be those associated with responses to sea level rise and storm surges. The productive nature of farmland along the Firth means it is unlikely that the response to these changes would be rewilding in the form of managed realignment or the creation of coastal woodlands. Instead, it is likely that flood defences would be upgraded resulting in the loss of reedbeds, islands and mudflats. Improved growing conditions would be reflected in the continued intensification and specialisation of agriculture, evident in further losses of hedges and tree lines and the introduction of new crops. Built influences would include renewable energy schemes and upgraded electricity transmission lines. In winter, snow cover on distant hills would be less common.

E1.23 These changes would combine to change the landscape's contribution to **quality of life**. While better summer weather could increase this area's importance for recreation, it is likely that most of these changes would weaken the landscape's aesthetic value and undermine its historic character.

Perth

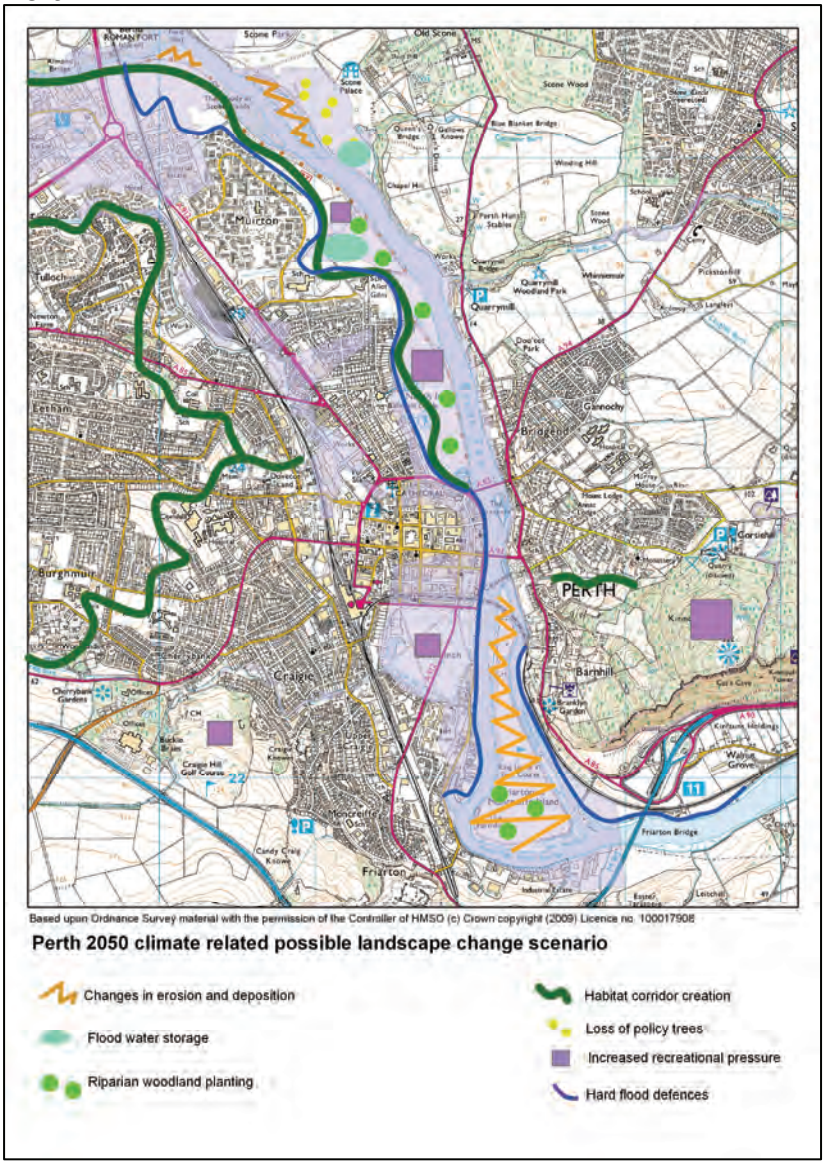


Figure 4: Perth 2050 Climate related landscape change

E1.24 Within the city of **Perth** the analysis highlights a range of potential climate related changes including changing use and management of greenspace, an upgrading of flood embankments and engineered flood defences through the city centre and along key transport infrastructure, and impacts on urban and parkland trees. It is likely that some of these changes could affect the distinctive character of the city centre, parks and river corridor. However, better summer weather in particular could encourage greater recreational use of green spaces in and around the settlement.

E1.25 It is likely that these changes would have a mixed effect on **quality of life**. Improved greenspace in and around Perth could bring recreational benefits, particularly during the drier summer months. However, any additional flood defence measures could have an impact on the city's historic character and sense of place. Wetter winters and drier, warmer summers could affect the health of urban trees, further undermining Perth's aesthetic values.

E1.26 The local analysis includes a review of four **socio-economic scenarios**, each of which reflects the influence of different political, economic and social values. These

suggest that the effect of differing policy frameworks on landscape character could be as profound as the direct effects of climate change. However, the greatest influence of the scenarios is in relation to their differing approaches to renewable energy development (large scale versus small scale wind energy, the development of biomass and tidal energy schemes). Secondary influences include the weight attached to designated areas, wider patterns of sustainable land use and management, and the scale and nature of recreation and tourism development. The Perth example highlights the likely influence of differing demands for housing, different strategies for accommodating growth, differing approaches to urban transport and, critically, different approaches to environmental quality, including the role of greenspaces.

Conclusions

E1.27 This research explores the potential for a wide range of climate related changes, each of which may affect different areas in different ways and over different timescales. Uncertainties associated with the climate change information and the way that natural and human systems will respond to these changes mean that the research has necessarily focused on potential scenarios of change rather than firm predictions.

E1.28 The research suggests that, overall, under the UKCIP02 and UKCP09 Climate Change Projections, human mitigation and adaptation measures may have a more significant influence on landscape character than the direct effects of climate change. This is an important finding, since there may be opportunities to influence the development and implementation of climate change mitigation and adaptation responses to ensure that landscape implications are taken fully into account. A review of four socio-economic scenarios confirmed that wider human influences (including policies on adaptation and mitigation) may be as important as the effects of climate change.

E1.29 The research also suggests that the combined influence of these direct, mitigation and adaptation impacts may be greatest in lowland and coastal landscapes reflecting the dominance of land management, settlement and land use in shaping landscape character and the likely impact of changing sea levels. This is in contrast to the uplands where landform is a more dominant factor and where, with the exception of developments such as windfarms and related infrastructure, change may be more gradual and subtle.

E1.30 All of this has implications for the way in which the landscape contributes to our quality of life. Using the framework of ecosystem services to consider the effects on inspiration and enrichment, health and well being, sense of place, cultural heritage values and recreation and tourism, reveals a mixed pattern of change which reflects the study's wider findings.

E 1.31 On the basis of the four detailed study areas described above, the research finds that ecosystem services may change the least in upland areas (particularly those falling within national designations such as National Scenic Areas and National Parks) and most in more intensively managed lowland areas. In part this reflects the dominant influence of the physical landform in contributing to inspirational, aesthetic and recreational values and in making upland areas less suited to agricultural intensification. Key interventions such as woodland expansion could be seen as being sympathetic to the underlying qualities of the landscape, subject to design considerations. In lowland areas, by contrast, changes including agricultural intensification, flood defence, renewable energy development and the implementation

of habitat networks (subject to design considerations) could combine to have a negative effect on inspirational and aesthetic values. Urban areas could be expected to see a mixture of positive effects on quality of life, largely as a result of enhancements in the quality and use of greenspaces, and negative impacts as a result of flood prevention measures and the adaptation of existing buildings to accommodate micro-renewables and cope with warmer summers and wetter winters.

E1.32 Perhaps reflecting the scale of possible changes associated with climate related landscape change, the work also finds that cultural heritage values were likely to be adversely affected in all four locations.

E1.33 Based on a limited number of local examples these findings suggest that while many upland landscapes in Tayside will continue to make a significant and positive contribution to quality of life in terms of inspirational, aesthetic, recreational and, to a lesser extent, cultural heritage values, the contribution of many lowland and urban landscapes will be reduced. For Scotland as a whole, this contrast may be most pronounced where upland areas benefit from protective designations, making major developments such as windfarms less likely. This suggests that careful management of protected landscapes should be accompanied by measures to maintain the contribution of undesignated landscapes and townscapes to quality of life.

1. INTRODUCTION

1.1. Land Use Consultants, in association with CAG Consultants, Sheffield University and the Environmental Change Institute at Oxford, have been commissioned by Scottish Natural Heritage to carry out the first stage of a study into the landscape implications of climate change in Scotland.

1.2. The aim of the study is as follows:

> *To develop a more detailed understanding of the predicted impacts of climate change on Scottish landscapes and their contribution to quality of life, taking account of natural processes, mitigation and adaptation responses.*

1.3. The first phase of the study (the subject of this research) develops and applies a methodology to determine the nature, scale, distribution, significance and likelihood of landscape change and what these mean for quality of life. Detailed consideration of implications for quality of life lay beyond the scope of this study so the project focused on developing a commentary based on the analysis of cultural ecosystem services (see paragraph 2.28) provided by the landscape in a series of four local case studies (see Section 5).

1.4. The second phase of the study will focus on raising awareness and engaging with stakeholders and communities to develop objectives and practical approaches to managing climate change impacts on the landscape and to influence decision making and practice in development planning and land-use management.

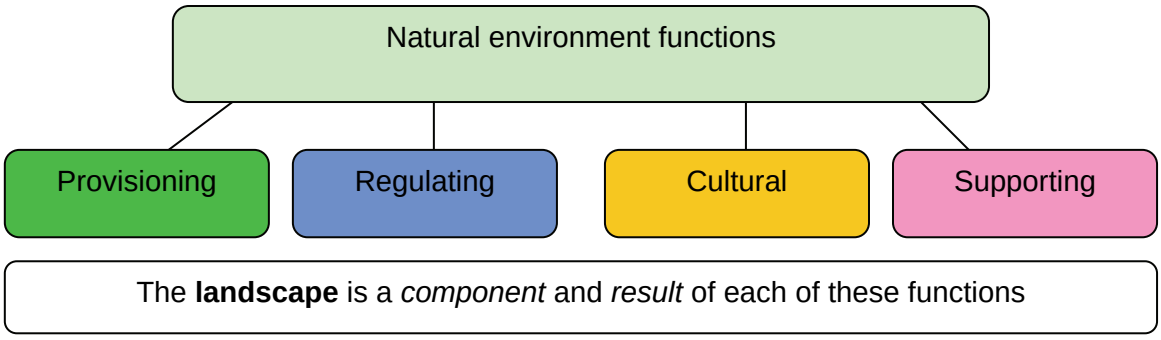
Purpose of the study

1.5. This study represents a starting point for the more detailed understanding and recognition of the landscape impacts of climate change and the role and value of landscapes within our everyday lives.

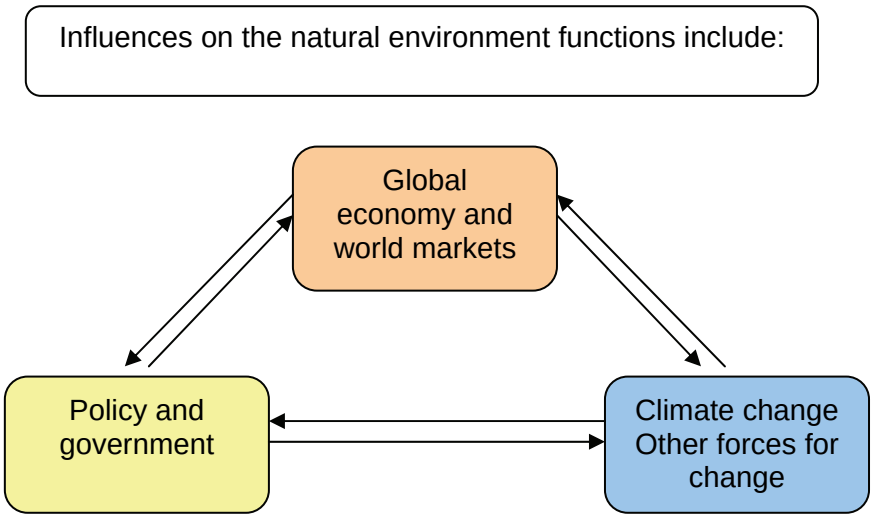
1.6. The following sections of the introduction provide a framework for the study, explaining the study scope and limitations.

Overview of study context

1.7. The following diagrams illustrate the framework for the study and the acknowledgement of the role of landscape within the wider environment. The natural environmental performs a range of functions, which can be defined under their role as ecosystem services (for further detail, see paragraph 2.28 and Appendix 1).



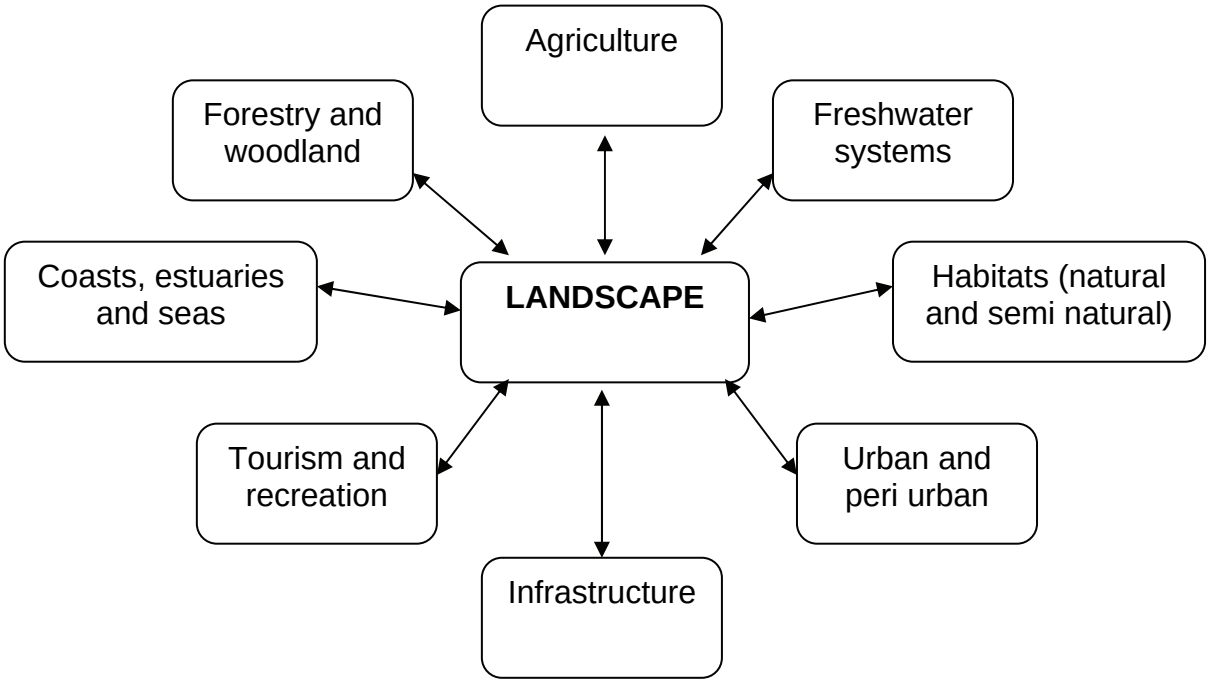
1.8. The role of the natural environment (and therefore the landscape) in fulfilling these functions is affected by a wide range of outside influences, of which climate change is one:



1.9. These influences interact with and affect each other and, as a result, the landscape we see. The study does not seek to address these wider influences, but acknowledges their role in shaping the future landscape. These are complex interactions and the study does not aim to define precisely or predict the landscape impacts resulting from climate change, but to explore a number of potential scenarios which may be influenced to varying degrees by global issues and policy and individual responses.

1.10. The impact of climate on the evolution of the landscape since the last ice age is inexorably linked to a range of processes from sea level rise, erosion, sediment transport and nutrient availability. This, alongside key variables such as temperature and precipitation, influences the natural vegetation growth, the nature of the habitats and species which they support and the patterns of settlement and land management. However, while past climate change and the subsequent landscape impacts of this have resulted from natural processes, the current climate changes are occurring as a result of human activities and progressing at a rapid rate. With knowledge of the likely future climate changes, we occupy a unique position which provides an opportunity to respond to these changes and manage their landscape impacts.

1.11. The following diagram illustrates the key topic areas within which landscape change has been explored through the study.



1.12. The study includes consideration of the relationship between the landscape and quality of life. This is explored through the concept of ecosystem services, i.e. what services does the landscape provide which contribute to quality of life, for four local case studies. The ecosystem services of relevance to this study have been identified as the following:

- inspiration and enrichment;
- health and wellbeing - physical and mental (links to regulating services, and includes human comfort such as urban temperatures);
- aesthetic values;
- sense of place;
- cultural heritage values;
- recreation and tourism.

1.13. The climate change impacts on the landscape and human responses to climate change are likely to alter the range of ecosystem services being delivered by the landscape.

Study scope and limitations

1.14. The Phase 1 Report does not seek to set objectives for landscape change, but to illustrate and raise awareness about the nature of such changes and the impacts that are most likely and most significant. From this it will be possible to identify the landscape changes which can be addressed, which will form a key focus of Phase 2 of the study.

1.15. Whilst aiming to provide a robust analysis of the likely landscape changes that will be associated with climate change, it is inevitable that the research has to deal with several layers of uncertainty.

1.16. The study is based largely on the interpretation and application of the UKCIP02 climate change scenarios. At the time of conducting the research, these were the most comprehensive and commonly used climate change scenarios for this type of project within the UK, and provided the most well informed projection of the changes that will affect the Scottish climate over the coming decades. It is possible that the magnitude, speed and distribution of these changes will differ from those currently being projected. Similarly, there are uncertainties about the way in which natural systems will respond to changes in rainfall, temperature, storminess and growing seasons. There is a further series of uncertainties associated with human responses to such change, in terms both of measures to mitigate and adapt to climate change (not least since an aim of the work is to inform policy in these areas). The indirect effects of climate change in Scotland may also be significantly influenced by the nature and severity of changes elsewhere in the UK, Europe and across the world. A final set of uncertainties relates to external factors such as the price of oil, or the overall direction of society's future development (e.g. as reflected in the UKCIP socio-economic scenarios). These uncertainties underpin the decision that the work should concentrate on the broad direction and magnitude of change, rather than aiming to reflect relatively subtle differences between different climate change scenarios and time frames.

1.17. As discussed previously, climate change is only one influencing factor on the landscape, and as a result the United Kingdom Climate Impacts Programme (UKCIP) socio-economic scenarios[5] (see Appendix 2) have been used to inform the interpretation of the study results, to explore the potential impact of different scenarios on the extent and degree of landscape change. There is also uncertainty within the climate change scenarios, which is discussed in more detail in Section 3.

UKCIP02 and UKCP09[6]

1.18. It was originally proposed that the study would make use of new climate change scenario data which had been due to be published in 2008. Delays meant that these data were published as the UKCP09 climate change projections, after the completion of this study. A review of the differences between the two sets of projections was carried out to determine the extent to which the research and its conclusions needed to be updated. The review, which is summarised in Chapter 2 and reported in detail in Appendix 11, concluded that, for most climate change variables, the differences between the two projections were relatively modest. Only one variable (winter precipitation) was identified as being significantly different in terms of scale and spatial distribution, requiring some parts of the analysis to be updated. Most of the research is therefore based on UKCIP02 data, with selective use of UKCP09 data. The validity of this approach was confirmed with the Scottish Climate Change Impacts Partnership (see Appendix 11 for more information).

1.19. The UKCIP02 climate change scenarios provide four alternative descriptions of how the climate of the UK might evolve over the course of this century. The alternatives result from uncertainty about future human trends and behaviour and how these might influence future global emissions of greenhouse gases. To address this emissions uncertainty, the UKCIP02 scenarios describe future climate change under four alternative futures, ranging from rapid economic growth with intensive use of

[5] See glossary
[6] Information obtained from www.ukcip.org.uk

fossil fuels (High Emissions) to increased economic, social and environmental sustainability with cleaner energy technologies (Low Emissions). For each of the four UKCIP02 scenarios, changes are described for three future thirty-year time-slices: 2011 to 2040 (the 2020s), 2041 to 2070 (the 2050s) and 2071 to 2100 (the 2080s). All changes in climate are given relative to the baseline period of 1961 to 1990. The information is displayed on a grid of 50km squares which cover the whole of the UK. The changes described for the next 30 or 40 years are broadly similar for all four scenarios, as they are largely influenced by past and current emissions of greenhouse gases. Over the second half of this century, the four scenarios are influenced to a greater extent by the amount of greenhouse gases we emit now and over future years and decades. The future climates that the scenarios describe therefore become increasingly different.

1.20. Not all of the changes described by UKCIP02 are given with the same confidence. Based on both expert judgment and comparison with other global climate models, some changes in future UK climate have been assigned a higher confidence than others.

1.21. UKCP09 scenarios provide more up to date and detailed projections than UKCIP02, employing recent advances in climate science to better quantify some of the uncertainties associated with climate modelling and information on projected future climate change for the UK up to 2099. The UKCP09 scenarios are presented as probabilistic projections including:

- The 10% probability projections indicate that the likelihood that the change in question will be less than that shown is 10%. UKCP uses the term 'very unlikely to be less than' (and therefore very likely to be more than) to describe such changes indicating a higher level of confidence of the effect occurring.

- The 90% probability projections indicate that the likelihood that the change in question will be less than that shown is 90% - it is very unlikely to be greater than that shown and therefore very likely to be less.

- The 50% probability projections indicate that the projected change is just as likely to be greater as it is to be less than the value shown. This is the central estimate and, importantly, does not indicate the projection that is most likely to occur.

1.22. Analysis of the more extreme probabilistic projections (e.g. 90% and 10%) allows the variation in potential changes to be explored, helping to inform the way in which the projections should be applied. For example, if there is relatively little difference between the scales of change which have a 90%, 50% and 10% probability of being exceeded, any conclusions based on the projections are likely to be reasonably reliable, providing a firm foundation for policy or other responses. On the other hand, if there is a significant difference between either the 90% or 10% projections and the 50% projection, the conclusions will be more tentative and, importantly, a judgment will need to be made about the level of risk that any subsequent response should adopt. Appendix 11 includes detailed comparison of probabilistic projections for temperature and precipitation for the three UKCP regions of Scotland (Eastern, Northern and Western Scotland). The analysis concluded that climate related landscape changes associated with temperature are, all other things being equal, more likely to occur than those associated with changes in rainfall.

Data scale and mapping

1.23. The issue of data scale adds a further level of uncertainty to the study. Different data sources are mapped at varying scales, and the UKCIP02 climate change scenarios

are mapped at a 50km grid scale. This presents key issues for the mapping process, whereby the different levels of accuracy from different data sources are brought together. This issue is discussed further in paragraphs 4.7 to 4.10.

1.24. The mapping is based primarily on direct impacts of climate change, as there are greater difficulties in mapping mitigation and adaptation impacts due to the lack of data on the locations where these may occur.

Structure of the report

1.25. The remainder of the report is structured as follows:

- Section 2: Methodology.
- Section 3: Future climate change in Scotland.
- Section 4: Scotland-wide pattern of climate related change.
- Section 5: Tayside detailed study area.
- Section 6: Conclusions.

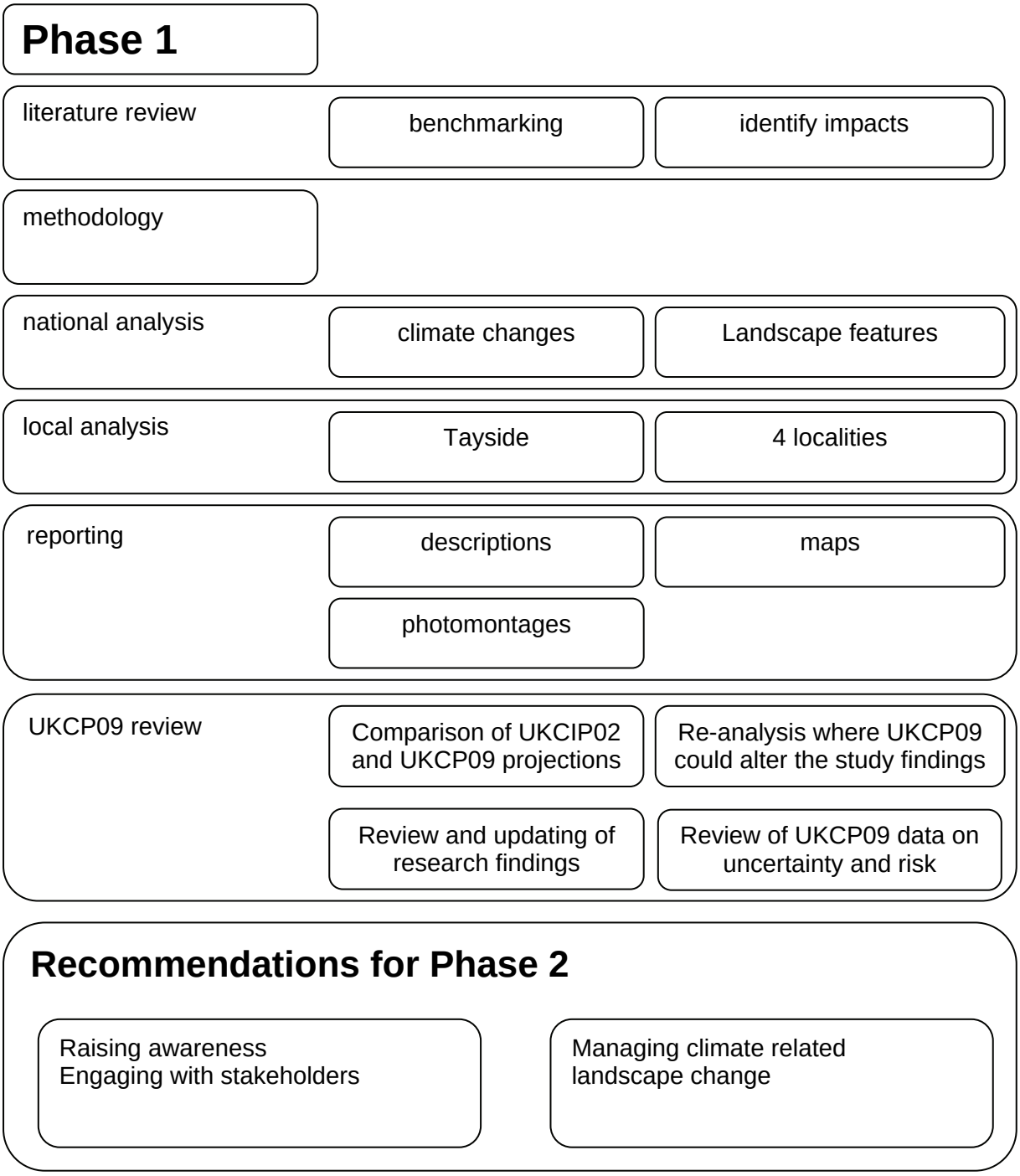
How to use this report

1.26. The research is intended to provide an overview of climate related landscape change, illustrated by national, regional and local case study analysis. In particular, the national analysis, reported in Section 4, is based on GIS analysis of climate change variables and the location of relevant landscape features. The resulting maps are indicative, suggesting where, all other things being equal, change is more or less likely to occur as a result of climate change. The maps are not intended for use at the local level, particularly because they use climate data which are provided at a much coarser scale (50km squares in the case of UKCIP02 and 25km squares in the case of UKCP09).

2. METHODOLOGY

INTRODUCTION

2.1. This section of the report sets out the project methodology and explores the application of the socio-economic scenarios and ecosystem services approach to the study. The diagram below provides an overview of the main study stages:



LITERATURE REVIEW

Benchmarking approaches to climate change and the landscape

2.2. The first study task was to review current practice in the analysis of climate change impacts on the landscape to ensure that the study is informed by current thinking. The study reviewed the way that climate related landscape change has been considered in:

- England and Wales, including the outcomes of the Research Council funded programme on building knowledge on climate change, including the Adaptation Strategies for Climate Change in the Urban Environment (ASCCUE) project conducted by Professor John Handley and Centre for Urban Regional Ecology (CURE) at the University of Manchester; and work at the University of East Anglia by Andrew Lovett and others in the School of Environmental Science. It also drew on experience from the Wittenham Clumps Heritage Landscape Project: Future Landscape Scenarios work conducted by the University of Oxford Environmental Change Institute;

- The rest of Europe, including the work on the effects of climate change on mountain landscapes used for skiing, carried out for the Alps, which formed part of the Visulands project. The Visulands project was carried out at the Swiss Federal Institute of Technology, ETH Zurich, and developed visualisation tools to support public involvement in the assessment of landscape change. Further detail is provided in Appendix 4.

2.3. The literature review also examined non-landscape work relating to climate change in Scotland in order to consider the kinds of changes that are being anticipated, and approaches to uncertainty.

2.4. This part of the literature review is presented in Appendix 4.

Identification of impacts

2.5. The literature review was used to identify potential types of climate related landscape changes. This included direct effects together with mitigation and planned and unplanned adaptation responses. The potential changes were recorded in a matrix and grouped by topic. Inevitably there is some overlap between topic areas (e.g. between forests and woodlands, habitats and agriculture), though each change has been recorded only once to avoid double counting. The matrix recorded the following information:

- topic area;
- type of change (direct, planned adaptation, unplanned adaptation, mitigation)[7];
- the landscape effect of the climate change;
- the climate variable(s) causing the landscape change (e.g. winter rainfall changes or increase in summer temperatures);
- the level of certainty attached to the climate change scenario information;
- a broad assessment of the likely timescale over which the change in question might be expected to occur;
- the broad geographic extent of the change.

[7] See glossary

2.6. Each change was also assigned a reference number. The changes recorded in an initial long matrix were prioritised in discussion with the project Steering Group to identify those that would be analysed in greater detail. The longer and shorter matrices are included in Appendix 5. The prioritisation of changes was based on the information recorded in the bullet points above and was intended to identify those which were most likely to have significant implications for the landscape and, consequently, for quality of life.

DEVELOPMENT OF STUDY METHODOLOGY

2.7. The literature review informed the development of the methodology which addressed the following questions:

- What are the climate changes likely to affect Scotland taking account of:
  - timescale;
  - geographic distribution;
  - scale and magnitude;
  - certainty /likelihood.

2.8. This included overall and seasonal changes in rainfall, temperature, winds and storminess and sea level changes.

- What kinds of landscape change could result from these climate changes?
  - Direct changes. Examples include flooding (fluvial, pluvial and tidal), changing patterns of vegetation and species distribution, coastal erosion and deposition, snow-lie, land instability and visibility;
  - Indirect ‘adaptation’ changes. Examples include planned measures to help species respond to climate change (e.g. habitat networks), measures to address direct changes such as flooding and less ‘planned’ changes such as changing patterns of agricultural production. These changes will themselves be influenced by policy factors (e.g. whether to work with natural flood processes or alternatively to implement ‘hard’ flood defences) and external factors (e.g. wider changes affecting the market for agricultural and forest products). This is likely to be particularly true in urban areas, reflecting, for example, the way that greenspaces and urban trees are planned for and managed;
  - Indirect ‘mitigation’ measures designed to reduce carbon emissions or increase carbon sequestration. Examples include on shore and offshore wind energy developments of various scales, hydro schemes, biomass production, active and passive solar, carbon capture and storage, nuclear power plants and energy related infrastructure including transmission lines and substations. Measures designed to reduce the need to travel, particularly by road and air could also have landscape implications at local and broader scales.

2.9. In identifying these changes, consideration was given as to the extent and means by which they could be influenced through development planning or land management planning. This explored:

- Where these changes will occur, and where they will be most pronounced, bringing together analysis of the coincidence between climate changes (direct and indirect) and the landscapes or landscape elements which would be affected.

- What this means in terms of landscape character and ecosystem services provided by the landscape. This considers the extent to which the character of the landscape would be affected by the change in question and how this could, in turn, affect (negatively or positively) its ability to deliver ecosystem benefits. This analysis considers the nature, scale, distribution, likelihood and significance of the landscape changes (distinguishing in particular between the last two aspects).

2.10. It is at this stage that the analysis brought together information on different climate related landscape changes to identify those landscapes which could experience the greatest change, either as a consequence of the nature or magnitude of a given change, or due to the combined impact of multiple changes. This information is explored at a national level and also at strategic and local levels, focusing on Tayside as a case study.

2.11. Finally, the research considered the extent to which negative effects could be reduced or positive changes enhanced through different policy frameworks at national, strategic or local levels. This could consider development planning, land management planning (e.g. through the Scottish Rural Development Programme) and mechanisms such as catchment management planning.

APPLICATION OF STUDY METHODOLOGY

National analysis

2.12. The application of the methodology at a national level is based on the prioritised list of landscape related climate changes (Table 5.5 Appendix 5). The landscape features identified as subject to change in this matrix were selected in terms of the relevant available data sources which could be used to graphically illustrate the distribution of these features.

2.13. The national level analysis explores the combined effects of different types of climate related landscape change. It also specifically explores coastal issues and the potential impacts on designated landscapes and on SNH wildland search areas.

National level mapping

2.14. National level mapping was carried out for a number of individual changes identified from the prioritised list of landscape changes in Appendix 5, Table 5.5. This process combined spatial datasets representing the distribution of the landscape ‘feature’ in question (for example, woodland, or areas over a particular altitude) and relevant components of the UKCIP02 climate change scenarios showing where climate changes could be more pronounced. This provides an indication of where the landscape ‘feature’ in question could be most affected by climate change. This is a relatively simplistic analysis, particularly given the coarse spatial resolution of the UKCIP02 data, but does represent a first attempt to map the likely scale and distribution of a selection of climate related landscape changes. Further detail on the national mapping is provided in Appendix 10.

2.15. A review of the UKCP09 climate change projections (which were published after the first phase of this research was completed) was used to identify areas where the new projections differed significantly from those published under UKCIP02. As a result

some of the national level mapping was re-run with updated climate change data. This is described in more detail later in this Chapter, and in Appendix 11.

Workshop discussion

2.16. As part of the study process a half day workshop for SNH and staff from across a wide range of disciplines was convened on 7th January 2009 to provide a forum for discussion on the study and its findings. This workshop involved presentation of the study findings to date and opportunity for discussion of the landscape impacts identified. The findings from the workshop informed the list of landscape impacts identified and included in the national and local level analysis. The key issues identified from the Workshop, together with a list of attendees, are set out in Appendix 3.

2.17. In addition to participation through the workshop, the project Steering Group and SNH staff provided valuable inputs to the study throughout the project process assisting in the identification of literature and data sources. The project Steering Group included representatives from Forestry Commission Scotland (FCS), Natural England (NE), Scottish Environment Protection Agency (SEPA), Historic Scotland (HS), Department of Environment Northern Ireland (DoENI), Perth and Kinross Council and from the People and Places Unit in SNH. The project team would like to acknowledge the assistance of the Steering Group throughout the course of the research.

Local analysis

2.18. This allowed more detailed analysis of landscape character and ecosystem services at a local level. This provided an opportunity to explore the combined effects of different types of climate related landscape change on the key characteristics of specific landscapes, and consideration of the likely implications for the provision of ecosystem services.

Methodology for selection of local study area

2.19. Criteria for selecting a study area included:

- the presence of a good cross section of landscape character types. While it was recognised that no single area could represent the full range of landscape character types found across Scotland, it was considered important that the study area should include upland, lowland, urban and coastal areas as far as possible;
- the likely incidence of a number of significant climate related landscape changes already explored at a national level. In part this reflected the types of areas identified in the previous bullet point, but also the presence of particular issues such as flooding or agricultural change;
- in addition, the study area was required to include an area designated for its special landscape qualities, such as a National Scenic Area or National Park.

2.20. On this basis, the Tay catchment provides the best fit. Key features include:

- Four National Scenic Areas and parts of the two National Parks;
- Tay Forest Park;
- Arable and horticultural farmland of Strathmore;

- Pasture and moorland;
- The River Tay, with a history of flooding;
- Firth of Tay;
- The sandy estuary and coast at Tentsmuir and Buddon Ness;
- Urban areas of Perth and Dundee
- Upland areas of mountain and moorland
- Importance of tourism around Loch Tummel, Pitlochry and Dunkeld.

Mapping

2.21. The catchment level mapping draws on the findings of the national level mapping exercise. This provides an overview of the key areas of change within the study area and informs the more detailed analysis described below.

Analysis

2.22. The first stage in the local analysis is the review of the 'shortlist' matrix (table 5.5, Appendix 5) and identification of the landscape elements which would be subject to the landscape changes identified in each of the three regional character types (Tayside Lowlands, West Highlands and Mounth Highlands) within Tayside. The main changes in the landscape character are summarised under the topic headings as used in the matrix.

2.23. The second stage is to take this information down to the landscape character unit level, drawing on the identified key landscape features subject to change, and to produce a revised landscape character unit description for the landscape character areas used for the more detailed study, illustration through photomontages for three landscape areas and an annotated map for the Perth urban area.

2.24. The finer grain analysis allows exploration of landscape changes at a more detailed and comprehensible scale, within the context of wider change across the area as a whole. This allows the exploration of more significant changes supported by both text description and illustrations. These significant changes are based on those landscape changes which were identified as having a higher degree of confidence and a higher landscape significance attached to them. However, there are a number of uncertainties and risks associated with the changes identified. The potential influence of these is explored through the interpretation of the four socio-economic scenarios.

2.25. The following sets out the approach to the analysis of landscape changes for the individual landscape character areas:

- description of landscape character area based on Tayside Landscape Character Assessment (1999);
- description of landscape character area in 2050 incorporating potential landscape change scenarios;
- exploration of variations in landscape scenarios under the four socio-economic scenarios;

- exploration of the implications of the changes in relation to the provision of ecosystem services.

2.26. The data presented in the SNIFFER Handbook of Climate Trends Across Scotland[8], provides information on historic patterns of change for different climate variables on a 5km grid. This information is interpreted in relation to the UKCIP02 projected trends and identifies the spatial variation across Scotland. This information has been used to inform the landscape character area analysis of future landscape scenarios at the more detailed, local scale.

SOCIO-ECONOMIC SCENARIOS

2.27. The UKCIP socio-economic scenarios have been used to inform the local level analysis. This information is used to provide a framework to illustrate how landscape change may vary according to different broad policy directions. Within this study, these scenarios are used descriptively to assist in addressing the issue of uncertainty, associated with human responses to climate change and their influence of different socio-economic and political futures. A number of strong policy messages associated with these scenarios are explored in Section 5.

2.28. The following table provides a brief summary of the scenarios, drawing out the key differences. Further information on the socio-economic scenarios is set out in Appendix 2, and explored in Section 5.

Table 2.1 Summary of UKCIP socio-economic scenarios

Scenario	Description
World Markets	Very rapid economic growth; population peaks mid-century; social, cultural and economic convergence among regions; market mechanisms dominate.
National Enterprise	Self reliance; preservation of local identities; continuously increasing population; economic growth on regional scales.
Global Sustainability	Clean and efficient technologies; reduction in material use; global solutions to economic, social and environmental sustainability; improved equity; population peaks mid-century.
Local Stewardship	Local solutions to sustainability; continuously increasing population at a lower rate than in 'national enterprise'; less rapid technological change than in 'global sustainability' and 'world markets'.

ECOSYSTEM SERVICES

2.29. The study brief suggested that research into climate related landscape change should include consideration of the effects in terms of ecosystem services - the benefits that people obtain from ecosystems.

2.30. The main categories of ecosystem services include:

- provisioning services – products obtained from ecosystems;

[8] See reference list at the end of this report

- regulating services – the benefits obtained from the regulation of ecosystem processes;

- cultural services - the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences;

- supporting services - those that are necessary for the production of all other ecosystem services, such as water cycling. They differ from provisioning, regulating and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. Some services, like erosion regulation, can be categorised as both a supporting and a regulating service, depending on the timescale and immediacy of their impact on people.

2.31. Many ecosystem services are highly interlinked. For example, primary production, photosynthesis, nutrient cycling and water cycling all involve different aspects of the same biological processes.

2.32. It was agreed that the study should be limited to examine the impacts on cultural services, and the following list identifies those cultural services agreed with the project steering group for inclusion within the study:

- Inspiration and enrichment. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture and advertising. They also provide a more informal aspect of inspiration and enrichment through providing an attractive and stimulating environment;

- Health and wellbeing. Physical and mental (links to some of the regulating services), and includes human comfort resulting from urban temperatures and people's immediate environment, where they live, work and undertake recreation;

- Aesthetic values. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks and scenic drives and in the selection of housing locations;

- Sense of place. Many people value the 'sense of place' that is associated with recognised features of their environment, including aspects of the ecosystem;

- Cultural heritage values. Many societies place high value on the maintenance of either historically important landscapes ('cultural landscapes') or culturally significant species;

- Recreation and tourism. This is dependant on healthy & attractive environments, landscape diversity, special landscapes and species. People often choose where to spend their leisure time based, in part, on the characteristics of the natural or cultural landscapes in a particular area.

2.33. A fuller description of the ecosystem services, based on work carried out by Defra, is set out in Appendix 1.

OUTPUTS

2.34. The final output of these two stages of the work included preparation of materials to communicate the results to a wider audience. This includes a plain English description of the changes that are judged most likely to occur or most significant in terms of their impact, maps showing their likely geographic distribution, a plain

English description of the landscapes that would be affected and the changes that they would experience, digitally manipulated photographs illustrating the changes (individually or in combination).

RECOMMENDATIONS FOR PHASE 2 OF THE RESEARCH

2.35. The final part of the work sets out recommendations for the second phase of the research. This focuses on raising awareness and engaging with stakeholders and communities to develop practical approaches to managing climate change impacts on the landscape and to influence decision making and practice in development planning. A key element of this is encouraging consideration of landscape change within wider climate change strategies and policies.

UKCP09 REVIEW

2.36. The UKCP09 climate change projections were published after the completion of the research described in previous sections. A review was therefore carried out to identify the key differences between the UKCIP02 and UKCP09 projections with the aim of identifying areas where differences between the two datasets could have implications for the research findings

2.37. The UKCP09 review comprised a series of discrete steps, as follows:

- Comparison of the UKCIP02[9] and UKCP09 projections[10], including comparative mapping for key climate change variables. This review was informed by discussions with a specialist adviser[11] from Scottish Climate Change Impacts Partnership (SCCIP);
- Identification of those elements of the Phase 1 analysis that require updating in the form of revised GIS mapping to reflect major differences between the UKCIP02 and UKCP09 projections;
- Re-running GIS mapping and analysis of the results for national, regional and local descriptions of climate related landscape change;
- Analysis of UKCP09 probabilistic projections to provide a commentary on the uncertainty associated with different climate change variables;
- Auditing of the Phase 1 Interim Report to identify those sections which require to be updated to reflect the differences between the UKCIP02 and UKCP09 projections, including the updated mapping;
- Consideration of how updated information should be presented within the updated (Final) Phase 1 Report.

2.38. The detailed results of the review are contained in Appendix 11, and reflected throughout this report.

UKCP09 climate change projections

2.39. UKCP09 projections differ from their predecessors in a number of respects, including:

- UKCIP02 projections were provided on a 50km grid whereas the UKCP09 projections use a 25km grid. The two grids are differently oriented and not directly comparable as a result;

[9] http://www.ukcip.org.uk/index.php?id=161&option=com_content&task=view
[10] http://ukclimateprojections.defra.gov.uk/
[11] See advice received from J. Hagg, SCCIP adviser in Appendix 11, Annex 2

- UKCIP02 scenarios were derived from a single UK climate model whilst the UKCP09 projections are based on an ensemble of different models. This limits the comparability of the two datasets;

- UKCIP02 used four emissions scenarios whereas the UKCP09 projections are based on 3 emissions scenarios. While the high and low emission scenarios are comparable, the medium scenarios are different (UKCIP02 included 'medium/low' and 'medium/high' emissions scenarios, whereas UKCP09 includes a single 'medium' emissions scenario). It is however worth noting that the differences between emissions scenarios are greatest after 2050, so qualified comparison of the UKCIP02 medium/high or medium/low emissions scenarios with the UKCP09 medium emissions scenario may be acceptable[12];

- UKCIP02 projections provided a single value for each emissions scenario / timeframe, whereas the UKCP09 projections provide a range of probabilistic values.

Differences between UKCIP02 and UKCP09 climate variables

2.40. The comparison of UKCIP02 and UKCP09 projections explored differences in the direction, scale and spatial pattern of climate change for a series of variables including winter precipitation, summer precipitation, winter temperatures, summer temperatures, autumn temperatures, annual temperatures and sea level rise.

2.41. For most of these variables, the analysis concluded that while the rate of change indicated by UKCP09 differed from that indicated by UKCIP02, the direction and broad spatial pattern of change remained the same (with one exception). Given that the mapping analysis carried out during the first phase of the research placed each variable onto a common scale (from least change to greatest change), it was concluded that, although the change should be reflected in the updated text where appropriate, there was no requirement to re-run the GIS mapping analysis since the overall patterns of change would be the same.

2.42. The one exception is the winter precipitation variable, where the UKCP09 projections suggest different rates, directions and spatial patterns of change than projected under UKCIP02. It was therefore concluded that a total of 13 national maps from the Phase 1 report should be re-run using the UKCP09 winter precipitation variable. It was confirmed that, where relevant, such analysis could combine information from the two sets of projections, though this should be noted in the accompanying text.

[12] See advice received from J. Hagg, SCCIP adviser in Appendix 11 (Annex 2)

3. FUTURE CLIMATE CHANGE IN SCOTLAND

INTRODUCTION

3.1. This section of the report provides a summary of the UKCIP02 climate change projections upon which the original research was based. It also includes the results of a comparison of these projections with the UKCP09 projections which were published after the research had been completed. This identifies those climate variables where there is significant difference between the two projections, requiring the analysis to be repeated using the more up to date information. This part of the report also summarises research by SNIFFER into past climate trends in Scotland providing a finer grain of information.

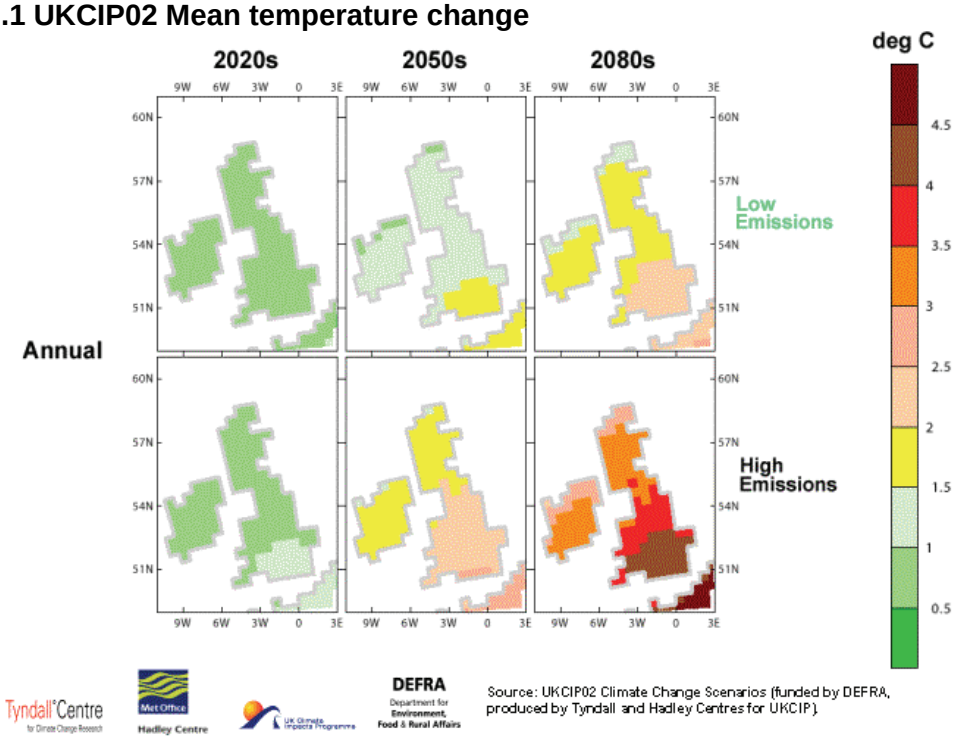
UKCIP02 CLIMATE CHANGE SCENARIOS FOR SCOTLAND

3.2. The UK Climate Impacts Programme (UKCIP) provides the most up to date information on future climate change in Britain at the time of undertaking this study. The UKCIP02 scenarios provide information relating to 2020, 2050 and 2080, covering high, medium and low emission scenarios. The implications for Scotland are described in SNIFFER – Business Risks of Climate Change to Public Sector Organisations in Scotland (2005) and summarised below. It should be emphasised that the scenarios provide descriptions of potential future conditions, but do not represent firm predictions or forecasts. The level of confidence for each of the changes is noted below. The maps illustrated are sourced from UKCIP02 Climate Change Scenarios (funded by Defra, produced by Tyndall and Hadley Centres for UKCIP).

3.3. **Average temperature –** As in the rest of the UK, by the end of this century Scotland will experience mean annual temperatures of between 0.5 and 1.0°Celsius warmer than present. In the 2050s the increase in average annual temperature for Scotland (1.0-1.5°C) will be less than that for most of England and Wales (1.5-2.0°C). However, these figures hide seasonal variations: in the 2050s most of Scotland will be warmer by 1.5-2.0°C in autumn and central and east Scotland will be warmer by 1.5-2.0°C in summer. The thermal growing season will lengthen. The number of very cold days will fall and the number of very hot days will rise. The confidence attached to these projected changes is high.

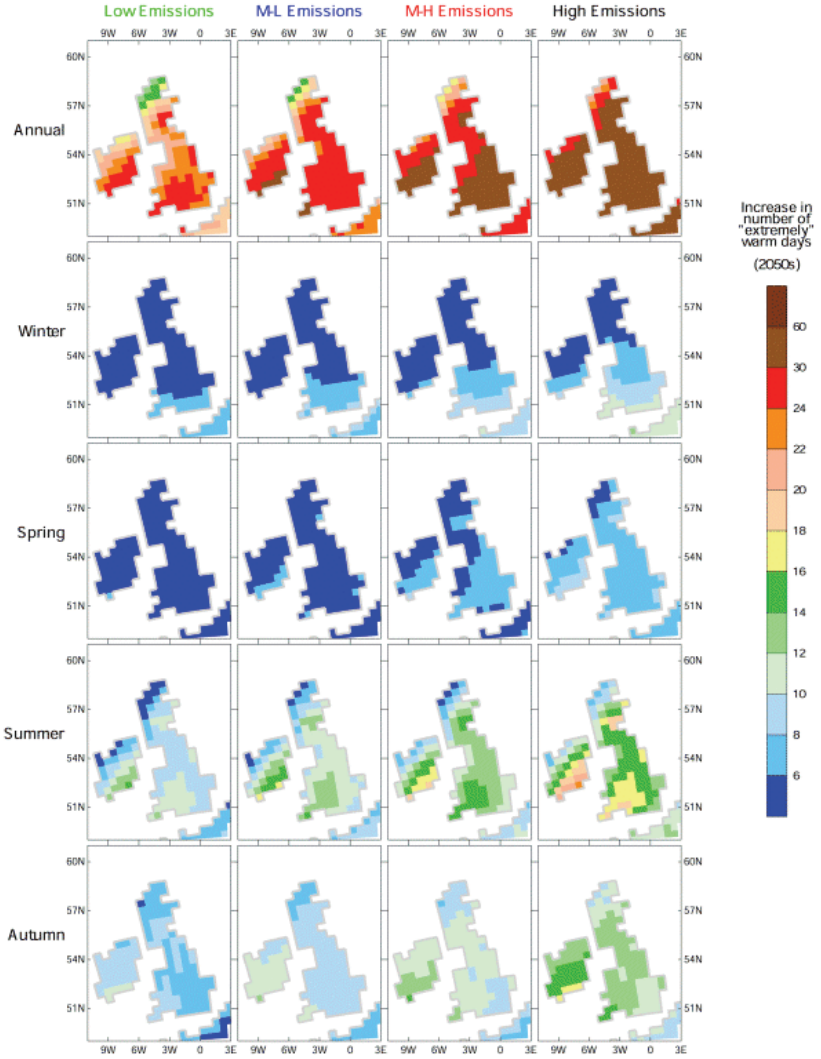
3.4. **Inter-annual temperature variability –** Inter-annual temperature variability is an indication of variability of climate from year to year. Winter and spring temperatures over the whole of the UK will become less variable, with north-west Scotland seeing a reduction in inter-annual variability of up to 20%. Summer and autumn temperatures will become more variable over the whole of Scotland, increasing by 20% or more in most of south and west by 2050. The average annual diurnal temperature range will also show an upward trend in Scotland over summer, though this will be more noticeable in south England. The confidence attached to these projected changes is high.

Figure 3.1 UKCIP02 Mean temperature change



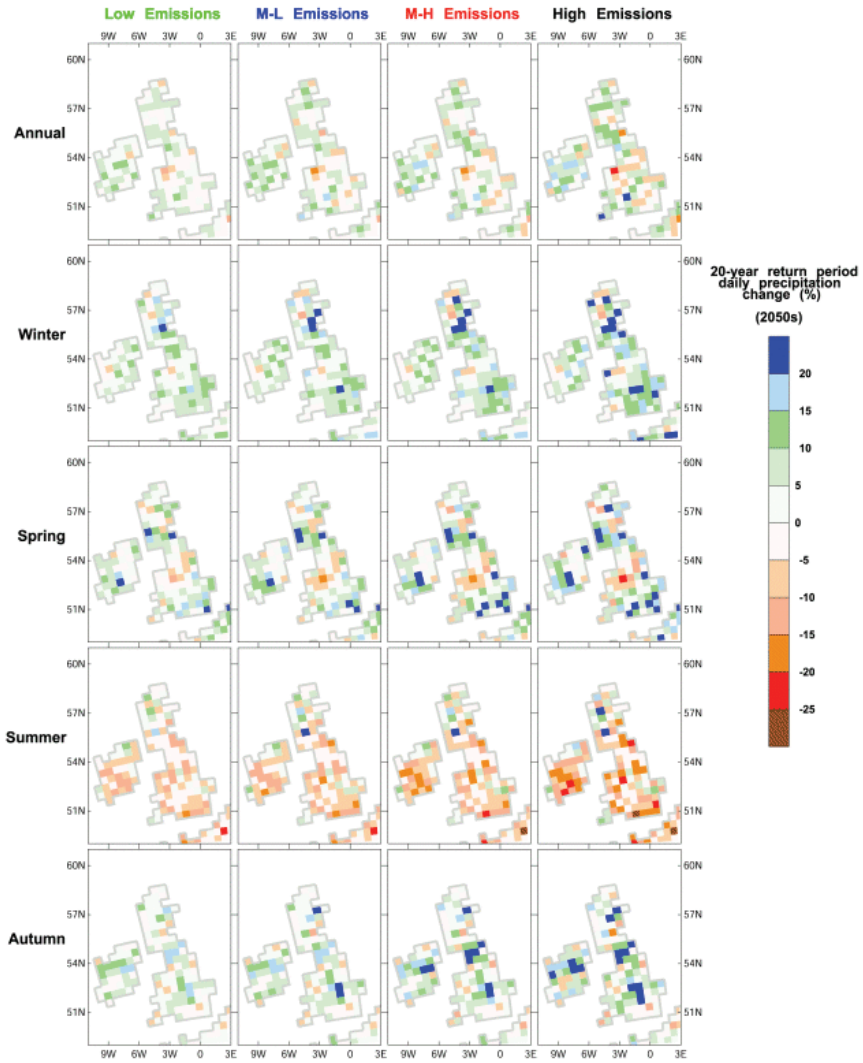
3.5. **Heat wave and rain storm frequency –** By 2080 rainfall events will, on average, be unaffected in north-west Scotland, 25-75% more intense in east Scotland, up to 100% more intense in west Scotland and more than 150% more intense in parts of south-west Scotland. Unlike changes in average temperature and rainfall, changes in rainfall intensity will increase the likelihood of flash flooding of Scottish rivers. Precipitation intensity will increase in winter. The confidence attached to these projected changes is high. The hottest (defined as those exceeding the 90th percentile) days will also get hotter in Scotland, by up to 4°C in the summer and autumn in the south. The situation will be more dramatic in England, with the hottest days getting hotter by up to 6°C. Changes will be less pronounced in winter, with the hottest days getting hotter by 1.5°C over most of Scotland. The confidence attached to these projected changes is high.

Figure 3.2 UKCIP02 Increase in number of 'extremely' warm days



Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

Figure 3.3 UKCIP02 20-year return period daily precipitation change (%)

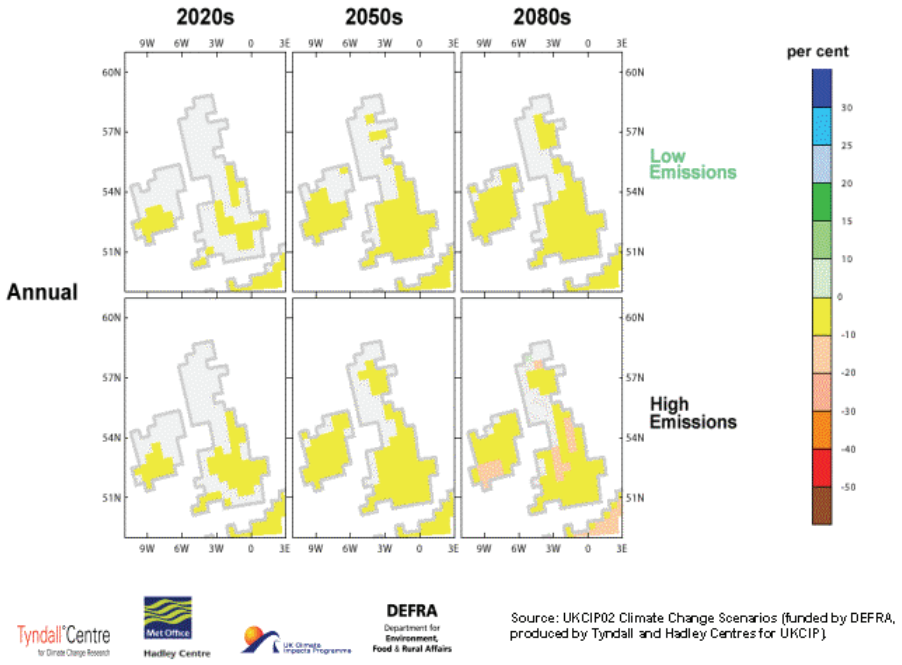


Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

3.6. **Sea level rise –** The UKCIP02 scenarios suggest a net sea-level rise for Scotland of between 15-28cm (accounting for changes in post-glacial vertical land movement) by the 2080s, an increase in peak surges and a modest annual average increase in tidal surges and waves due to an increasing frequency of severe winter gales. The confidence attached to these projected changes is high or medium.

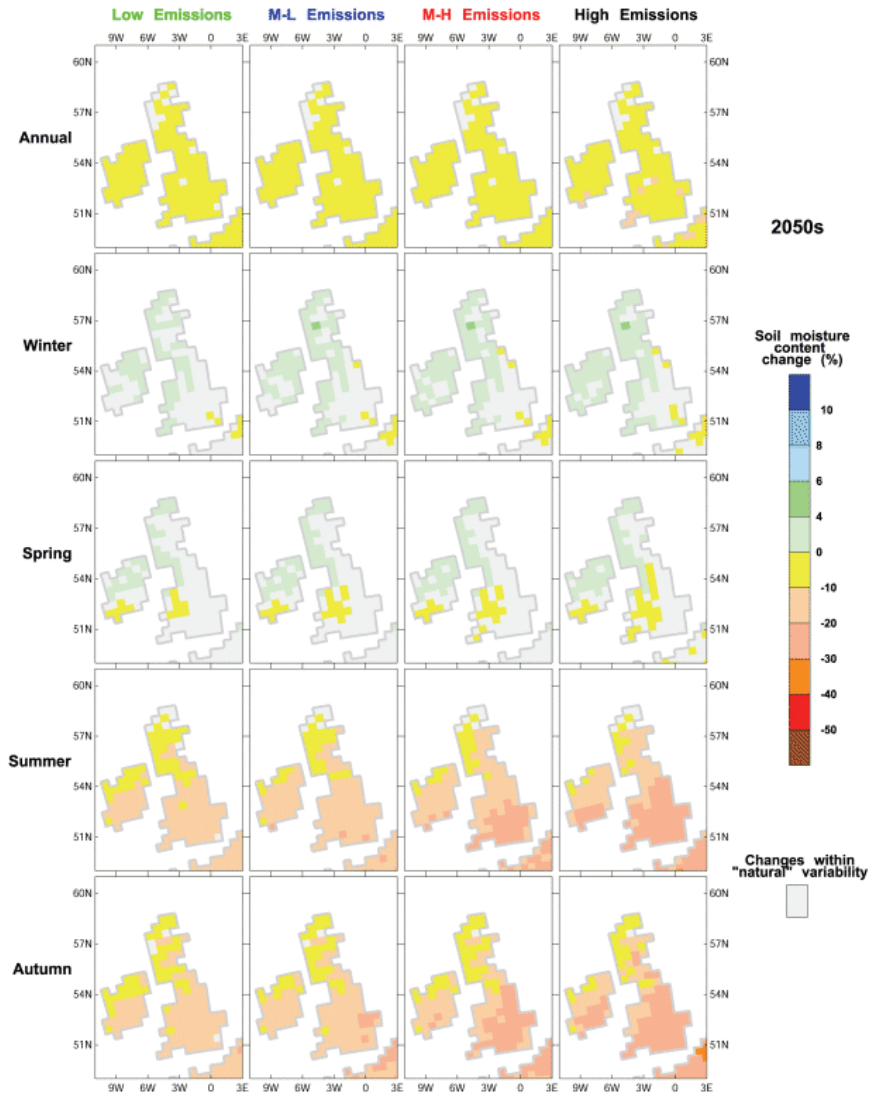
3.7. **Average precipitation –** Annual precipitation in the 2020s and in the 2050s will be similar to present, although there may be a decline of up to 10% along the Scottish east coast. Again, these figures hide more significant seasonal variations for Scotland. In the 2020s, winters along the east and Argyll and Ayrshire coasts will be up to 10% wetter than present, whereas summers in Scotland will be up to 10% dryer than present, with a 10-20% decrease in precipitation over central parts and the Borders. By the 2080s, there will be 40-60% less winter snowfall over the Cairngorms, with up to 80% less along parts of the Scottish east coast. This could change the pattern of river flows associated with snow melt. The confidence attached to these projected changes is high or in the case of snowfall changes, medium.

Figure 3.4 UKCIP02 Mean precipitation change



3.8. **Soil moisture** – The greatest changes are in summer and autumn with a reduction in soil moisture in summer and autumn of 10-40% across the whole of lowland Scotland. Soil moisture levels are likely to be up to 10% higher across the whole of Scotland in winter. The confidence attached to these projected changes is medium.

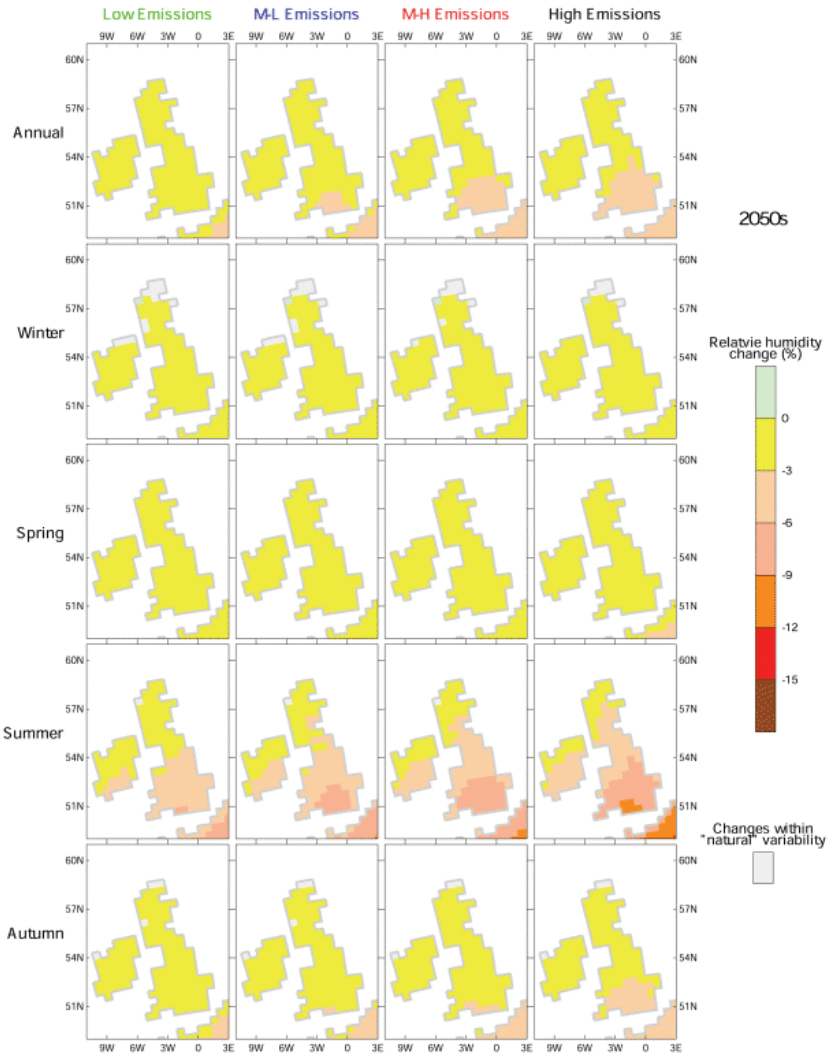
Figure 3.5 UKCIP02 Soil moisture content change (%)



Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

3.9. **Humidity** – Relative humidity decreases slightly across the whole of Scotland in spring and summer and all of Scotland bar the extreme north and north west in autumn and winter. The confidence attached to these projected changes is medium.

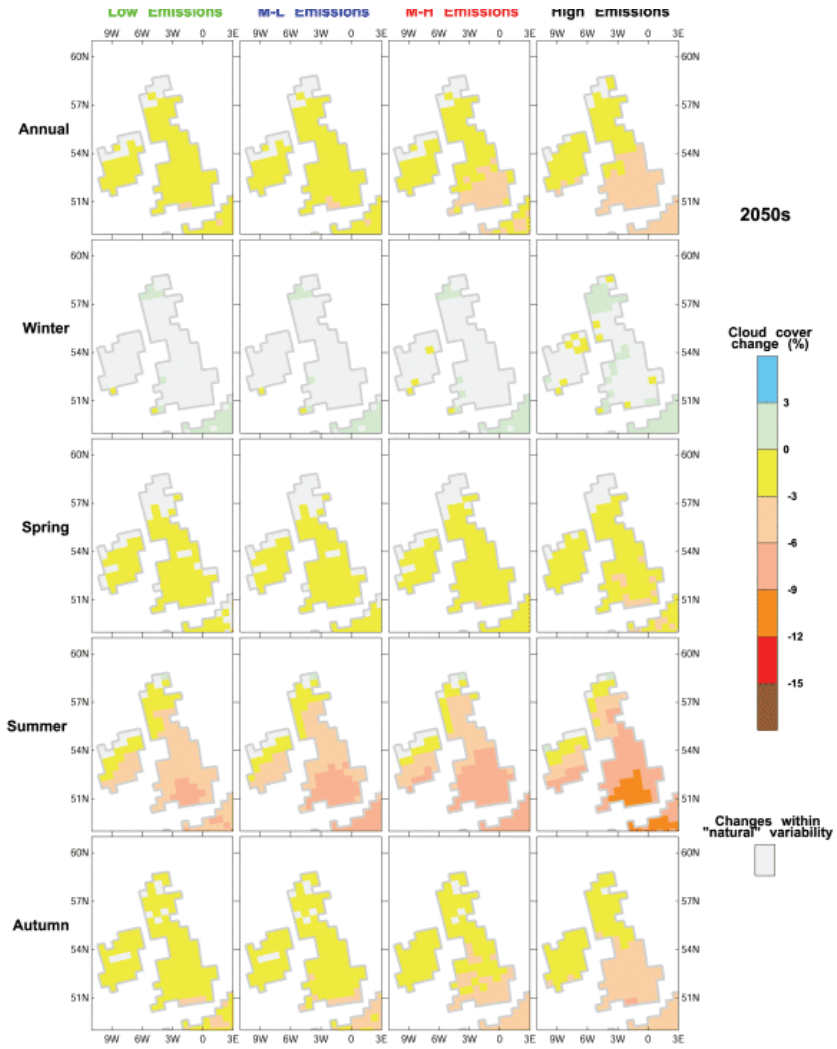
Figure 3.6 UKCIP02 Relative humidity change (%)



Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

3.10. **Cloud cover –** There is anticipated to be a slight reduction in cloud cover in the summer, except in the extreme north and north west, and a slight increase in winter cloud cover in some northerly areas. The confidence attached to these projected changes is low.

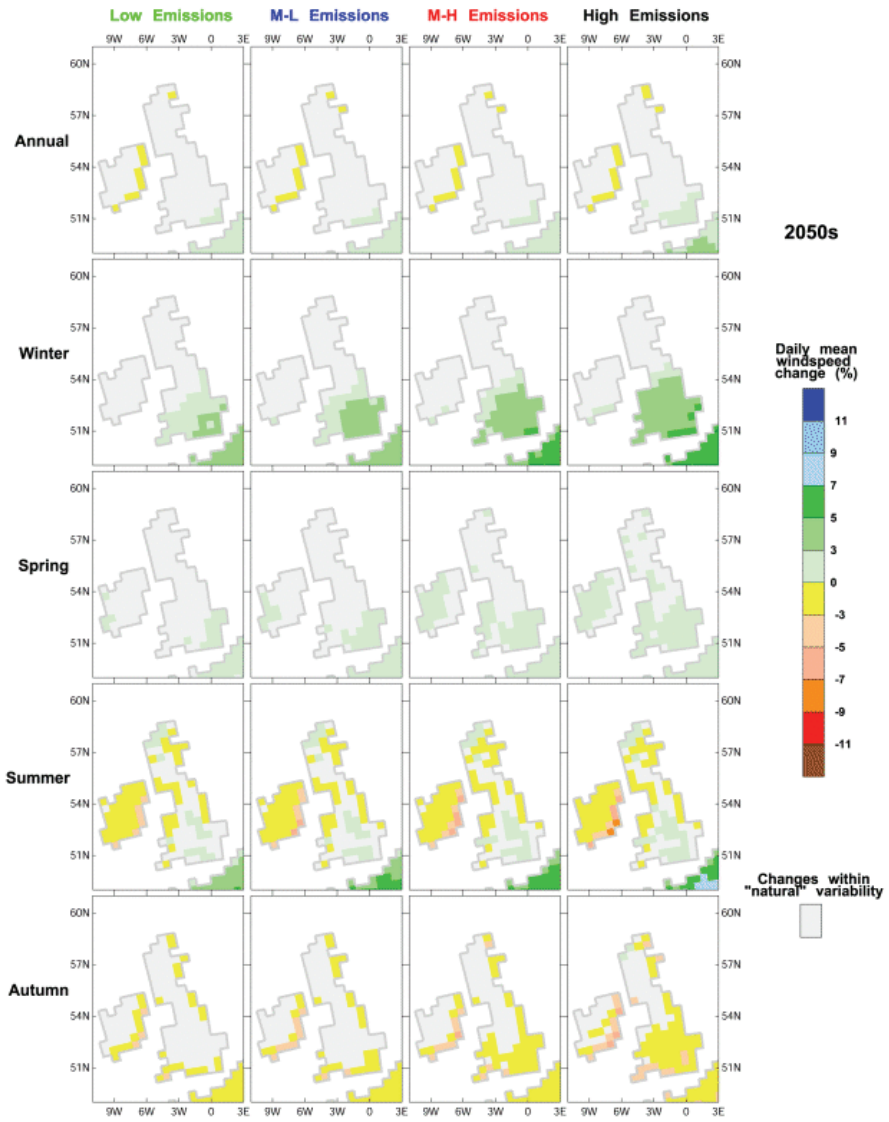
Figure 3.7 UKCIP02 Cloud cover change (%)



Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

3.11. **Average wind speed –** By 2080, the wind speed with a recurrence interval of 2 years (i.e. a typical wind speed) is set to increase in south west Scotland by 2-4% in winter and decrease across most of south and central Scotland by up to 2-6% in summer. The changes are of similar magnitude to those projected for parts of England and Wales. The confidence attached to these projected changes is low.

Figure 3.8 UKCIP02 Daily mean windspeed change (%)



Source: UKCIP02 Climate Change Scenarios (funded by DEFRA, produced by Tyndall and Hadley Centres for UKCIP)

Comparison of UKCP02 and UKCP09 climate change variables

3.12. This section sets out a comparison of the UKCIP02 and UKCP09 projections, focusing on climate change variables most relevant to Phase 1 of this research into the effects of climate change on landscape and quality of life. This analysis compares the high emissions scenarios for both sets of projections, focusing on the 30 year time slice, centred on 2050. This reflects the lack of an equivalent to the UKCIP02 medium-high emission scenario (used in the Phase 1 research) in the suite of UKCP09 projections. This section also explains the changes made to the Phase 1 Interim Report as a result of the differences between the two sets of projections.

Winter precipitation

3.13. The UKCIP02 2050 high emissions scenario projections (Figure 3.9a) suggested that virtually all of Scotland could experience an increase in winter precipitation in 2050, with the smallest changes affecting the north west (up to 5% increase), large increases experienced along the east coast and central and southern Scotland (up to 16% increase) and largest increases in localised areas in the east (up to 24%).

3.14. While the largest increases suggested by the UKCP09 2050 high emissions scenario projections (Figure 3.9b) are similar to those in the 02 projections (23%), there are some important differences in the spatial pattern of change. Firstly, some areas may now be more likely to experience a slight decrease in winter rainfall of up to 1.5%. These areas include the wider Cairngorms massif. Secondly, it now appears that parts of the west coast, Hebrides and Northern Isles, along with the east coast may experience the largest increases in winter rainfall (up to 24%), with most of the remaining coastal fringes and southern Scotland experiencing increases of up to 16%.

3.15. Figure 3.9c shows a comparison of the two projections confirming that UKCP09 projections show some areas as having up to 14% less winter precipitation than the 02 projections and large areas of the eastern Highlands and Southern uplands experiencing reductions of up to 8% than previously projected. Parts of the west coast, the Hebrides and Northern Isles are shown as having between 8 and 24% more rainfall than previously predicted.

3.16. These are significant differences in the direction, scale and spatial pattern of change and it was therefore concluded that all the GIS analyses using the winter precipitation climate change variable should be re-run.

Other changes

3.17. The following variations did not require maps to be re-run, however, the changes are noted in the commentaries in Sections 4 and 5. More detail is also contained in Section 2 of Appendix 11.

Summer precipitation

3.18. The UKCIP02 projections suggested that all of Scotland with the exception of parts of the inner and Outer Hebrides and the Northern Isles could experience a decrease in summer precipitation. These decreases might be greatest in parts of central Scotland, southern Scotland and in the central Highlands. The UKCP09 2050 projections show a similar pattern, though the scale decrease is now lower than previously suggested. See **Figure 3.10**.

Winter temperature

3.19. The UKCIP02 projections suggested that all of Scotland could experience an increase in average winter temperatures. The increases could be greatest in southern and central Scotland, together with the Grampians and lowest around the western coastal fringes and Outer Hebrides. The UKCP09 projections show a broadly similar pattern, though the maximum projected increase is now greater than previously suggested. See **Figure 3.11**.

Summer temperature

3.20. The UKCIP02 projections suggested that all of Scotland could experience an increase in average summer temperatures. The increases could be greatest in southern and central Scotland, together with the Grampians and lowest around the western coastal fringes and Outer Hebrides. The UKCP09 projections show a broadly similar pattern, though the maximum increase could now be greater than previously suggested. See **Figure 3.12**.

Autumn temperature

3.21. The UKCIP02 projections suggested that all of Scotland could experience an increase in average autumn temperatures. The increases might be greatest in southern, central and much of Highland Scotland away from the far north and parts of the east coast and lowest around the Outer Hebrides (up to 1° Celsius increase). The UKCP09 projections show a similar pattern. See **Figure 3.13**.

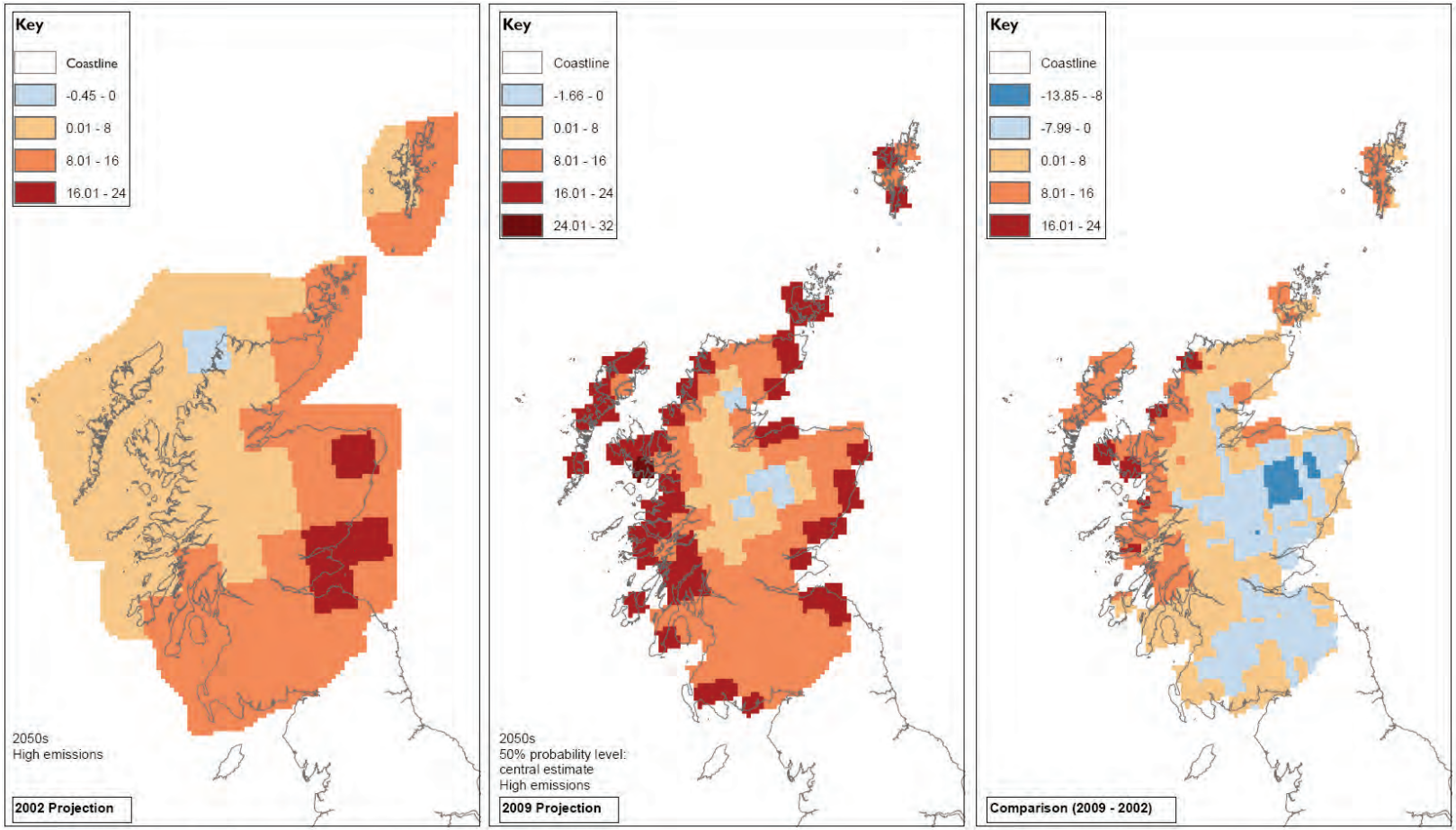
Annual temperature

3.22. The UKCIP02 projections suggested that all of Scotland could experience an increase in average annual temperatures. The increases could be greatest across most of mainland Scotland and lowest around the west coast and Hebrides. The UKCP09 projections show a similar pattern, though the scale of change has increased. See **Figure 3.14**.

Figure 3.9a
Winter precipitation (UKCIP02)

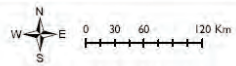
Figure 3.9b
Winter precipitation rainfall (UKCP09)

Figure 3.9c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Winter Precipitation (% change from current precipitation)

UKCIP02 and UKCP09 data are shown on the 5km^2 grid that was used to combine information during Phase 1 of the work. The UKCIP02 data have been interpolated across cell boundaries, whereas the UKCP09 data are based on the value at the centre-point of each 5km cell, reflecting advice that probabilistic projections should not be averaged.



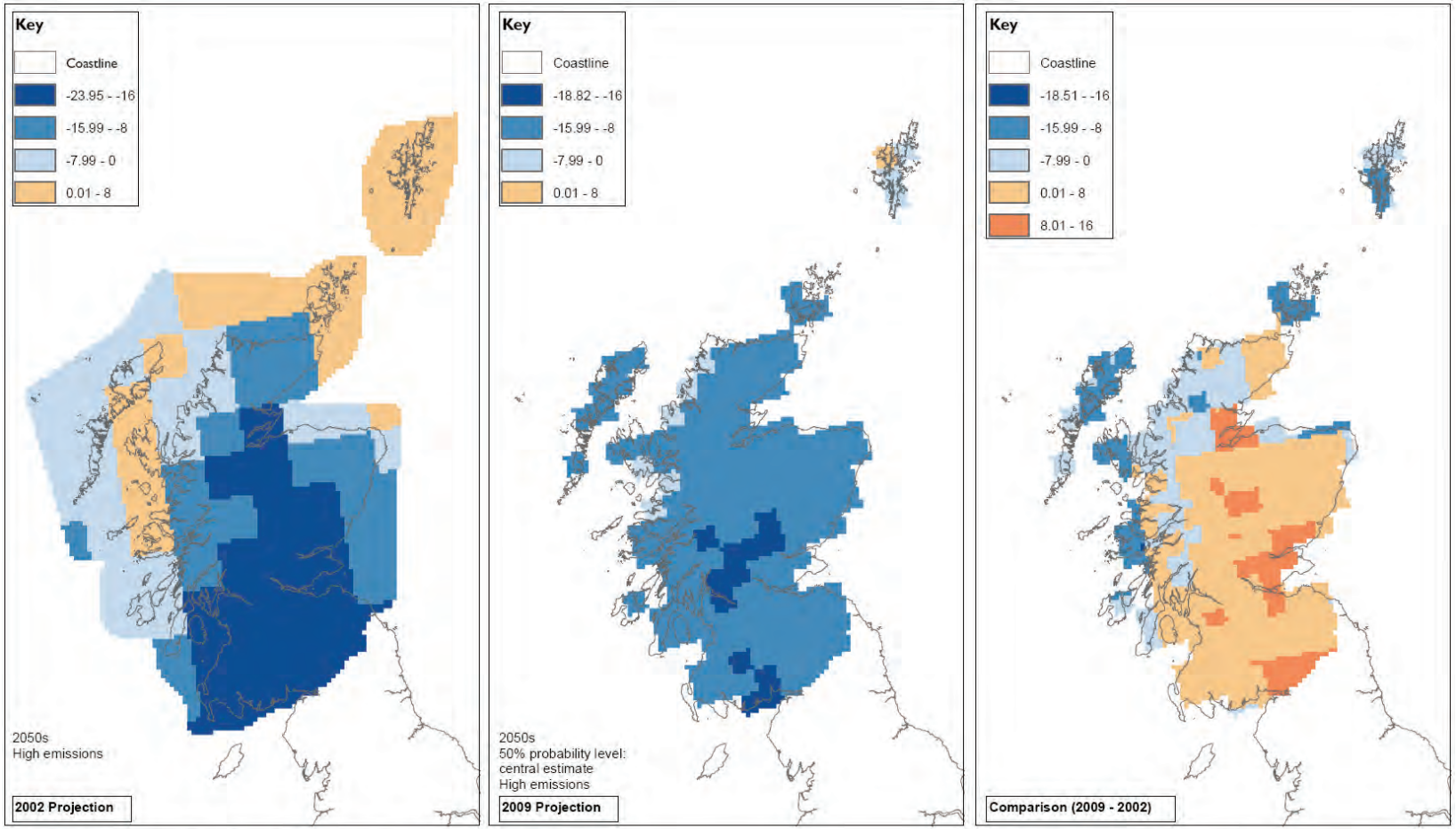
Source: UKCIP02, UKCP09

File: S:\4800\4809 Climate Change and Landscape Phase 2\GIS\Themes\ArcGIS9\4503-02_005_Winter_Rain_Comparison_High.mxd

Figure 3.10a
Summer precipitation (UKCIP02)

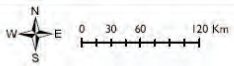
Figure 3.10b
Summer precipitation (UKCP09)

Figure 3.10c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Summer Precipitation (% change from current precipitation)

UKCIP02 and UKCP09 data are shown on the 5km^2 grid that was used to combine information during Phase 1 of the work. The UKCIP02 data have been interpolated across cell boundaries, whereas the UKCP09 data are based on the value at the centre-point of each 5km cell, reflecting advice that probabilistic projections should not be averaged.

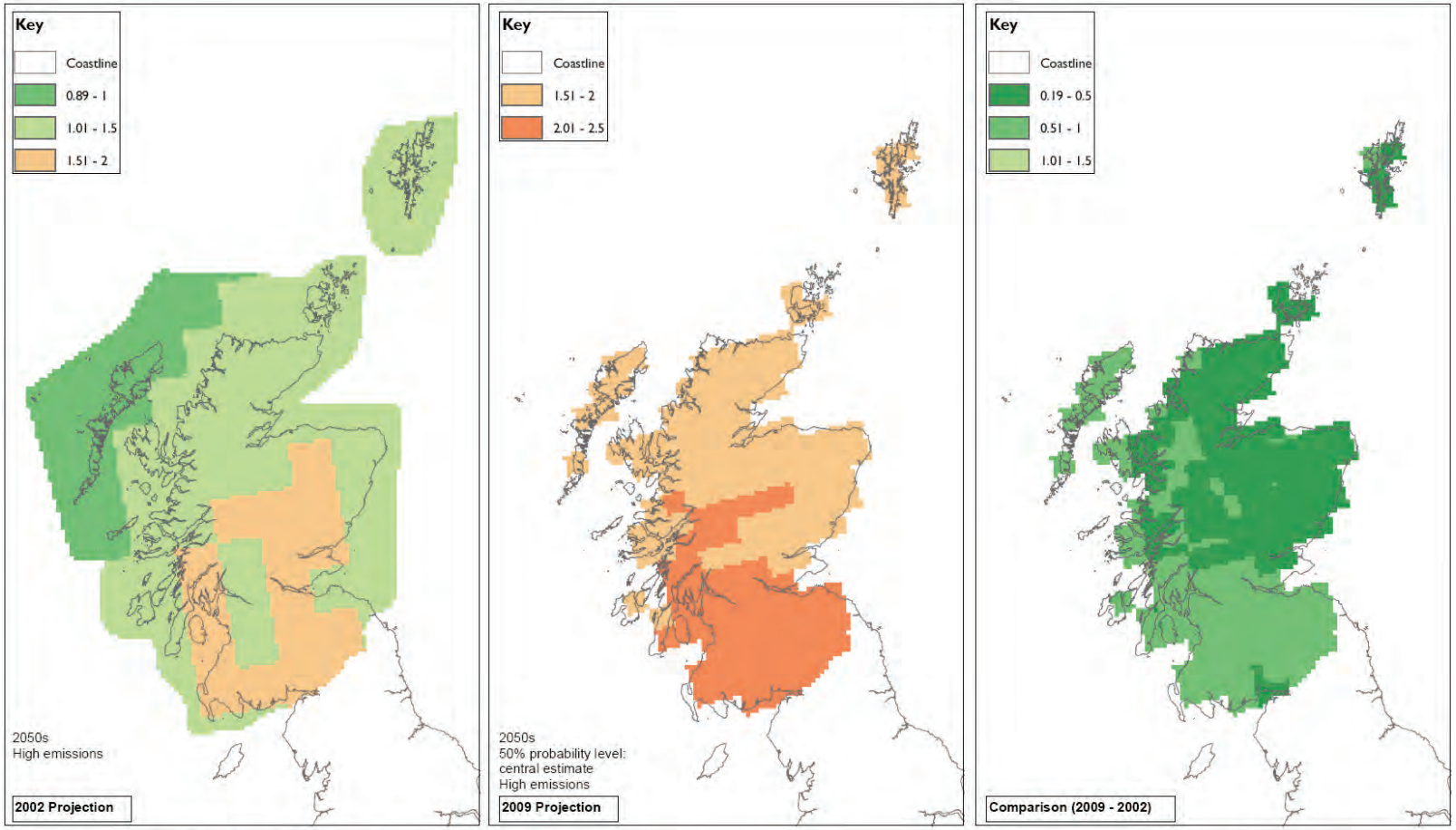


Source: UKCIP02, UKCP09

Figure 3.11a
Winter temperature (UKCIP02)

Figure 3.11b
Winter temperature (UKCP09)

Figure 3.11c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Winter Temperature (°C)

UKCIP02 and UKCP09 data are shown on the 5km^2 grid that was used to combine information during Phase 1 of the work. The UKCIP02 data have been interpolated across cell boundaries, whereas the UKCP09 data are based on the value at the centre-point of each 5km cell, reflecting advice that probabilistic projections should not be averaged.

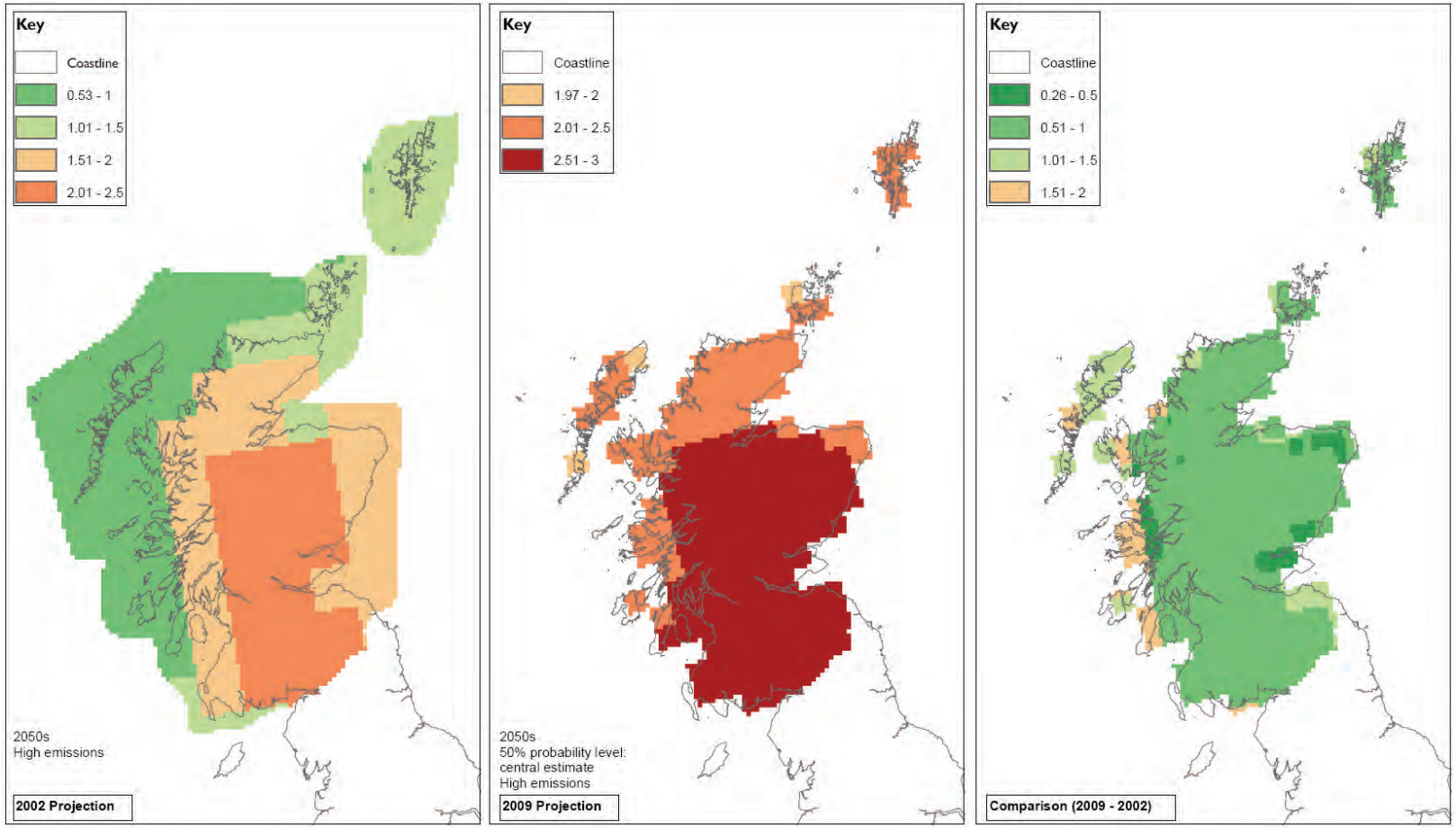
N W E S 0 30 60 120 Km

Source: UKCIP02, UKCP09

Figure 3.12a
Summer temperature (UKCIP02)

Figure 3.12b
Summer temperature (UKCP09)

Figure 3.12c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Summer Temperature (°C)

UKCIP02 and UKCP09 data are shown on the 5km^2 grid that was used to combine information during Phase 1 of the work. The UKCIP02 data have been interpolated across cell boundaries, whereas the UKCP09 data are based on the value at the centre-point of each 5km cell, reflecting advice that probabilistic projections should not be averaged.

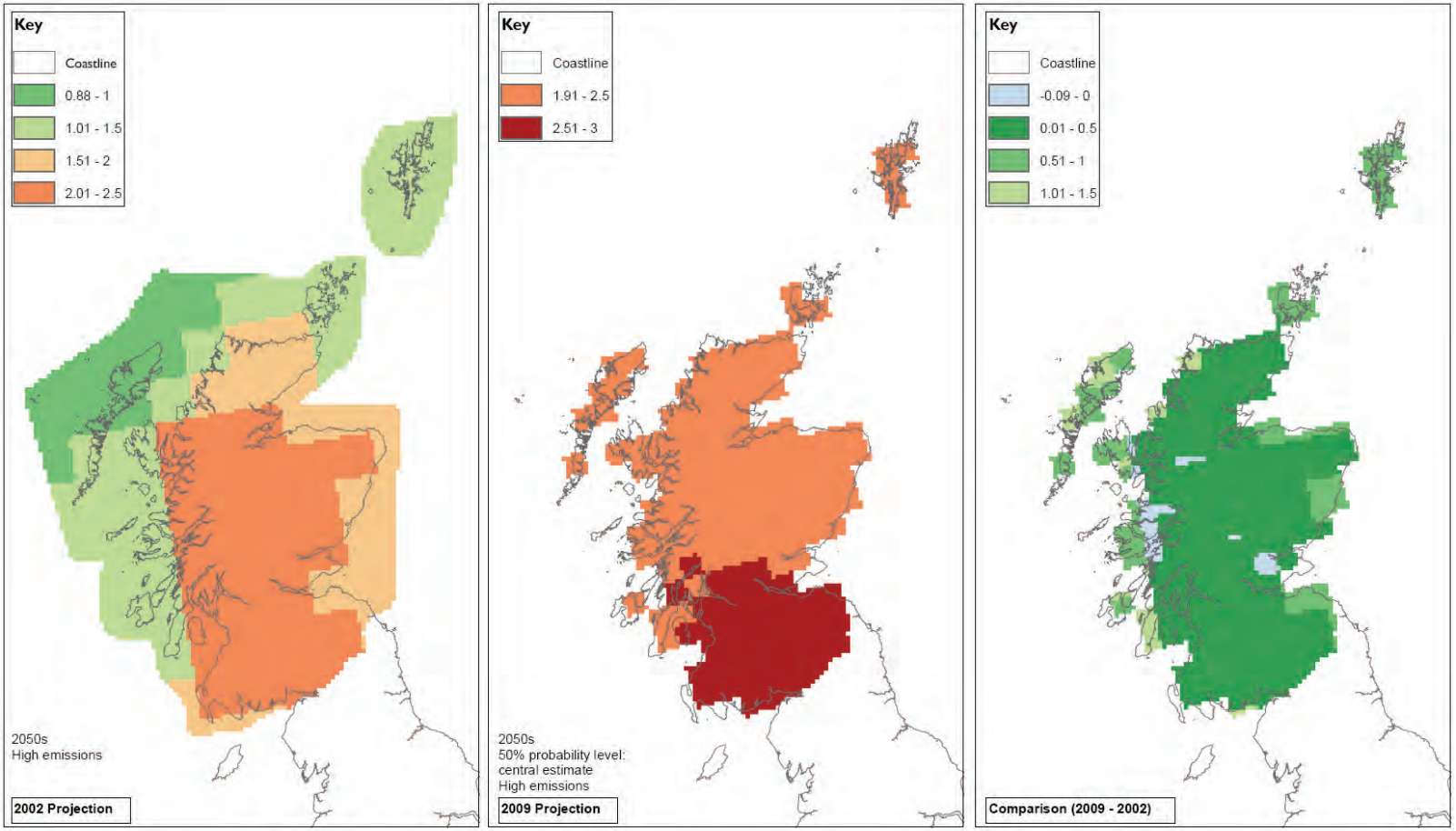
N W E S 0 30 60 120 Km

Source: UKCIP02, UKCP09

Figure 3.13a
Autumn temperature (UKCIP02)

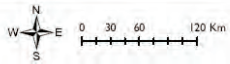
Figure 3.13b
Autumn temperature (UKCP09)

Figure 3.13c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Autumn Temperature (°C)

UKCIP02 and UKCP09 data are shown on the 5km^2 grid that was used to combine information during Phase 1 of the work. The UKCIP02 data have been interpolated across cell boundaries, whereas the UKCP09 data are based on the value at the centre-point of each 5km cell, reflecting advice that probabilistic projections should not be averaged.

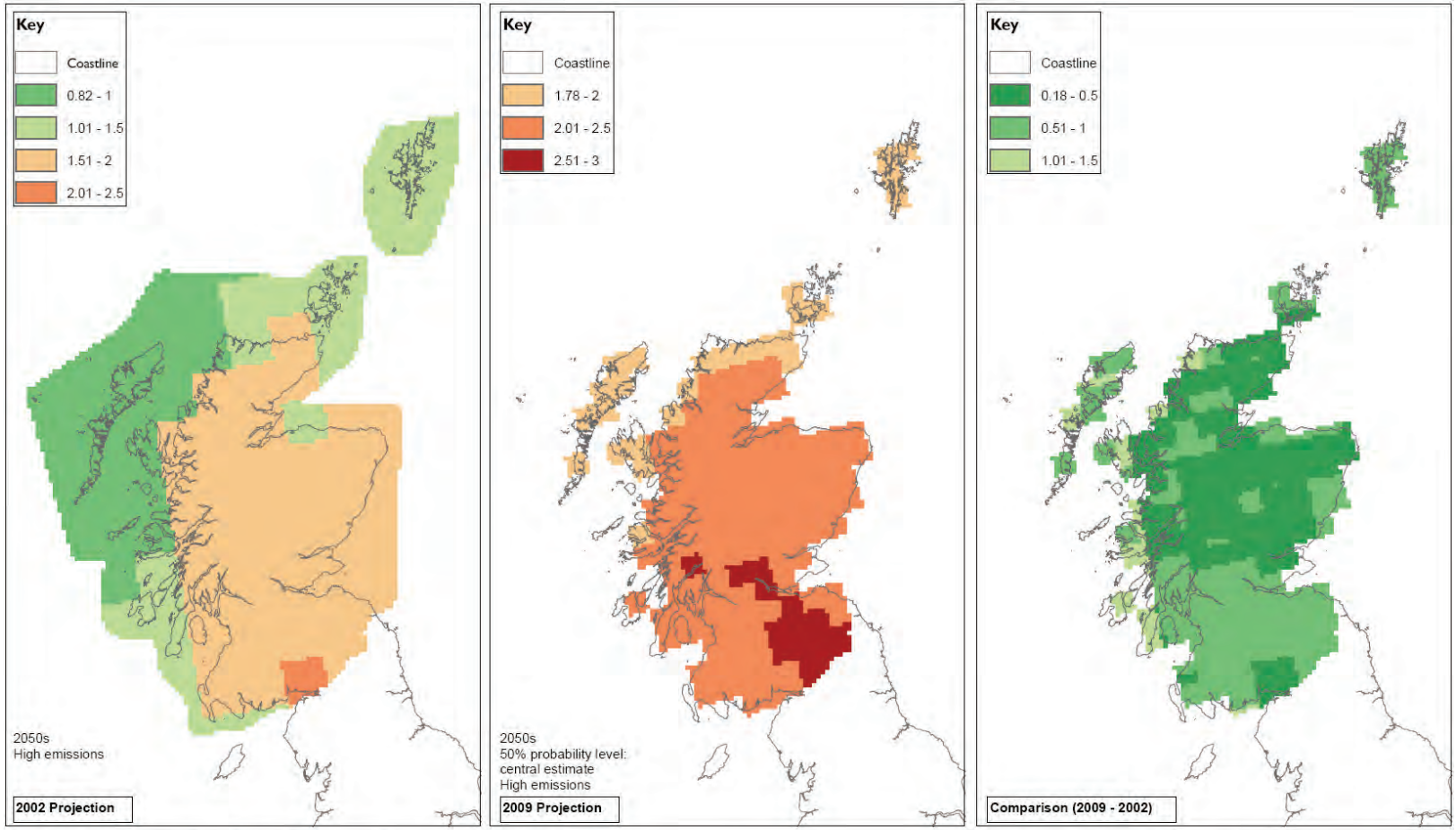


Source: UKCIP02, UKCP09

Figure 3.14a
Annual temperature (UKCIP02)

Figure 3.14b
Annual temperature (UKCP09)

Figure 3.14c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Annual Temperature (°C)

UKCIP02 and UKCP09 data are shown on the 5km^2 grid that was used to combine information during Phase 1 of the work. The UKCIP02 data have been interpolated across cell boundaries, whereas the UKCP09 data are based on the value at the centre-point of each 5km cell, reflecting advice that probabilistic projections should not be averaged.

N W E S 0 30 60 120 Km

Source: UKCIP02, UKCP09

File: S:\4800\4809 Climate Change and Landscape Phase 2\GIS\Themes\ArcGIS9\4503-02_007_Annual_Temp_Comparison_high.mxd

Sea level rise

3.23. Phase 1 of the research into the effects of climate change on landscape and quality of life drew on research into sea level rise carried out for the Scotland and Northern Ireland Forum for Environmental Research (published as FRM10 in 2008[1]). This research presented estimates for sea level change around the Scottish coast between 2000 and 2080. These were based on the IPCC global mean sea level projections adjusted to reflect geological and isostatic rebound modelling, similar to those used in the UKCIP02 projections. This research has been updated in the light of the UKCP09 projections[2].

3.24. The UKCP09 projections include new figures for sea level rise using the modelling approach described above (emission scenarios, timescales, probabilistic projections) combined with the latest assessment of land movement around the UK coast which differ from those used in the earlier research into sea level rise. The latter have been revised downwards slightly, resulting in an upward adjustment in sea level projections.

Table 3.1: 2080 sea level projections for Edinburgh, cm

	High emissions	Medium emissions	Low emissions
FRM10 (in line with UKCIP02)	+6 to +35	+1.6 to +24	
UKCP09 50% percentile	+31.4	+24.4	+18.6
UKCP09 5% / 95% percentiles	+7 to +54	+5 to +45	+4 to +32

See paragraphs 1.21 and 1.22 of Appendix 11 for explanation of percentiles

3.25. These figures suggest that the UKCP09 projections lie towards the upper end of the FRM10 UKCIP02 projections.

3.26. The update to the research concludes that the spatial pattern of change is broadly the same as reported in FRM10, though no new maps are available. A relative sea level rise of around +30-35 cm over the period 1990 to 2095 at Edinburgh compares with 25-30 cm in the Clyde Estuary, around 40-45 cm in the Western Isles and Orkney Islands and around 50-55 cm in the Shetland Islands.

3.27. The UKCP09 projections include an additional scenario based on high plus plus emissions (H++). This scenario is intended to represent the effects of the melting of large ice sheets on sea level rise, an area where there is a current lack of scientific understanding. While this is considered to be a very unlikely scenario, the projections suggest that beyond the end of the century sea levels could rise by between 93cm and 1.9m.

3.28. The updated research also considers the issue of storm surges. It concludes that storm surges show considerable less change in overall height (and consequently less influence on coastal flood risk) compared to sea level rise around the Scottish coast. However, taking the H++ emissions scenario for sea level and combining this with surge predictions from the higher emissions estimate give much more significant increases in the effect of surge tides on coastal flooding.

[1] SNIFFER (2008) Coastal Flooding in Scotland: A Scoping Study, Project FRM10

[2] Update to Project FRM10: Coastal Flooding in Scotland: A Scoping Study, in the light of the UK Climate Projections (2009) report http://www.sniffer.org.uk/Webcontrol/Secure/ClientSpecific/ResourceManagement/UploadedFiles/updated%20summary%20Nov%2009.pdf

3.29. While the scale of projected sea level rise is somewhat greater than suggested by the UKCIP02 scenarios, the spatial implications (when viewed at a national level) are broadly similar. It was concluded that these differences should be noted, but GIS analysis using the revised sea level projections should not be re-run.

SNIFFER Handbook of Climate Trends

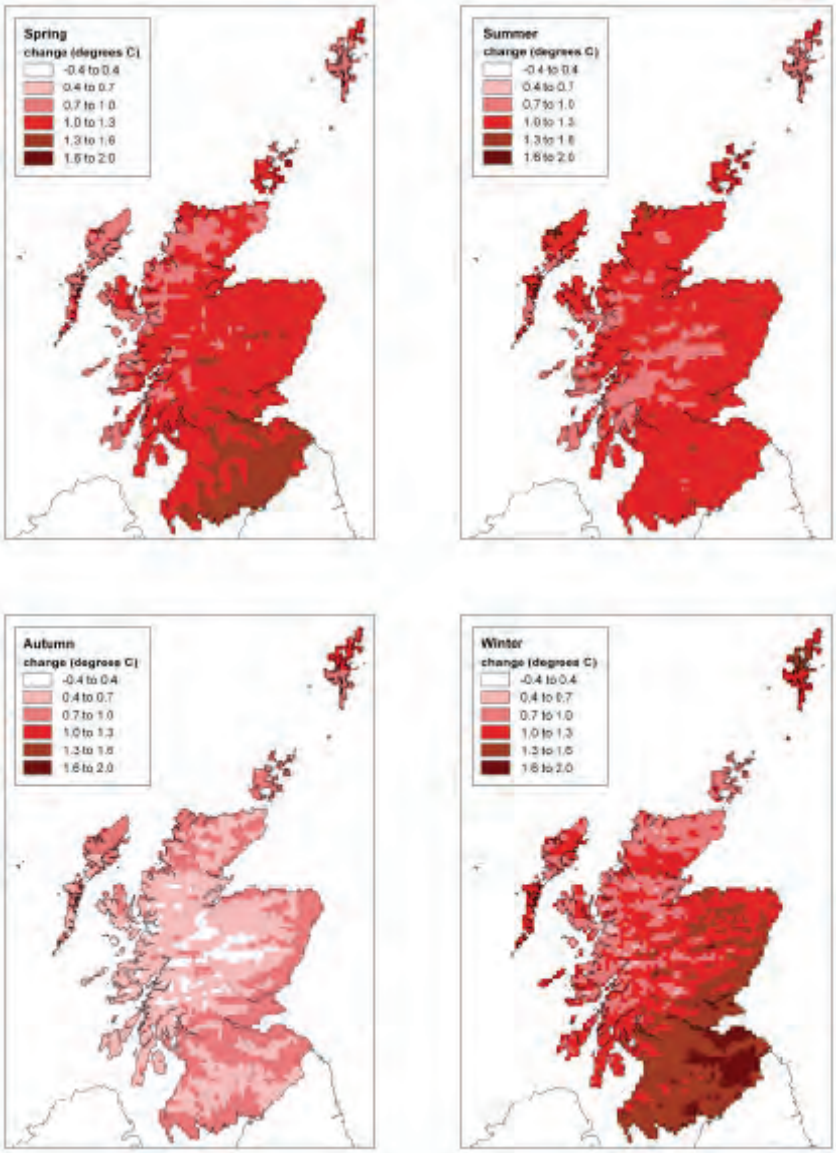
3.30. The SNIFFER (2006) report 'Patterns of Climate Change Across Scotland' presents the changes in climate across Scotland in the last century, and provides a benchmark against which to measure future climate change. The results are examined in relation to the Tayside pilot area in order to draw out any key regional variations in likely future climate change, and the possible implications of these. Tayside lies within the 'East Scotland' region, as defined in the SNIFFER study.

Temperature

- The greatest increases in average temperature have taken place during spring and winter and the largest are in southern and eastern Scotland in winter.
- There are no significant spatial trends in the 24 hour minimum temperature.
- Daily temperature range: Only east Scotland has demonstrated a fall in average daily temperature range.
- Heating degree days represent those days when heating of homes and businesses is required and represents the difference between internal and average outside temperature. The spatial distribution is similar to that for average temperatures, with the southerly, coastal and lower lying areas showing the greatest reductions in days when heating is likely to be required.
- Growing degree days records the number of days where the mean temperature is above a threshold representing the temperature at which plants are photosynthetically active (taken to be 5°C). All areas show an increase in growing degree days.
- Length of the growing season based on the period of time between the first time mean temperatures rise above 5°C on five consecutive days and the first time mean temperatures fall below 5°C on five consecutive days. East Scotland has the shortest growing season by a few days, however all regions have seen an increase in the length of the growing season. The length of the growing season has increased the least in the more mountainous upland areas.
- Data on the start and end of the growing season show an increase in both the start and end of the growing season, with the greatest increase in the west.
- Extreme temperature range: No clear trend is identified.
- Length of summer heat wave and winter cold spell show an increase in the length of both across the three regions, with a reduction in the length of cold spells in winter in both east and west Scotland.
- Air Frost: Days of air frost show an overall decrease across spring, autumn and winter. The largest changes include some of the islands and upland areas.
- Ground Frost: Days of ground frost show an overall decrease across Scotland, with an increase in Orkney and Shetland.
- Early and late season frosts: The data shows an overall increase in the length of the frost free season.

Figure 3.15 Climate trends: average temperature

Patterns of change in average temperature (in ºC) between 1961 and 2004 for each season (Source: SNIFFER A handbook of climate trends across Scotland, 2006)



Precipitation

- Higher average annual precipitation throughout Scotland.
- Clear upward trend in winter precipitation. The eastern areas show the least increase in winter precipitation, however in autumn the east is the only region to become wetter.
- Snow cover: The percentage change in days of snow cover shows an overall reduction in each region across all seasons, with the largest percentage change in spring and autumn, however the greatest change is in the west.
- Days of heavy rain each year: East Scotland is drier than north and west Scotland and shows the lowest level of increase in precipitation annually and across each season.

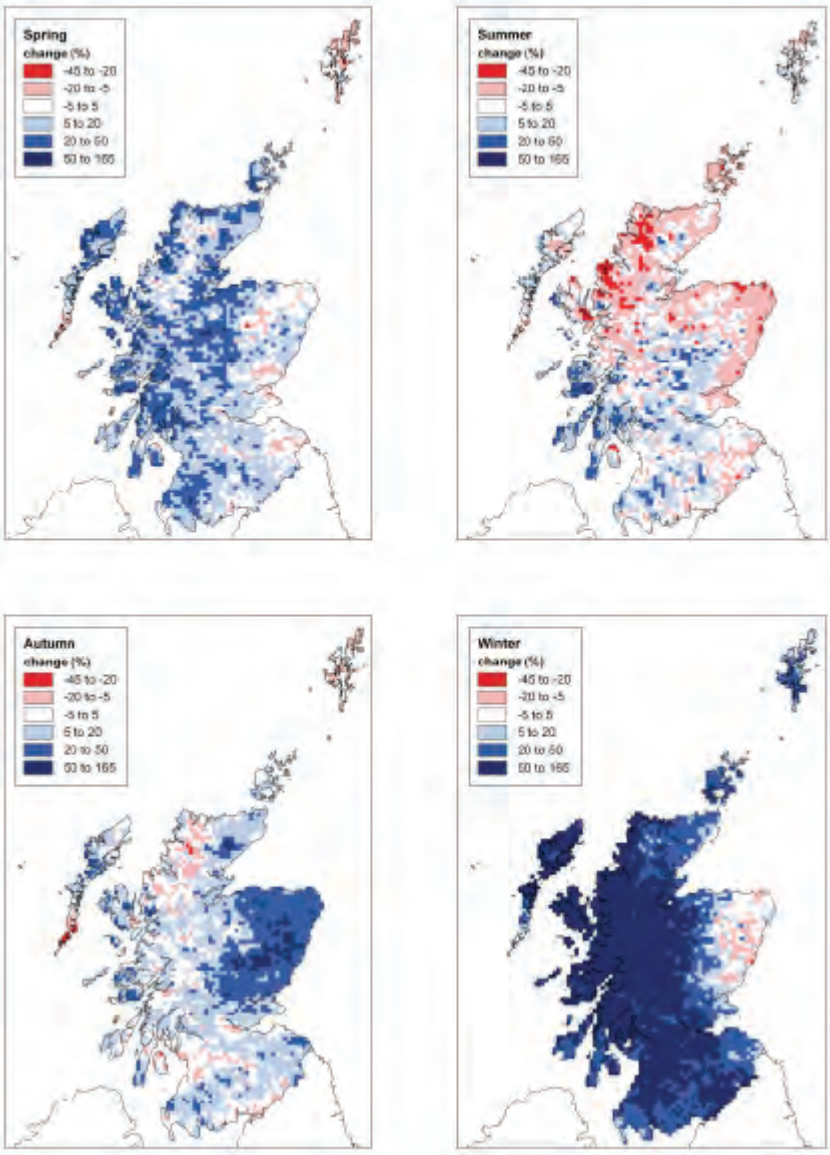
- Number of consecutive dry days: There has been an increase in the number of consecutive dry days in each year in the east.

- Average rainfall intensity: A trend in increasing rainfall intensity in east and west Scotland.

- Maximum five-day precipitation total: A clear increasing trend, with an increase across most of Scotland.

Figure 3.16 Climate trends: precipitation

Patterns of change in precipitation totals (as a percentage) between 1961 and 2004 for each season. (Source: SNIFFER A handbook of climate trends across Scotland, 2006)

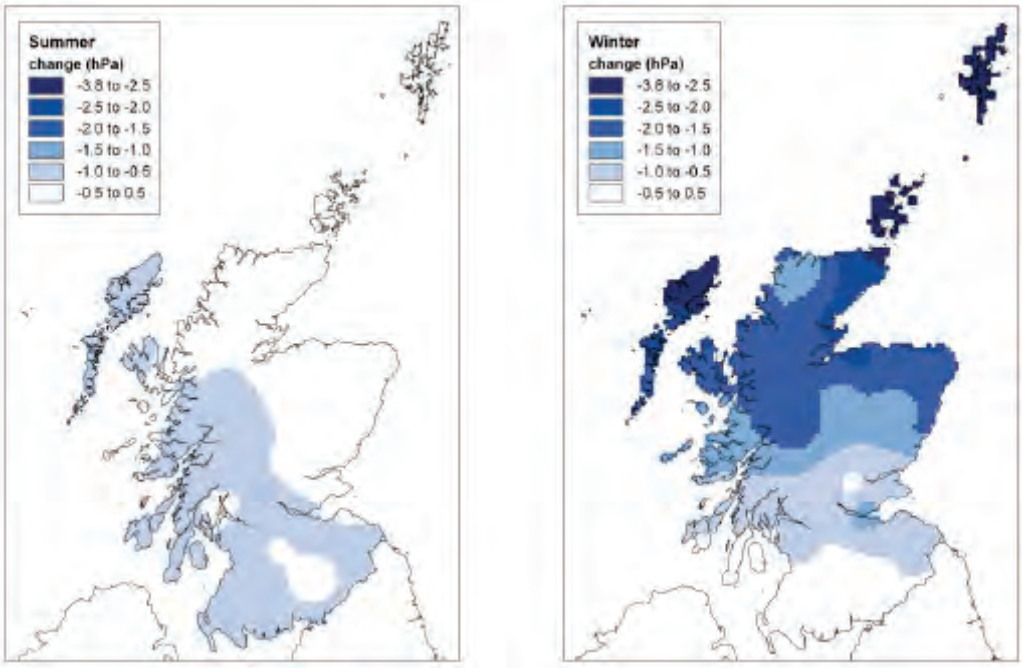


Air pressure related variables

- Average air pressure at sea level: no clear trends.
- Average wind speed each year: Based on the average wind speed at three Scottish recording stations, the records for Leuchars show a trend of decreasing average wind speeds in the last forty years.
- Days of gale each year: No clear trend.

Figure 3.17 Climate trends: sea level air pressure

Patterns of change in the average sea level air-pressure (in hPa) each year, between 1961 and 2004, for the summer and winter quarters (Source: SNIFFER A handbook of climate trends across Scotland, 2006)

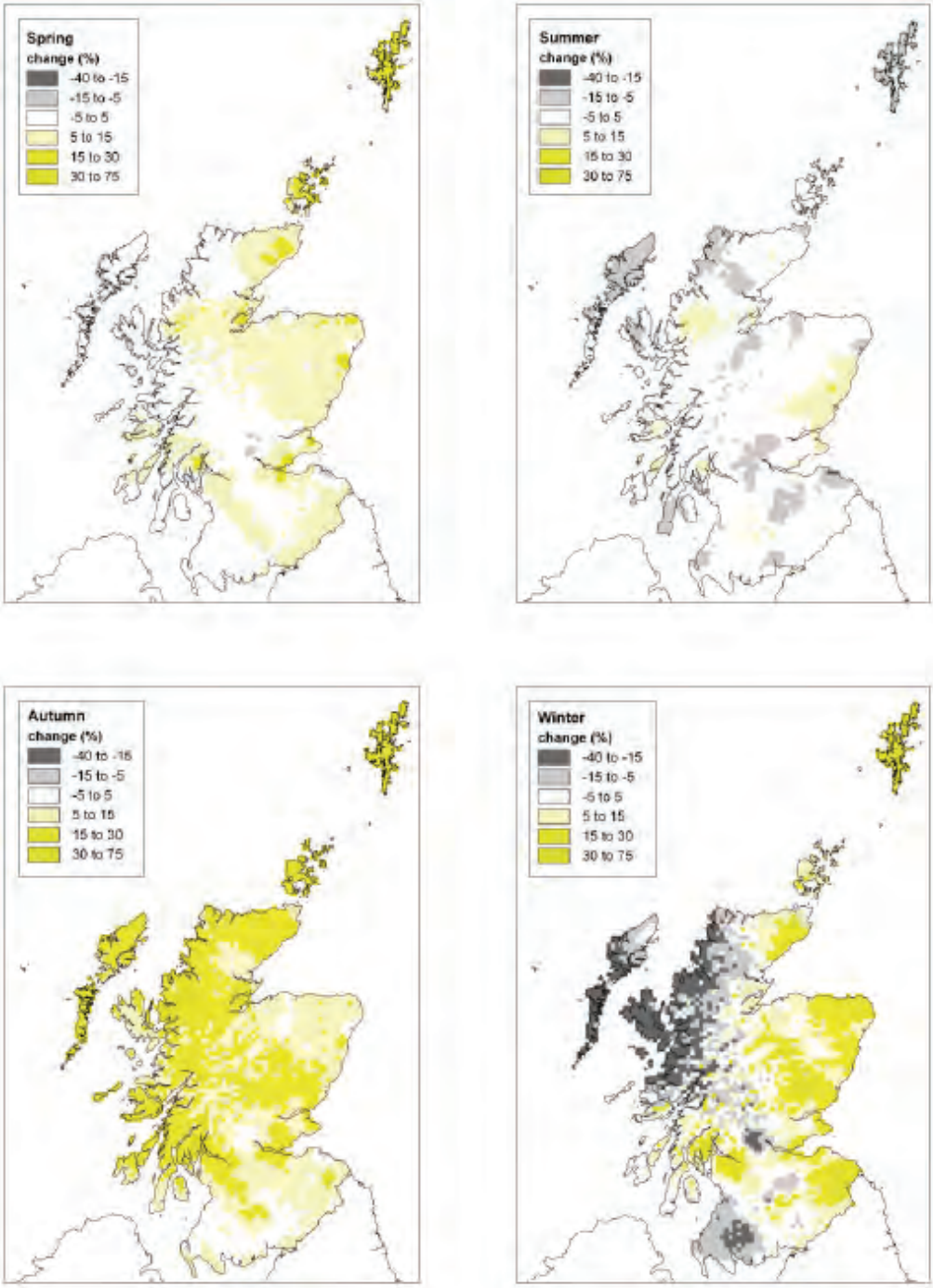


Sunshine related variables

- Sunshine hours: No clear trends, however east Scotland has become sunnier in all three seasons since 1961. In eastern Scotland, greatest increases in autumn and winter, and across parts of Fife and Angus.
- Cloud cover: No obvious trends.

Figure 3.18 Climate trends: sunshine hours

Patterns of change in sunshine hours (as a percentage), between 1961 and 2004, for each season (Source: SNIFFER A handbook of climate trends across Scotland, 2006)



Summary

3.31. The SNIFFER climate trends data provides an indication of how climate changes may vary across Scotland, and in particular how regional variations in Scotland may affect the case study area. The SNIFFER climate trends are based on historical data, and have a finer grain of detail whereas the UKCIP climate change scenarios look to the future and are at a coarser scale.

4. SCOTLAND-WIDE PATTERN OF CLIMATE RELATED CHANGE

INTRODUCTION

4.1. This part of the report sets out the results of the analysis. It describes the potential landscape changes (see Appendix 5) at a national level based on the climate related landscape changes listed in Appendix 5, Table 5.5.

LANDSCAPE CHANGES – NATIONAL LEVEL

4.2. This section provides a descriptive overview of the key climate related landscape changes that were explored at a national level. It is based on the original matrix of landscape changes identified from the literature review and is drawn together under a series of topic area headings. The spatial distribution of a number of changes is mapped and described in relation to the 21 Natural Heritage Zones (see Figure 4.1 and paragraph 4.6). Table 4.1 lists the changes mapped and the data sources used as the basis for this mapping.

4.3. Historic Land Use Assessment (HLA) data could be used in future assessment processes to inform the impact of climate related landscape change on the historic environment. Although historic influences on the landscape are incorporated within the process of landscape character assessment, HLA data provides an additional layer of information which can be used to interpret the landscape. HLA data can be used to provide a picture of the degree of change which a landscape has experienced and whether the existing landscape is likely to include a high proportion of historic features or to have been significantly modified.

4.4. The national maps illustrate the potential locations of areas affected by the climate related landscape changes identified. The maps are based on likely climate trends for 2050, based on the UKCIP02 medium-high emissions scenario. The distribution of landscape features on which the mapping is based draws on the current distribution of these features, and does not take account of future change. The maps provide an indication of the potential degree of landscape change, but do not represent predictions. The mapping has been carried out for a selection of potential landscape changes and is not exhaustive, but provides an illustration of possible patterns of change within the limitations of the study. There is significant scope to further explore the application of the mapping methodology developed, and for the identification of additional data sources.

4.5. The mapping is based primarily on direct impacts of climate change, as there are greater difficulties in mapping mitigation and adaptation impacts due to the lack of data on the locations where these may occur and influence of policy. Exceptions to this include the mapping of areas where pressure for wind energy development, is likely to be greatest. Table 4.1 provides a list of the changes mapped. The table identifies the certainty associated with the climate change variable, and also if the change is a direct impact, an adaptation response or mitigation action. A greater level of certainty can be attributed to direct changes which result from climate change variables with a high level of certainty. A lower level of certainty can be attributed to landscape changes which result from adaptation responses, as there are a greater number of variables which could influence the outcome of these, however some may already be in place through existing policy. Mitigation responses may have a higher or lower level of certainty depending on the existing policy framework.

Table 4.1 Landscape changes mapped at a national level including data sources used for mapping

						Timeframe (yrs)				
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	<10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Forests and woodlands	62	Mixed broadleaves – species mix – increase in beech and sycamore – outcompeting oak, ash and elm resulting in changing woodland composition – loss of native species, increase in new species	Figure 4.2a and 4.2b	Broadleaves, National Inventory of Woodlands & Trees (NIWT)	T2: Autumn temperature change (TEMP)				High	Direct, high
Forests and woodlands	63	Damage to woodlands caused by summer drought resulting in early leaf fall and dying trees	Figure 4.3a and 4.3b	National Inventory of Woodlands & Trees (NIWT)	P2: Average decrease in summer precipitation (PREC)				High	Direct, high
Forests and woodlands	64	Damage to woodlands caused by winter flooding resulting in early leaf fall and dying trees especially on poorly draining soils and where linked to summer drought – most evident in eastern Scotland	Figure 4.4a and 4.4b	National Inventory of Woodlands & Trees (NIWT)	P1: Average change in winter precipitation (PREC)				High for precipitation, medium for soil moisture	Direct, high

Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	Timeframe (yrs) <10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Forests and woodlands	65	Wind throw damage to woodland caused by extreme winds, exacerbated by wetter winters	Figure 4.5a and 4.5b	National Inventory of Woodlands & Trees (NIWT)	P1: Average change in winter precipitation (PREC) W1: average wind speed change in the winter (WIND)				High for precipitation, medium for soil moisture, low for windspeed (averaged as medium)	Direct, high
Forests and woodlands	66	Fire damage and prevention measures in response to increased risk of fire damage to woodlands (greatest in eastern and southern Scotland), linked to increase in recreation activity	Figure 4.6a and 4.6b	National Inventory of Woodlands & Trees (NIWT) All areas except remote, SE Urban-Rural classification	T2: Autumn temperature change (TEMP) P2: Average decrease in summer precipitation (PREC) T4: change in daily max. temperature in Summer-Autumn (TMAX)				High	Direct, high

						Timeframe (yrs)				
Topic	**Appendix 5, Tables 5.4 and 5.5)**	**Landscape change**	**Map figure number**	**Topographic\ Landscape data**	**Climate\Flooding data**	**<10**	**10-100**	**100+**	**Climate change certainty (for climate change variable)**	**Landscape change certainty (direct or adaptation or mitigation)**
Forests and woodlands	48	Riparian woodlands – more frequent and extensive with increase in lowland flooding – a part of flood management	Figure 4.7a and 4.7b	National Inventory of Woodlands & Trees (NIWT)	SEPA Fluvial Flooding risk SEPA Coastal Flooding risk				High	Direct and adaptation, high
Freshwater systems	1	Flood management comprising – upland land management (closing drains, woodland establishment), temporary flood storage, diversion of flood flows away from urban areas, green roofs, SUDS, one way valves, raising floor levels, increasing drain capacity, flood resilient design and materials, doubling flood defences	Figure 4.8a and 4.8b	Urban, SE Urban-Rural classification Moorland, Landcover	P1: Average change in winter precipitation (PREC) SEPA Fluvial Flooding risk				High	Adaptation, medium

						Timeframe (yrs)				
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	<10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Freshwater systems	5	Increase in river flooding severity and frequency, especially in Western Scotland. Events resulting in damage to property, crops, habitats. Human response of flood protection, catchment management.	Figure 4.9a and 4.9b	SEPA Fluvial Flooding risk	P1: Average change in winter precipitation (PREC)				High	Direct, high
Freshwater systems	6	Flood damage to river banks and flood plains resulting in scouring and erosion of river valleys and floodplains and deposition downstream	Figure 4.10a and 4.10b	SEPA Coastal Flooding risk SEPA Fluvial Flooding risk	P1: Average change in winter precipitation (PREC)				High	Direct, high
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.11	Sea level rise	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Sea level rise data				n/a	Direct

						Timeframe (yrs)				
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	<10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.12	Surge risk	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Surge risk data				n/a	Direct
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.13	Wave fetch	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Wave fetch data				n/a	Direct
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.14	Combined risk	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Combined risk data				n/a	Direct
Coast, estuaries and sea	3	Flooding in inner estuaries and erosion of mudflats and shingle banks	Figure 4.15a and 4.15b	Estuaries, digitised Intertidal Area, Landcover Mudflats-saltmarsh, landcover	SEPA Coastal Flooding risk P1: Average change in winter precipitation (PREC) W1: average wind speed change in the winter (WIND)				High	Direct, high

						Timeframe (yrs)				
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	<10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Urban	9	Stress on green infrastructure caused by summer drought and high temperatures, winter rainfall, pests and disease and increased use resulting in damage or modification of urban greenspace	Figure 4.16a and 4.16b	Urban-Peri Urban, SE Urban-Rural classification	P2: Average change in summer precipitation (PREC) T2: Autumn temperature change (TEMP)				High	Direct, high
Urban	8	Increased demand and use of green and blue infrastructure in urban areas. Increased provision, use and management.	Figure 4.18a and 4.18b	Urban-Peri Urban, SE Urban-Rural classification	T2: Autumn temperature change (TEMP) T4: change in daily max. temperature in Summer-Autumn (TMAX)				High	Adaptation. medium

						Timeframe (yrs)				
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	<10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Tourism	14	Changing tourism products, destinations. Increasing provision of outdoor recreation infrastructure and associated facilities. Including increased erosion in upland areas, and increased pressure on coastal resources	Figure 4.17a and 4.17b	All areas except remote, SE Urban-Rural classification	T1: Average annual temperature increase (TEMP) T2: Autumn temperature change (TEMP) T3: Increased difference between summer-winter (TEMP) P2: Average decrease in summer precipitation (PREC) C1: Increased cloud cover (TCLW) SN1: Change in snowfall (SNOW) T4: change in daily max. temperature in Summer-Autumn (TMAX)				High (for temperature and precipitation predictions) Medium for snow cover and low for cloud cover	Adaptation, medium

Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	Timeframe (yrs) <10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Infrastructure	19c	Further development of wind energy at domestic and commercial scales	Figure 4.19	Scottish Natural Heritage Windfarm Footprint and Turbine datasets					n/a	Mitigation, high
Infrastructure	18	Increase in water infrastructure associated with export resulting in new large reservoirs, aqueducts etc	Figure 4.20a and 4.20b	Upland areas (200m+) in the Borders, OS Panorama height data	P1: Average change in winter precipitation (PREC) P2: Average decrease in summer precipitation (PREC)				High	Adaptation, High
Infrastructure	21	Biomass power plants resulting in industrial type buildings in rural locations	Figure 4.21	Coniferous forests, NIWT Arable Farmland, digitised farm types					n/a	Mitigation, medium
Habitats (natural and semi natural)	72	Damage to peatland – quicker erosion, gullying and bogbursts	Figure 4.22a and 4.22b	Peat, Landcover	P1: Average change in winter precipitation (PREC)				High	Direct, high

Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	Timeframe (yrs) <10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Habitats (natural and semi-natural)	39	Changes in peat accumulations – growth where temp and rainfall increase, decay where rainfall decreases	Figure 4.23a and 4.23b	Blanket Bog, Landcover Peat, Landcover	T1: Average annual temperature increase (TEMP) P1: Average change in winter precipitation (PREC) P2: Average decrease in summer precipitation (PREC)				High	Direct, high
Habitats (natural and semi-natural)	36	Biodiversity – more rapid decomposition and nutrient recycling – affecting nutrient status of some habitats – montane and moorland – resulting in invasion of grasses	Figure 4.24a and 4.24b	Upland areas (600m+), OS Panorama height data Heather Moorland, Landcover	T2: Autumn temperature change (TEMP)				High	Direct, high
Habitats (natural and semi-natural)	31	Loss of arctic-alpine species resulting in changing micro character of highest uplands	Figure 4.25a and 4.25b	Upland areas (600m+), OS Panorama height data	T2: Autumn temperature change (TEMP)				High	Direct, high

Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	Timeframe (yrs) <10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Habitats (natural and semi-natural)	27	Impact on heather moorlands from damage through fire and change in extent and distribution	Figure 4.26a and 4.26b	Heather Moorland, Landcover	T1: Average annual temperature increase (TEMP) T2: Autumn temperature change (TEMP) T3: Increased difference between summer-winter (TEMP)				High	Direct, high
Agriculture	41	Shelter belts to shade and shelter livestock and crops in farmed areas – especially those with livestock and with sensitive crops	Figure 4.27a and 4.27b	Intensive farming (all areas except LFA), digitised farm types	T2: Autumn temperature change (TEMP) P1: Average change in winter precipitation (PREC) W1: average wind speed change in the winter (WIND)				High (for temperature and precipitation) Low for windspeed	Adaptation, medium

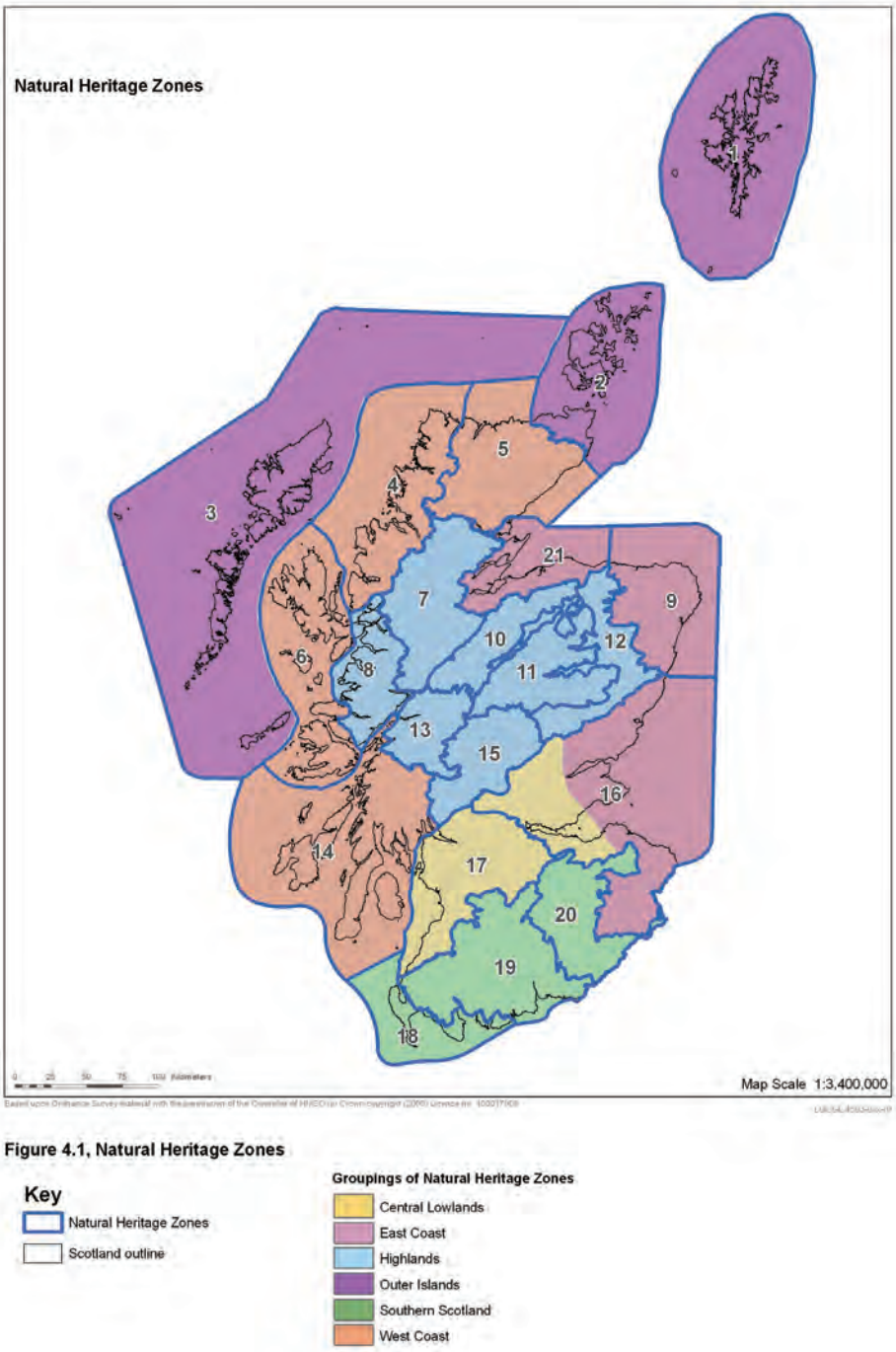
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	Timeframe (yrs) <10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Agriculture	43	Loss of field boundary and other farmland trees due to storm damage and stress resulting in more open farmland landscapes	Figure 4.28a and 4.28b	Intensive farming (all areas except LFA), digitised farm types	T1: Average annual temperature increase (TEMP) P1: Average change in winter precipitation (PREC) P2: Average decrease in summer precipitation (PREC) W1: average wind speed change in the winter (WIND)				High (for temperature and precipitation) Low for windspeed	Direct, high
Agriculture	75	Flood damage to agricultural crops – from rainfall, sea and flood storage projects	Figure 4.29a and 4.29b	Intensive farming (all areas except LFA), digitised farm types	P1: Average change in winter precipitation (PREC) SEPA Fluvial Flooding risk SEPA Coastal Flooding risk				High for precipitation, medium for extreme sea level	Direct and adaptation, high

						Timeframe (yrs)				
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	<10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Agriculture	87	Arable – potential increase in productivity if nitrogen and soil moisture – requirement for greater on-farm storage of crops resulting in new, larger farm buildings	Figure 4.30a and 4.30b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	T2: Autumn temperature change (TEMP)				High	Direct and adaptation, high
Agriculture	88	Increased requirement for irrigation of arable resulting in irrigation infrastructure – sprays and booms	Figure 4.31a and 4.31b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	T3: Increased difference between summer-winter (TEMP) P2: Average decrease in summer precipitation (PREC) SM1: Change in soil moisture during summer-autumn (SMOI)				High	Adaptation, medium

						Timeframe (yrs)				
Topic	Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Topographic\ Landscape data	Climate\Flooding data	<10	10-100	100+	Climate change certainty (for climate change variable)	Landscape change certainty (direct or adaptation or mitigation)
Agriculture	94	Sowing and harvesting affected by wetter winters – possible shift from autumn to spring sowing resulting in more winter stubbles or move to cover crops	Figure 4.32a and 4.32b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	P1: Average change in winter precipitation (PREC)				High	Adaptation, medium
Agriculture	98	New or novel crops and potential conversion from pasture to arable	Figure 4.33a and 4.33b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	T2: Autumn temperature change (TEMP)				High	Adaptation, medium

4.6. Natural Heritage Zones were defined by SNH as part of the Natural Heritage Futures[1] programme and represent areas with similar natural heritage characteristics which contribute a distinctive identity resulting from the interaction of geology, landforms, landscapes, wildlife and land use. These are listed and illustrated in Figure 4.1, below.

Figure 4.1: Natural Heritage Zones



1 Shetland

2 N Caithness and Orkney

3 Western Isles

4 NW Seaboard

5 Peatlands of Caithness and Sutherland

6 Western Seaboard

7 Northern Highlands

8 Western Highlands

9 NE Coastal Plain

10 Central Highlands

11 Cairngorm Massif

12 North East Glens

13 Lochaber

14 Argyll West and Islands

15 Breadalbane and East Argyll

16 Eastern Lowlands

17 West Central Belt

18 Wigtown Machairs and Outer Solway

19 W. Southern Uplands and Inner Solway

20 Border Hills

21 Moray Firth

[1] http://www.snh.org.uk/strategy/NHF00.asp, http://www.snh.org.uk/futures/Data/index.htm

Mapping Methodology

4.7. A series of maps have been produced which illustrate the potential degree of a range of climate related landscape changes. The main stages in this process involved the mapping of the distribution of landscape features within 5km squares, and combining these with identified climate data. For example, the mapping of potential damage to woodland caused by summer drought first mapped the percentage of woodland cover within 5km squares and combined this with the climate data on summer precipitation change (based on 50km squares).

4.8. The resulting maps illustrate potential landscape change at a 5km grid square resolution, which incorporates the UKCIP02 climate data. Greater accuracy could be achieved through the use of finer grain climate data, as the current 50km grid squares are a coarse representation of the climate variables and adjacent grid squares may have sharply contrasting values, which do not reflect the geographical influences on the ground.

4.9. For each climate variable the degree of change predicted by UKCIP02 has been put onto a common scale, stratified between maximum and minimum values. Where more than one climate variable is identified as influencing the landscape change, the average of the percentage change for the variables was used. For some climate variables the difference between these values is small, and for others it is larger.

4.10. The maps resulting from this analysis are discussed under each topic in the 'mapped analysis' section. In most cases, maps are paired, with the first showing the current distribution of the landscape 'feature' in question and the second showing the distribution of the degree of change to that feature as a result of climate change. The second map uses colour coding to indicate where changes would be least (blue), moderate (yellow) and greatest (red). White areas on both maps show where the landscape feature in question is currently not present.

4.11. The maps include a summary table illustrating the certainty of the climate data, the timescales of the landscape impact and the data sources used for the maps. The certainty of the climate data, is based on the UKCIP data and likely timescales for landscape impacts were made by professional judgement. The certainty attributed to the data sources reflects professional judgement of the certainty of that data source in representing the landscape change being mapped. Uncertainty can reflect both direct impacts, such as changes to ecosystems, and adaptation or mitigation responses.

Forests and Woodlands

Current Patterns

4.12. Woodlands cover 17.1% of Scotland's land area, of which native tree species comprise 29% of the total forest area. The highest densities of forests and woodlands are found in Argyll and Bute, Dumfries and Galloway, around Inverness and the Moray Firth. Woodlands provide an important recreation resource both for the wider tourism market and for local communities. Significant progress has been made in improving the design and location of forests, enhancing their role within the landscape and increasing diversity. The Scottish Forestry Strategy (2006)[2] sets a target of achieving a 25% woodland cover by 2050.

[2] http://www.forestry.gov.uk/pdf/SFS2006fcfc101.pdf/$FILE/SFS2006fcfc101.pdf

Future Change

4.13. Changing patterns of precipitation and temperature, combined with potential changes in weather patterns such as increased storminess and severe weather events have potential impacts on the forest and woodland resource. The Forestry Commission Scotland 'Climate Change Action Plan 2009 – 2011'[3] promotes a climate change sensitive approach to sustainable forest management, and identifies a comprehensive range of mitigation and adaptation strategies for Scotland's forests and woodlands. The landscape implications of such changes include:

- woodland expansion to increase carbon sequestration (mitigation), to support biodiversity priorities and enhance the quality of the environment;
- increase in farm woodland (shelter belts, woodland component of habitat networks, sequestration and fuel) (adaptation and mitigation), including birch in the central and eastern Highlands and eastern Scotland, but a potential loss of existing field boundary trees, and field boundaries due to stress (temperature, changes in rainfall, storm damage) (impact);
- use of broader range of non-native species in productive conifer and broadleaf forests, where compatible with biodiversity, and greater diversity to improve resilience to pests and climate (adaptation). There is also an intention to increase the biodiversity contribution of woodlands of plantation origin for structural and species diversity, and their value as part of the forest habitat network;
- utilising woodland to contribute to environmental protection through expansion of wet woodlands, especially where they contribute to flood management, use of woodland for slope stabilisation and protecting river banks from erosion (adaptation);
- increase in woodland managed on continuous cover (Low Impact Silvicultural System) basis (adaptation);
- potential benefits for pinewoods, especially in west and central Highlands, though potential for colonisation by native broadleaf. In addition, it is likely that some commercially grown species will become less suited to condition in the east of Scotland (impact);
- impact on Atlantic oakwoods as a consequence of milder winters, warmer summers and more frequent and severe storms. Possible colonisation by native tree species and also beech (impact);
- in general, non-native broadleaves including beech and sycamore outcompeting oak, ash and elm (impact);
- stress caused by summer drought or combination of summer drought and winter waterlogging (most likely in eastern Scotland, depending on soils) (impact);
- increased damage caused by fire, storm damage, and pests and disease (impact).

Mapped Analysis

- *Mixed broadleaf change (Figure 4.2a and 4.2b)*: These maps show the current distribution of broadleaf woodlands and where there is greatest potential for

[3] http://www.forestry.gov.uk/pdf/fcfc124.pdf/$FILE/fcfc124.pdf

climate change to affect their species mix. The analysis indicates that most areas will experience relatively little change. The principal exception is the central and western Highlands including glens just to the north of the Highland Boundary Fault, parts of Argyll and areas to the south west of Inverness where change could be more extensive. This change is judged to have a high level of certainty and likely to occur from the medium term onwards.

- *Woodland damage by summer drought (Figure 4.3a and 4.3b)*: These maps show the current distribution of forests and woodlands and those areas where there is greatest potential for reductions in summer rainfall to have an impact upon them. The analysis shows that in most areas the effects could be relatively limited. There are, however, particular areas where this analysis suggests that the impacts of summer drought could become more significant. These include parts of the southern uplands in Dumfries and Galloway and the more westerly parts of the Scottish Borders, Argyll, the fringes of the Cairngorm Massif and areas around Inverness. This pattern of change broadly coincides with those areas where forests and woodlands are most concentrated. This change is judged to have a high level of certainty and likely to occur from the medium term onwards.

- *Woodland damage by winter flooding (Figure 4.4a and 4.4b)*: These maps show the current distribution of forests and woodlands and those areas where there is likely to be the greatest increase in winter rainfall. Again, the analysis shows that in most areas the effects could be relatively limited and that those areas where greatest change is likely coincide with key concentrations of forests and woodland. These include parts of the southern uplands in Dumfries and Galloway and the more westerly parts of the Scottish Borders, Argyll, the fringes of the Cairngorm Massif and areas around Inverness. This change is judged to have a high level of certainty and likely to occur from the medium term onwards.

- *Woodland damage caused by extreme winds and wet winters (Figure 4.5a and 4.5b)*: These maps show the current distribution of forests and woodlands and those areas where a combination of potential extreme winds and wet winters damage them. The analysis shows a somewhat different pattern to those described above with the greatest potential changes shown in more 'exposed' peripheral areas such as the southern uplands, Argyll (including the Kintyre peninsula and Mull), and the north eastern flanks of the Cairngorms Massif. This change is judged to have a moderate to high level of certainty and likely to occur from the medium term onwards.

- *Risk of fire damage to woodland (Figure 4.6a and 4.6b)*: These maps show the current distribution of forests and woodlands in those areas of Scotland not classified as 'remote' in the Scottish Executive (now Scottish Government) urban-rural classification and those areas likely to experience warmer and drier summers and autumns and therefore at greater risk from human induced fire damage. The maps suggest a pattern of impact that broadly reflects the existing distribution of woodland and forests in this area, with particular concentrations in Dumfries and Galloway and the Scottish Borders, and in those parts of the Highlands most accessible from the Central Belt, Aberdeen and Inverness. This change is judged to have a high level of certainty and likely to occur from the medium term onwards.

- *Riparian woodlands (Figure 4.7a and 4.7b)*: Increased flooding risk and woodland may result in the creation of new areas of woodland along river corridors and within the wider catchment. These maps show the current distribution of forests

and woodlands together with SEPA's coastal and fluvial flood risk areas. The analysis suggests a concentration of activity within the lowland parts of Scotland including Stirling, Fife, Angus and Moray together with areas along the Solway Firth. There is also likely to be an expansion of woodland within Highland glens and the middle and upper parts of catchment where this helps reduce downstream flood risks. This change is judged to have a high level of certainty and likely to occur from the short term onwards.

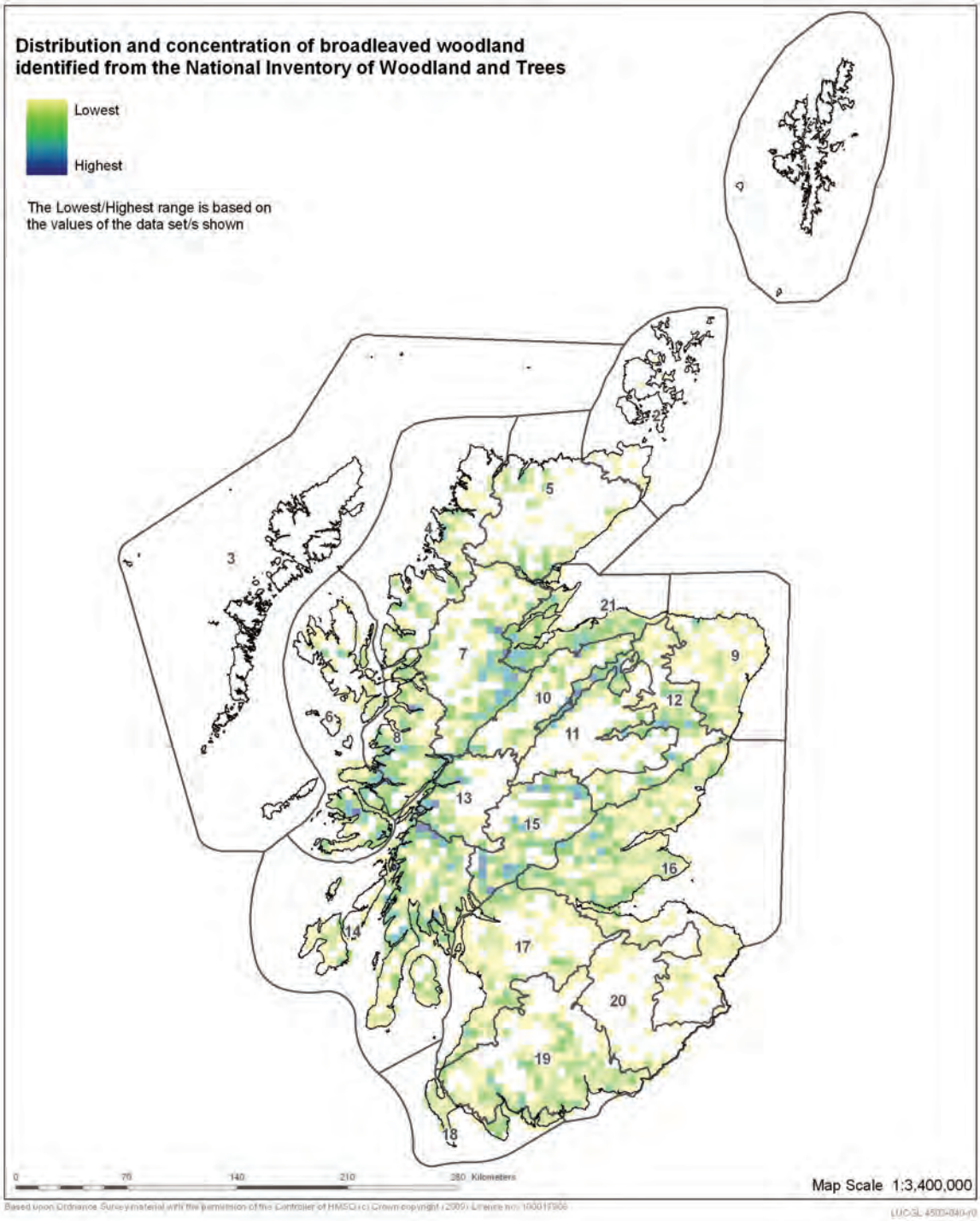


Figure 4.2a, Change 62

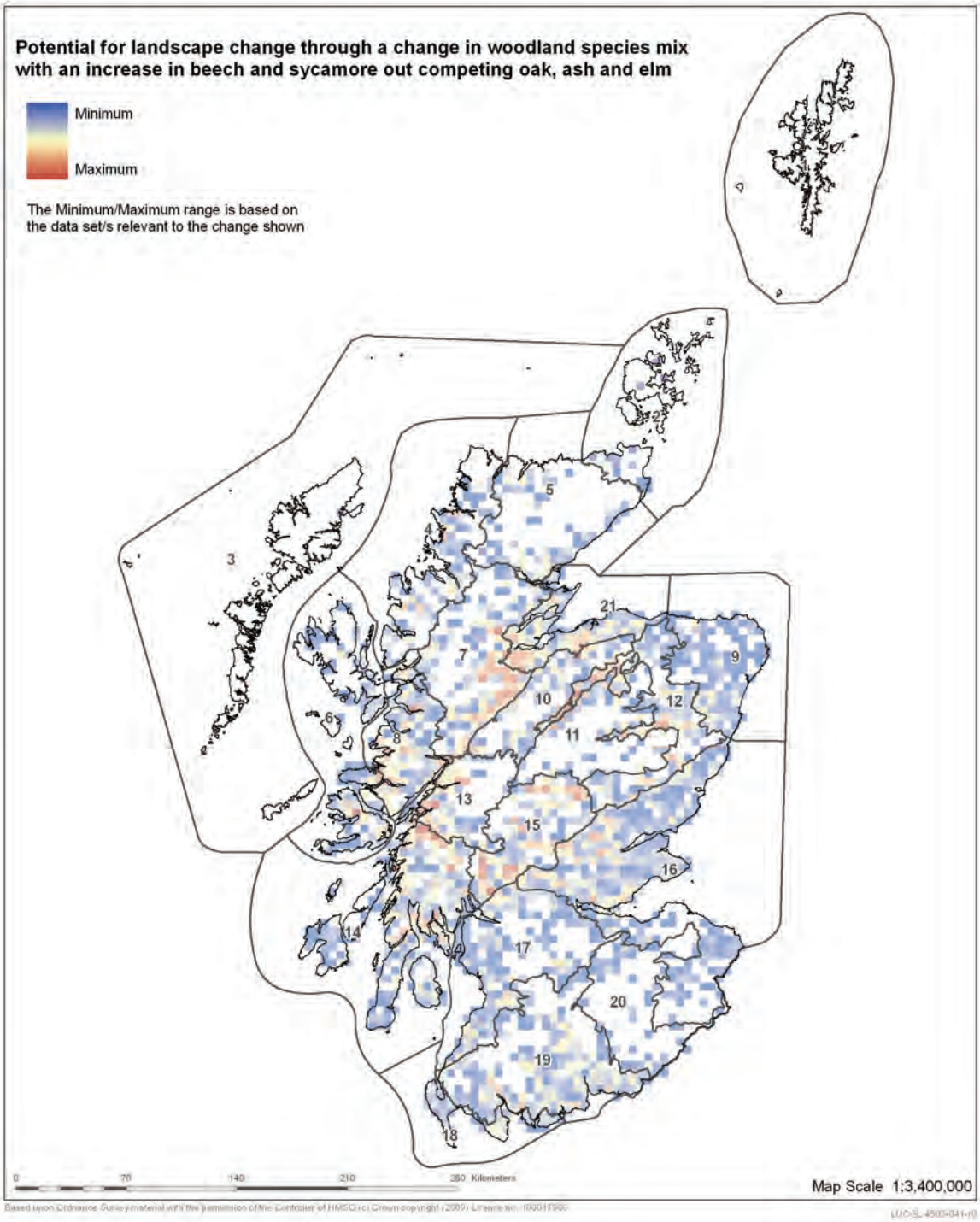


Figure 4.2b, Change 62

- Change distribution based on comparison of broadleaved forestry areas identified from the National Inventory of Woodland and Trees with climate change variable T2: Autumn temperature change

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

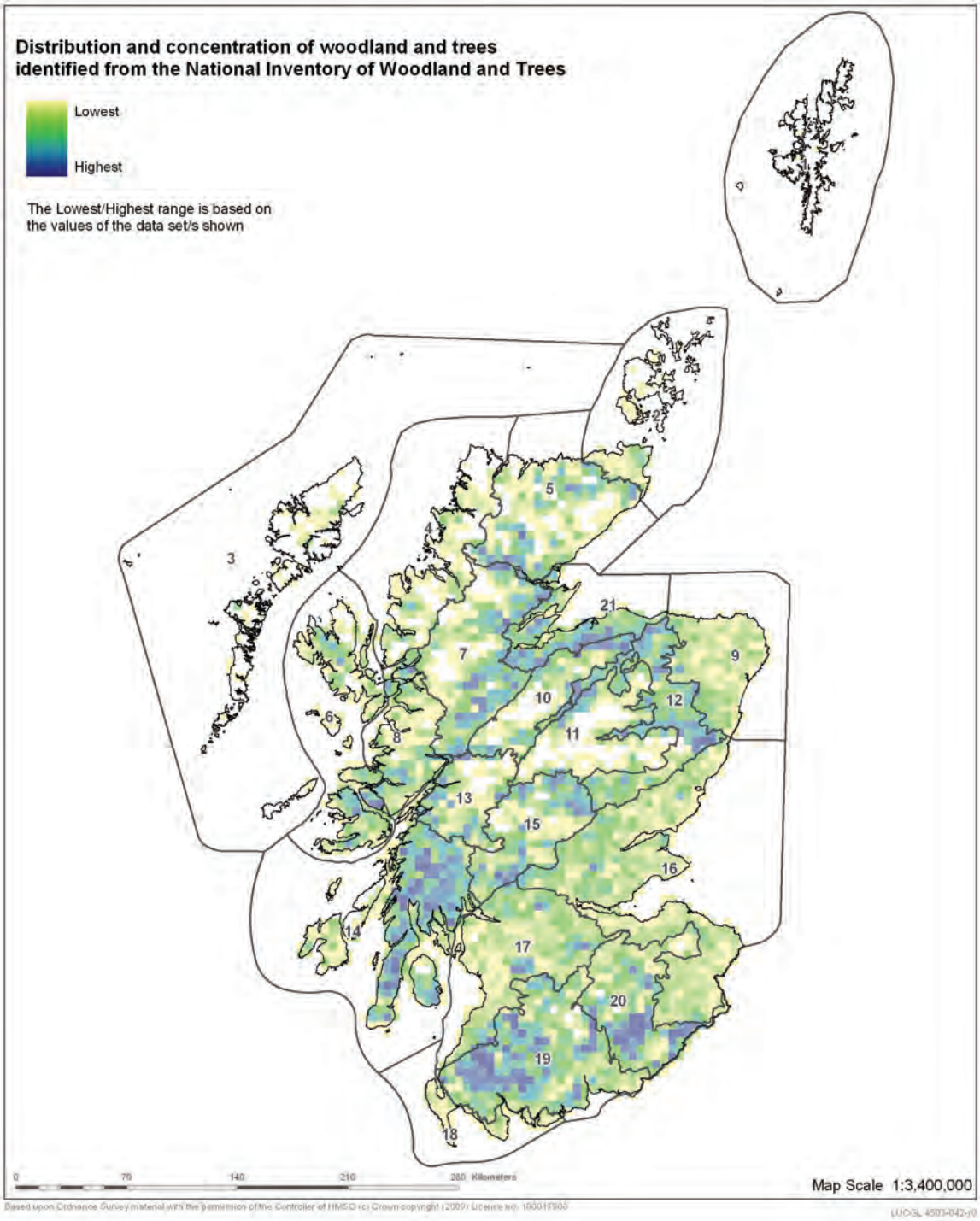


Figure 4.3a, Change 63

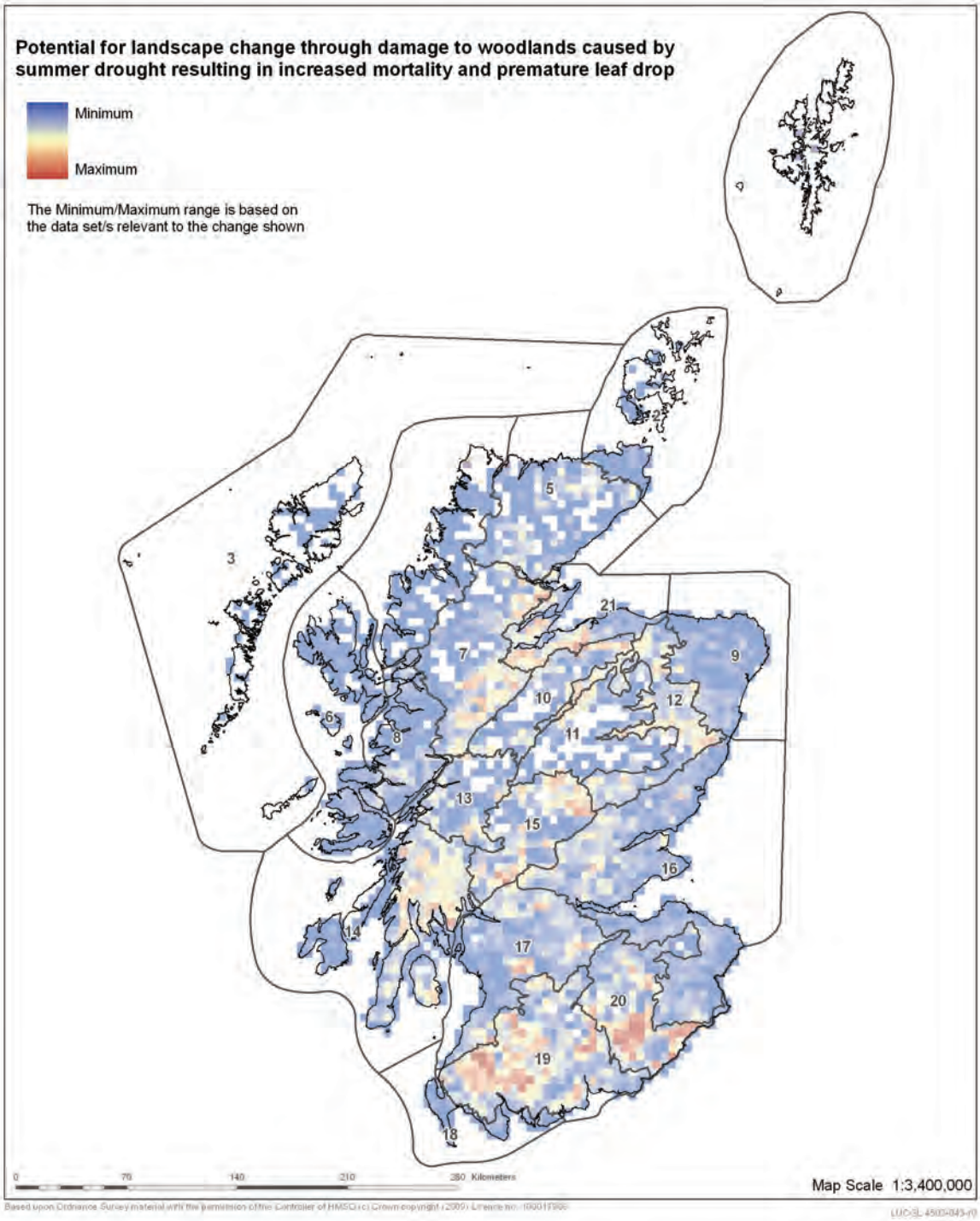


Figure 4.3b, Change 63

- Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with climate change variable P2: Average decrease in summer precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

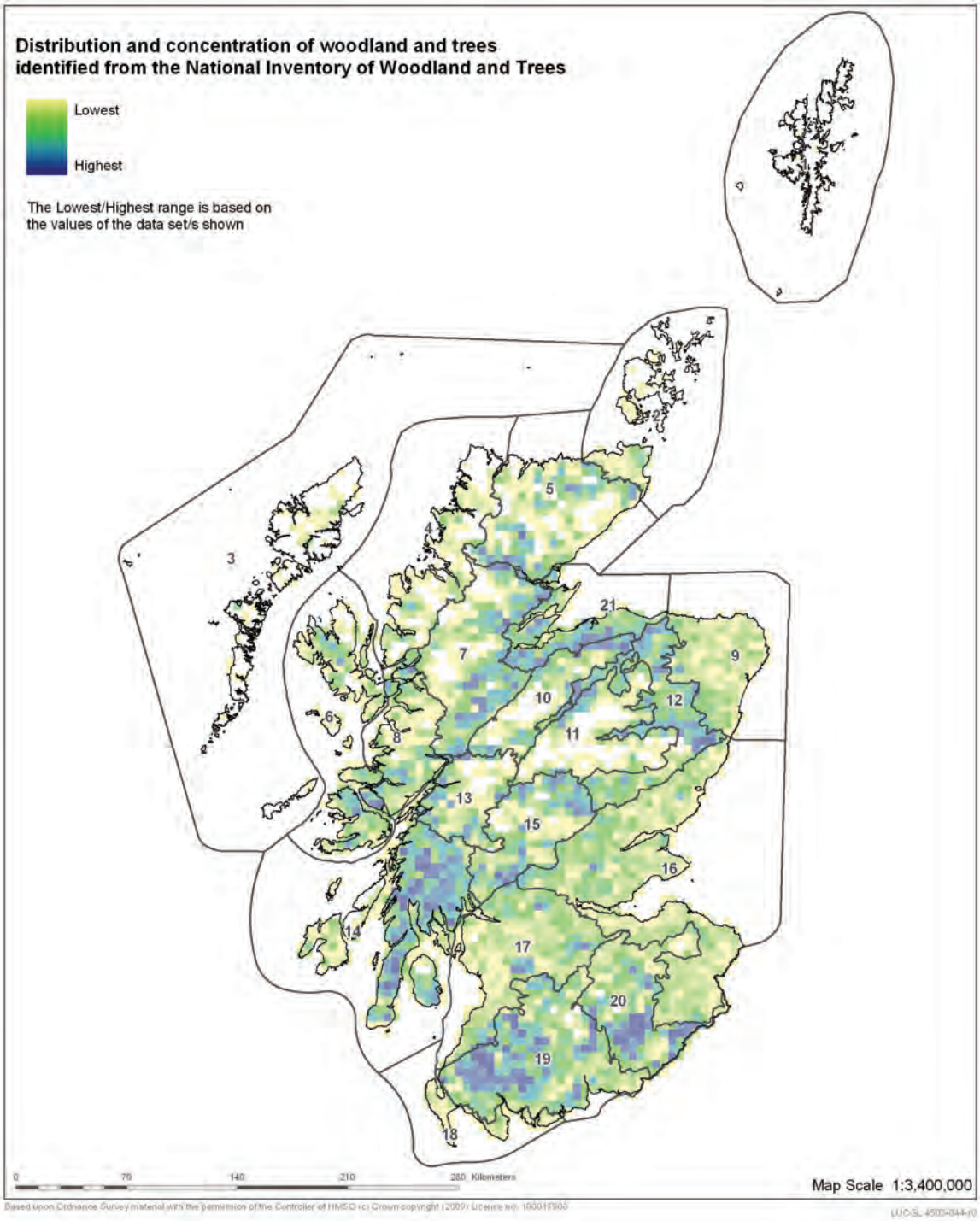


Figure 4.4a, Change 64

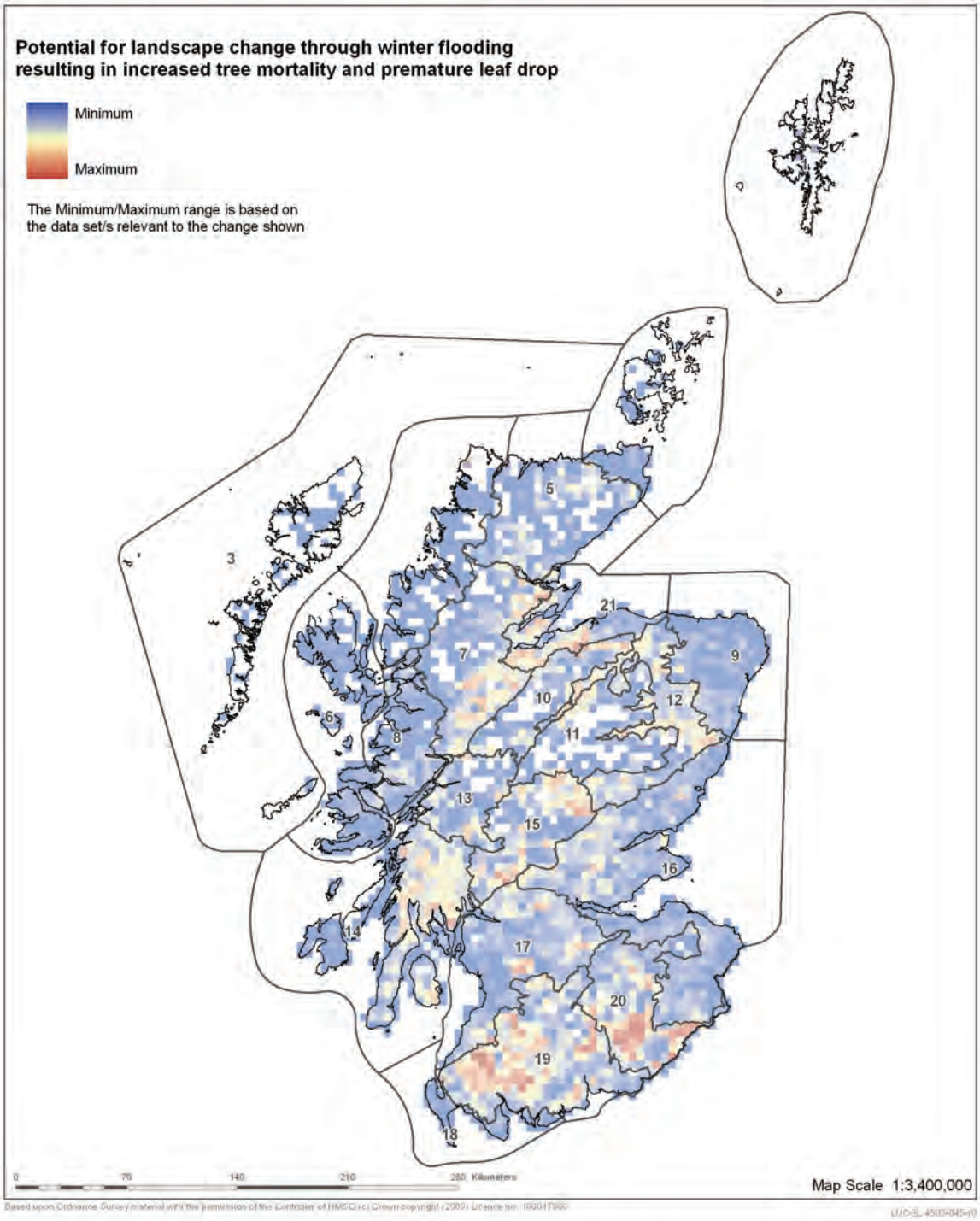


Figure 4.4b, Change 64

- Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

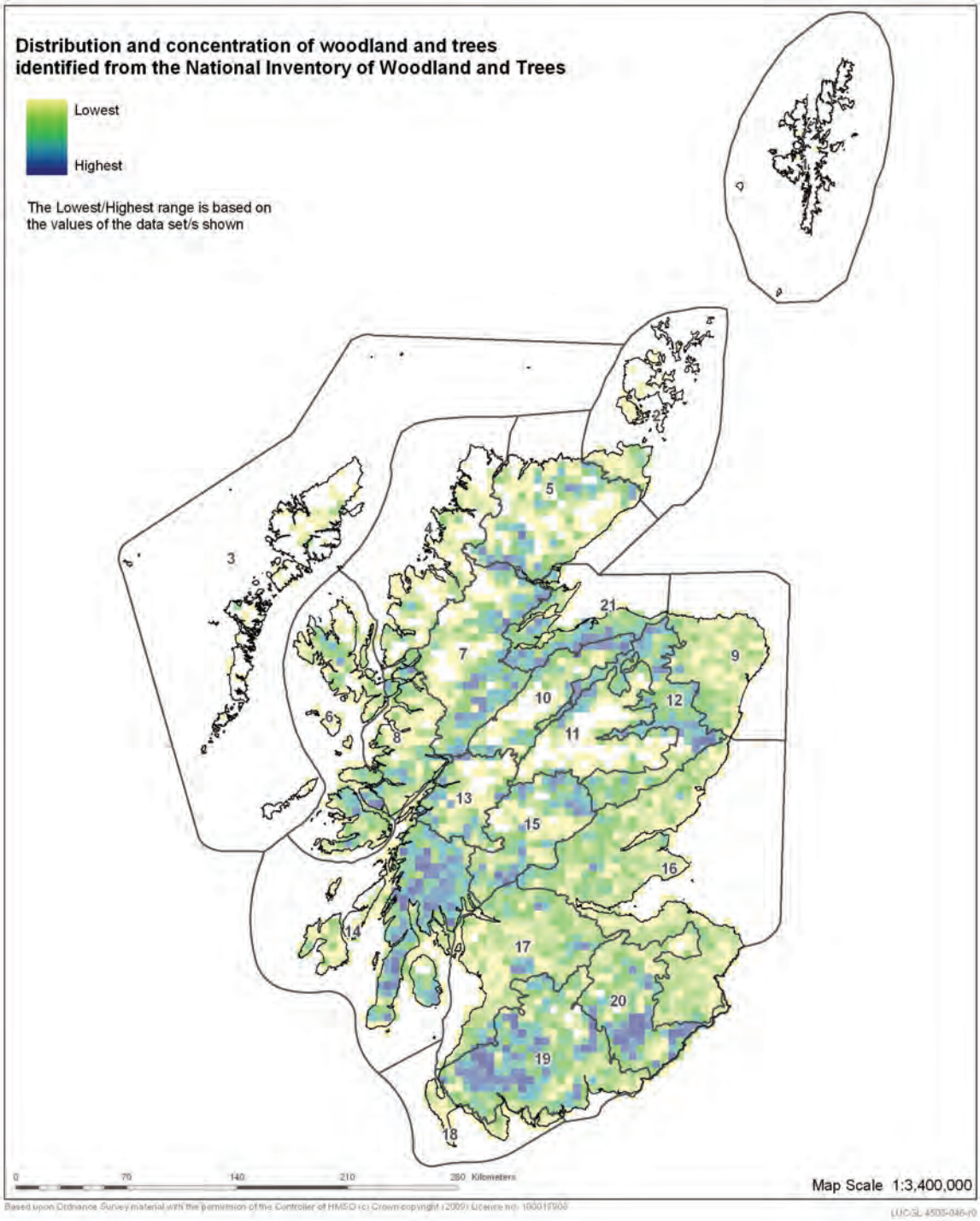


Figure 4.5a, Change 65

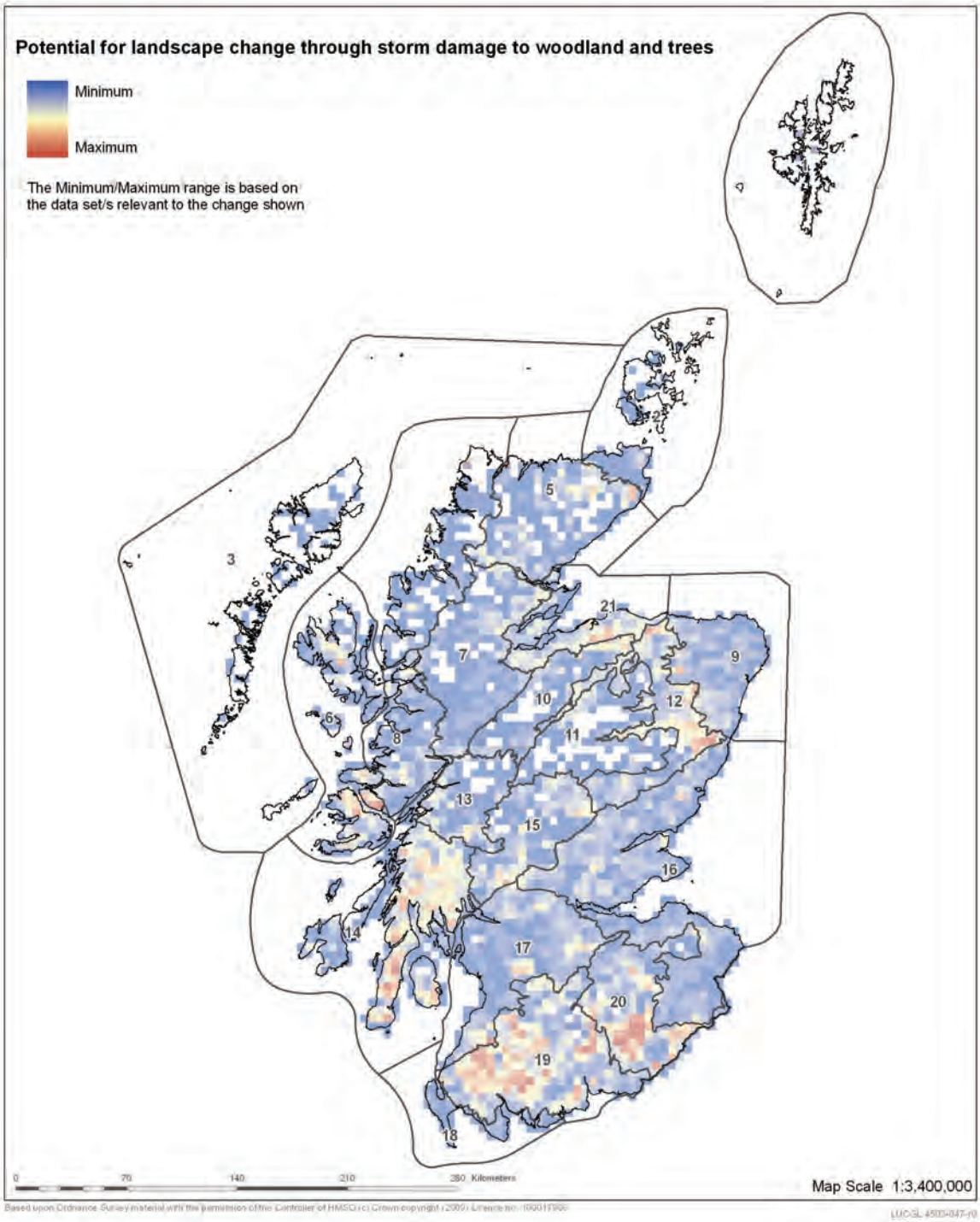


Figure 4.5b, Change 65

- Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with climate change variable P1: Average change in winter precipitation and W1:average wind speed change in winter

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

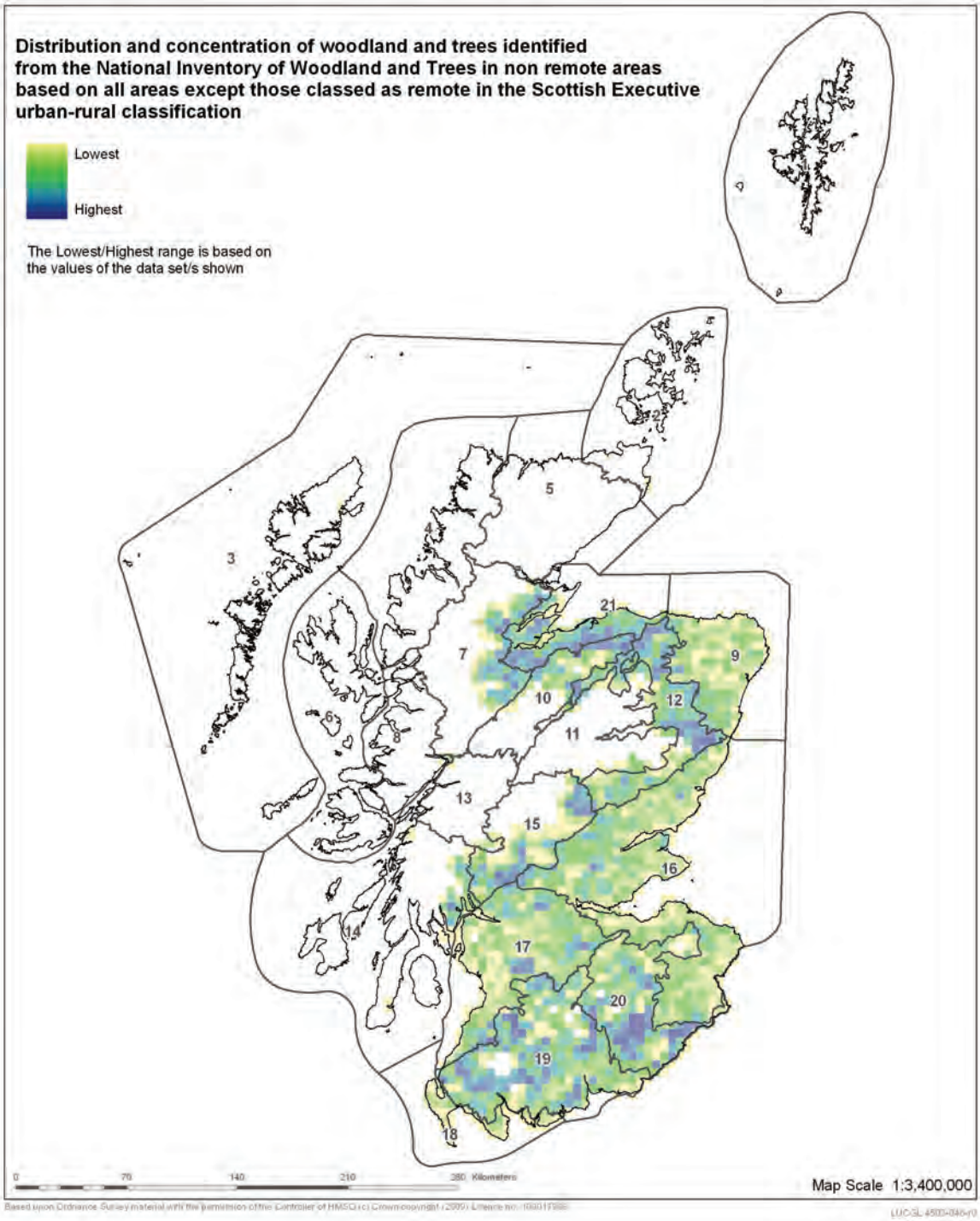


Figure 4.6a, Change 66

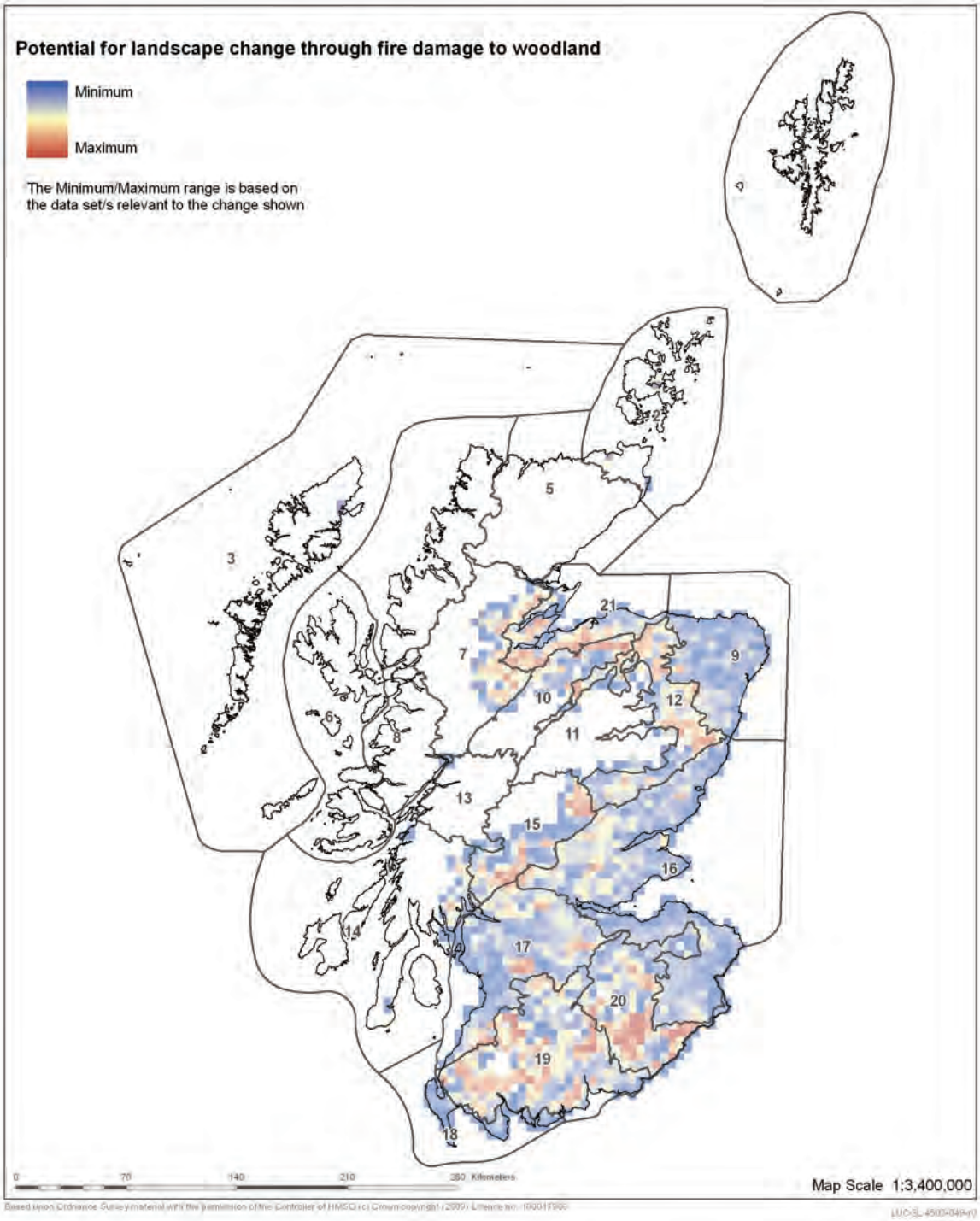


Figure 4.6b, Change 66

- Change distribution based on comparison of areas woodland and trees identified from the National Inventory of Woodland and Trees, all areas except those classed as remote in the Scottish Executive urban-rural classification, and the climate change variables T2: Autumn temperature change, P2: Average decrease in summer precipitation and T4: Change in daily maximum temperature in summer and autumn

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

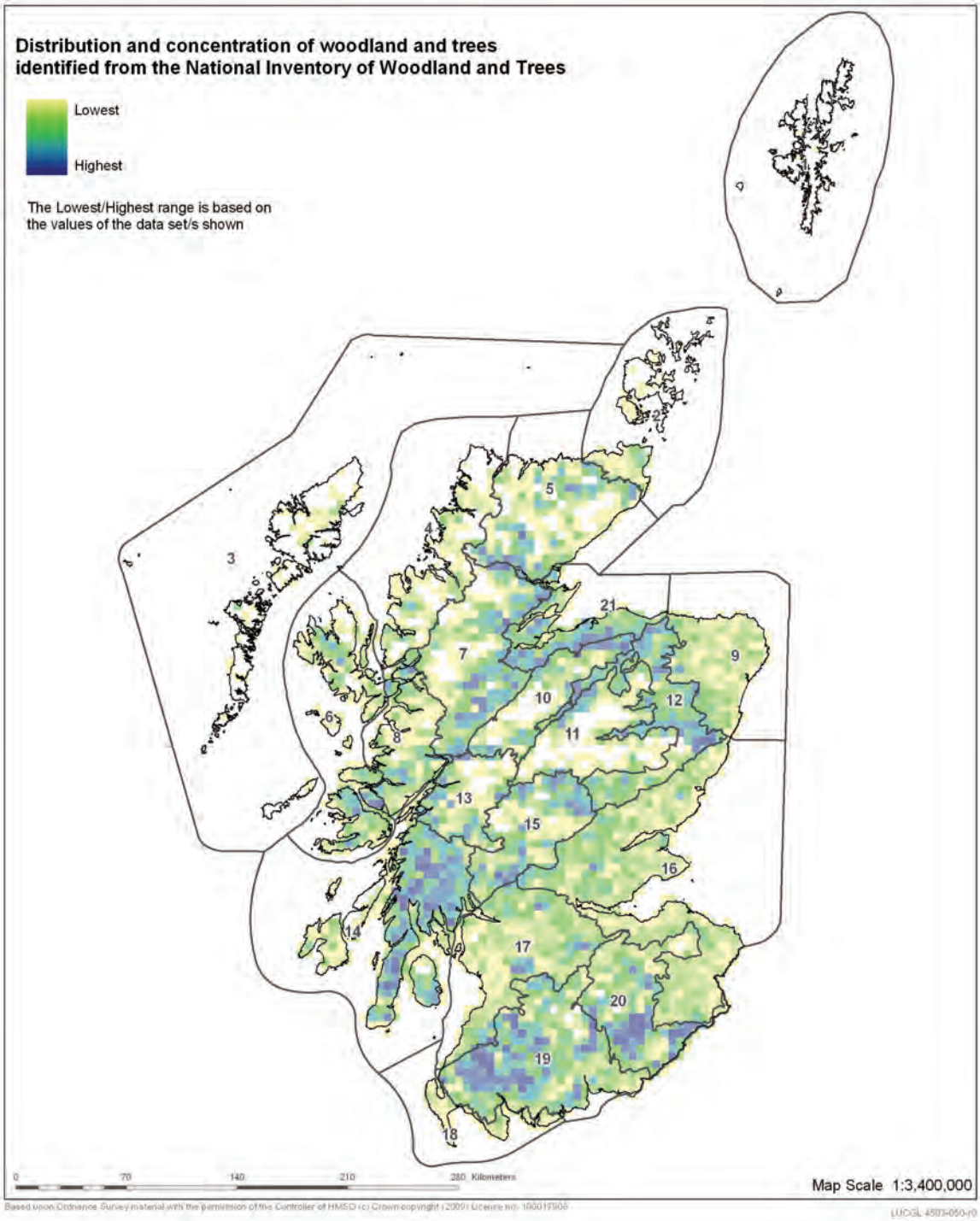


Figure 4.7a, Change 48

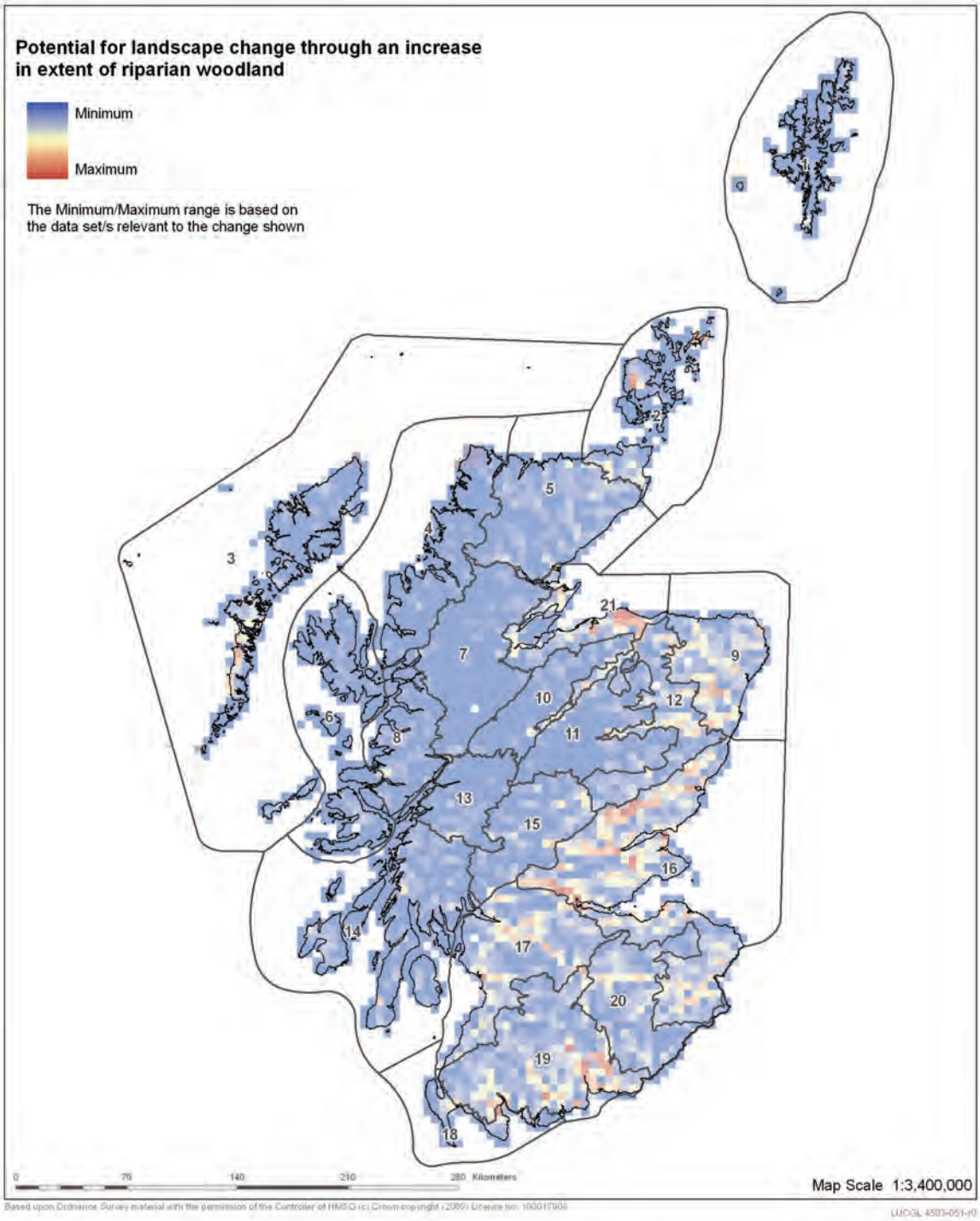


Figure 4.7b, Change 48

- Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with SEPA coastal and fluvial flood risk areas

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

Freshwater Systems

Current Patterns

4.14. Scotland is well supplied with a number of large scale lochs and reservoirs and extensive rivers systems as well as numerous smaller water bodies. Key demands on the freshwater systems include the abstraction and flow regulation for electricity generation, drinking water supply and agricultural abstraction. Impacts on the water resource include diffuse and point source pollution which are influenced by land use and development. The lochs and river systems are also important for the natural heritage and provide recreational and navigational resources. The freshwater systems play a role in flood management and regulation, although influenced by activities within the wider catchment.

Future Change

4.15. Changing patterns of rainfall could result in an increase in the frequency and severity of fluvial flooding events. These are likely to be most significant in areas where there are already flooding issues and/or where the largest increases in rainfall are anticipated or in constrained areas downstream. The landscape implications of the increased risk and incidence of such flood events include:

- short term visual impacts of floodwaters (impact);
- changing patterns of erosion and deposition, with implications for local landscapes (impact);
- changes in river courses (impact);
- damage to crops, habitats and property (impact);
- catchment scale 'soft' flood management measures including the rewilding of upland bogs and moors, woodland planting in middle and upper catchments to slow run-off and more locally to stabilise river banks and slopes, restoration of functional floodplains to provide flood storage (adaptation);
- localised 'hard' flood defences where settlements, properties, historic sites etc require flood protection (adaptation);
- upgrading of river structures (culverts, bridges etc) to accommodate increased flows (adaptation);
- the further development of small and larger scale hydro-schemes (mitigation) and water storage and export.

Mapped Analysis

4.16. *Flood Management (Figure 4.8a and 4.8b)*: These maps explore the potential for management measures where these are required to protect urban areas. Measures could include green roofs, flood storage, diversion of flood flows, raising of building floor levels, strengthening of flood defences and SUDS. The analysis maps the location of urban areas, moorlands (where upland flood management measures may be implemented) and those areas identified by SEPA as being at greatest risk from fluvial flooding and compares these with areas likely to experience the greatest increases in winter precipitation. Although more detailed, catchment based analysis would be required to build up a more accurate picture of change, this analysis does highlight a number of areas where an increase in flood management could be expected. This includes key urban areas including Glasgow, Edinburgh, Dundee and

Aberdeen. Further concentrations of activity are indicated in parts of the Scottish Borders and the eastern side of the Cairngorm mountains. This change is judged to have a medium to high level of certainty and is likely to occur from the medium term onwards.

4.17. *Fluvial Flooding (Figure 4.9a and 4.9b):* These maps show areas currently identified by SEPA as being at risk from fluvial flooding with those areas likely to experience an increase in winter precipitation, potentially adding to existing levels of risk. There may be other areas which could be placed at risk of flooding for the first time, though more detailed catchment level analysis would be required to identify them. Increases in fluvial flooding will result in damage to property and infrastructure and greater demand for upgraded flood defence measures. The analysis suggests that much of central, southern and eastern Scotland will experience an increase in the risk of fluvial flooding. Western, northern and central Highland areas are likely to experience much lower levels of change. This is likely to reflect both the anticipated increases in rainfall and the different patterns of river systems and settlement in these areas. This change is judged to have a high level of certainty and likely to occur from the medium term onwards.

4.18. *Flood Damage* (*Figure 4.10a and 4.10b*): These maps show areas currently identified by SEPA as being at risk from fluvial and coastal flooding with those areas likely to experience an increase in winter precipitation. Again, there may be other areas which could be placed at risk of flooding for the first time, though more detailed catchment level analysis would be required to identify them. Increases in fluvial flooding will result in temporary impacts due to inundation, but could also result in erosion and damage to riverbanks and floodplains, including the loss of vegetation, different patterns of deposition and even the realignment of river courses. The analysis suggests that much of central, southern and eastern Scotland will experience an increase in the risk of damage to river banks and floodplains. Western, northern and central Highland areas are likely to experience much lower levels of change. This change is judged to have a high level of certainty and likely to occur from the medium term onwards.

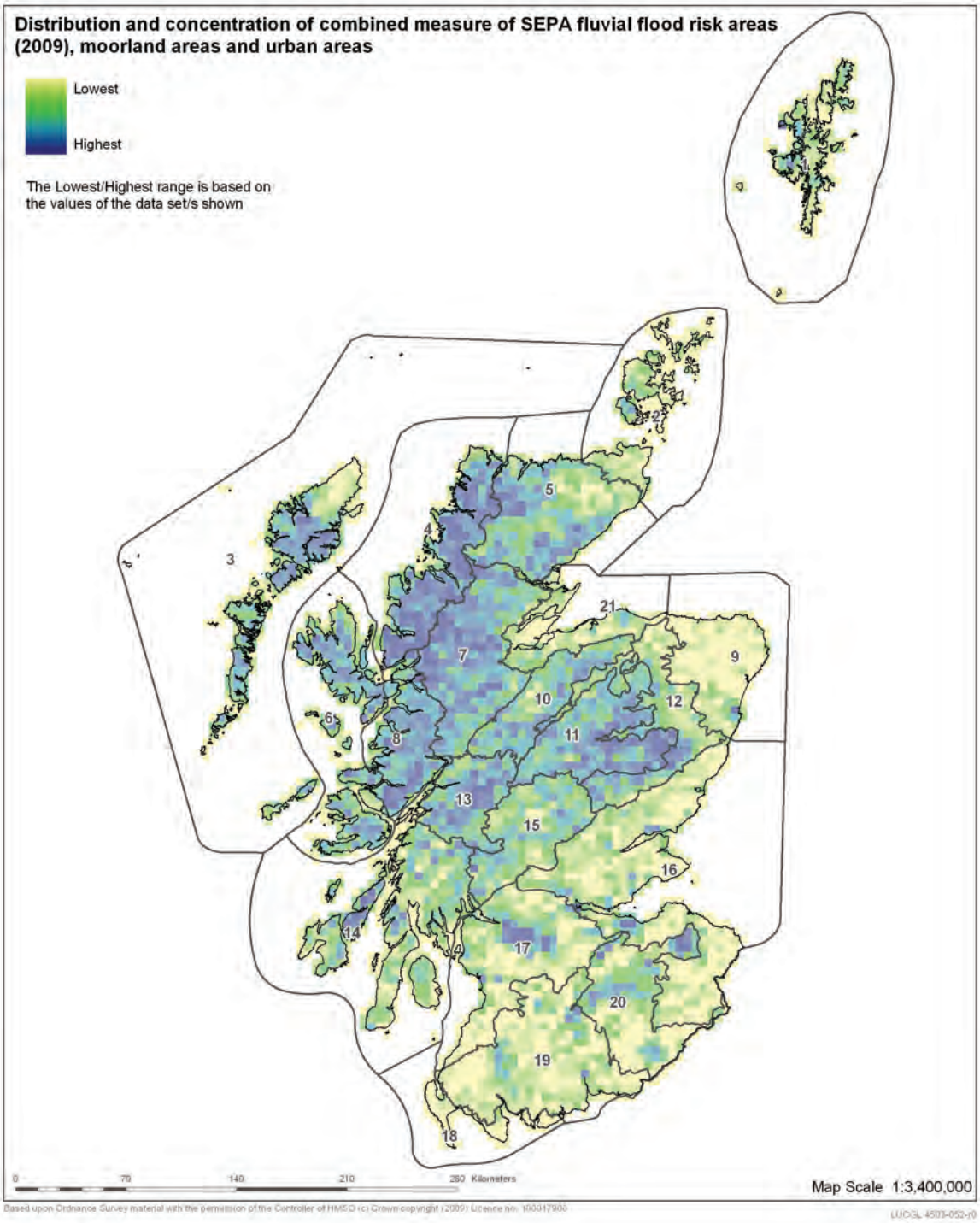


Figure 4.8a, Change 1

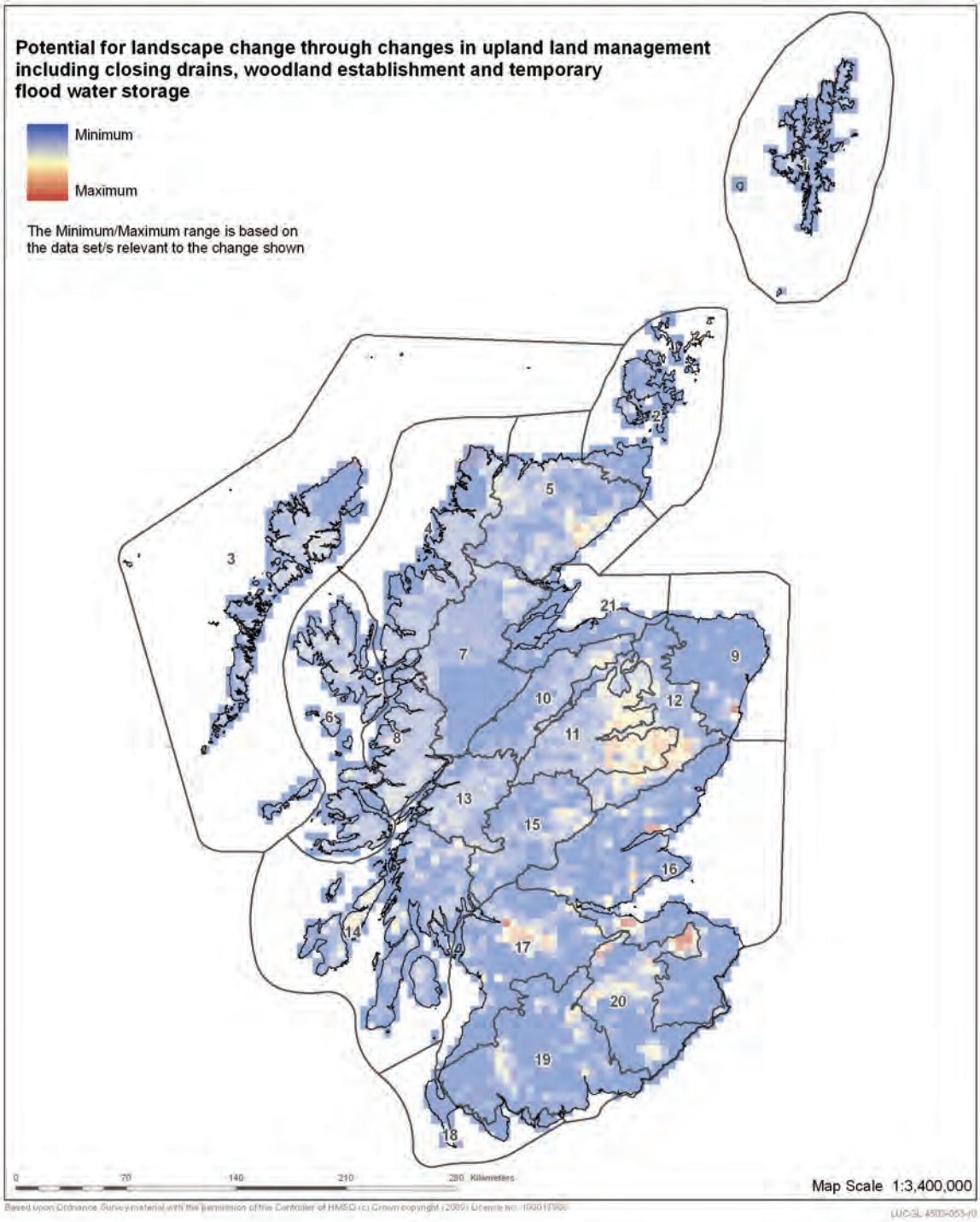


Figure 4.8b, Change 1

- Change distribution based on comparison of the location of urban areas as defined in the Scottish Executive Urban-Rural classification and areas of moorland, with climate change variable P1: Average change in winter precipitation and combined measure of SEPA fluvial flooding risk for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009)

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

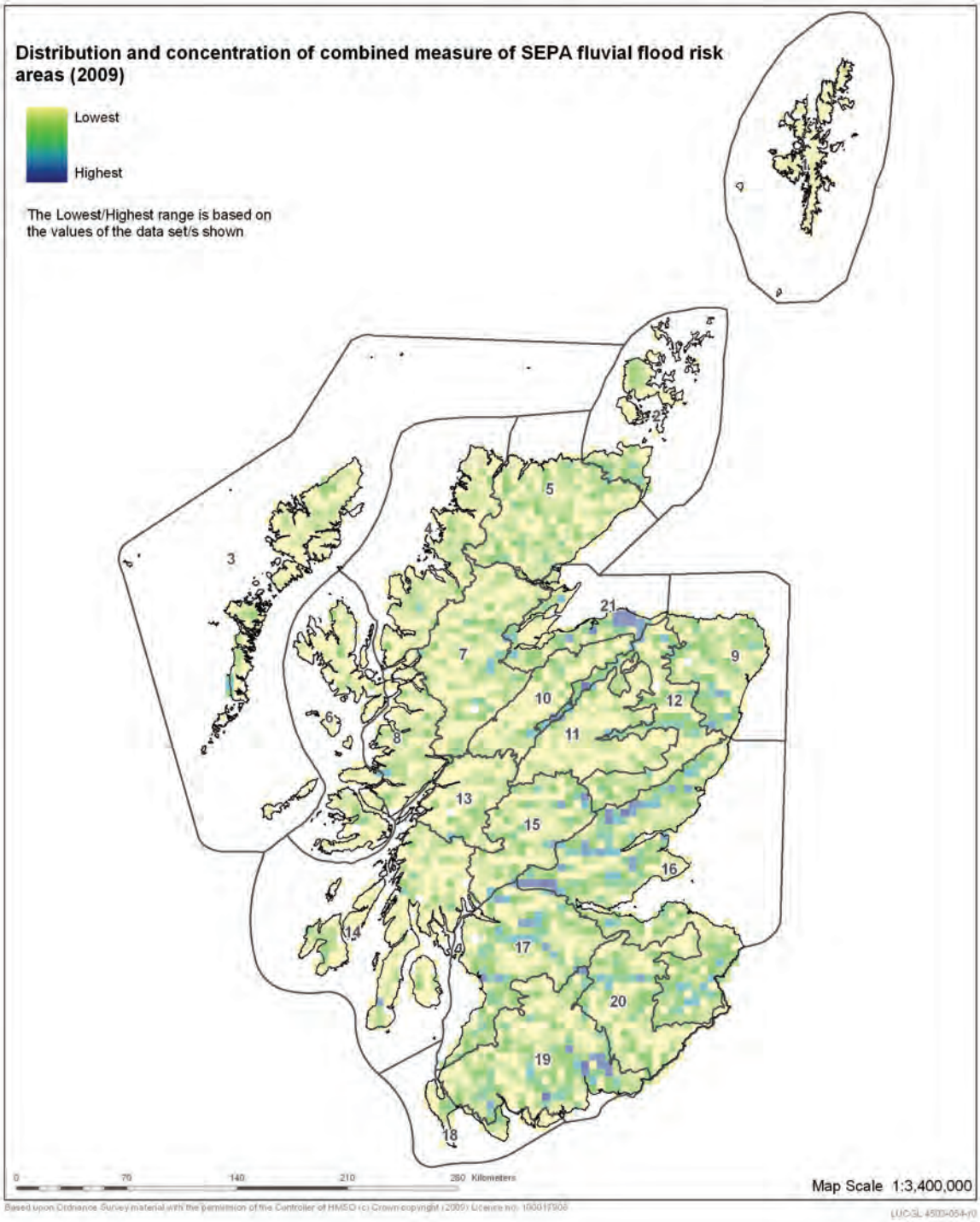


Figure 4.9a, Change 5

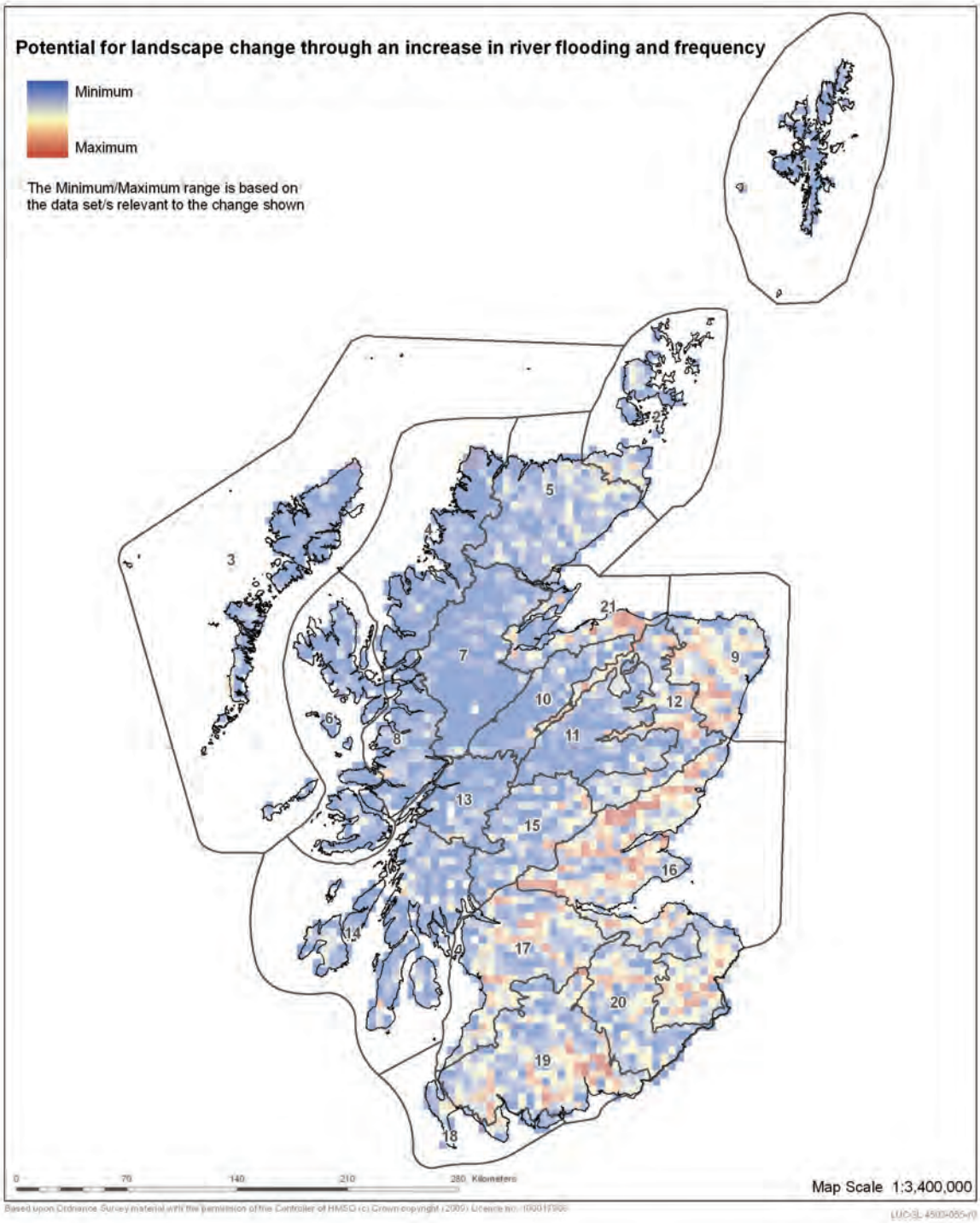


Figure 4.9b, Change 5

- Change distribution based on comparison of combined measure of SEPA fluvial flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

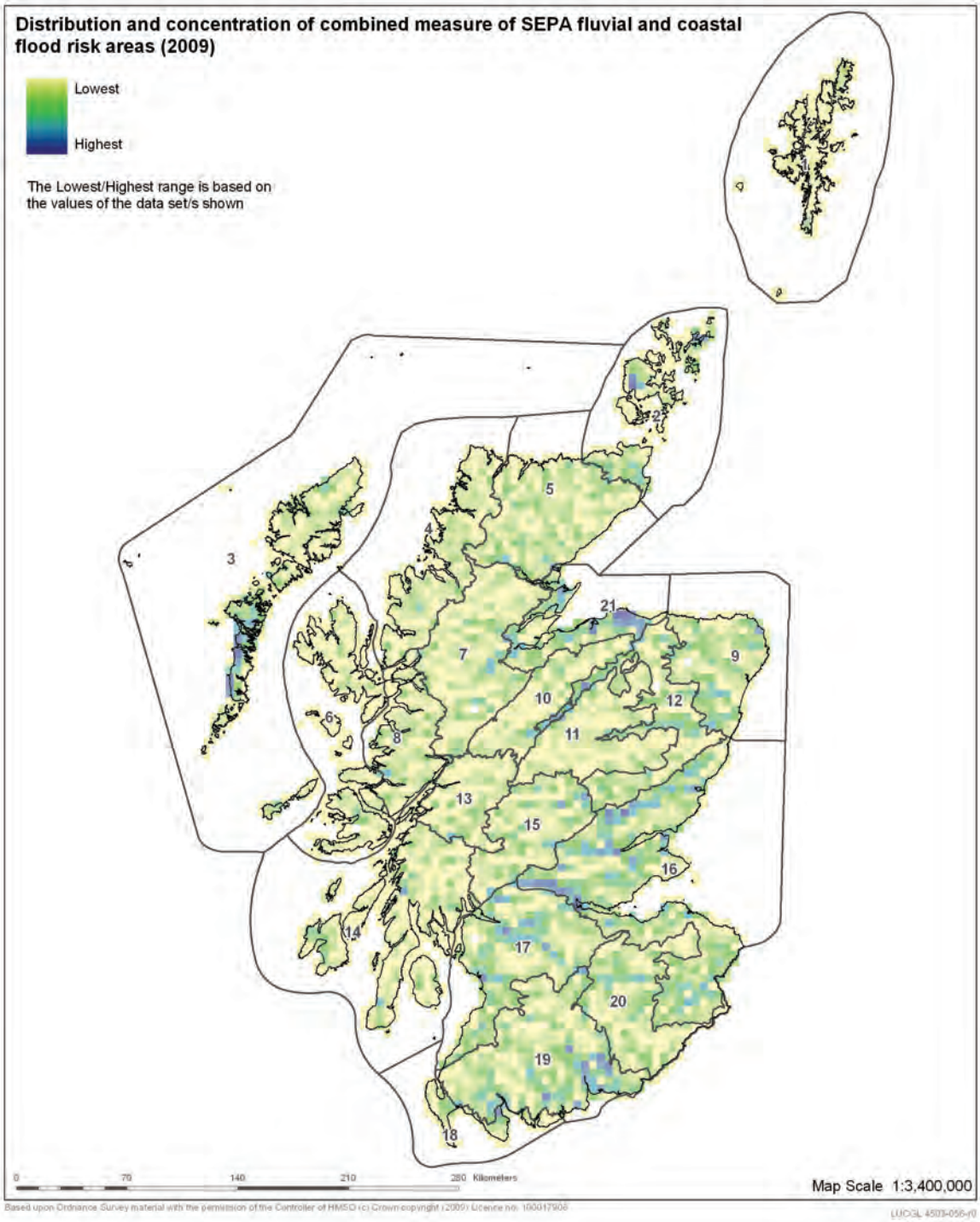


Figure 4.10a, Change 6

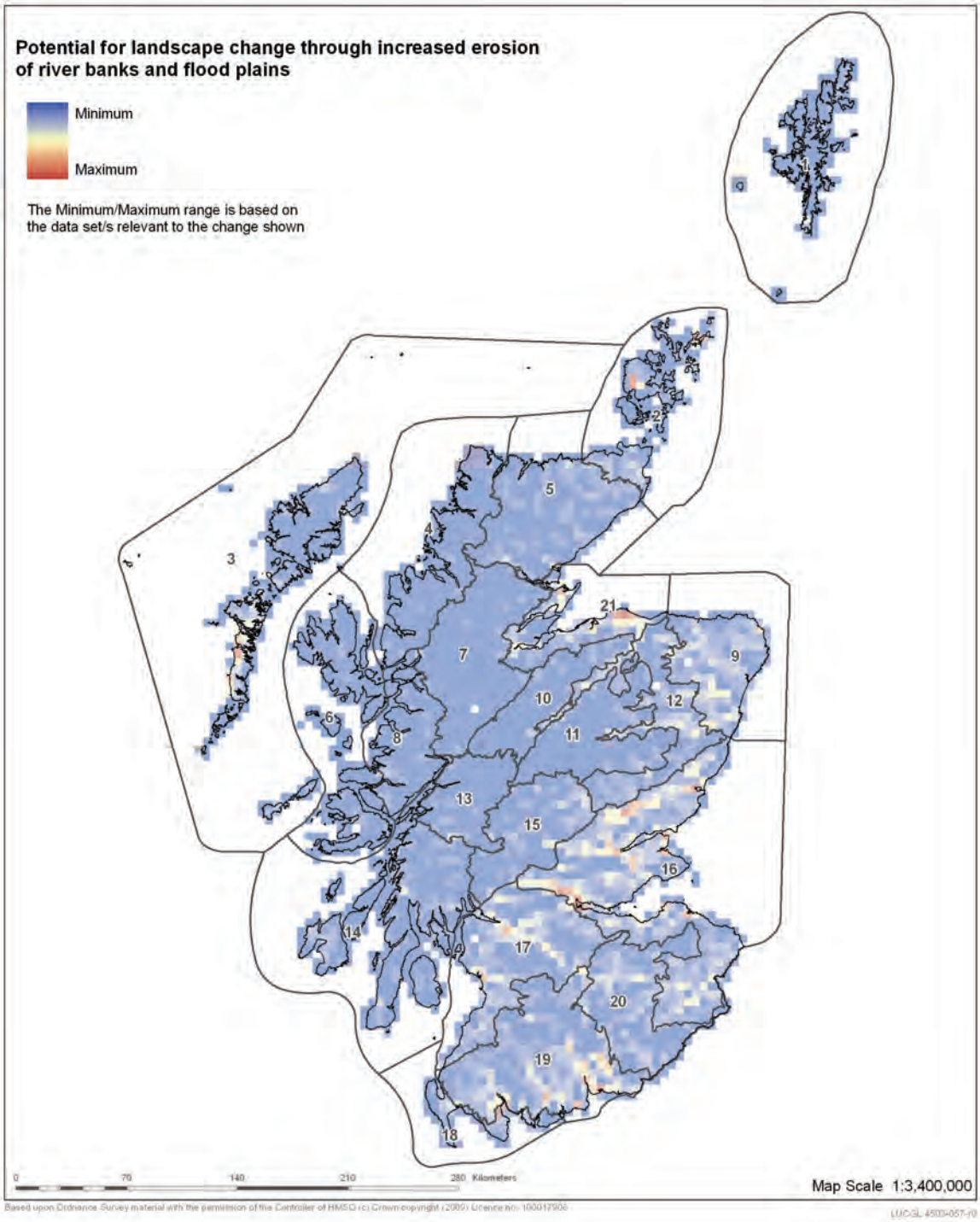


Figure 4.10b, Change 6

- Change distribution based on comparison of combined measure of SEPA fluvial flood risk and coastal flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

Coasts, Estuaries and Sea

Current Patterns

4.19. Scotland's coast is notable for its scale and variety. It is long relative to the country's size and often highly indented. The island archipelagos to the west and north further add to this resource. The west coast is rugged and characterised by mountains, sea lochs and islands. The north coasts tend to be abrupt and exposed and adjacent to deep water. The east coast is characterised by three major estuaries and a broad, fertile coastal strip. Key issues for the coastal zone include fishing and aquaculture, for which water quality is important. The coastal environment is also important for its natural and cultural heritage, but is also under pressure for navigation, ports and harbours and renewable energy generation. Along the west and north west coasts, the mountainous terrain and indented coastline mean that settlement and transport links are often, by necessity, located within a relatively narrow coastal zone. The large scale firths provide extensive intertidal habitats, but along with the areas of dune and soft coast are vulnerable to sea level rise and erosion.

Future Change

4.20. Coasts are likely to experience a combination of changing sea levels, increased incidence of storm surges and changes in wave heights. The incidence of these effects varies around the Scottish coastline, reflecting orientation, the influence of tidal streams and the nature of the coastline itself. The landscape implications of changing sea levels, storm surges and wave heights include:

- an increase in the incidence of coastal flooding along low-lying sections of coast (impact);
- an increase in the incidence of storm tides affecting in particular firths, estuaries, sea-lochs and islands (impact);
- impacts on coastal recreation sites e.g. golf courses and coastal paths (impact);
- impacts on historic coastal sites (impact);
- changing patterns of coastal erosion and deposition (impact);
- an increase in the use of managed realignment to maintain soft flood defences and coastal habitats (adaptation);
- increased incidence of coastal squeeze where sections of low-lying coast are protected by hard flood defences (adaptation);
- the development of tidal barrages and or tidal lagoons to generate power (mitigation);
- the development of wave and tidal stream energy projects (mitigation);
- the development of offshore windfarms (mitigation).

Mapped Analysis

4.21. Research into coastal flood risk has been undertaken by SNIFFER[4]. The impacts of sea level change around Scotland are influenced not only by the predicted increases in sea level but by the nature of the coast, state and nature of coastal defences and

[4] SNIFFER (2008) FRM10 Coastal Flooding in Scotland: A Scoping Study

rate of isostatic rebound. The research was based upon a review of historical and current flood risk in Scotland.

4.22. *Rising sea levels (Figure 4.11)*: This map shows the scale of sea level rise predicted around the Scottish Coastline. It indicates that the Orkney and Shetland archipelagos are likely to experience the most significant rises in sea level, followed by the Outer Hebrides, north and northwest coasts and Skye.

4.23. The highest levels of sea level rise in Orkney and Shetland present particular issues for the coastal settlement pattern in these areas. Other areas of vulnerability will include low lying coastal settlements with soft coastlines and limited coastal defences. Comments at the SNH staff workshop suggested that that the sea level rise data was a potential underestimate of the risk. There are uncertainties about the accuracy of current sea level rise forecasts, with some suggestions that they may underestimate significantly the change that is already starting to take place. The sea level rise data is based on the assumption that the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES) A1B will apply.[5]

4.24. *Surge risk (Figure 4.12*): Surge risk is defined as those areas at greatest flood risk during a storm surge event and is greatest in firths and sea lochs. The maps shows that surge risk is greatest along the inner firths on the east coast including the Firth of Tay, Firth of Forth and Moray Firth and, in the west, on the inner and outer Firth of Clyde (including sea lochs such as Loch Fyne) and along the Solway Firth. Many of these firths and lochs are settled with potential implications for Inverness, Perth, Stirling and Glasgow, together with many smaller coastal settlements and transport routes. Given that the impact of surge risk is likely to be influenced by the rate of sea level rise, a lower level of certainty should be attached to this analysis.

4.25. *Wave fetch (Figure 4.13*): Wave fetch is defined as the distance over which wind blows from a constant direction and has a direct influence on wave height. More sheltered locations such as firths, sea lochs and highly indented coastlines are likely to experience the lowest wave fetch with highest figures predicted for exposed islands, points and promontories.

4.26. *Combined risk (Figure 4.14):* SNIFFER's mapping of the combined risk of rising sea levels, surge and wave fetch shows the highest level of risk on the coastal edge of the Solway Firth, Ayrshire, the Firth of Clyde and Argyll and Bute, the estuaries of the Forth and Tay and the Moray Firth. Parts of the Orkney and Shetland island coast are also at a high combined risk. These areas of highest combined risk are coincident with several of the main population centres.

4.27. C*oastal flooding (Figure 4.15a and 4.15b)*: These maps show the distribution of low lying coastal areas including estuaries, intertidal zones, mudflats and saltmarsh and areas at risk of coastal flooding with those areas likely to experience an increase in winter precipitation and windspeed. The analysis shows a similar pattern to that identified by the SNIFFER data (in Figures 4.11 – 4.14), with greatest risks of flooding identified in the eastern firths, the Solway Firth and inner Firth of Clyde. Again, the areas of highest risk are coincident with several of the main population centres together with smaller coastal settlements. This change is judged to have a high level of certainty and likely to occur in the longer term.

[5] Intergovernmental Panel on Climate Change (2000) IPCC Special Report Emissions Scenarios http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

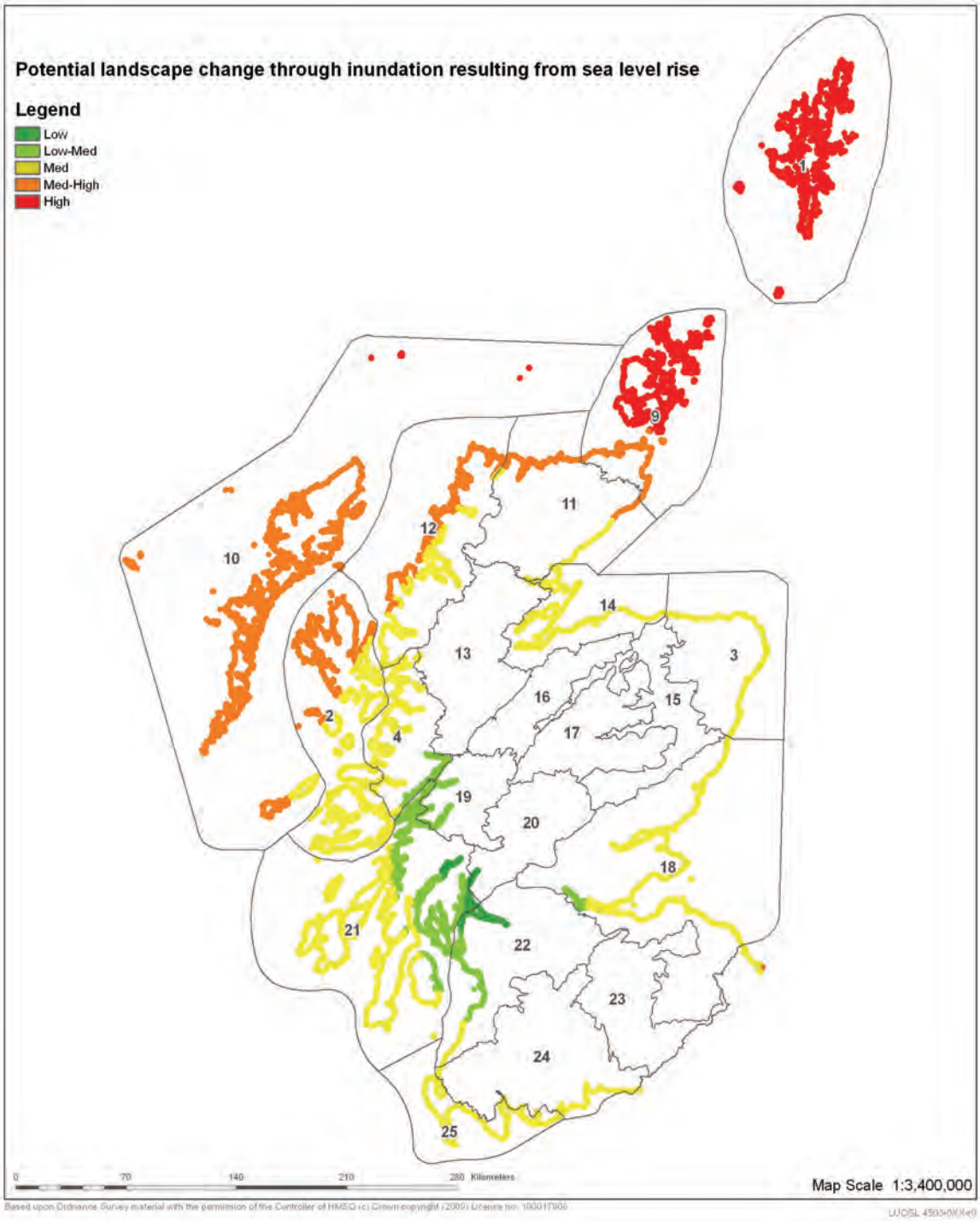


Figure 4.11, Change distribution of sea level rise

- Estimate of sea level change (cm) around the Scottish coast between 2000 and 2080. The estimate takes the global mean sea level change projection from IPCC AR4 and subtracts the GIA component (isostatic rebound) based on Shennan and Horton (2002) and Smith et al. (2006). These estimates assume that IPCC scenario SRES A1B will apply.
  Data source: SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study

Certainty level: Uncertain (high number of variables)

Timescale of change (years)	<10	10-100	100+

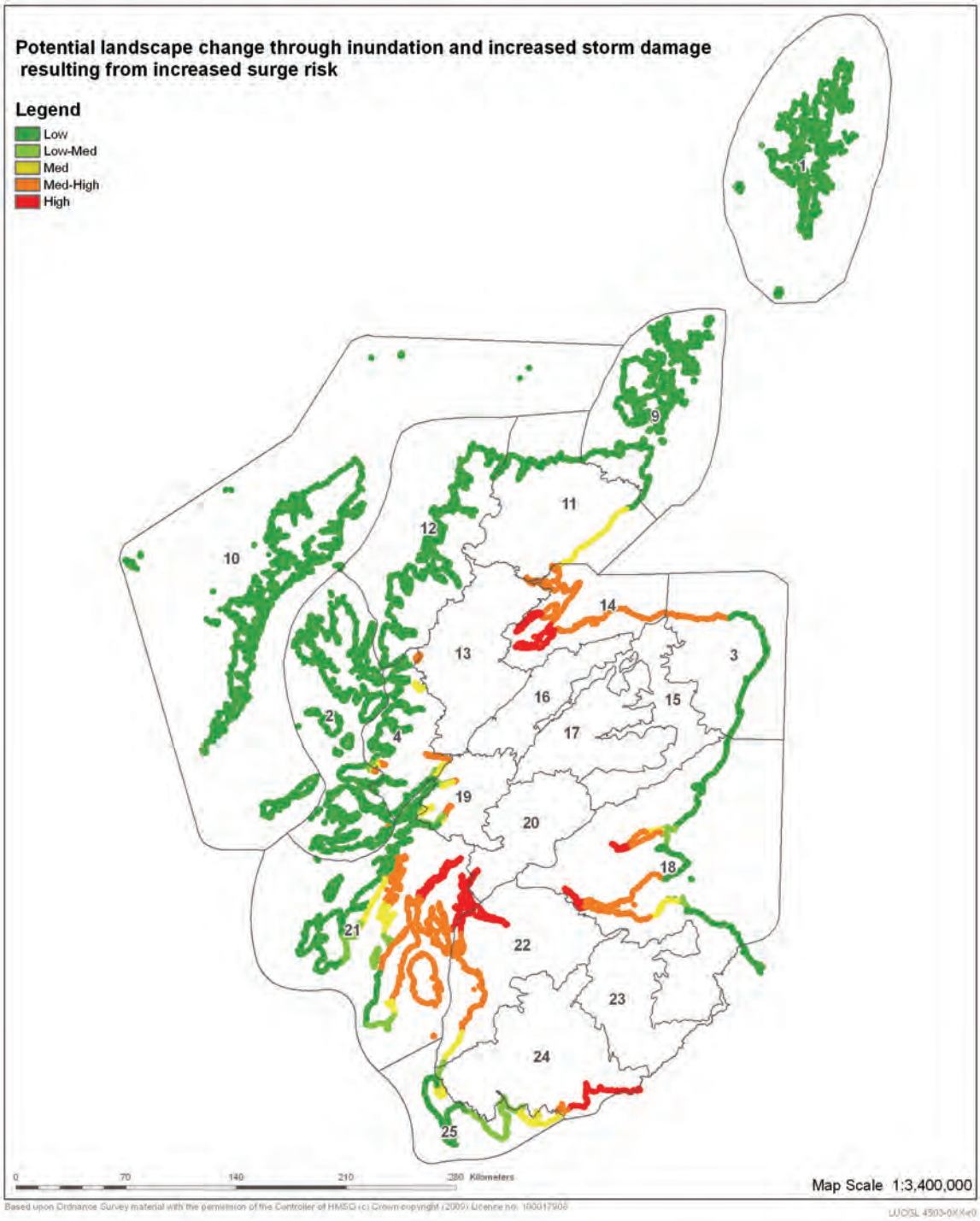


Figure 4.12, Change distribution of surge risk index

- Surge hazard assessment based on analytical consideration of potential for wind set-up of surges in inlets around the Scottish coast. The greatest uncertainty is associated with the south west coastal areas due to the hydrodynamic complexities of the Irish Sea.

Data source: SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study

Certainty level: Uncertain (high number of variables)

Timescale of change (years)	<10	10-100	100+

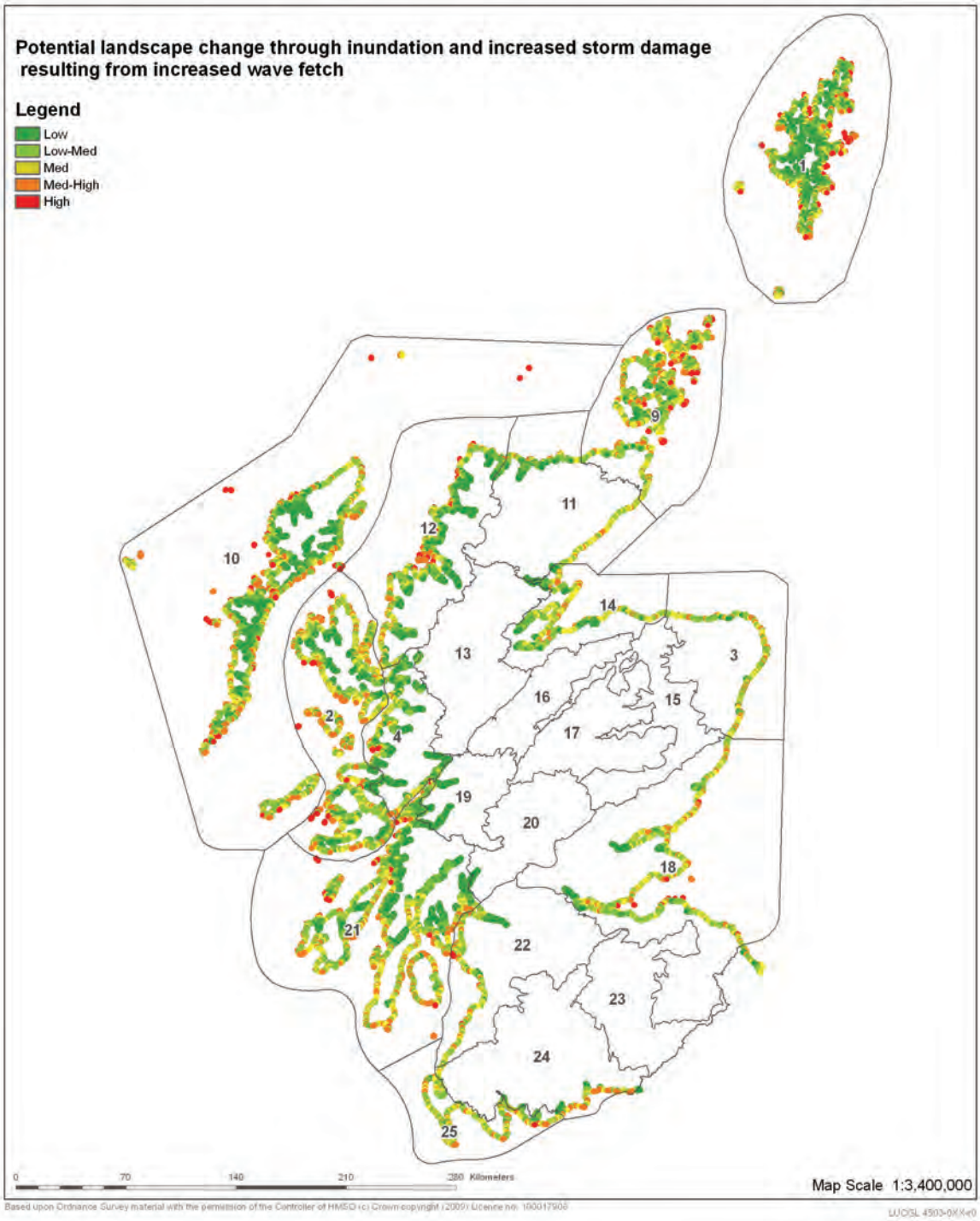


Figure 4.13, Distribution and impact of wave fetch

▸Data source: SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study

Certainty level: Uncertain (high number of variables)

Timescale of change (years)	<10	10-100	100+

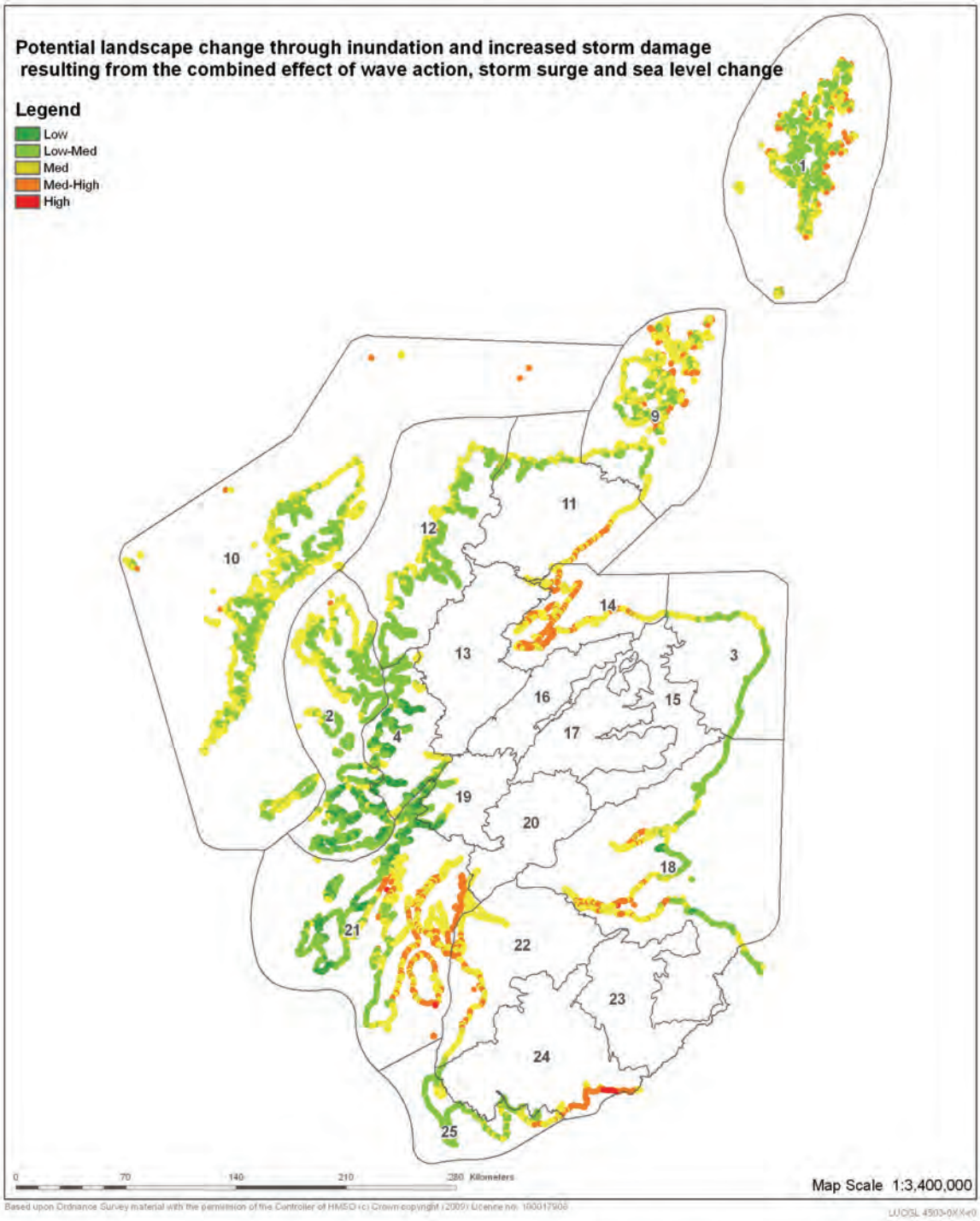


Figure 4.14, Combined effect of wave action, storm surge and sea level change

- Indicative assessment of future flood hazard in the 2080s based on the combined effect of wave action, storm surge and sea level change. The contribution from each is weighted respectively wave 40%, surge 40%, sea level 20%.
  Data source: SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study

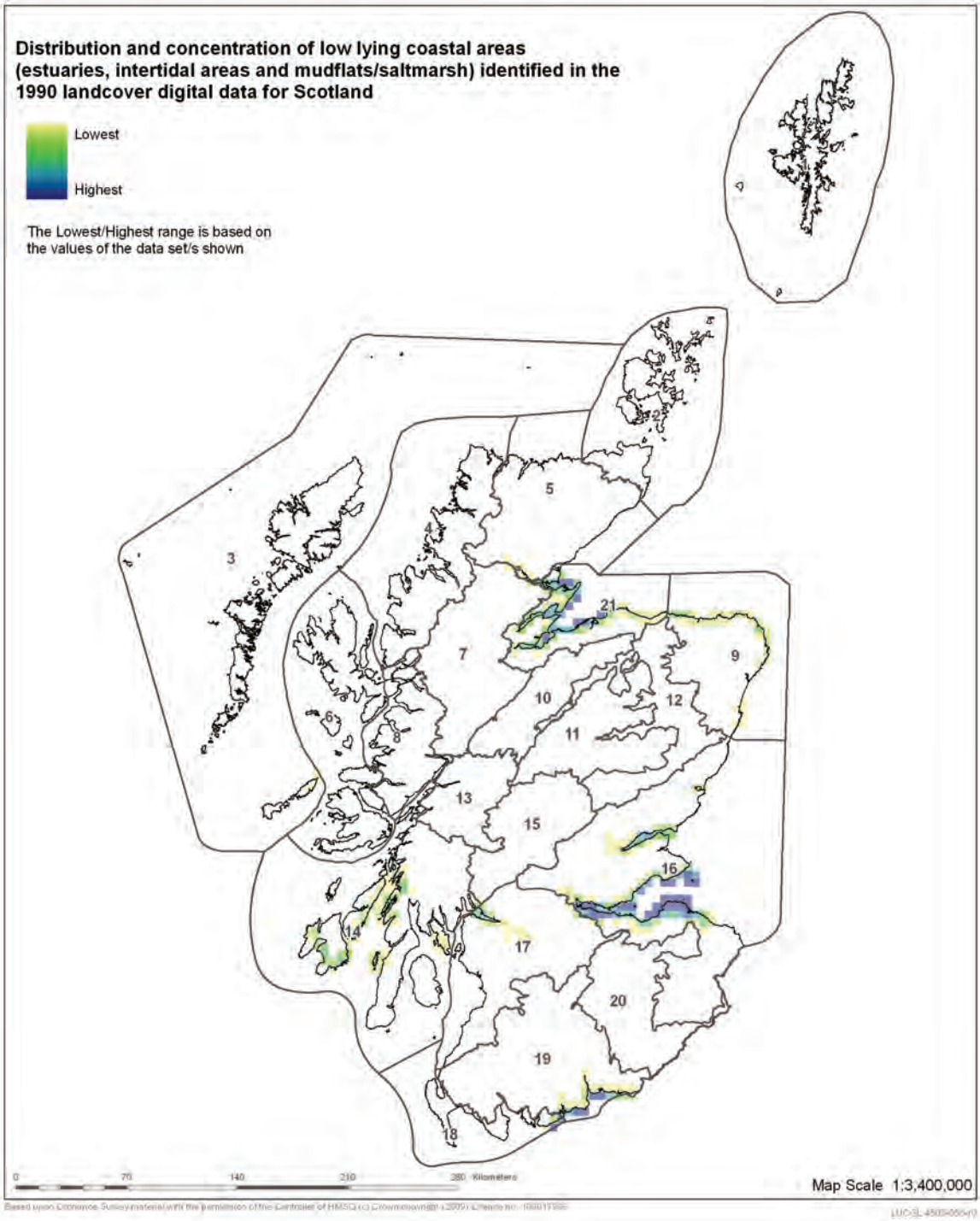


Figure 4.15a, Change 3

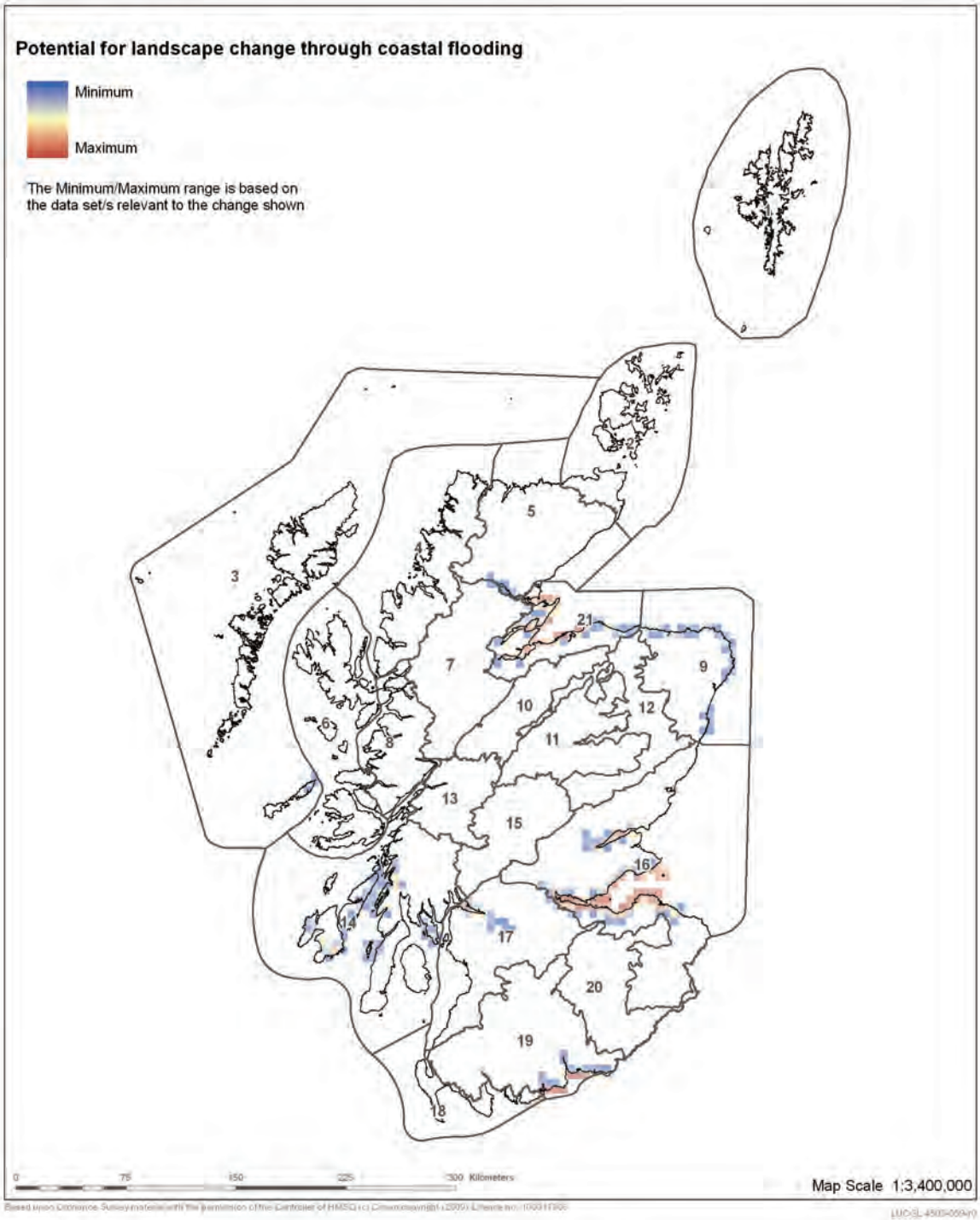


Figure 4.15b, Change 3

- Change distribution estuaries, intertidal areas and mudflats-saltmarsh identified in the 1990 landcover digital data for Scotland, with combined measure of SEPA coastal flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) , and climate change variables P1: Average change in winter precipitation, W1: Average wind speed change in the winter

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

Urban and Peri-Urban

Current Patterns

4.28. Scotland's urban areas are focused around the main rivers and coasts with the main population centres of Glasgow, Edinburgh, Dundee, Aberdeen and Inverness. Population density is greatest across the central belt and lowest in the north west.

Future Change

4.29. Climate change could result in a number of changes affecting urban and peri-urban environments including:

- an increase in the risk of fluvial, coastal and pluvial[6] flooding resulting in the upgrading of riparian flood defences, the use of existing greenspaces to accommodate flood storage and the increased provision of Sustainable Urban Drainage Schemes (SUDS) associated with new development. Green infrastructure will play an increasing role in adapting to change; (adaptation)

- an increase in demand for high quality greenspace within and around settlements in areas experiencing increased summer temperatures and reductions in summer rainfall (adaptation);

- an emphasis on habitat enhancement and connection to improve existing habitat networks through dense urban areas, create new networks where opportunities allow, therefore helping to reverse fragmentation and help species adapt to changing climate space (adaptation);

- an increase in drought and flood stress affecting urban greenspaces and urban trees, particularly in areas experiencing a combination of increasing summer temperatures, increasing summer 'drought' and increasing winter precipitation (impact);

- an trend towards decentralisation of population from urban areas experiencing summer urban heat island effects, with an increase in the population of surrounding rural and coastal areas (adaptation);

- possible changes in the design and construction of buildings to reflect rising summer temperatures, increased winter rainfall and mitigation responses relating to micro-renewables and energy efficiency (mitigation) and the requirement for cooling equipment (adaptation) which could change the appearance of existing buildings and affect the character of the historic environment.

Mapped Analysis

4.30. *Stress on Green Infrastructure (Figure 4.16a and 4.16b):* The maps show those parts of Scotland where there is likely to be a concentration of green infrastructure resources such as urban greenspace, country and regional parks and recreation sites in the countryside easily accessible from the main centres of population. Stress could result from a combination of changing climatic conditions (particularly drier and warmer summers), increased levels of use and greater prevalence of pests and diseases. The analysis suggests that the central belt, parts of the east coast and pockets around settlements such as Inverness are likely to see increased pressure and stress on green infrastructure.

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[6] Pluvial flooding is defined as flooding resulting directly from overland flow of rainfall before the water enters drainage systems.

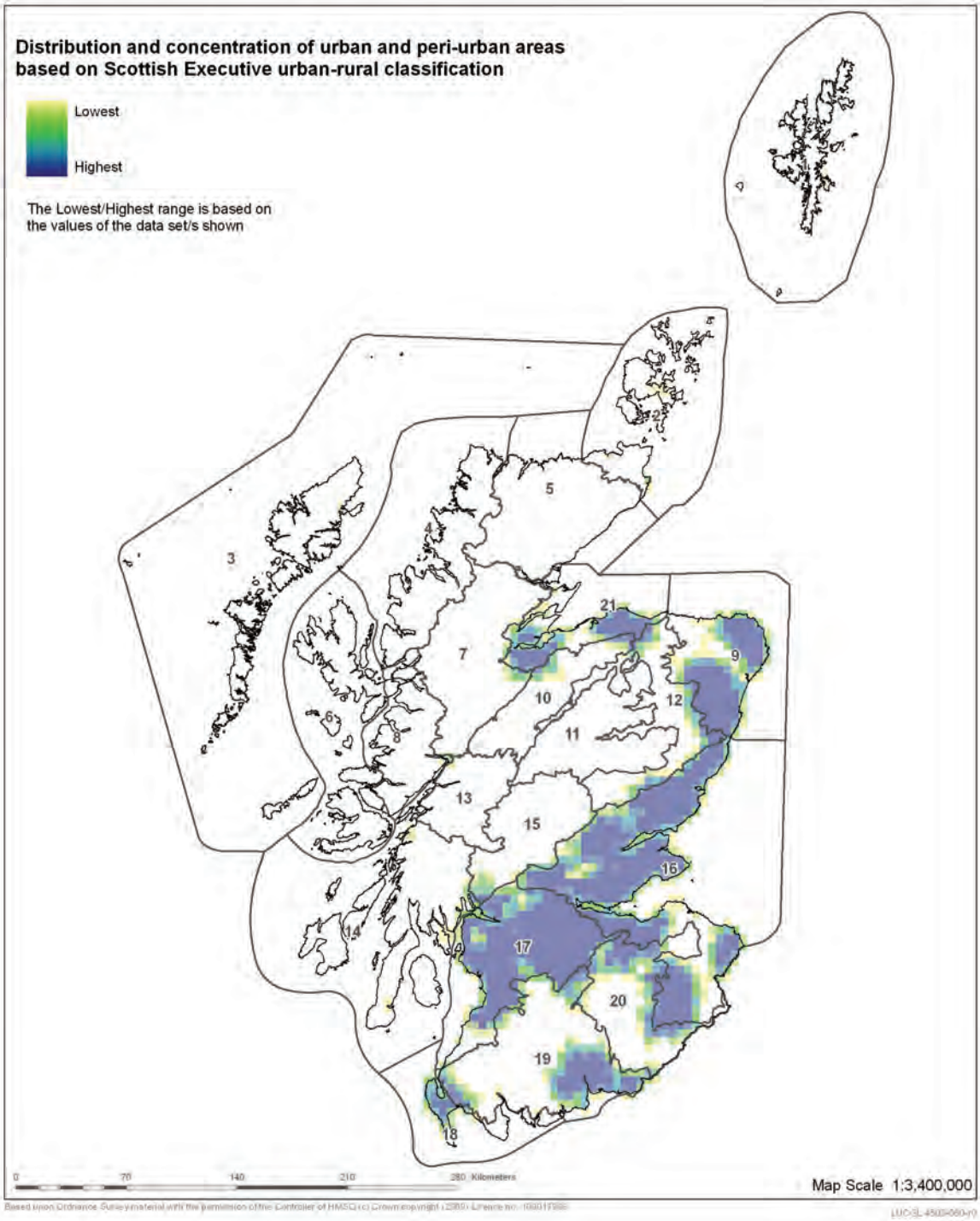

Figure 4.16a, Change 9

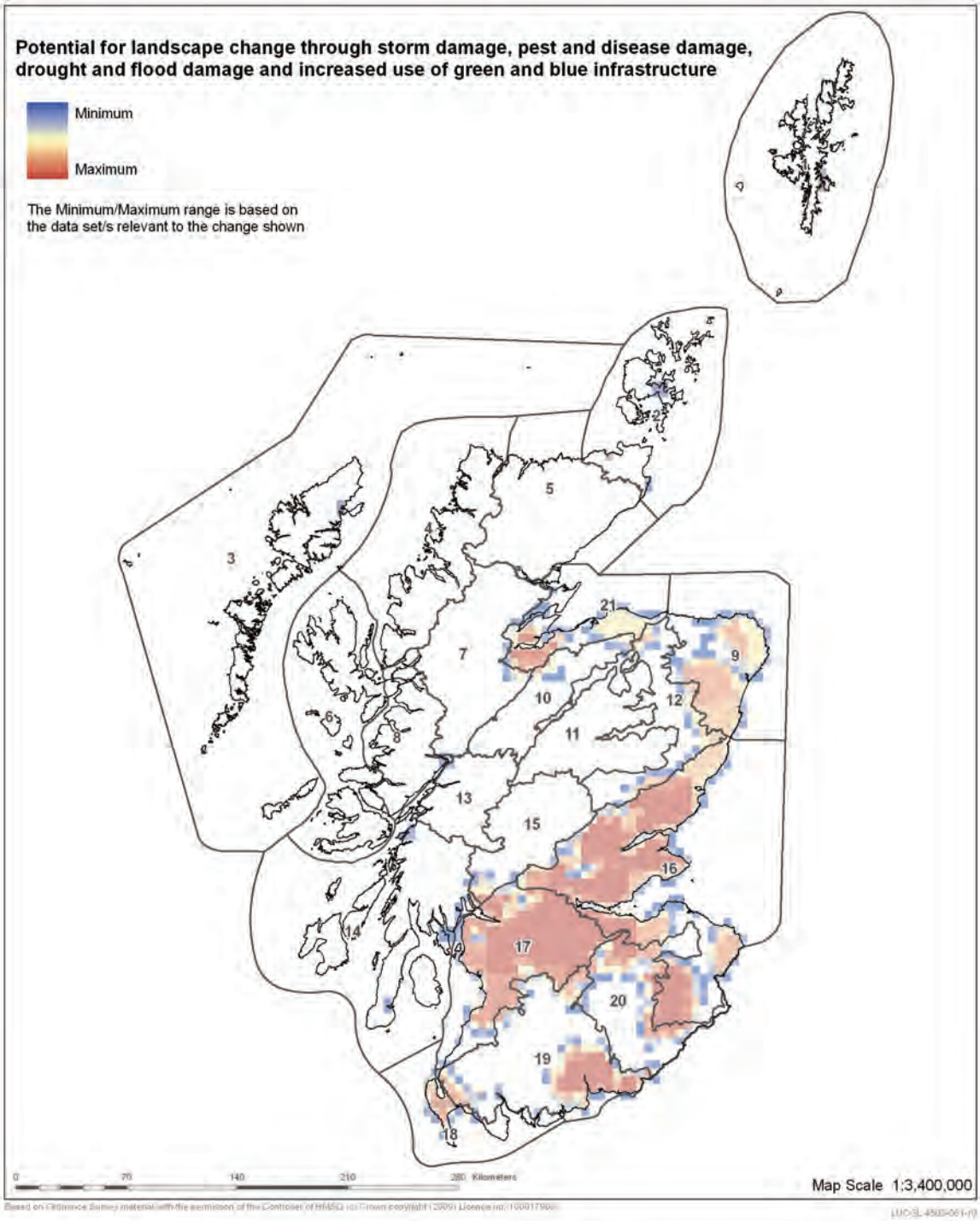

Figure 4.16b, Change 9

- Change distribution based on comparison of urban and peri-urban areas identified in the Scottish Executive urban-rural classification with climate change variables T2: Autumn temperature change and T4: Change in daily maximum temperature in the summer-autumn

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

Tourism and Recreation

Current Patterns

4.31. Scotland is an important tourism destination which has demonstrated a growth in the importance of overseas tourists. The pattern of tourism for UK residents has shown a significant increase in short breaks. Scotland has a particular role in niche tourism markets reflecting the high quality landscape, wildlife, archaeology, water environment and formal recreational activities such as golf. The protected landscapes of the two National Parks, National Scenic Areas and National Nature Reserves provide further illustration of the value of Scotland's landscape for tourism and recreation. Coastal areas also offer an important tourism and recreation resource, (wild or remote areas also offer an important recreation resource) with a large number of high quality beaches on both west and east coasts and on islands, many close to concentrations of population. At a more local scale the network of regional parks, country parks, local nature reserves and urban greenspace provide important everyday recreation resources for local communities.

Future Change

4.32. Climate change could have a number of different effects on tourism and recreation in Scotland, with implications for facilities and infrastructure and also for the way in which people experience the landscape. Key landscape implications could include:

- an increase in the volume of recreation and tourism activity facilitated by lower rainfall and higher temperatures in the summer months. The length of the summer tourism season could be extended. This could have a number of effects including further development of formal and informal recreation infrastructure, particularly in the more accessible parts of Scotland, and in areas around the principal settlements (adaptation);

- at a local level there could be increased pressure on key visitor areas, trails and path networks. Higher temperatures and lower rainfall could increase the risk of fire (impact);

- increased levels of summer tourism and recreation and development of new facilities could provide new opportunities for people to experience the landscape and engage in active outdoor recreation. This could have implications for wildland qualities which are important in many remoter parts of Scotland (adaptation);

- the situation in winter may be rather different. Climate change is likely to result in changing patterns of snowfall and changes in its duration and stability. Overall, it is likely that snow lie will become less reliable, particularly below 800 metres. This will threaten the survival of ski centres and related businesses and encourage diversification into non-snow activities. Higher winter temperatures and increased winter rainfall, cloud and rain will result in an overall change in the character of the winter landscape, and people's experience of it (impact and adaptation).

Mapped Analysis

4.33. *Tourism and Recreation Pressure (Figures 4.17a and 4.17b and 4.18a and 4.18b)*: These maps show those parts of Scotland not classified as remote since these are likely to experience the greatest absolute increases in recreation activity (including demand and use of green and blue infrastructure), together with those areas likely to experience greatest changes in temperature and rainfall. The analysis suggests that increases in activity could be spread throughout much of non-remote Scotland,

though with lower rates of increase in some of the more peripheral coastal areas such as Ayrshire, Moray, Aberdeenshire and the Lothians. This analysis does not take account of the smaller increases in activity which could occur in remoter areas of Scotland and which could have a disproportionate impact on wildland qualities. These changes are judged to have a moderate to high level of certainty and likely to occur from the medium term onwards.

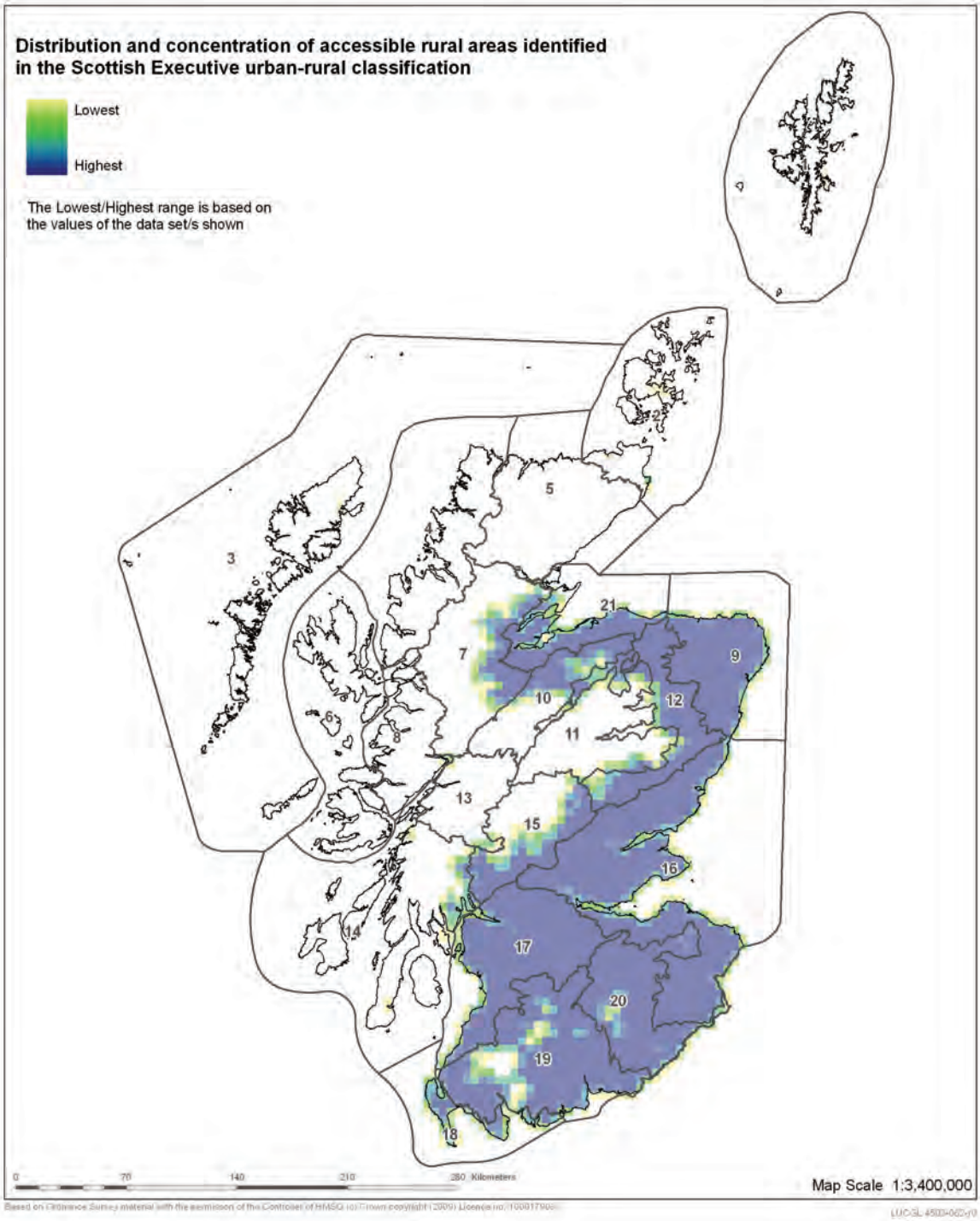

Figure 4.17a Change 14

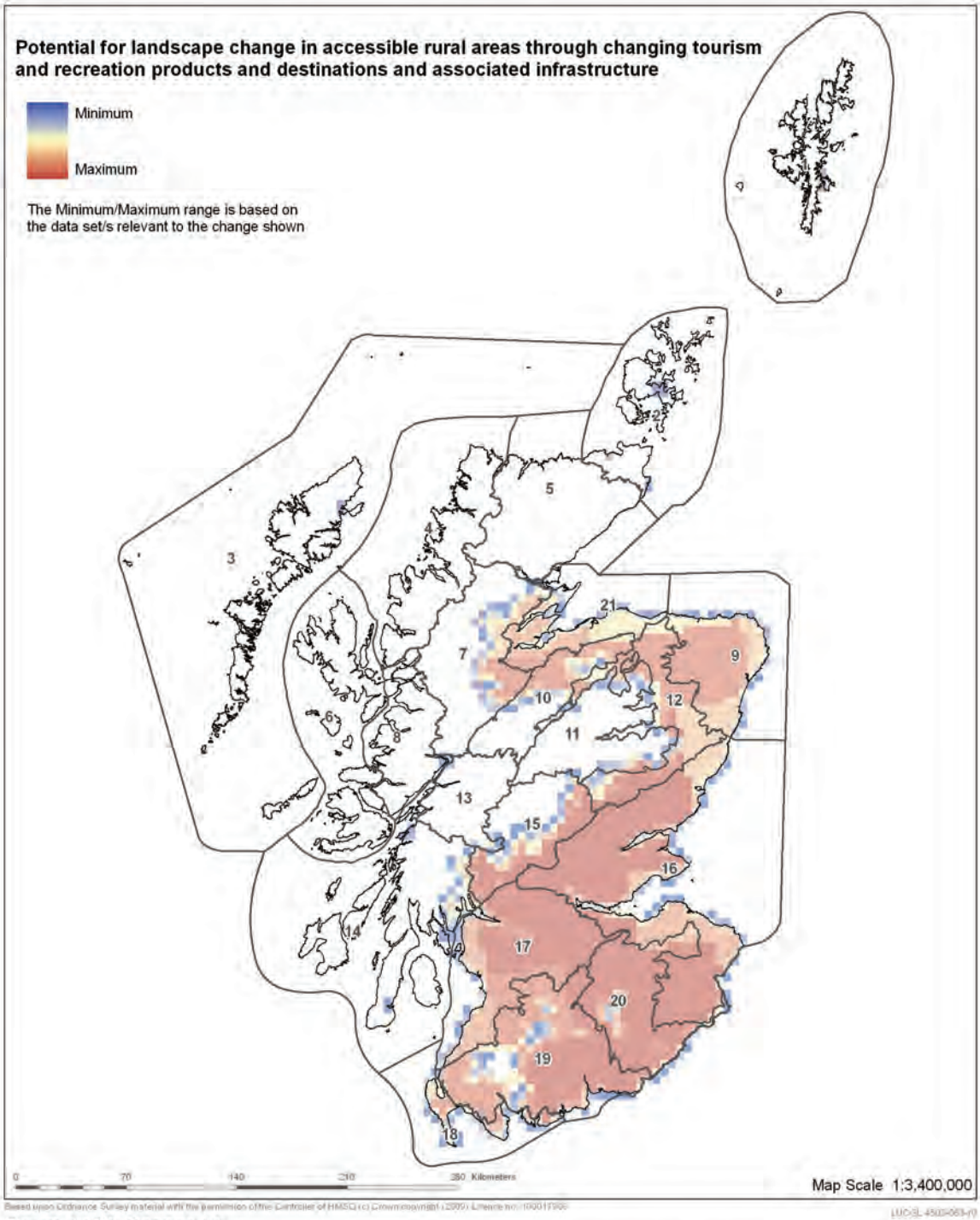

Figure 4.17b, Change 14

- Change distribution based on comparison of all areas except those classed as remote in the Scottish Executive urban-rural classification and climate change variables T1: Average annual temperature increase, T2: Autumn temperature change, T3: Increased difference between summer-winter temperature, P2: Average decrease in summer precipitation, C1: Increased cloud cover, SN1: Change in snowfall, T4: Change in daily maximum temperature in summer-autumn

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

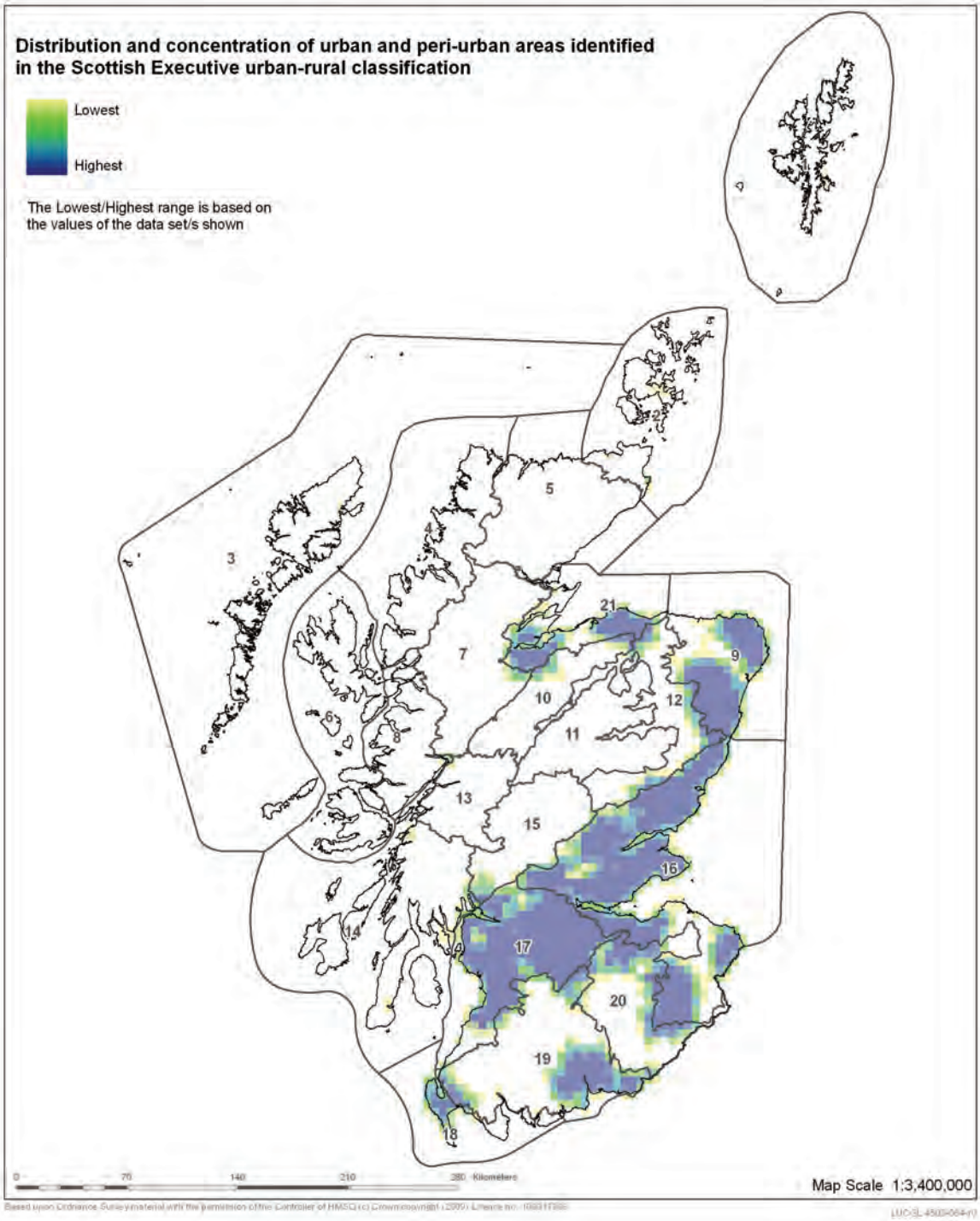

Figure 4.18a, Change 8

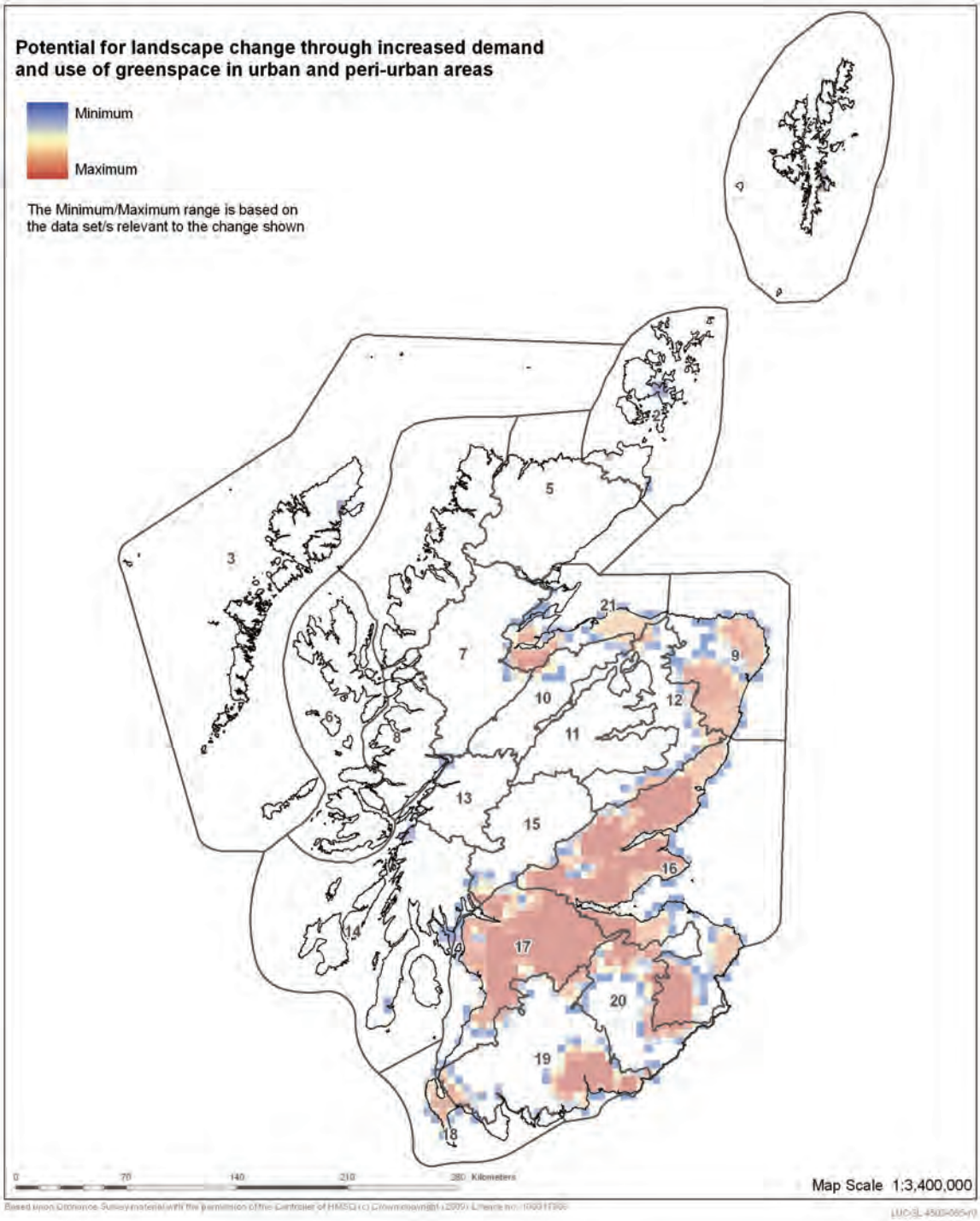

Figure 4.18b, Change 8

- Change distribution based on comparison of urban and peri-urban areas identified in the Scottish Executive rural-urban classification with climate change variables T2: Autumn temperature change, T4: Change in daily maximum temperature in summer-autumn

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

Infrastructure

Current Patterns

4.34. There is a dense network of roads throughout central and eastern Scotland, however there are a number of individual key routes which connect communities to the north and west which are vulnerable to events such as landslides. The rail network connects many parts of Scotland, and several new routes are planned or in the process of being reinstated. Ports and harbours play an important role in the Scottish economy and support ferry routes.

4.35. Renewable energy development is an important feature in the Scottish landscape, and the pattern of wind energy development extends around the northern and eastern coastal fringes, across central Scotland and into southern Scotland. The extent of wind energy development is likely to continue to increase in the future, where this is not constrained by to the limitations of grid infrastructure. Other factors such as the existing constraints associated with Civil Aviation Authority safeguarded areas (which may be addressed in the future through technical solutions), and the possibility that increases in wind speeds associated with storminess could affect wind farm operation, may influence the location of wind farm development. The electricity distribution system includes a hierarchy of transmission lines linking the north coast, eastern Scotland, west coast and central Scotland and through southern Scotland to England.

Future Change

4.36. Changing climate is likely to have a number of implications for infrastructure in Scotland, partly in relation to ensuring that systems are sufficiently robust to cope with changes in rainfall, sea levels or temperature, and to respond to changing demands for water and power. Key changes affecting the landscape could include:

- the upgrading of road and rail infrastructure (drains, culverts, flood lagoons, etc.) to cope with increased rainfall. This is likely to be most significant in areas experiencing the greatest increases in rainfall, particularly during the winter months (adaptation);

- the increased use of Sustainable Urban Drainage Systems (SUDS) to manage rainfall runoff in urban areas and to reduce the risk of pluvial and fluvial flooding. This is likely to take the form of permanent or intermittent flood storage areas, permeable surfaces and wider use of green-roofs. This is likely to be most significant in areas experiencing the greatest increases in rainfall, particularly during the winter months (adaptation);

- the management of areas where increased rainfall could result in slope instability threatening transport infrastructure. Responses may include protective forestry, the construction of debris channels and engineered drainage, the use of shelters over roads and railways and the realignment of roads to avoid areas of greatest risk (adaptation);

- the adaptation or abandonment of port and harbour infrastructure in response to rising sea-levels (adaptation);

- the risk of sea-level rise and increased storminess flooding coastal settlements and transport infrastructure (impacts) and responses in terms of flood defences and possibly in the longer term, the abandonment or rerouting of roads or rail routes to reduce the risk of flooding and flood damage (adaptation);

- the development of reservoirs and water infrastructure to supply other parts of the UK, most likely in parts of southern Scotland with high and increasing levels of rainfall (adaptation);

- the further development of windfarms - focusing on upland areas within 20km of the national grid, excluding National Parks (mitigation). However there is uncertainty over the longer term future energy mix;

- further development of the national grid – focusing on grid strengthening projects in the National Planning Framework (mitigation);

- development of offshore windfarms, affecting marine and coastal landscapes particularly off the coast of Dundee, Angus, Fife and East Lothian, Argyll and the islands and the Solway Firth (mitigation);

- small scale wind energy schemes – community and domestic (mitigation);

- tidal, tidal current and wave energy schemes (mitigation);

- biomass power plants in areas with a high proportion of forests (20%+) or areas of farmland suitable for biomass production (arable and general cropping) (mitigation);

- upgrading of waste water treatment plants to cope with storm flows (local) (adaptation).

Mapped Analysis

4.37. *Wind energy development (Figure 4.19):* This map shows the geographic distribution of existing, approved or proposed onshore windfarm developments in Scotland, distinguishing between different sizes of schemes. It suggests current concentrations of interest in the southern uplands and other hills to the south of the central belt, a series of locations in Argyll and Bute, Stirling, Fife and Angus, together with the north side of the Spey valley, the east coast to the north of Inverness, and Lewis. Areas where there is much less activity include much of the Highlands, reflecting the presence of landscape and other designations and the lack of a robust electricity transmission grid network. It is likely that implementation of grid reinforcement schemes (including Beauly to Denny, Loch Broom to Beauly and along the East Coast) could further reinforce this pattern. These changes are judged to have a moderate to high level of certainty and likely to occur from the medium term onwards. This analysis does not taken into account existing and proposed offshore windfarms.

4.38. *Water Infrastructure for Export (Figure 4.20a and 4.20b)*: This map shows the geographic distribution of areas over 200m within southern Scotland. Areas over 200m were identified as the potential location of reservoirs, aqueducts and pipelines to capture rainfall and export it southwards. Increase in water infrastructure associated with export will potentially be limited to the south of Scotland, particularly the Southern Uplands. These changes are judged to have a moderate to high level of certainty and likely to occur from the short term onwards.

4.39. *Biomass power plants (Figure 4.21)*: This map show where there is a concentration of arable land capable of supporting the cultivation of energy crops such as Miscanthus or short rotation willow and coniferous forests which could act as a source of wood fuel, supporting the potential development of biomass power plants. The analysis shows the greatest potential along the east coast, reflecting the potential to grow energy crops within existing agricultural areas (subject to

competition for other crops), and reflecting key concentrations of forest cover in Dumfries and Galloway, Argyll, Moray and around Inverness. These changes are judged to have a high level of certainty and likely to occur from the short term onwards.

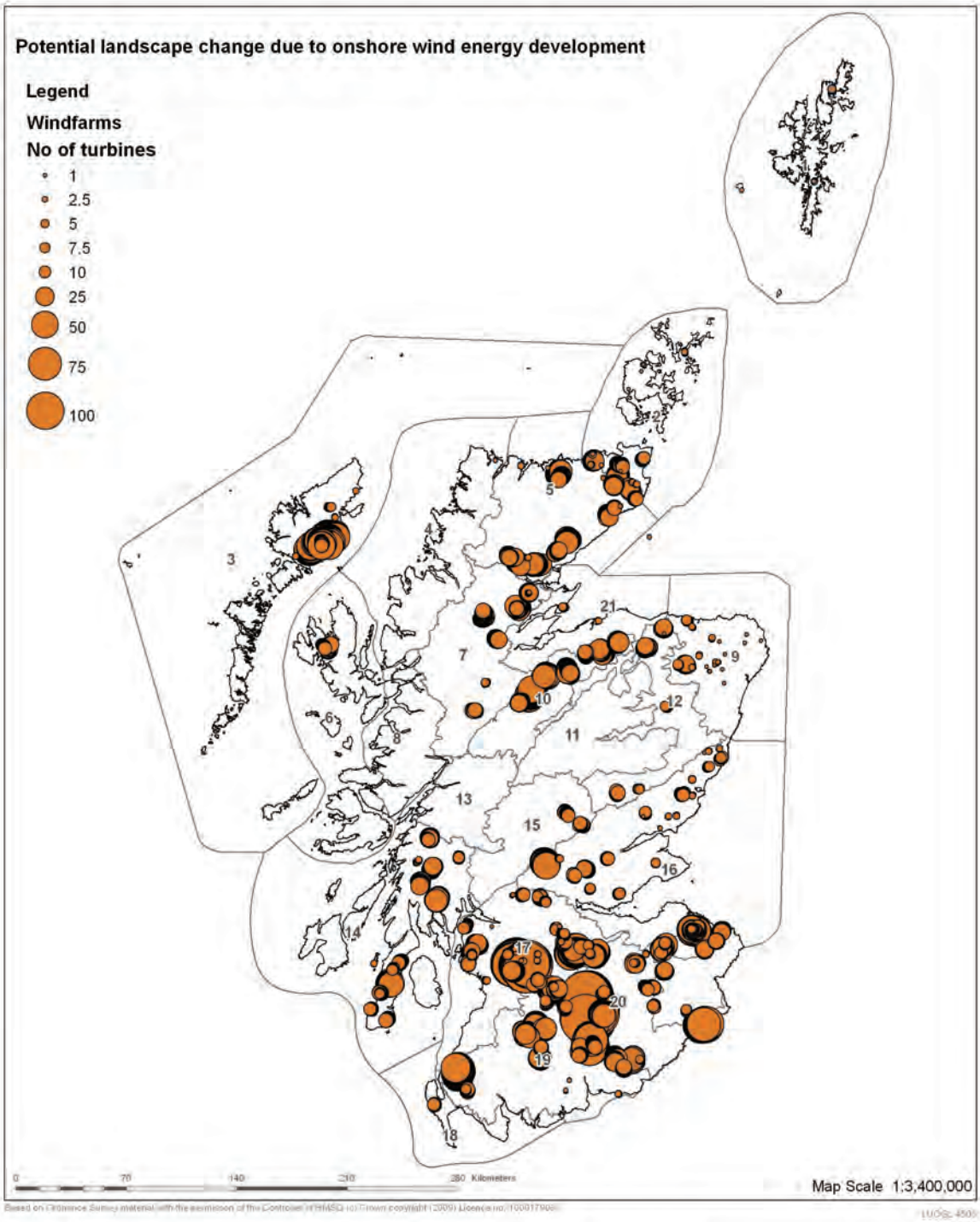

Figure 4.19 Potential landscape change by onshore wind energy development

- Distribution based on SNH Windfarm Footprint and Turbine datasets 2009

Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

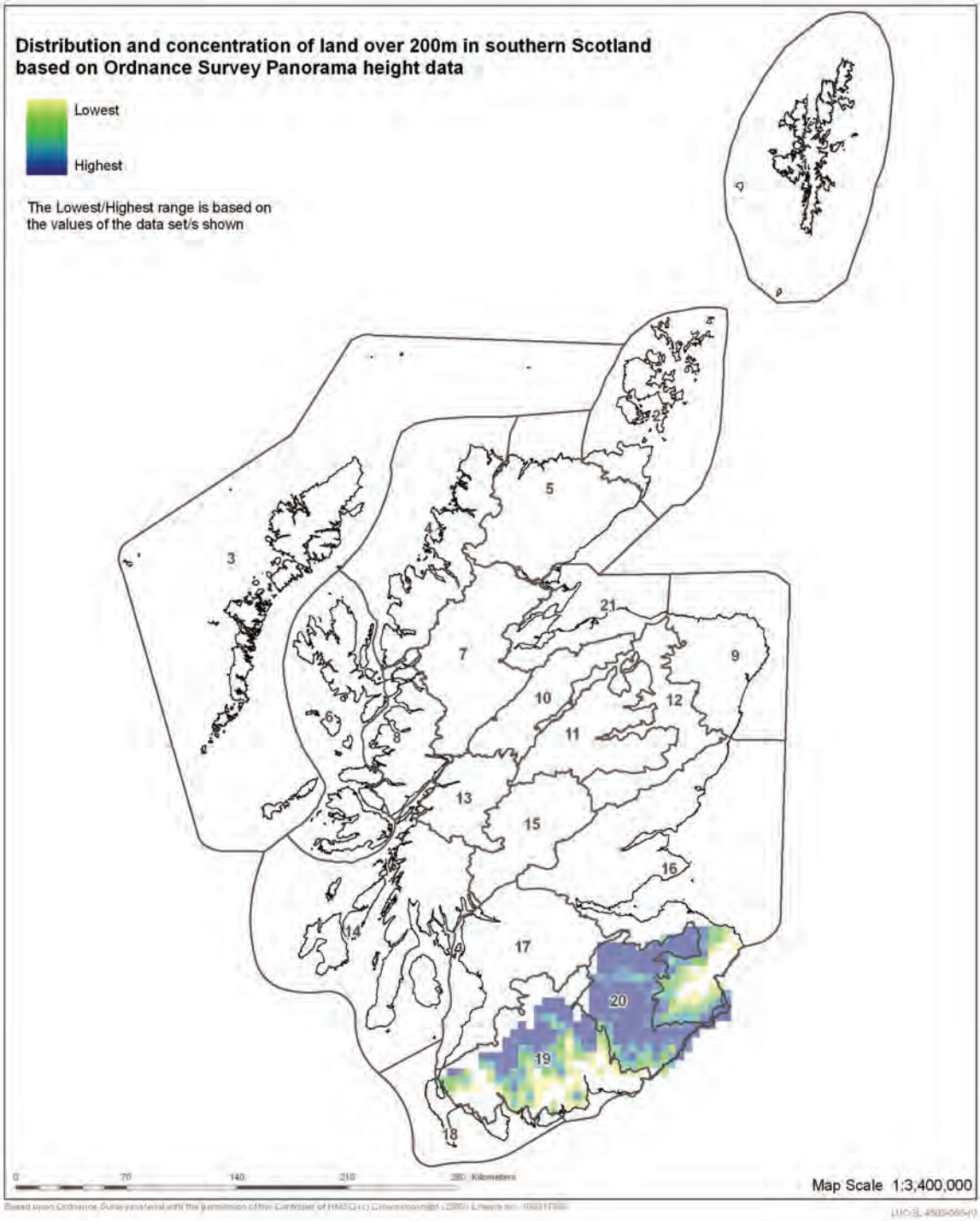

Figure 4.20a, Change 18

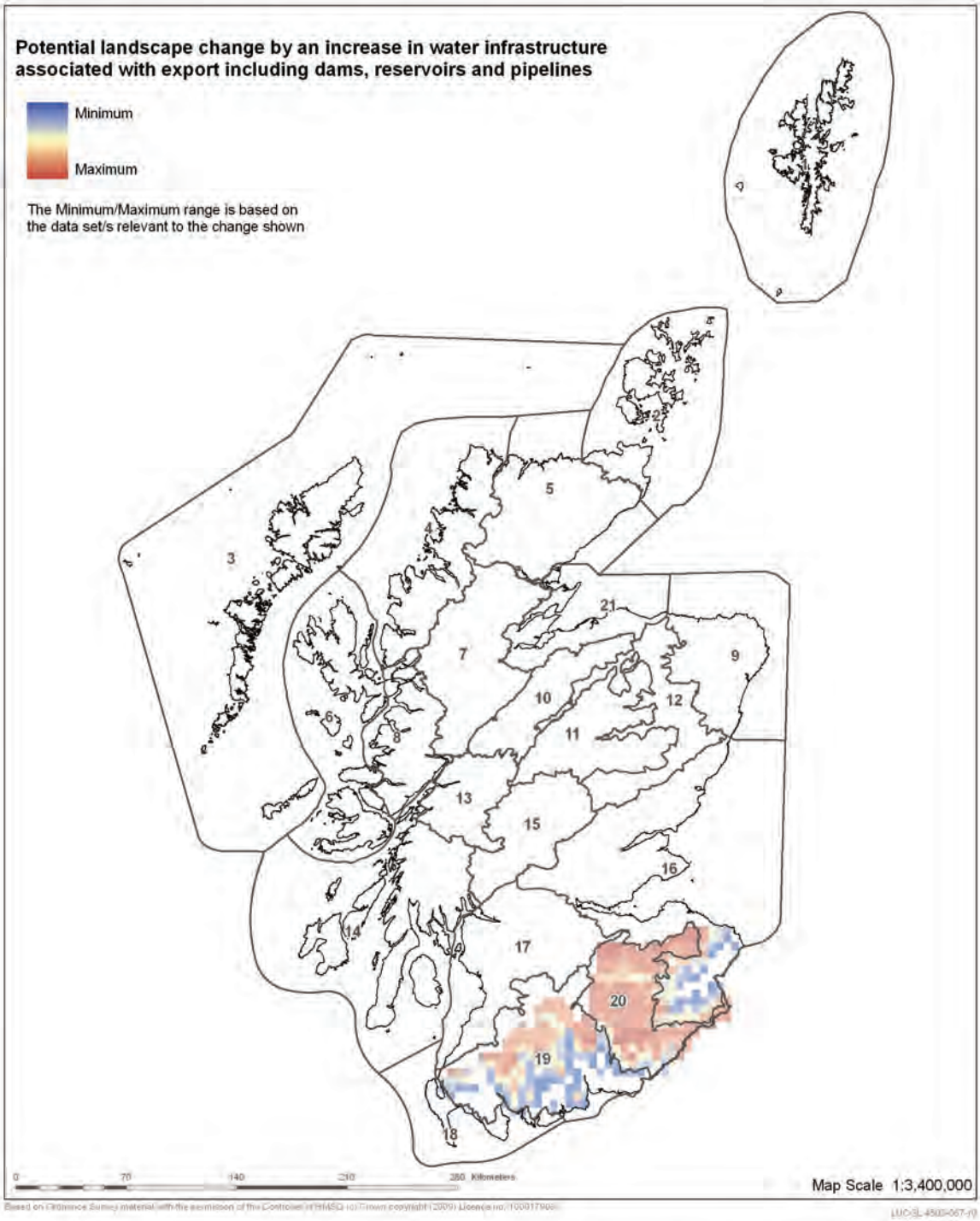

Figure 4.20b, Change 18

▸ Change distribution based on comparison of land over 200m in southern Scotland based on Ordnance Survey Panorama height data with climate change variables P1:Average change in winter precipitation and P2: Average decrease in summer precipitation climate change variables

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

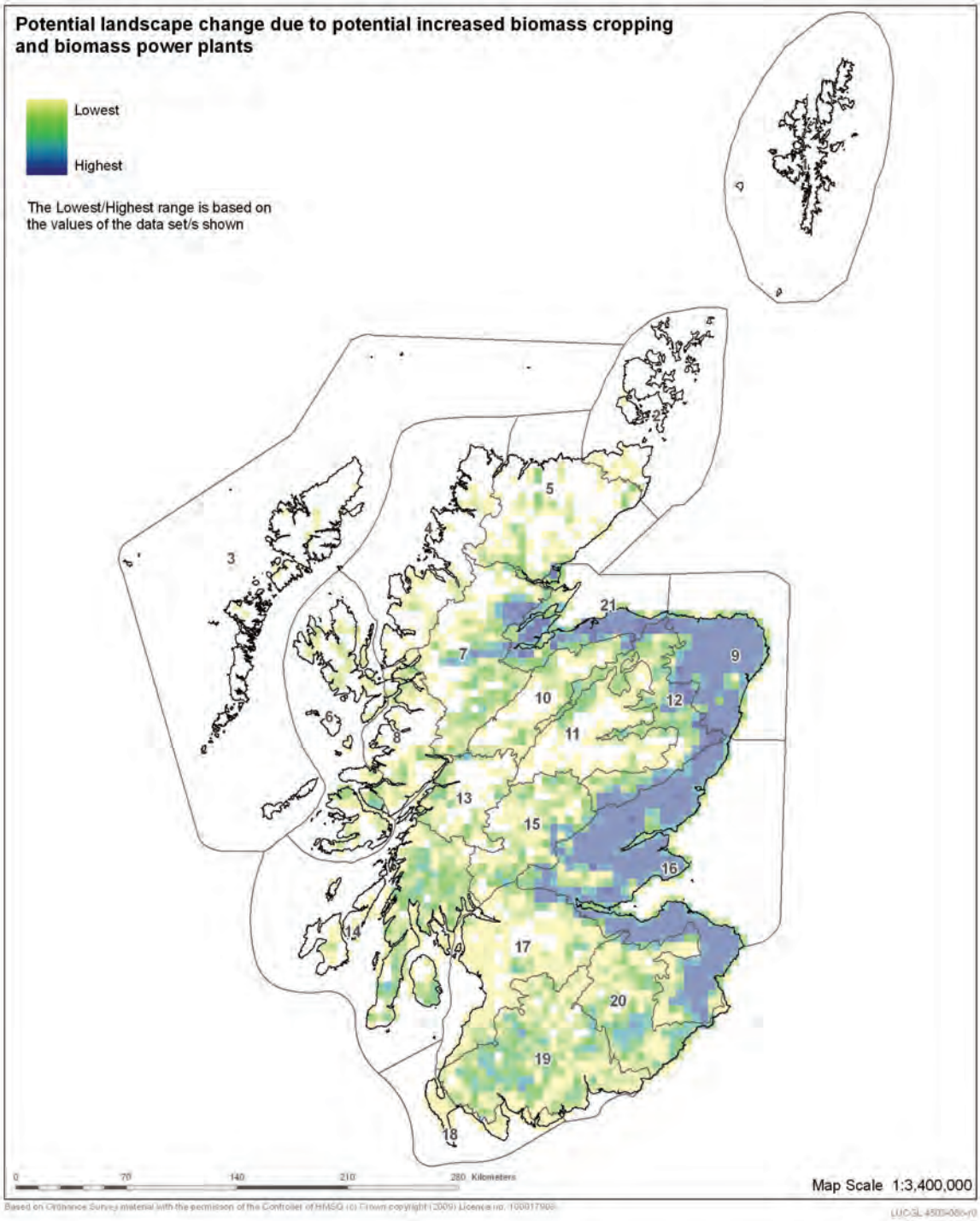

Figure 4.21 Change 21

- Distribution based on areas of coniferous forestry identified from the National Inventory of Woodland and Trees and arable farm type

Habitats (Natural and Semi Natural)

Current Patterns

4.40. Habitats fall within many of the other topic areas explored in this section of the report including agriculture, forests and woodland, freshwater and coasts. The habitats of Scotland are strongly influenced by land management practices. The extent of native woodland is low, however the area of woodland is expanding and there are policy objectives to enhance the diversity of habitats. Similarly, while the ecological value of some urban areas may be low, there is policy support for the creation of habitat networks extending into and across towns and cities, in many cases linked to enhanced greenspace networks. Heather moorland and peatbog are key components of the upland landscape and the coast and freshwater, rivers and wetlands are integral elements. Threats to habitats include changes in land management, habitat loss and fragmentation from built development. Some habitat types are more resilient, others are more vulnerable.

Future Change

4.41. Climate change is likely to have a range of impacts on habitats in Scotland. While some of these will have a very local effect on the landscape, many could result in more significant and widespread effects. The latter include:

- impacts on heather moorlands resulting from a combination of altered management e.g. abandonment of muirburn (mitigation), increased fire risk and changing rainfall patterns (impact);

- change in montane plant communities as a consequence of reduced snow lie, a reduction in freeze thaw cycles, increased erosion (impact);

- positive and negative changes affecting peatlands resulting from rewilding initiatives (re-wetting, removal of trees) (mitigation and adaptation) and the impacts of increased winter rainfall (erosion, bog bursts etc) combined with summer drying (impact). Wetter areas could see increased rates of peat formation, drier areas could see reductions (impact);

- development of habitat networks, particularly in lowland agricultural areas and through urbanised areas (adaptation);

- the effects of changing species' climate space including move uphill and north (impact);

- increased nutrient recycling resulting in the enrichment of currently nutrient poor habitats. This could result in the invasion of grasses into upland moorlands with a loss of mosses, peat and heather (impact);

- rewilding of floodplains and creation of upland woodlands where these contribute to catchment wide flood management (adaptation);

- possible increased colonisation by non-native species (impact)

- improved conditions for pinewoods in west and central Highlands resulting from drier summers (impact);

- potential expansion of native woodland, particularly at high levels in response to higher tree line. The current natural treeline is generalised at around 500m. Expansion based on natural regeneration could raise the treeline by 100m over

100 years. Expansion based on planting or seeding could raise the treeline to 1200m over the same period (impact);

- potential loss of coastal and estuarine habitats due to sea-level rise, coastal squeeze and changing patterns of erosion and deposition (impact and adaptation);
- potential loss of freshwater and riparian habitats due to flood damage, changed erosion and deposition (impact);
- change in Atlantic oakwoods due to wetter, milder winters and drier, warmer summers, resulting in colonisation by native and non-native species (impact);
- change in species composition of eastern oak woods (impact);
- expansion of birch woodlands in farmed parts of the central and eastern Highlands, and eastern Scotland (adaptation).

Mapped Analysis

4.42. *Damage to Peatland (Figure 4.22a and 4.22b)*: The maps show the current distribution of peatlands combined with analysis of those areas likely to experience greatest increases in winter rainfall. While higher winter rainfall could support continued or enhanced peat formation, it could also result in damage from erosion and more dramatic events such as bog-bursts. Areas likely to experience the greatest degree of change include the peatlands of Caithness and Sutherland, parts of the central Highlands the Cairngorms and Breadalbane and East Argyll. The Outer Hebrides, the north and west coast, including parts of Argyll and Bute are also likely to experience higher levels of change. These landscapes are typically located within the more remote and upland environments some distance from the main population centres, and peatland is an intrinsic characteristic of these remote environments. These changes are judged to have a high level of certainty and likely to occur from the medium term onwards.

4.43. *Changes in peat accumulation (Figure 4.23a and 4.23b):* These maps show the current distribution of peatlands combined with those areas likely to experience both an increase in winter rainfall and a reduction in summer rainfall. Under these circumstances it is possible that the peat will dry out and die back during the summer and suffer erosion during the winter. Areas likely to experience the greatest degree of change include the peatlands of Caithness and Sutherland, much of the Highlands, Argyll, the inner and Outer Hebrides and the Shetland Isles. These landscapes are typically located within the more remote and upland environments some distance from the main population centres. These changes are judged to have a high level of certainty and likely to occur from the medium term onwards.

4.44. *Invasion of grasses into montane and moorland habitats (Figure 4.24a and 4.24b):* These maps show the current distribution of heather moorland combined with likely changes in temperature. More rapid decomposition and nutrient recycling may affect the nutrient status of some habitats, in particular the invasion of grasses into montane and moorland habitats. The areas with the greatest potential change are likely to include much of the Highlands, particularly the Cairngorms massif. Again, these landscapes are typically located within the more remote and upland environments some distance from the main population centres. These changes are judged to have a high level of certainty and likely to occur from the medium term onwards.

4.45. *Changes in upland plant communities above 800m (Figure 4.25a and 4.25b):* These maps show areas above 800m in altitude combined with likely changes in temperature. Milder winters and reductions in frost action and snow lie could have a significant impact on sub-alpine plant communities, in turn changing the character of many upland summits and plateaux. As would be expected, the greatest changes are likely to affect higher areas particularly the Cairngorms massif and other inland hill ranges such as the Monadhliath. These landscapes comprise the main upland areas which, although located away from the main population centres, are important for tourism and recreation. These changes are judged to have a high level of certainty and likely to occur from the medium term onwards.

4.46. *Changes in extent of heather moorland (Figure 4.26a and 4.26b):* These maps show the current distribution of heather moorland combined with those areas where there is likely to be an increase in temperature. The extent of heather moorland may decrease in response to changing temperature and management practices. The extent of areas likely to experience change in heather moorland cover are extensive. Areas likely to experience the greatest change are the central, northern and western highlands including the north west seaboard, the peatlands of Caithness and Sutherland, the western seaboard and the Western Isles. Changes within Argyll and Bute and the southern uplands across and Border Hills are also likely to be apparent.

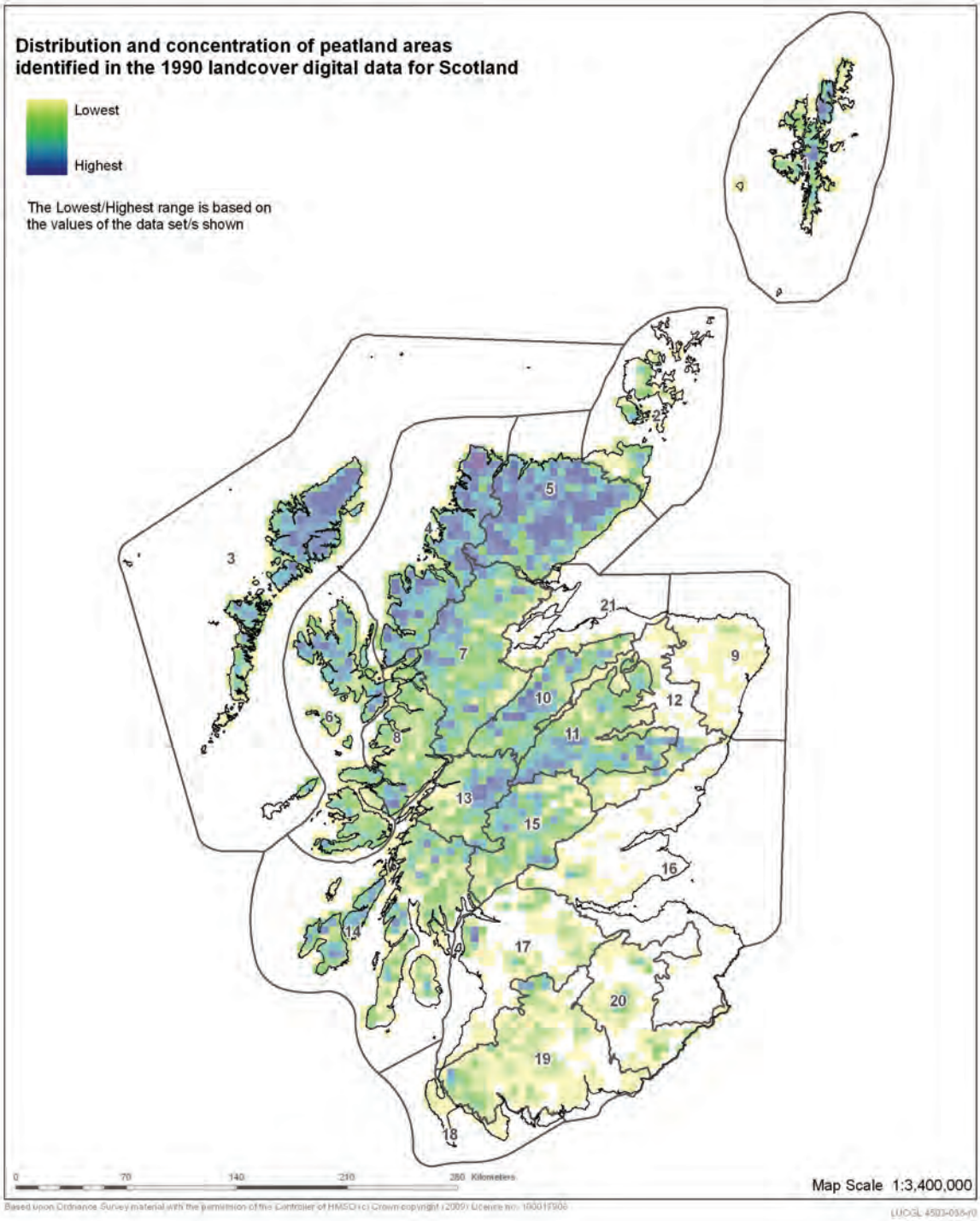

Figure 4.22a, Change 72

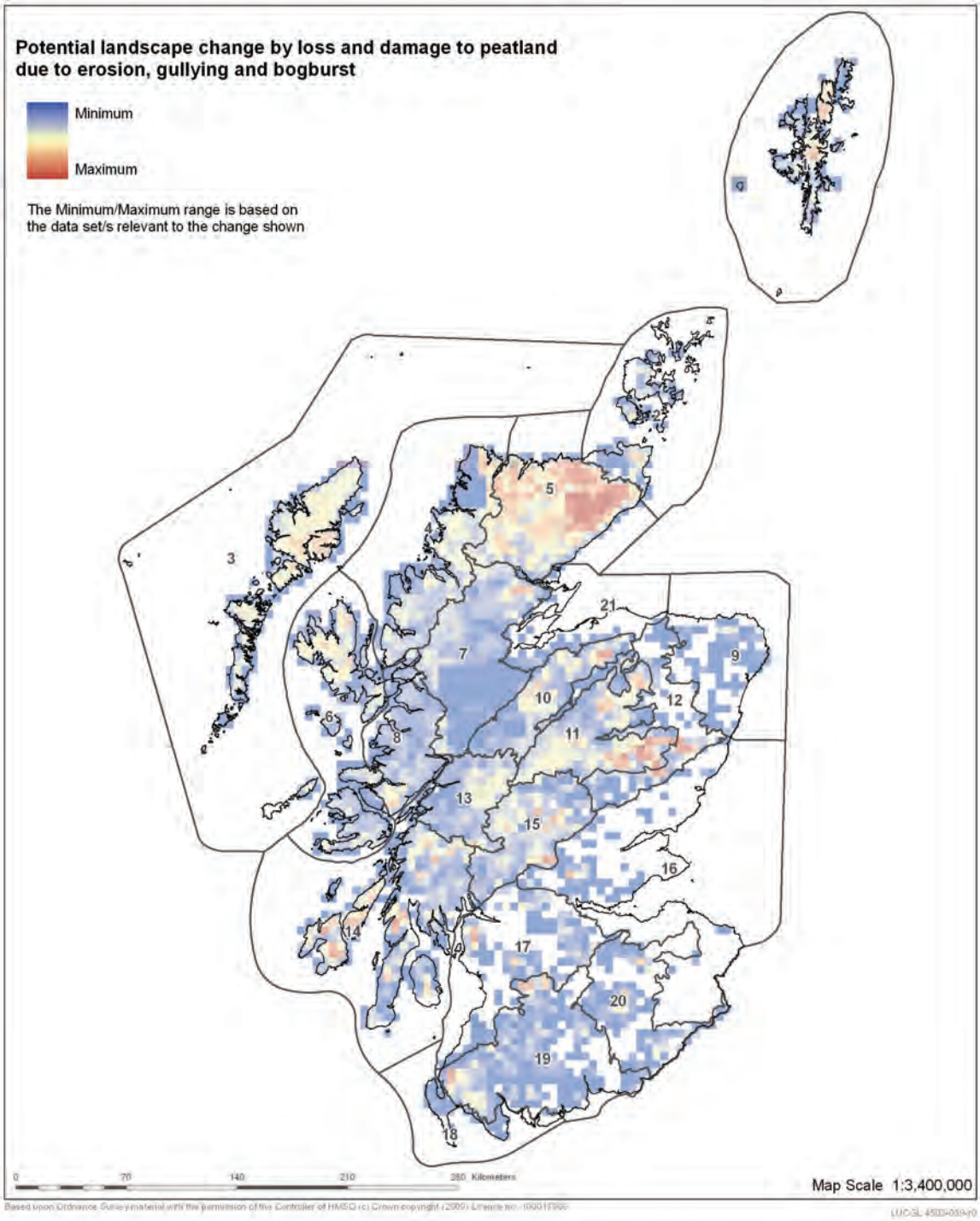

Figure 4.22b, Change 72

▸ Change distribution based on comparison of peatland areas identified in the 1990 landcover digital data for Scotland with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

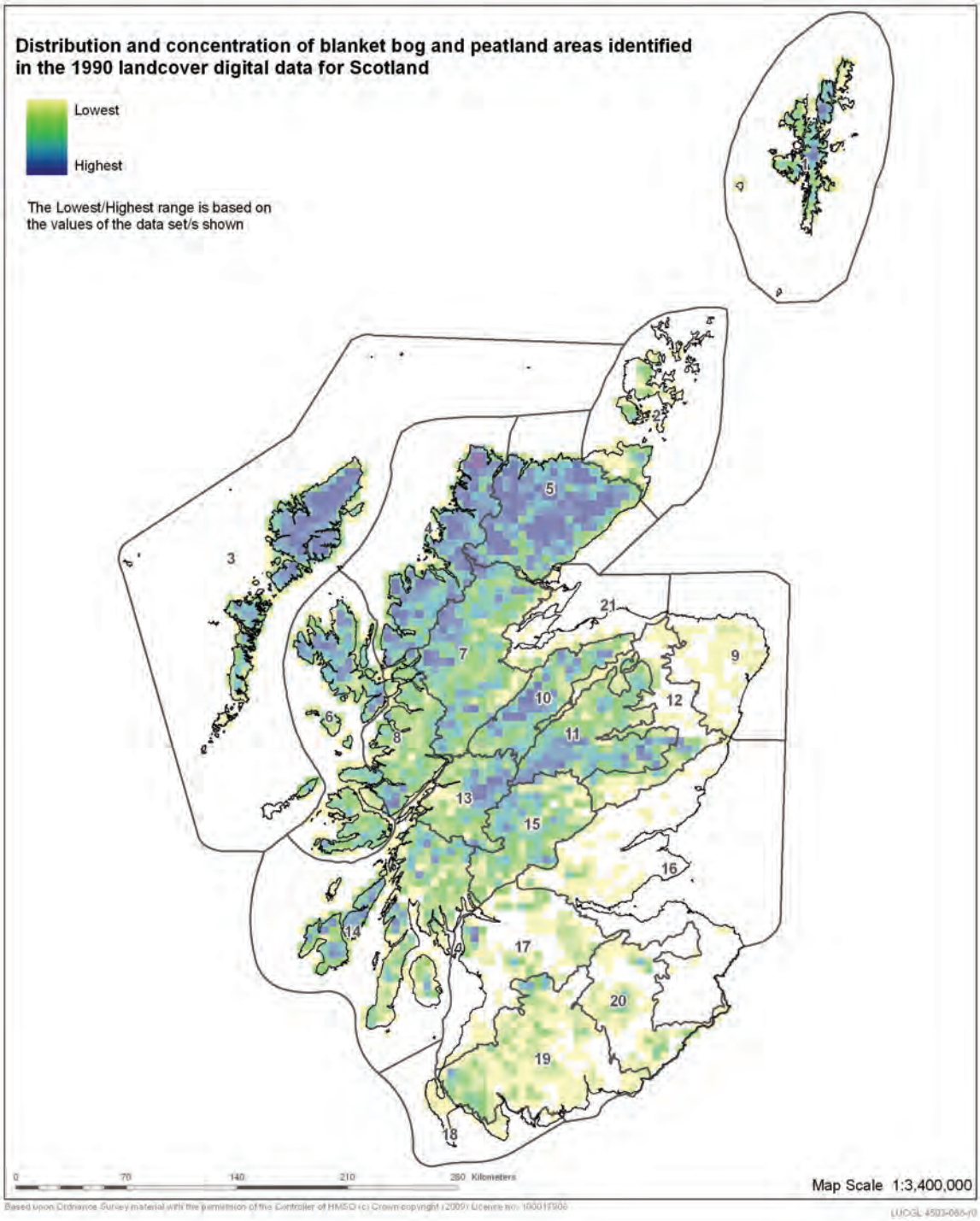

Figure 4.23a, Change 39

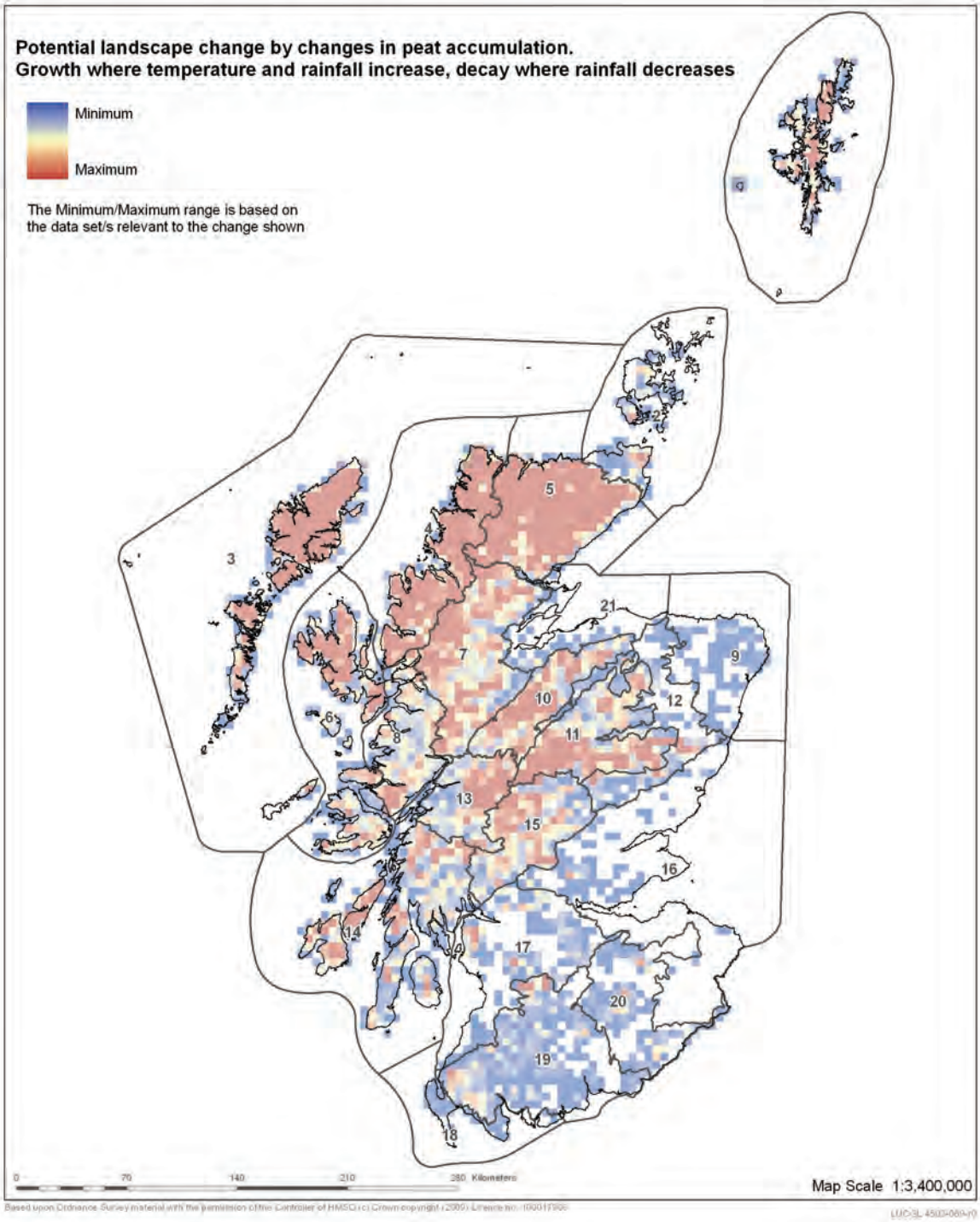

Figure 4.23b, Change 39

- Change distribution based on comparison of blanket bog and peatland areas identified in the 1990 landcover digital data for Scotland with climate change variables T1: Average annual temperature increase, P1: Average change in winter precipitation, and P2: average decrease in summer precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

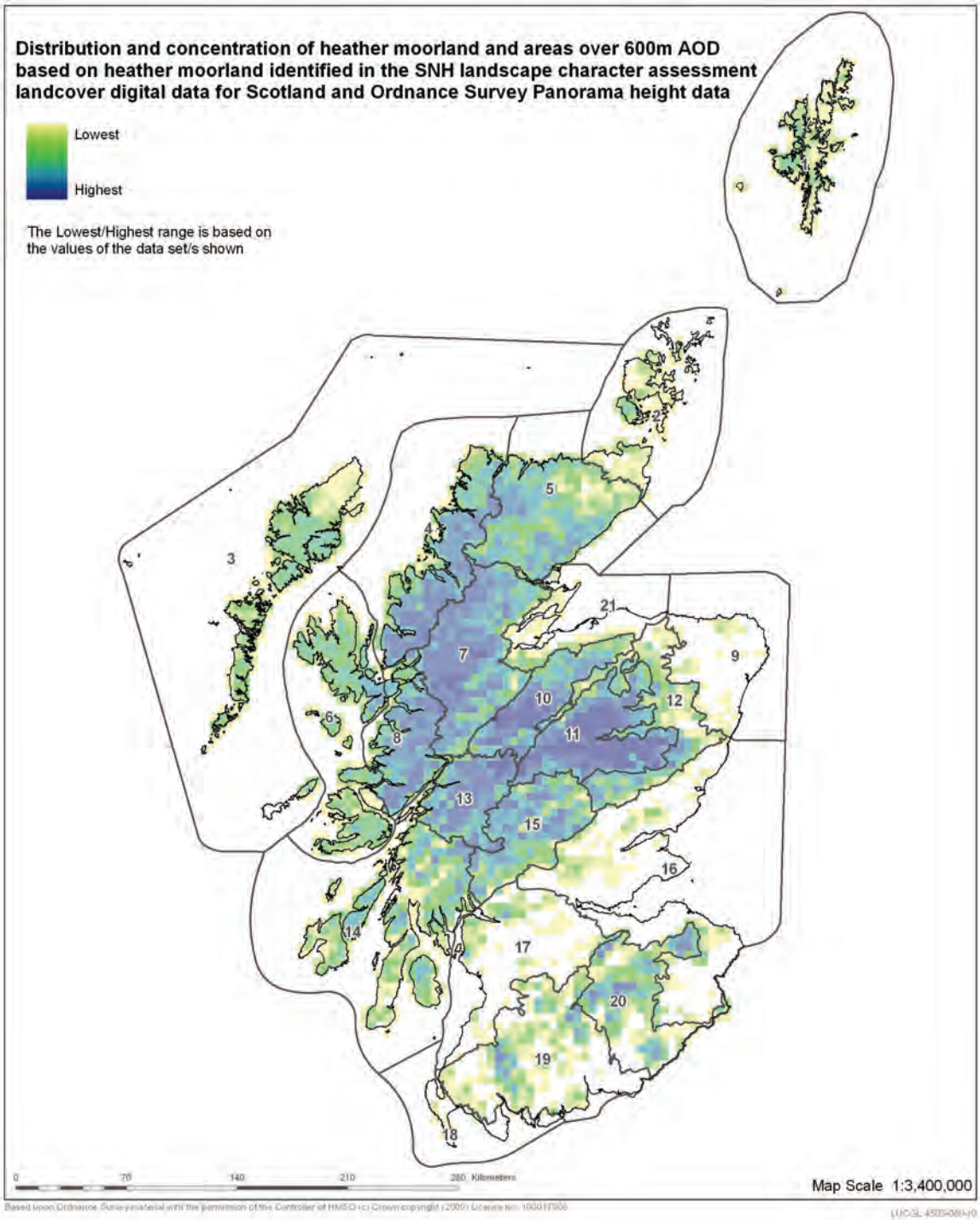

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Figure 4.24a, Change 36

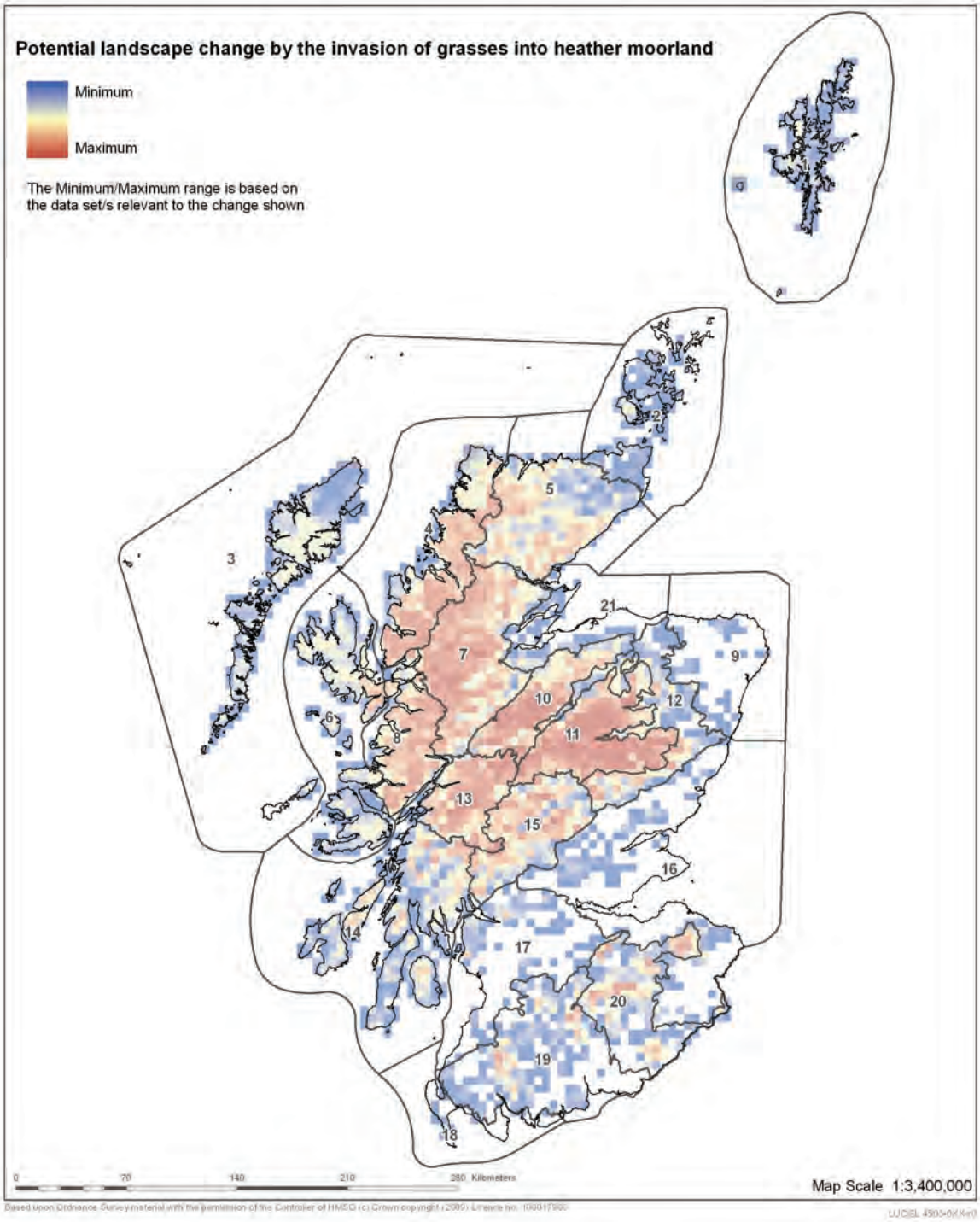

Figure 4.24b, Change 36

- Change distribution based on comparison of heather moorland and areas over 600m AOD identified in the SNH landscape character assessment landcover digital data for Scotland and Ordnance Survey Panorama height data with climate change variable T2: Autumn temperature change

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

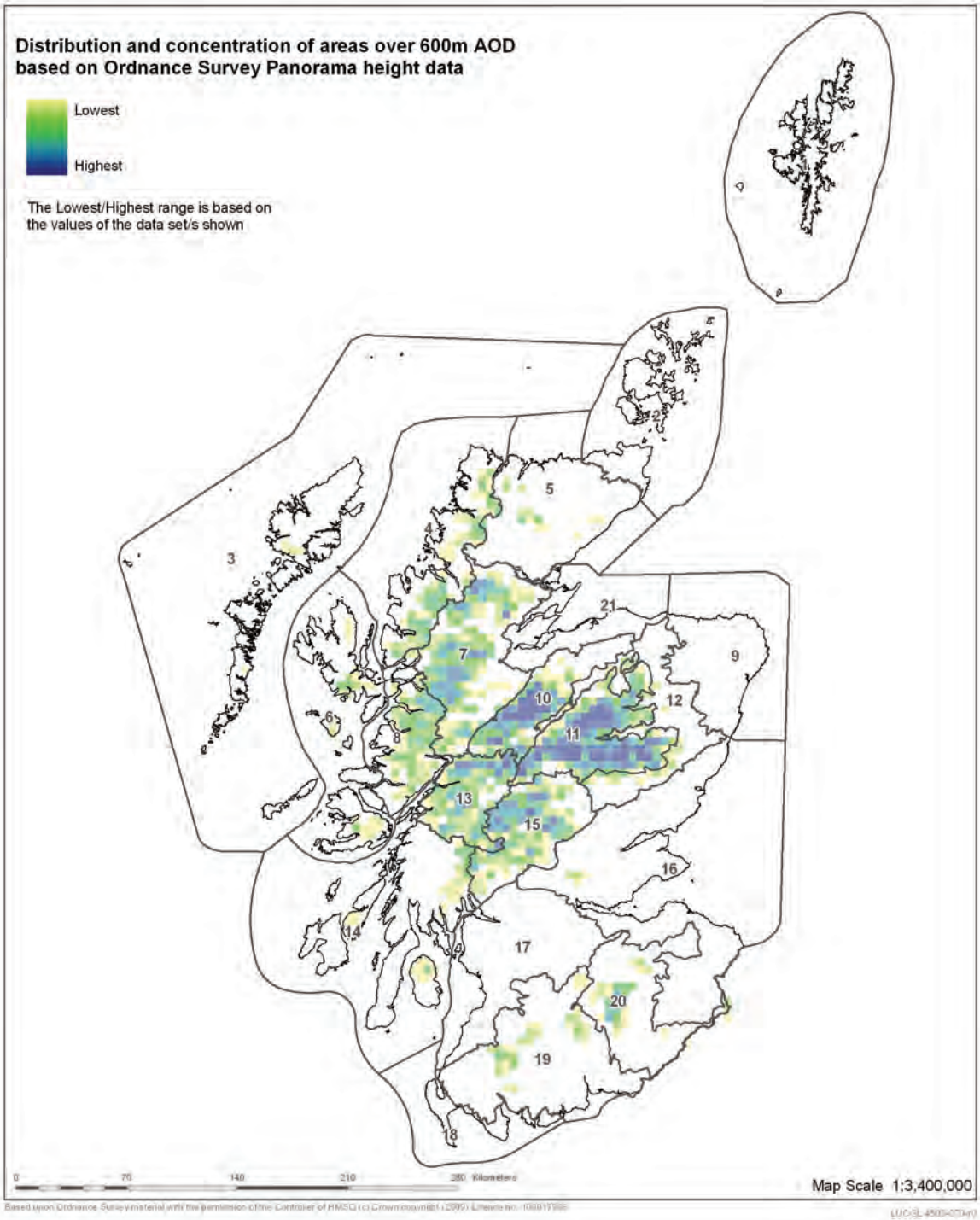

Figure 4.25a Change 31

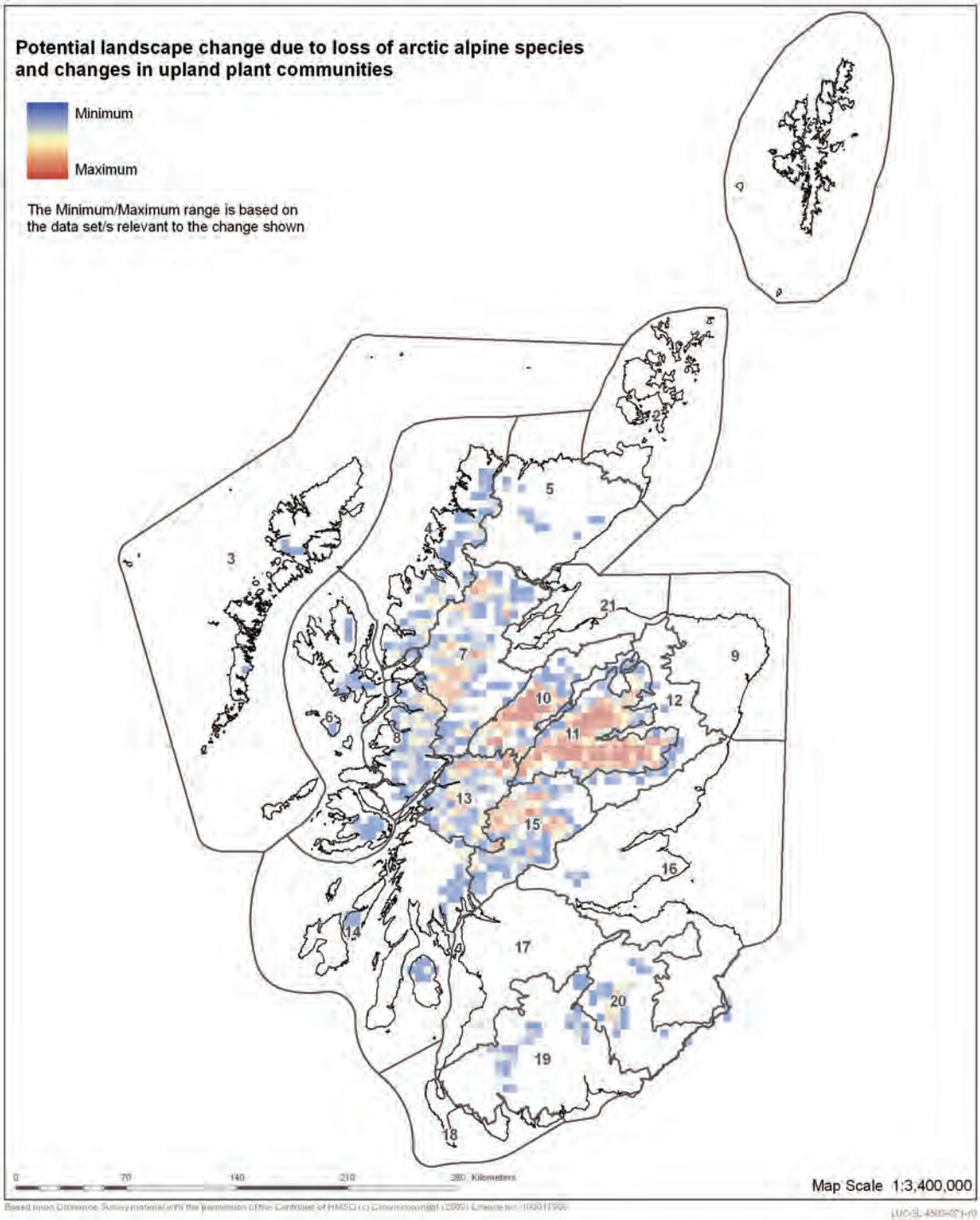

Figure 4.25b, Change 31

▸ Change distribution based on comparison of areas above 600m AOD based on Ordnance Survey Panorama height data with climate change variable T2: Autumn temperature change

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

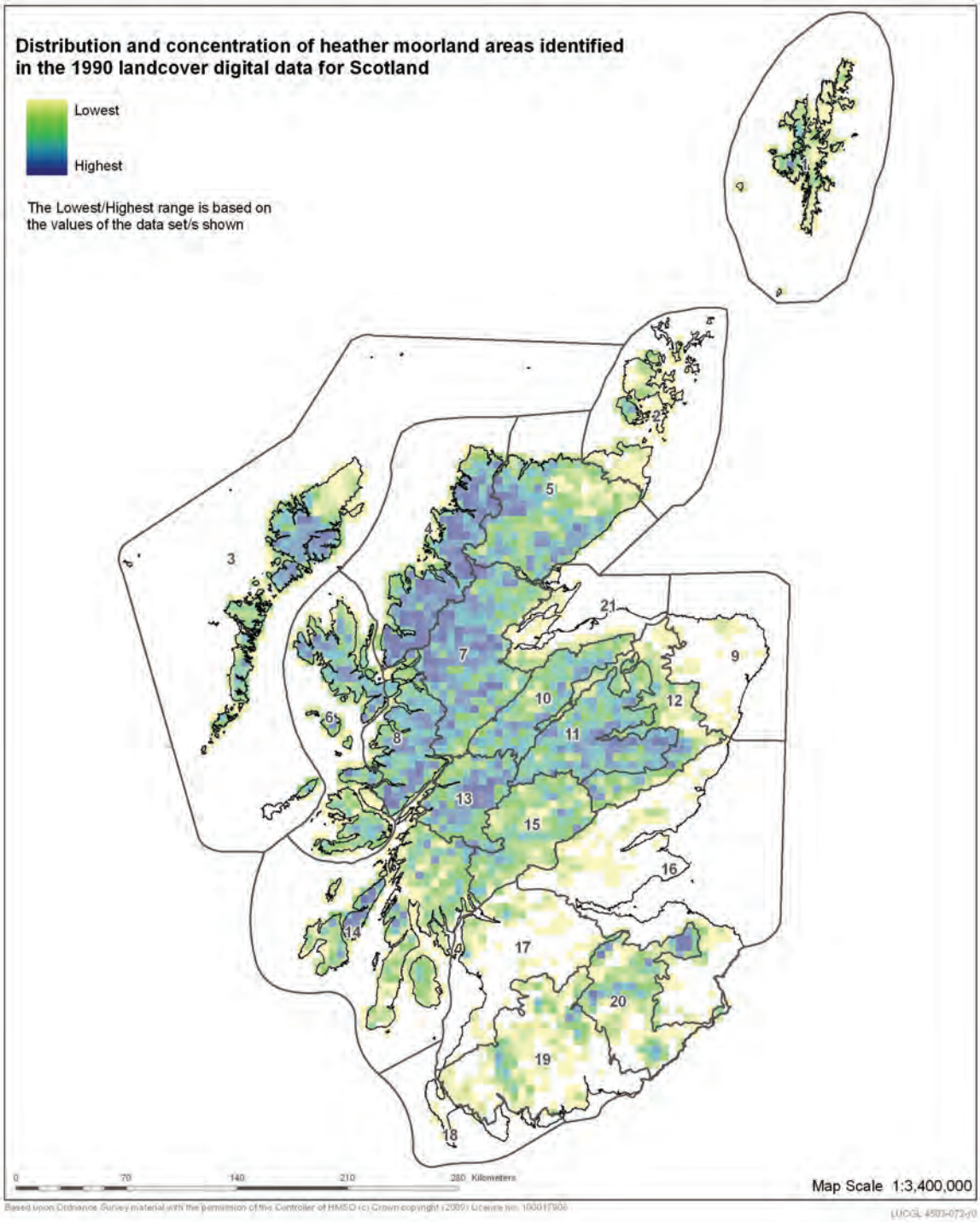

Figure 4.26a, Change 27

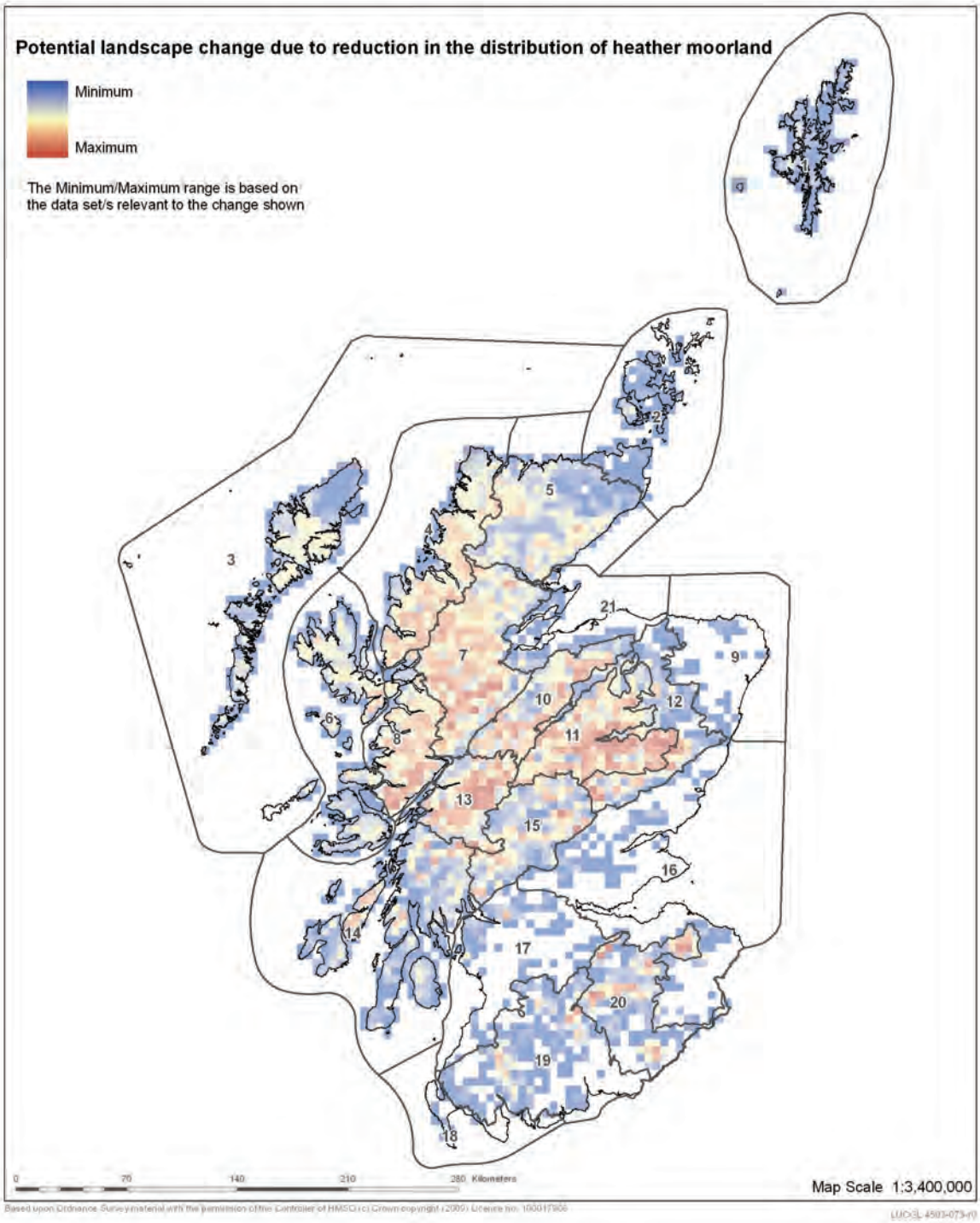

Figure 4.26b, Change 27

- Change distribution based on comparison of heather moorland areas identified in the 1990 landcover digital data for Scotland with climate change variables T1: Average annual temperature increase, T2: Autumn temperature change, T3: Increased difference between summer-winter temperature

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

Agriculture

Current Patterns

4.47. The distribution of farm types in Scotland is a product of underlying geology, soil type, climate and elevation. The majority of the upland and island landscapes are lower quality sheep and cattle grazing land. Dairy farming is concentrated in southern Scotland, Ayrshire and the central belt. Cereals are generally concentrated around the coastal fringe including the north east and north of Inverness. The Lothians, Fife and the east and north coast are used predominantly for general cropping with areas of horticulture west of Edinburgh, Fife and west of Dundee. Poultry production is concentrated west of Edinburgh and through Fife, with pockets in the north east. There is some uncertainty in relation to the direction of change in agriculture which reflects the complexity of the influences on this sector. This includes the potential competition for land for biodiversity, flood management, development, forests and food production, and the volatile economic influences.

Future Change

4.48. Agricultural activity is likely to experience a range of changes as a result of climate change and many of these could have implications for the landscape. Changes in temperature and rainfall could have an influence on the range of crops that can be grown and areas that are suitable for outdoor stock rearing. Other influences could include summer water shortages, the expansion of biomass and energy crops, an increased prevalence of pests and diseases and an improved market due to more severe climate change impacts elsewhere in the UK and Europe. Key landscape changes could include:

- reductions in summer rainfall could result in changes in on-farm water management. This could include on-farm water storage and the greater use of irrigation equipment in arable and horticultural areas (adaptation);

- new farm buildings may be required in order to provide improved accommodation for cattle, pigs and poultry (insulation to protect against summer temperatures and protection from winter rain), and expanded crop storage where cereal and potato productivity increases due to extended growing season, higher summer temperatures and increased CO_2 concentrations (adaptation). New buildings may also be required to accommodate farm based renewable energy including biomass and anaerobic digestion plants, though these are likely to be of a scale similar to many existing farm buildings (mitigation);

- changing patterns of agricultural cultivation in response to changes in rainfall, increased temperatures and an extended growing season, together with potential improvement in Scotland's competitive advantage over other agricultural areas (adaptation). Changes could include an expansion of cereal and general cropping into areas currently used for dairy, cattle and sheep and a further phase of field enlargement and field boundary loss. New crops, including biomass and other energy crops may be introduced and there could be a further expansion of crops such as oilseed rape. Sowing may start earlier and harvesting could take place later. However, increased winter rainfall could result in a shift from autumn to spring sowing (adaptation);

- an intensification of pastoral activity, particularly in currently marginal areas and possibly with an expansion uphill, with an increase in sheep and cattle grazing within more remote upland areas. It is possible that poultry farming may expand, though it is likely this will be in existing poultry production areas, particularly those relatively accessible to urban areas and the transport network. There may be

changes in the choice of livestock breeds and an increase in outdoor rearing, where this is compatible with patterns of increased winter rainfall (adaptation);

- there may be changes in the pattern of woodland cover and trees on farms. It is likely that there will be an expansion of on-farm woods, partly to increase carbon sequestration (mitigation), partly to provide shelter for stock and crops from winter rain and wind, shade from summer sunshine, and partly to contribute to habitat networks to reverse fragmentation and facilitate species adaptation (adaptation). On the other hand, it is possible that a combination of summer droughts and winter waterlogging, storm damage and field enlargement could result in an accelerated loss of field boundary trees (impact);

- there are likely to be very local changes in landscape as a result of on-farm measures to reduce soil erosion (adaptation). These include the use of ground cover crops, particularly during the winter period, the move to ploughing across slopes, improved field drainage, careful timing of ploughing and other operations involving heavy machinery, and the relocation of field gates to minimise the runoff from poached areas.

Mapped Analysis

4.49. *Shelter belts to shade and shelter livestock and crops (Figure 4.27a and 4.27b):* These maps show the those parts of Scotland where more intensive agricultural activity is currently concentrated, (all agricultural areas excluding less favoured areas are used as a proxy for these areas) combined with areas likely to experience greatest increases in summer temperatures, winter rainfall and wind speed. The analysis suggests that this requirement for shelterbelts is likely to apply across most of lowland agricultural Scotland, though with greatest concentrations along the east coast including the Lothians, parts of Fife, Angus and Aberdeenshire. An increase in the size and frequency of shelter belts for shading will potentially be most notable in areas surrounding population centres and along main infrastructure routes. These changes are judged to have a moderate to high level of certainty and likely to occur from the medium term onwards.

4.50. *Loss of field boundary trees (Figure 4.28a and 4.28b):* These maps show the those parts of Scotland where more intensive agricultural activity is currently concentrated, combined with areas likely to experience higher winter rainfall, lower summer rainfall and an increase in wind speeds. The analysis suggests a similar pattern of change to that described in paragraph 4.48, with impacts across the whole of lowland agricultural Scotland, but with greatest concentration along the east coast. Loss of field boundary trees will potentially be most visible in areas surrounding population centres and along main transport infrastructure routes. Field boundary loss will result in fields appearing larger and more expansive in their nature. These changes are judged to have a moderate to high level of certainty and likely to occur from the medium term onwards.

4.51. *Agricultural flood damage (Figure 4.29a and Figure 4.29b)*: These maps show those parts of Scotland where more intensive agricultural activity is currently concentrated, combined with areas identified by SEPA as being at risk of coastal and fluvial flooding, and areas experiencing greatest increases in winter rainfall. The analysis suggests that the risk of flood damage to agriculture will occur along the Solway Firth, within the middle reaches of the River Forth, within Strathmore where rivers emerge from the Angus Glens, and on the Moray coast. Notable changes will potentially include visible flooding of fields and flood damaged crop fields and pasture. These changes are judged to have a high level of certainty and likely to occur from the medium term onwards.

4.52. *Increased arable production (Figure 4.30a and 4.30b):* These maps show those parts of Scotland where there is an existing concentration of arable production and where climate change could lead to further intensification of activity. This could be reflected in field enlargement, the displacement of other crops and stock rearing, the loss of woodlands and demand for new agricultural buildings. The analysis suggests that the changes would be most pronounced in parts of the Borders, in Fife, Perthshire and Angus, and parts of Aberdeenshire and the BIack Isle to the north of Inverness. It is possible that arable cultivation will expand into areas that are currently pastoral in character, including the lower parts of Highland glens, the slopes of lowland hills such as the Sidlaws or Ochils, and more extensive dairy and cattle areas such as Ayrshire. New areas of arable production will be most visible from areas surrounding urban centres and from main infrastructure routes. These changes are judged to have a moderate to high level of certainty and likely to occur from the medium term onwards.

4.53. *Increased irrigation (Figure 4.31a and 4.31b):* These maps show those parts of Scotland where there is an existing concentration of cereal production, general cropping, horticulture and mixed farming and where reductions in summer rainfall may result in an increased requirement for irrigation. The analysis suggests that the changes would be most pronounced in parts of the Borders, in Fife, Perthshire and Angus, and parts of Aberdeenshire and the BIack Isle to the north of Inverness. It is expected that associated irrigation structures will be visible from surrounding urban centres and from main infrastructure routes within these likely areas of increase. These changes are judged to have a medium to high level of certainty and likely to occur from the medium term onwards.

4.54. *Affected sowing/harvesting (Figure 4.32a and 4.32b):* These maps show those parts of Scotland where there is an existing concentration of cereal production, general cropping and horticulture combined with increases in winter precipitation. In areas along the east coast it is likely that there will be a need to reduce the use of machinery during the winter months to prevent excessive soil damage and erosion. This is likely to precipitate a move towards later sowing or the use of winter ground cover crops. These changes are judged to have a medium to high level of certainty and likely to occur from the medium term onwards.

4.55. *New or novel crops (Figure 4.33a and 4.33b):* These maps show those parts of Scotland where arable agriculture is currently concentrated, combined with areas likely to experience greatest autumn temperature change. The potential distribution of new or novel crops is likely to occur within existing arable farmland areas, reflecting the better soils and existing climatic variations. This distribution is concentrated in the east of the country in the Eastern Lowlands, North East Coastal Plain and Moray Firth, with some change in the North East Glens, and West Central Belt. These changes are judged to have a medium to high level of certainty and likely to occur from the medium term onwards.

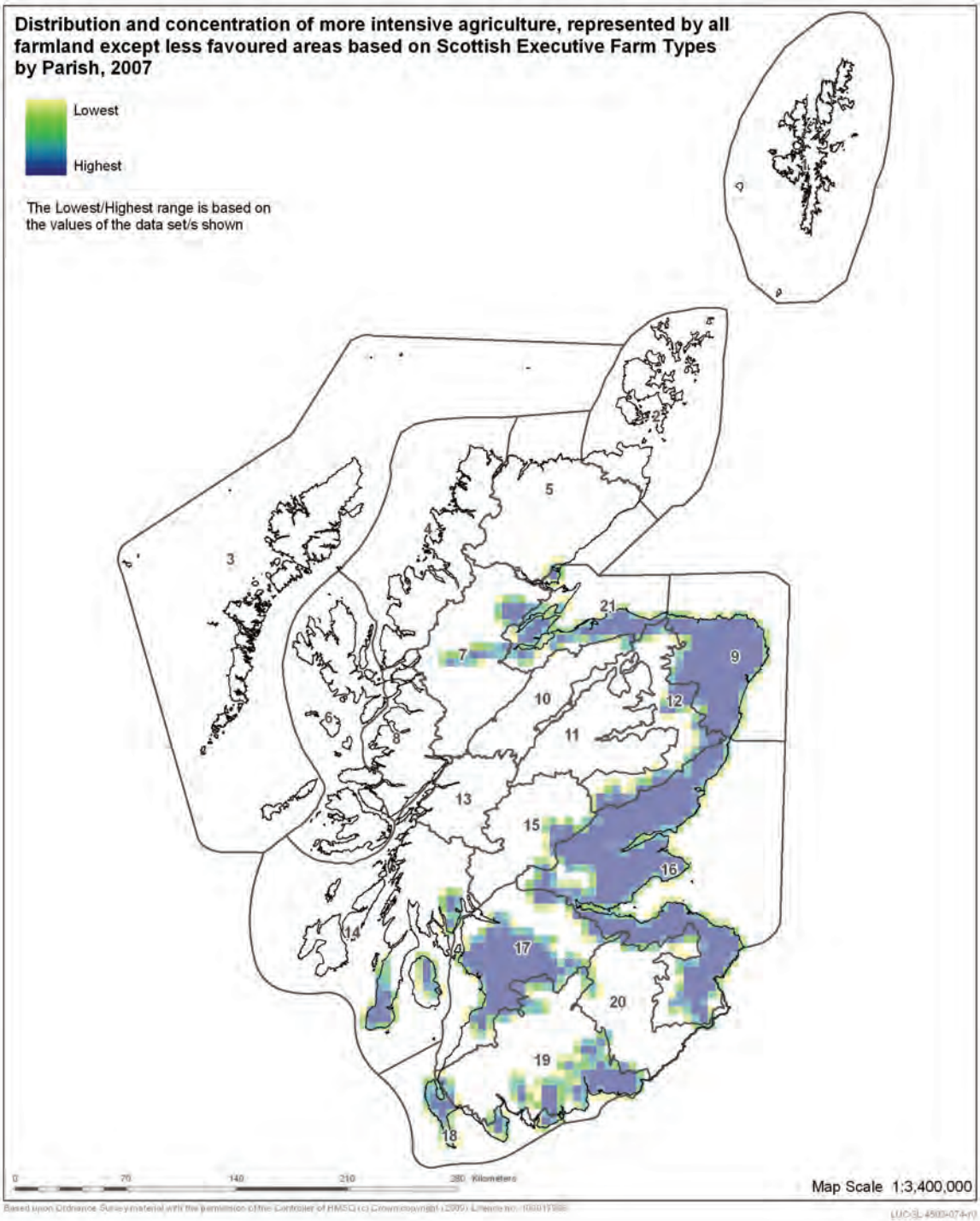

Figure 4.27a Change 41

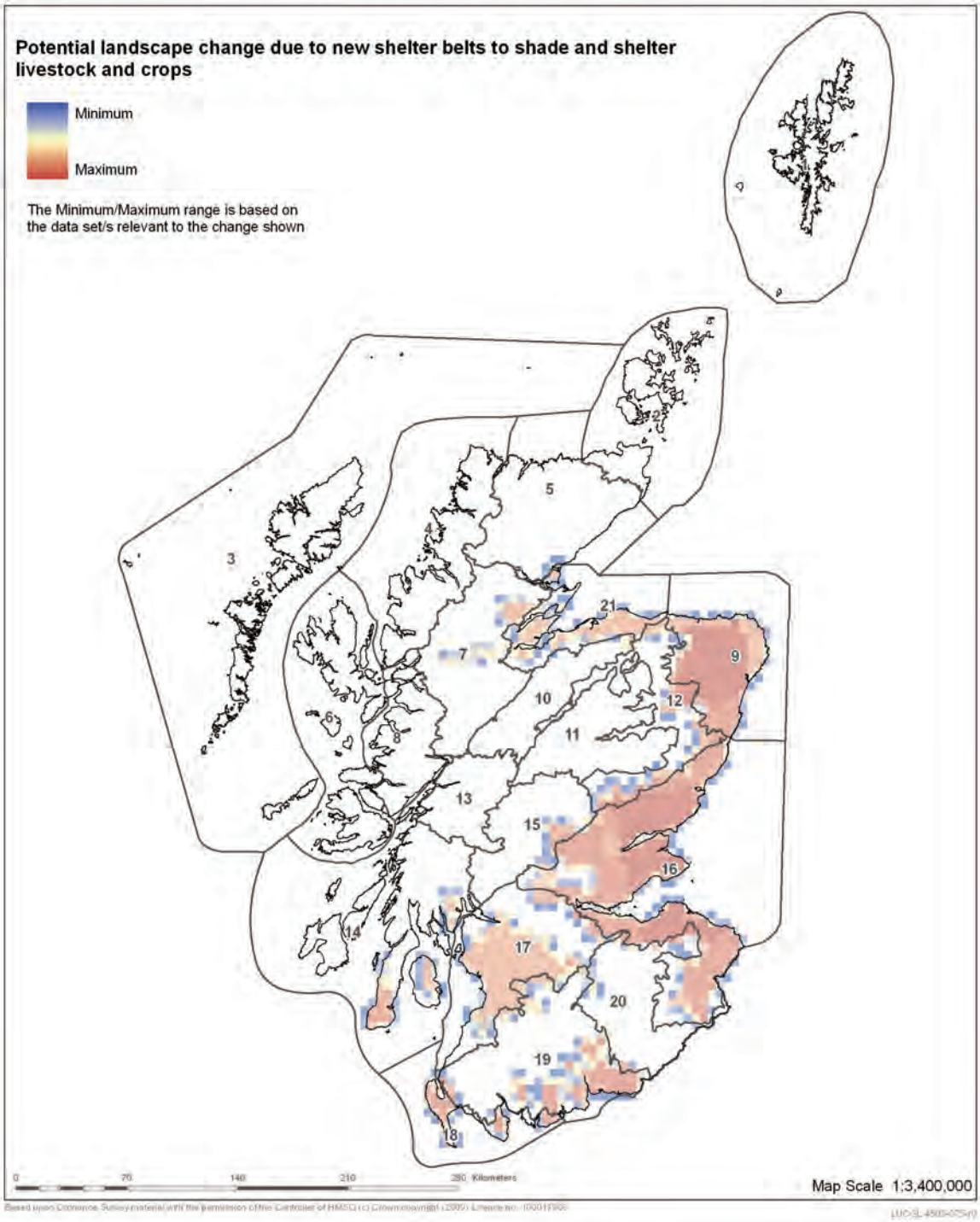

Figure 4.27b, Change 41

- Change distribution based on comparison of more intensive agriculture represented by all farmland except less favoured areas with climate change variables T2: Autumn temperature change, P1: Average change in winter precipitation, and W1: Average wind speed change in the winter climate change variables

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

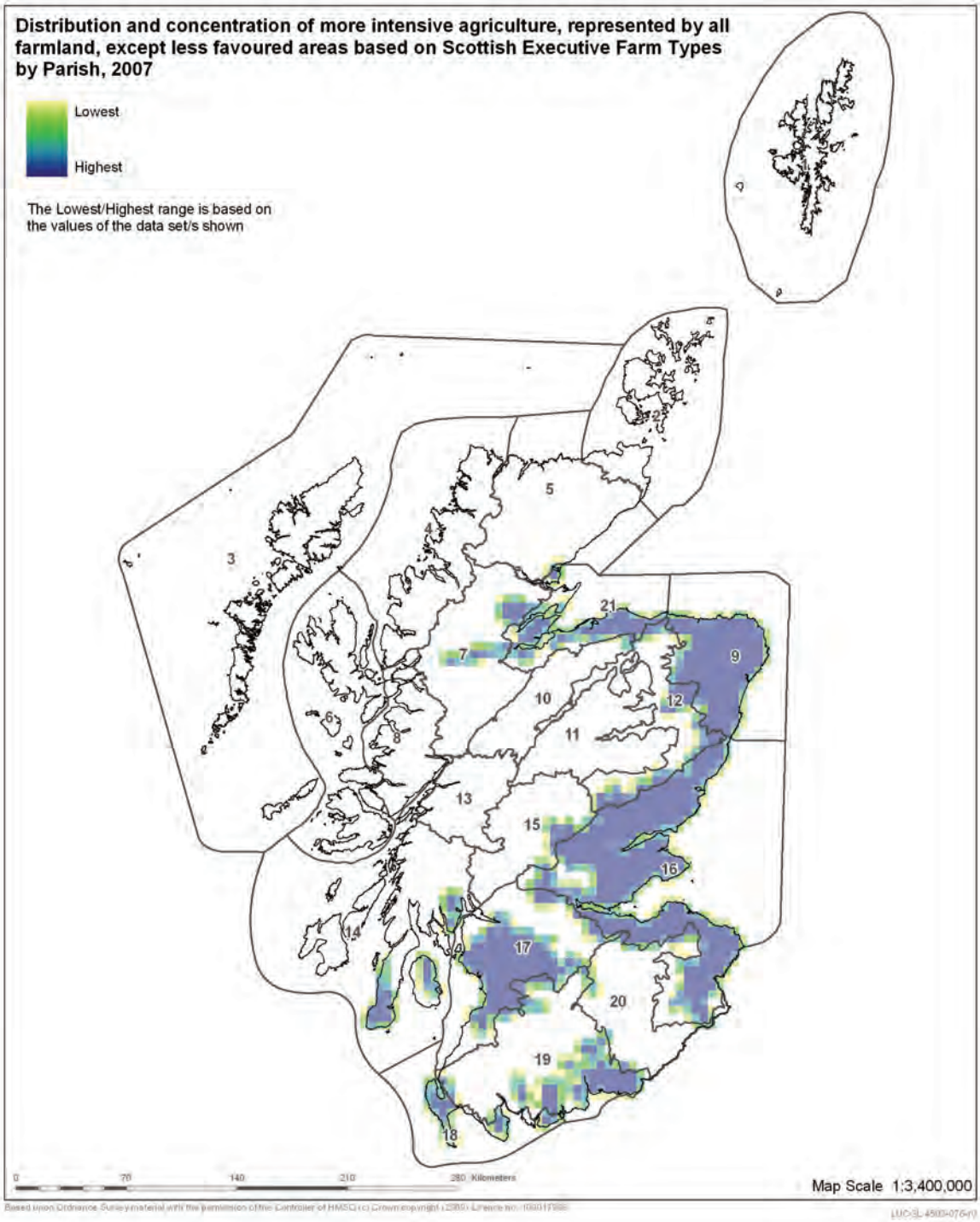

Figure 4.28a, Change 43

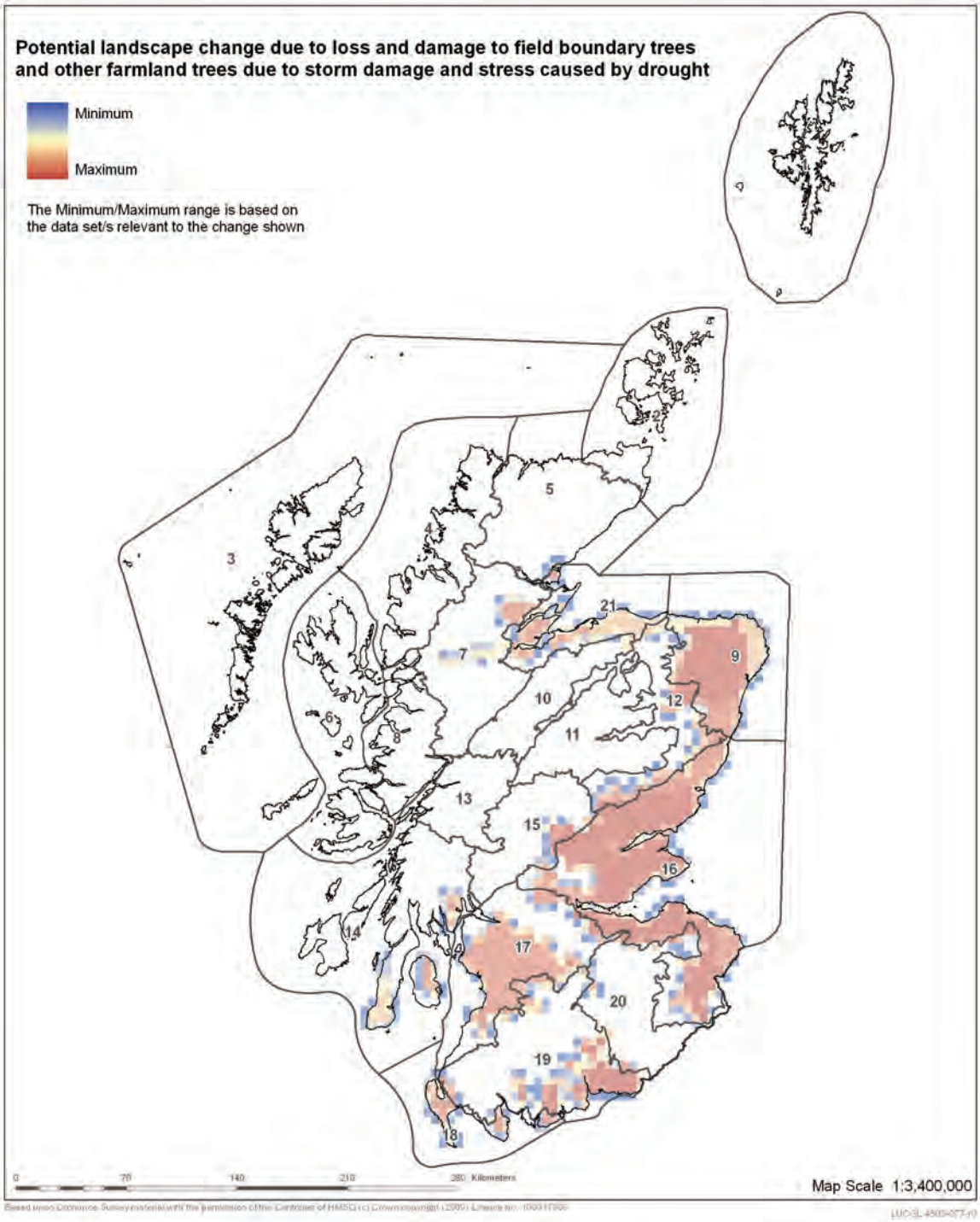

Figure 4.28b, Change 43

- Change distribution based on comparison of more intensive agriculture, represented by all farmland excluding less favoured areas with climate change variables T1: Average annual temperature increase, P1: Average change in winter precipitation, P2: Average decrease in summer precipitation and W1: average wind speed change in the winter

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

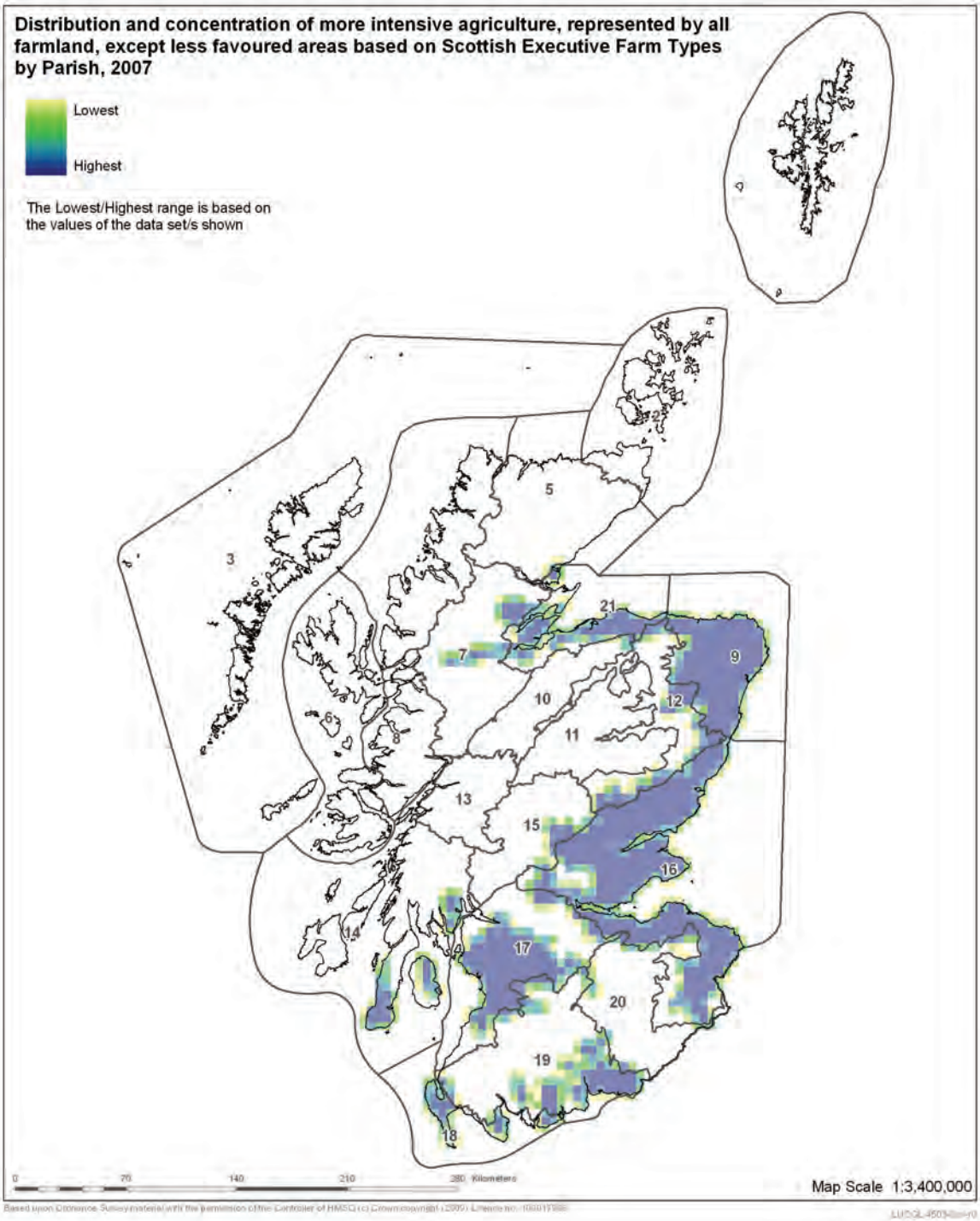

Figure 4.29a, Change 75

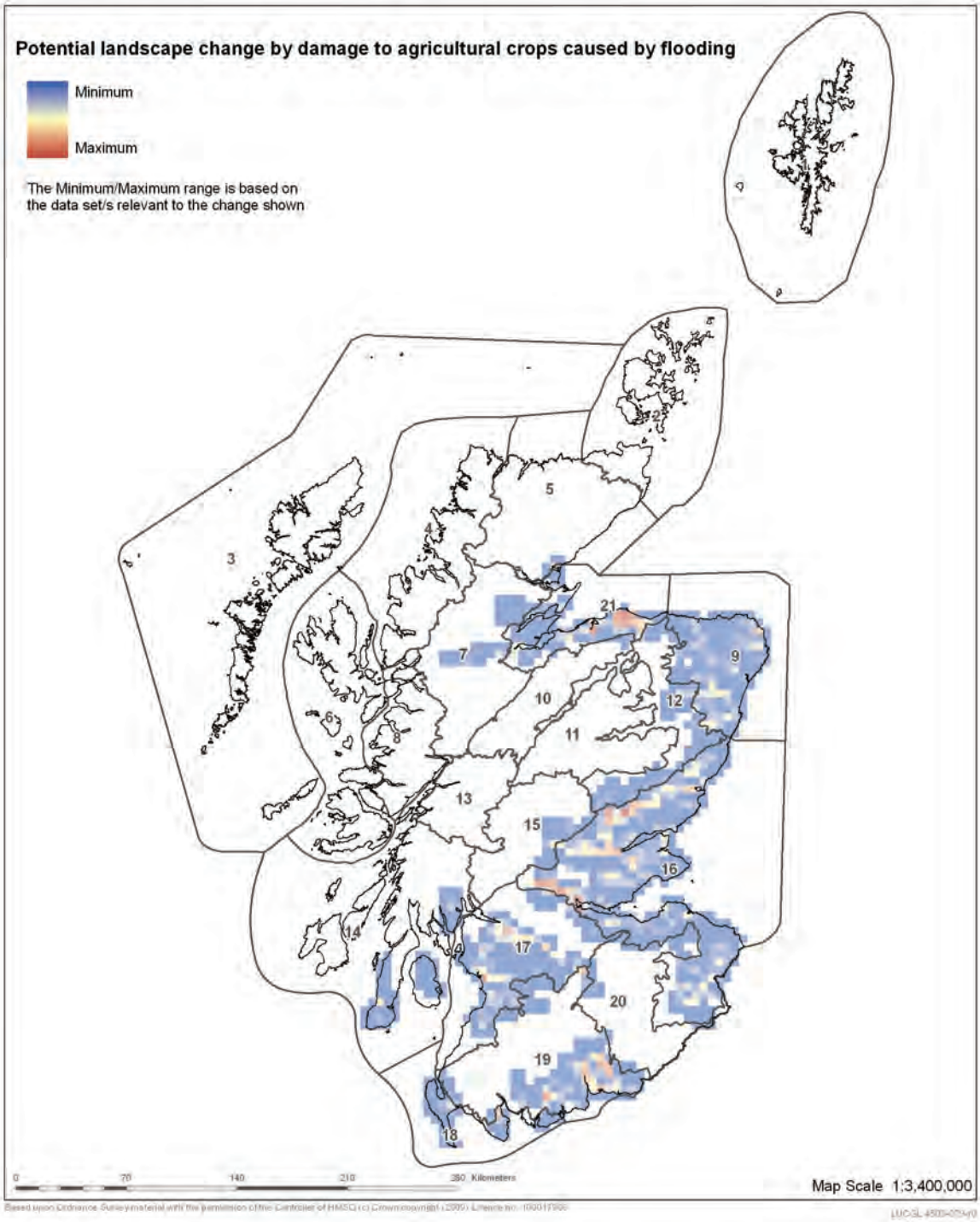

Figure 4.29b, Change 75

- Change distribution based on comparison of more intensive agriculture represented by all farmland excluding less favoured areas with SEPA coastal and fluvial flooding risk and climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

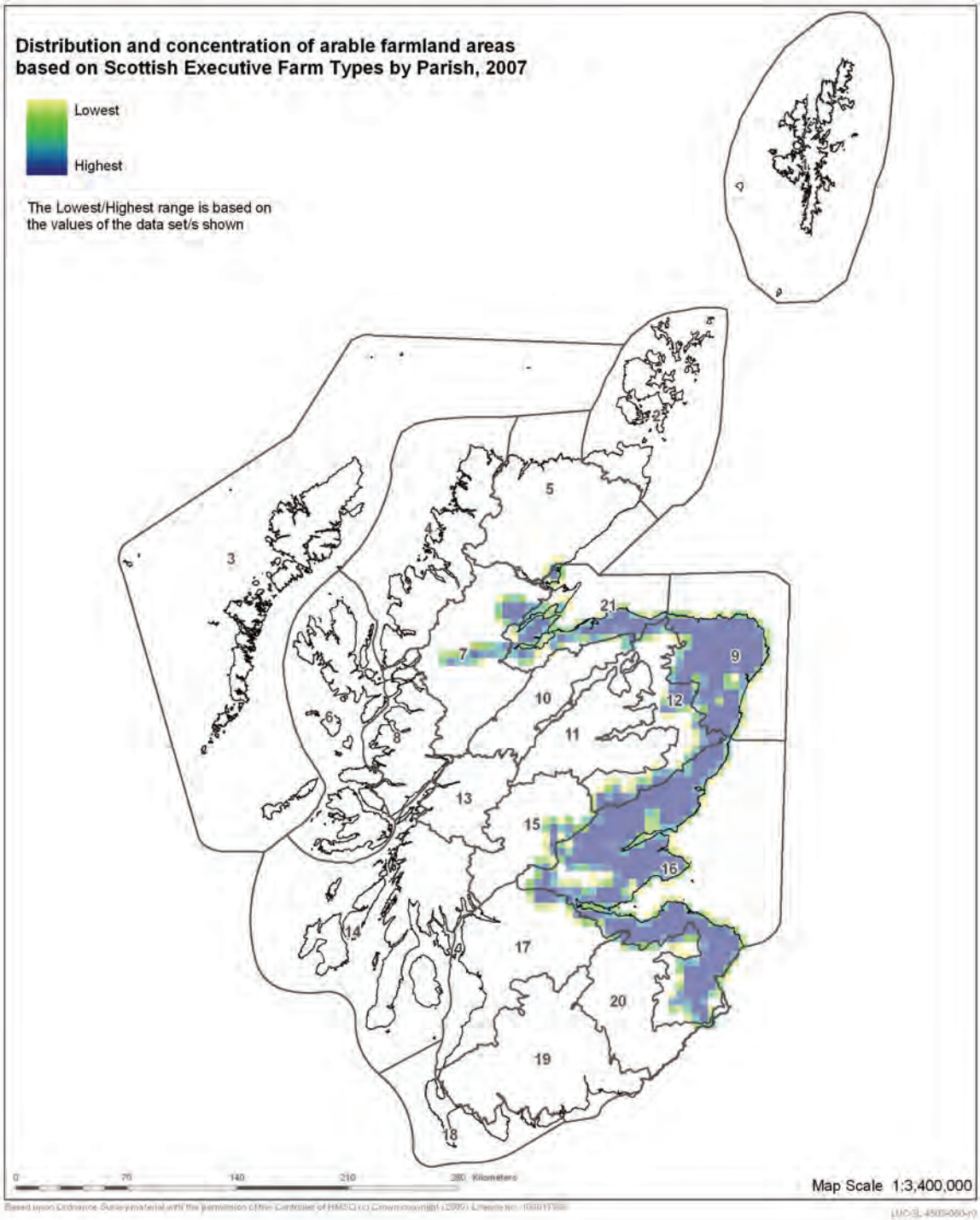

Figure 4.30a, Change 87

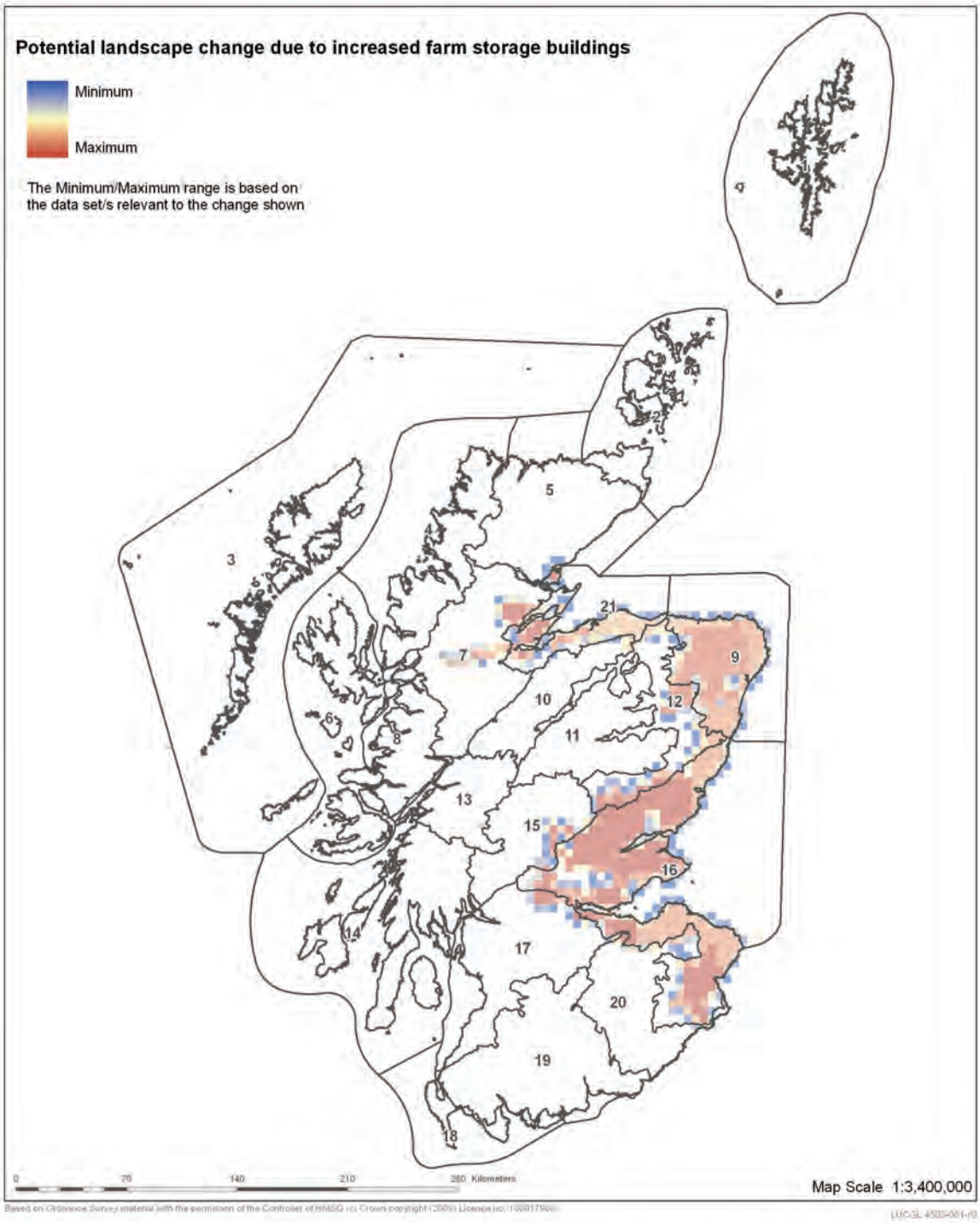

Figure 4.30b Change 87

- Change distribution based on comparison of arable farmland areas (including cereals, general cropping, horticulture and mixed farming farm types) with climate change variable T2: Autumn temperature change

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

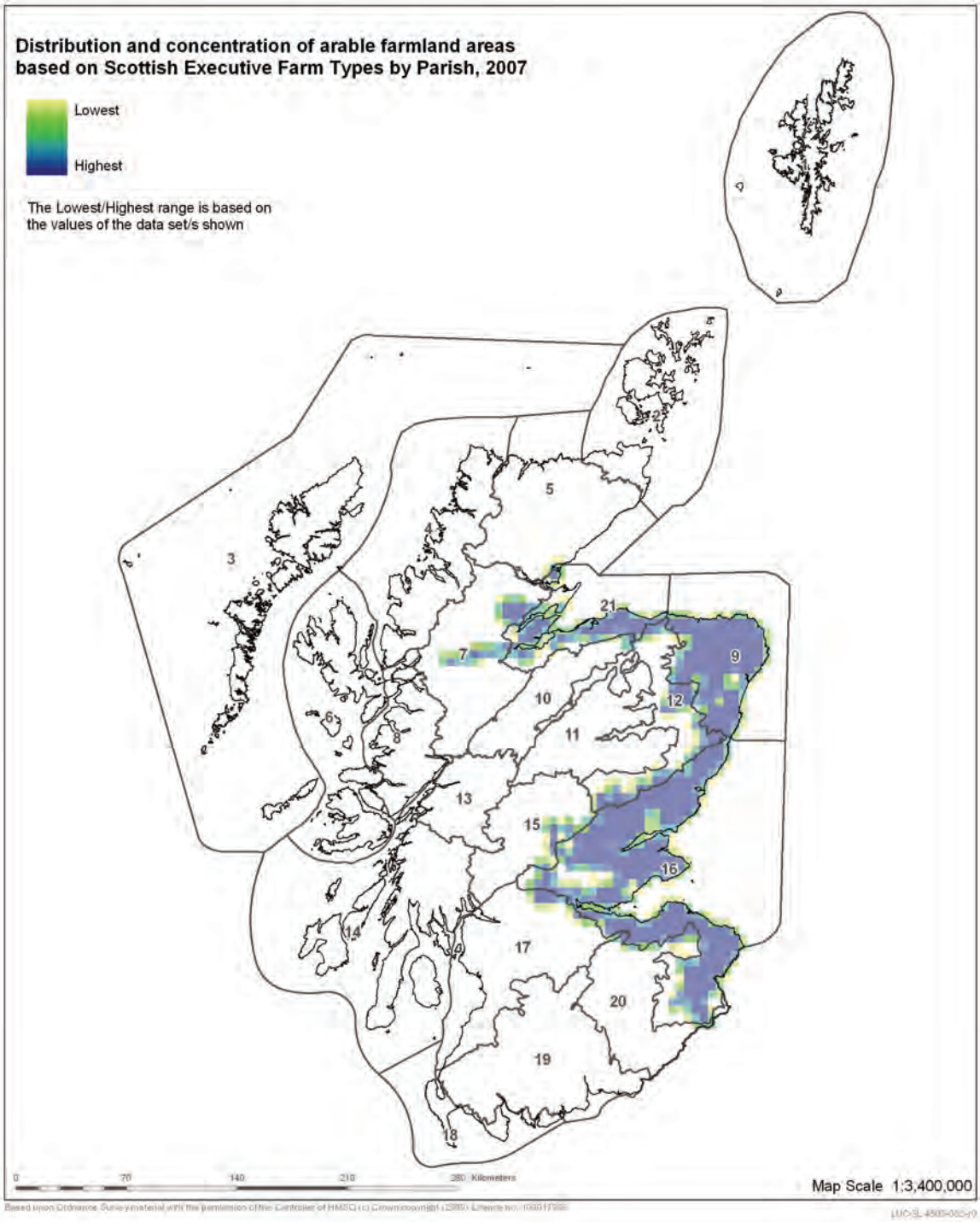

Figure 4.31a, Change 88

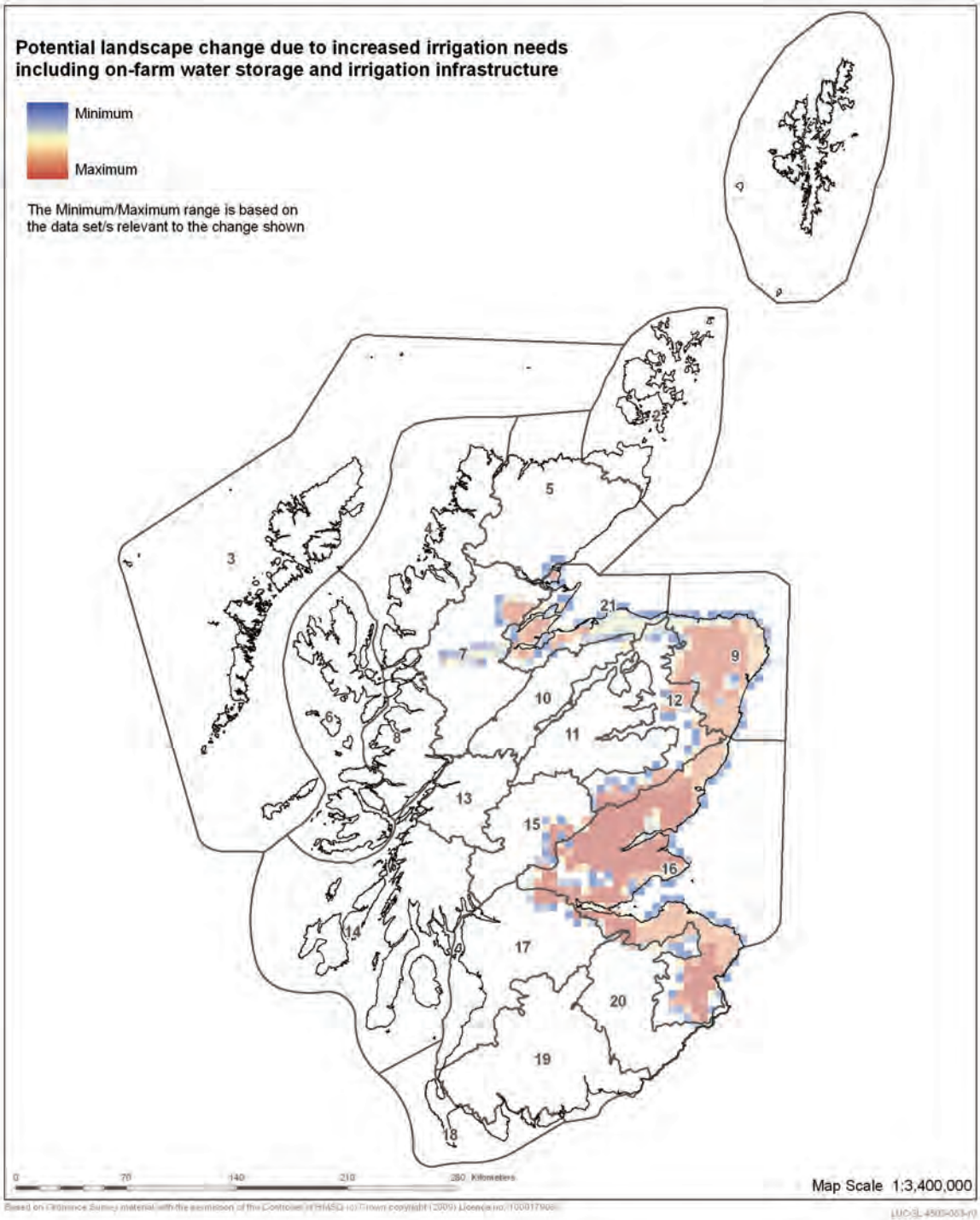

Figure 4.31b, Change 88

- Change distribution based on comparison of arable farmland areas (including cereals, general cropping, horticulture and mixed farming farm types) with climate change variables T3: Increased difference between summer-winter temperature, P2: Average decrease in summer precipitation, SM1: Change in soil moisture during summer-autumn

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

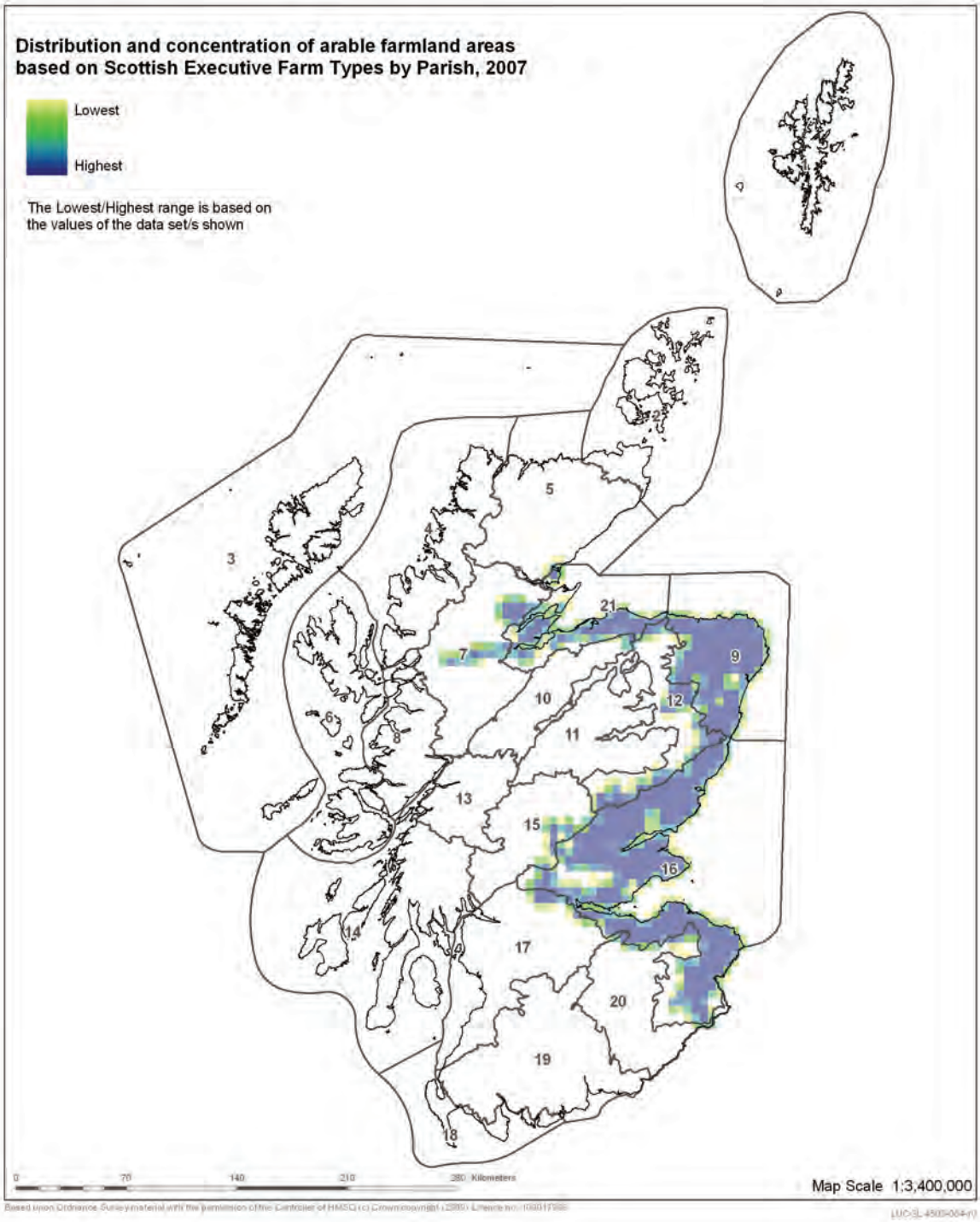

Figure 4.32a, Change 94

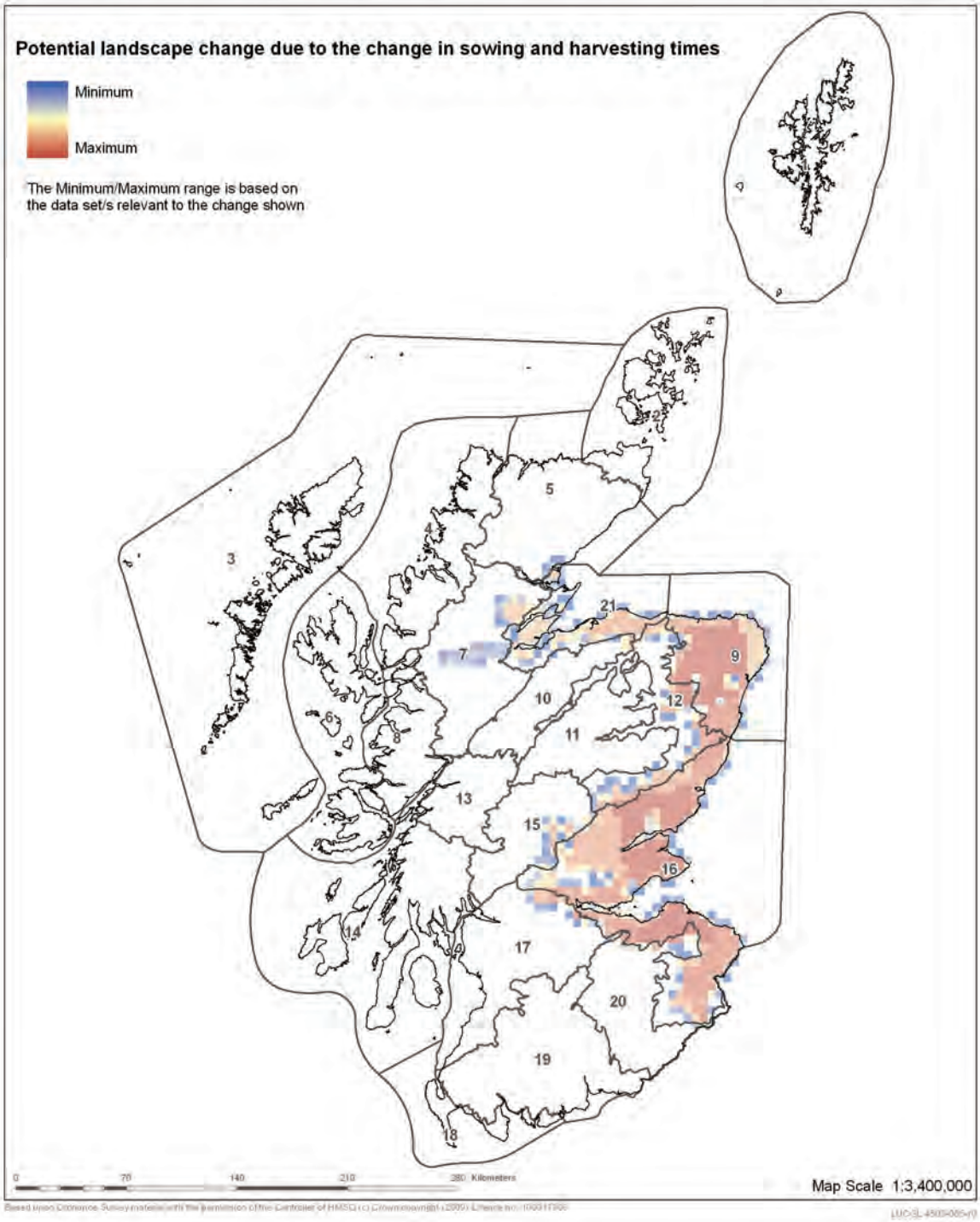

Figure 4.32b, Change 94

▸ Change distribution based on comparison of arable farmland areas (including cereals, general cropping, horticulture and mixed farming farm types) with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

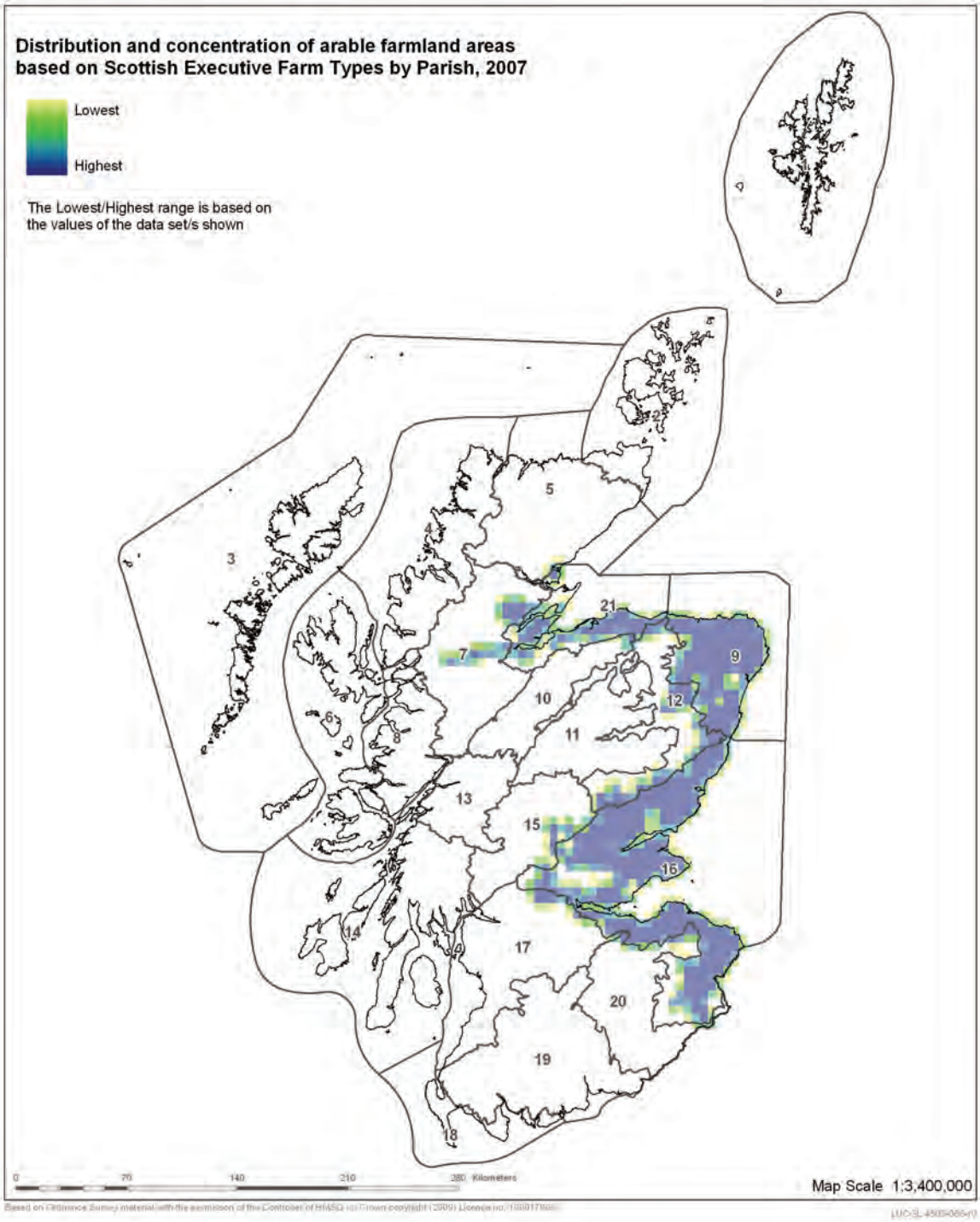

Figure 4.33a, Change 98

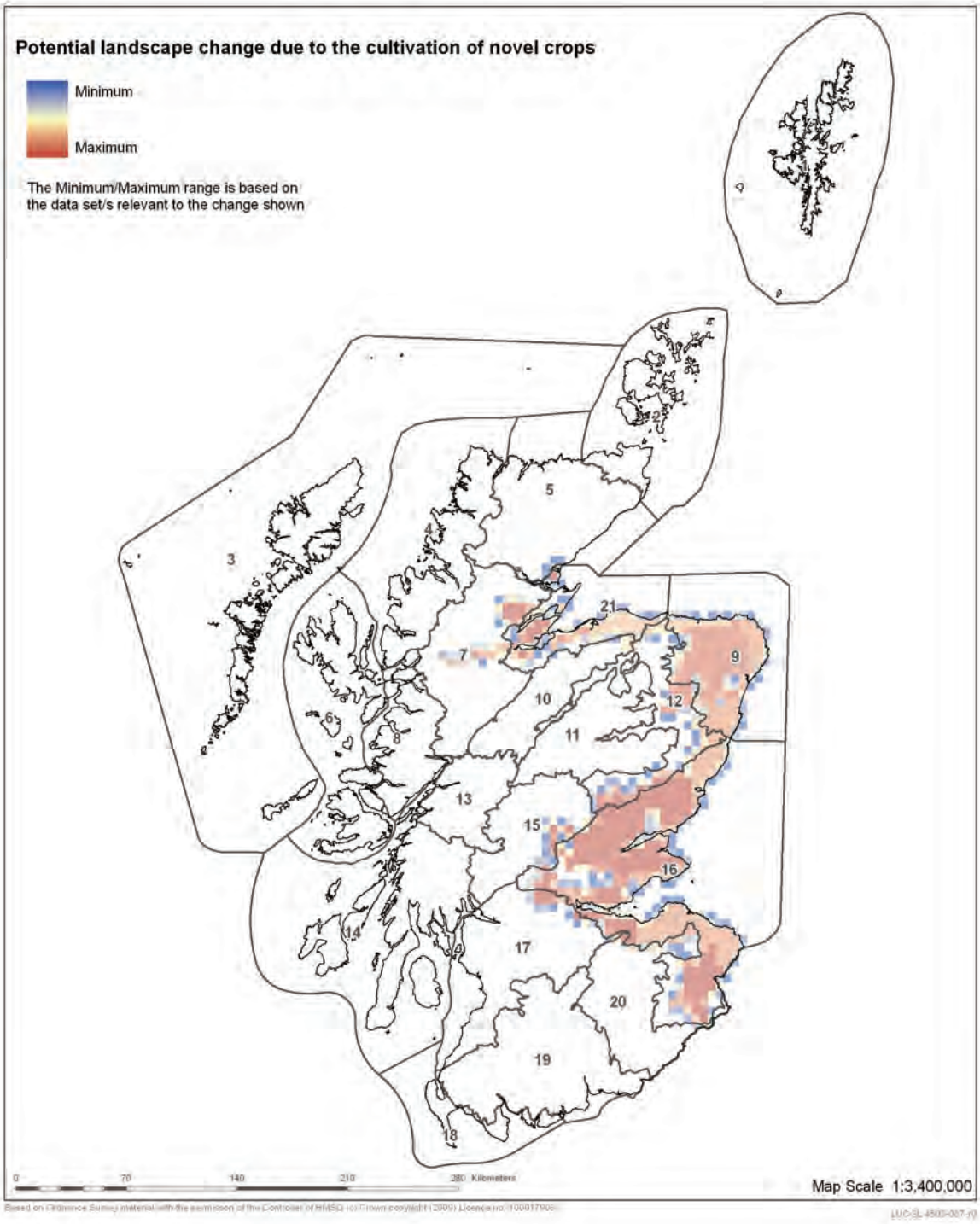

Figure 4.33b, Change 98

- Change distribution based on comparison of arable farmland areas (including cereals, general cropping, horticulture and mixed farming farm types) with climate change variable T2: Autumn temperature change

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

Historic Environment

Current Patterns

4.56. The historic environment is an intrinsic element of the Scottish landscape contributing to the character of the built and rural environment, and contributing to the economy. World Heritage Sites, listed buildings, conservation areas, scheduled monuments and gardens and designed landscapes all contribute to the historic landscape. Numerous historic resources remain unrecorded or unknown. The historic management of the landscape has a strong influence on the landscape of today, through the presence of field patterns, trees, hedgerows, stone walls and slate fences.

Future Change

4.57. Climate change is likely to have a number of implications for the historic environment. In its broadest sense, the kinds of changes described in previous sections are likely to result in cumulative changes in the historic character of the wider landscape. There are also likely to be a number of very specific, and potential significant implications (e.g. management of rainwater for historic buildings, increased salt contamination and accelerated decay of vulnerable stone, increased biological growth on stone, impacts on and potential loss of unique coastal historic sites due to sea level rise or the risk of subsidence to historic structures) which, while of importance for cultural heritage, are also explored under the other relevant topic headings where they form part of wider landscape change. The following areas have been identified as being of particular relevance to the wider landscape:

- the combination of drier and warmer summers, in combination with wetter winters could increase the stress affecting veteran trees resulting in their potential loss (impact);

- more dramatic shifts in seasonal moisture levels may result in accelerated decay of stone and an increased need for maintenance both of buildings and individual stones and monuments (impact);

- the same trends could affect the character of historic gardens and designed landscapes, including their influence on the wider countryside. Effects could include a loss of mature trees, impacts on mature woods and an increase in disease and pests (impact);

- changing sea levels, increased incidence of coastal flooding (impact) and potential responses in the form of hard flood defences or managed realignment (adaptation) could have implications for marine and coastal heritage including harbours, military infrastructure, coastal settlements etc.;

- the development of riparian flood defences could affect the character of historic settlements (adaptation);

- the development, particularly retrofitting, of micro-renewables could also affect the character of historic settlements (mitigation);

- changing patterns of agricultural production (including expansion of arable into current dairy or cattle areas, or the introduction of new crops, including energy crops) (adaptation and mitigation), amalgamation of farm units, and the loss of field boundary trees (impact) could have physical or perceptual impacts on historic rural landscapes;

- woodland expansion to increase carbon sequestration (mitigation), contribute to habitat networks (adaptation), provide shelter for crops and stock (adaptation) or provide a source of wood fuel (mitigation) could have physical or perceptual impacts on historic rural landscapes.

Overview

4.58. The remainder of this chapter provides an overview of these climate related landscape changes in terms of:

- implications for broad groupings of Natural Heritage Zones;
- implications for population and the pattern of multiple deprivation across Scotland;
- implications for designated landscapes and their special qualities;
- implications for SNH Wildland Search Areas.

Natural Heritage Zones

4.59. Many of the climate related landscape changes described in the preceding sections have distinctive spatial patterns, reflecting the distribution of landscape 'features' in question and the differential incidence of climate changes across the country. This section draws this information together to provide an overview based on broad groupings of Natural Heritage Zone. This gives an impression of which area are likely to experience the greatest climate related landscape change.

4.60. Table 4.2 summarises the mapped analysis, illustrating the degree of change in each Natural Heritage Zone. This provides an indication, for example, of the areas likely to experience the greatest levels of change and those types of change which are likely to occur across larger parts of Scotland. This summary is based on the limited number of mapped changes and the degree of change identified is based on a visual interpretation of the maps, providing an indicative summary. Areas described as high are likely to experience a high degree of change over a large proportion of the area, areas described as medium are those likely to experience a high degree of change over approximately half of their area, areas described as low are likely to experience a high degree of change over a small proportion of their area.

4.61. Table 4.2 highlights in yellow where a high level of change is identified for a particular Natural Heritage Zone, and NHZ with medium or low levels of change are also identified. The table also indicates where the change mapped is a direct climate change impact or an adaptation or mitigation response.

4.62. The implications of these mapped changes, together with other direct, adaptation and mitigation impacts is summarised in the following sections for six groupings of Natural Heritage Zones (as illustrated in Figure 4.1).

East Coast

4.63. This grouping of Natural Heritage Zones comprises much of the Eastern Lowlands, the North East Coastal Plain and Moray Firth. Changes are likely to include **direct** impacts such as an increased risk of flooding along river corridors, low-lying sections of coastline and inner Firths. These will result from a combination of increased winter rainfall, rising sea levels and storm surges. Other direct effects could include impacts on trees, woodland and forests as a consequence of wetter winters, drier summers and the greater prevalence of pests and diseases. This, together with some of the

adaptation impacts described below, could have a significant impact on the character of some landscapes across the east coast.

4.64. There are also likely to be significant impacts associated with **adaptation** to climate change. These will include responses to the increased risk of flooding along rivers, firths and the coast. These could include the upgrading of hard flood defences to protect property, settlements and infrastructure, or the implementation of catchment wide approaches which would see the re-wilding of river floodplains and extensive woodland planting to help slow the speed of run-off. There is likely to be a similar combination of measures along the coast and firths with some areas subject to managed realignment whilst harder flood defences are brought forward in others. Perhaps the most extensive adaptation effects are likely to be in terms of agricultural change. These areas are the most productive agricultural areas in Scotland and climate change could lead to further intensification of activity leading to a demand for new buildings, field enlargement and the introduction or expansion of novel crops. There may also be a need for additional irrigation. Woodland is likely to experience change too, as habitat networks are developed to help species adapt, shelter belts established to provide shelter and shade, and the choice of species for productive forestry changes. Much of this area is accessible from key population centres so it is likely that improved summer weather will result in an increase in visitor activity, possibly creating demand for visitor related development, but also increasing the risk of human induced fire associated with drier summers.

4.65. Measures to **mitigate climate change** will also be evident in these areas. Depending on the market for other agricultural produce, it is possible that there could be an expansion use in the use of existing farmland to cultivate biomass and energy crops including Miscanthus and willow. There could also be continued pressure for on-shore and offshore windfarm development and, potentially at least, the development of tidal power schemes on one or more firths. There may be some expansion of woodland and forests to provide further carbon sequestration, but the competition with agriculture may limit this.

4.66. All these changes suggest there could be significant implications for **quality of life** given that these areas include several of Scotland's larger towns and cities together with key road and rail transport routes.

Central Lowlands

4.67. This grouping of Natural Heritage Zones comprises West Central Belt and part of the Eastern Lowlands (overlapping with the description of the east coast above). This is the most populated part of Scotland and includes the Glasgow conurbation and the city of Edinburgh together with many former industrial settlements, new towns and smaller towns and villages. This area has some of the highest levels of deprivation in Scotland (see paragraphs 4.91 onwards). The area includes rural and coastal areas such as Ayrshire.

4.68. **Direct** impacts in these areas will include increases in the incidence of flooding resulting from higher winter rainfall and more intense rainfall events. This could include pluvial flooding in larger settlements where existing drainage infrastructure is unable to cope with the volume of run-off. There is also likely to be an increased risk of flooding along the Firth of Forth, Firth of Clyde and to a lesser extent the Ayrshire Coast as a consequence of sea level rise and the increased risk of storm surges. Woodland and trees may also experience direct impacts resulting from competition from non-native species, an increase in the risk of pests and disease and stress caused by a combination of wetter winters and drier summers. This could affect woodlands, field boundary trees and urban trees.

4.69. The effects of climate change **adaptation** could include responses to fluvial, pluvial and coastal flood risk based on a combination of hard flood defences, wider use of SUDS and approaches based on re-wilding of coasts and catchments. It is possible that agricultural activity will be adapted to climate change, for example by substituting arable cultivation for dairying, though this is less certain than the kind of intensification anticipated on the east coast. It is likely that recreational activity will adapt to warmer and drier summers by making greater use of urban greenspaces, access networks, country and regional parks and the wider countryside. This could place pressure on existing resources and increase the risk of accidental fire, but will mean that more people are able to enjoy the natural heritage close to where they live. Urban greenspaces are also likely to provide a focus for the development of habitat networks across the central belt. Although not mapped here, it is likely that the built form of urban areas will also undergo change. Wetter winters and warmer, drier summers may provide contrary influences on the use of outdoor space and the design of buildings. There is, however, likely to be an increase in the demand for cooling equipment but also the take up of features such as green roofs.

4.70. **Mitigation** measures may take a slightly different form to those in other parts of Scotland. While there is likely to be continued interest in windfarm development, there is likely to be an emphasis on small scale renewable energy equipment (such as solar water heating) within settlements and on the wider use of biomass energy sources and anaerobic digestion technology in rural areas. Projects such as the Central Scotland Green Network and are likely to support an increase in multi-functional woodland which also contributes to carbon sequestration.

4.71. The effects of these changes on **quality of life** are likely to be mixed. Better summer weather and improved greenspaces in and around settlements are likely to enhance recreational opportunities, with knock on benefits for health. Other changes in the urban environment could conflict with the historic built character of towns and cities. Changes affecting rural and semi rural areas are likely to be more limited, though could include further loss of field boundary trees.

Southern Scotland

4.72. This grouping of Natural Heritage Zones comprises the Wigtown Machairs and Outer Solway, the West Southern Uplands and Inner Solway and Border Hills.

4.73. The most significant **direct** impacts in this area could include an increased risk of flooding and flood damage resulting from a combination of increased winter rainfall and, within the inner Solway, the increased risk of surge tides allied to rising sea levels. It is possible that sea level change and changes in erosion and deposition could also affect low lying areas elsewhere on the coast. Woodland and forests are also likely to be affected by the summer drought on the one hand and increased winter rainfall on the other. Woodlands may change in composition as species' range changes and in response to possible increases in pests and diseases. Drier summers could result in a heightened fire risk, particularly if recreation activity increases in response to climate change (adaptation – see below). In some of the lower lying, agricultural areas such as the Tweed Valley, climate change could have an impact on patterns of field boundary trees and shelter belts.

4.74. Climate change **adaptation** could result in a number of changes to the landscape of southern Scotland. Increases in fluvial flood risk are likely to be reflected in a combination of hard flood defences where rivers flow through settlements, particularly at or near the coast where there is a risk that impacts could be compounded by surge tides. However, there is also scope for a range of re-wilding initiatives which could include the re-establishment of natural floodplains and woodlands where these help

slow the rate of run-off. This could affect the character of those areas which are not already heavily forested. Other forms of adaptation could include an increase in recreation activity, facilitated by better summer weather. This could place pressure on existing resources such as the network of longer distance routes or the Seven Staines Mountain Bike Trails, and areas such as the Galloway Forest Park or St Mary's Loch. Finally, it is possible that southern Scotland will develop reservoirs, aqueducts and pipelines to capture rainfall and export it southwards to other parts of the UK where water shortages are increasingly likely. This could have a significant impact on the landscape of the area, depending on the scale of infrastructure required.

4.75. Measures to **mitigate** climate change will also have an impact. It is likely that there will be continued development of windfarms across this area and an expansion of power infrastructure to serve new schemes and to facilitate export of power from Scotland to England. Woodland cover may also be expanded in part to achieve increased carbon sequestration.

4.76. While these changes will combine to have an influence on **quality of life** in southern Scotland, the impacts may be less than in some other parts of the country. While there may be benefits in terms of increased recreation activity, it is likely that new development associated with electricity and water infrastructure could affect the inspirational and aesthetic values of the landscape.

West Coast

4.77. This grouping of Natural Heritage Zones comprises Argyll West and Islands, the Western Seaboard, and North West Seaboard. This area is often remote and sparsely settled, with a dramatic coastline of islands, cliffs and deep sea lochs. It includes some of the larger and more settled islands including Arran, Mull and Skye.

4.78. The **direct** impacts of climate change could be more significant than the effects of **adaptation** and **mitigation**. Native broadleaf woodland, including the distinctive areas of Atlantic oakwoods, may be adversely affected by a combination of storm damage, colonisation by other species, changes in summer and winter rainfall patterns and potential increases in pests and diseases. Changes in peat accumulation and invasion of grasses into heather moorland could be significant, particularly in the North West Seaboard Natural Heritage Zone. The effects of sea level rise are likely to affect much of this area, with a particular impact on coastal settlement and communications.

4.79. Adaptation changes are likely to focus on the need to protect coastal settlements and communications infrastructure. Although these areas lie outside the most easily accessed parts of Scotland where the largest growth in recreation and tourism activity could be concentrated, it is possible that relatively small increases could have an impact on the wildland qualities that are an important part of the west coast's appeal to many residents and visitors.

4.80. Mitigation measures are likely to focus on an expansion of existing woodland cover where exposure, land quality and other constraints permit, the development of biomass power plants to serve local communities and small scale hydro schemes. There will be continued interest in windfarm development in this area, though this is likely to be focused in areas currently well served by the electricity transmission grid, or where upgrades are implemented.

4.81. It is likely that the most significant effects on **quality of life** will be associated with the need to respond to rising sea levels. This would have significant impacts on communities' well being, as well as implications for historic buildings, structures and

settlements. Depending on its design and location, new woodland could contribute to the aesthetic and inspirational qualities of the west coast. Any further loss of native woodlands would have a negative effect. Development associated with renewable energy could have an adverse impact on aesthetic and inspirational value of the landscape. Increases in recreation activity could benefit new visitors, but could impact on others' perceptions of wildness and remoteness.

Highlands

4.82. This grouping of Natural Heritage Zones comprises Breadalbane and East Argyll, Lochaber, the Western Highlands, Northern Highlands, Central Highlands, Cairngorm Massif, North East Glens and Peatlands of Caithness and Sutherland. These areas are dominated by the presence of mountains and glens, though they also include part of the west and north coasts, and the less elevated parts of Caithness and Sutherland.

4.83. **Direct** impacts from climate change within the highlands are likely to include a range of changes in upland landscapes. Milder winters will lead to a reduction in the number of days of snow lie and impacts on plant communities that depend on low temperatures. While some peatlands may benefit from wetter, milder winters, others could be damaged by erosion and the effects of drier summers. Heather moorland could be colonised by grasses and subject to greater fire risk from lightening and human activity. Woodlands are also likely to experience change. It is possible that conditions for native pine woodlands could improve, particularly in currently wetter parts of the west highlands. At the same time, woodland and forests are likely to be at greater risk of damage from storms, fires and pests. Settlements and communications on the coast could be affected by sea level rise.

4.84. The effects of climate change **adaptation** are likely to include changes in woodland and forestry practice. More exposed locations are likely to be avoided whilst there will be an ongoing trend towards the use of continuous cover forestry in lower areas. Species choice will change, particularly in the east where conditions are likely to be less well suited to the cultivation of Sitka spruce. There is likely to be an expansion of birch woodland within highland glens, particularly where this provides shelter for stock and crops or where it contributes to habitat networks. It is possible that agricultural activity within the glens could increase as the climate improves and Scotland's competitive advantage grows in response to climate change impacts elsewhere, though much will depend on wider economic factors. Although these areas lie outside the 'accessible' parts of Scotland where the largest growth in recreation and tourism activity could be concentrated, it is possible that relatively small increases could have an impact on the wildland qualities which are central to many people's enjoyment of the highlands. The onset of milder and wetter winters is also likely to reduce opportunities for people to experience winter activities including walking, ice-climbing and snow sports. Existing ski areas across the highlands will need to further diversify the range of activities they offer, which could also have landscape impacts.

4.85. **Mitigation** measures in the highlands are likely to include the continued development of windfarms, particularly in areas served by existing or planned electricity transmission grid connections. There is also likely to be an expansion of woodland, partly with the aim of increasing carbon sequestration. Rewilding of moorlands would be carried out to retain or increase the carbon storage of upland soils.

4.86. It is likely that some of the key influences on **quality of life** will reflect the combined impact of these direct, adaptation and mitigation changes on the landscape's inspirational and aesthetic values. In part this will be derived from changing patterns

of vegetation and less frequent or lasting snow. It will also reflect the potential for greater numbers of visitors to currently remote areas, possible changes in agricultural activity within the glens, and the impact of energy infrastructure, particularly windfarms and associated power lines. There will also be mixed impacts in terms of summer and winter recreation and the associated health benefits.

Outer Islands

4.87. This grouping of Natural Heritage Zones comprises Shetland, North Caithness and Orkney and the Western Isles. The Western Isles include remote and vulnerable communities already experiencing depopulation and economic decline. Shetland and Orkney are less vulnerable in economic terms, but share many of the issues associated with remote, island communities.

4.88. Some of the most significant **direct** impacts in the outer islands include the effects of sea level rise, increases in coastal flooding and changes in patterns of coastal erosion and deposition. These effects are likely to be most pronounced in the Western Isles where the chain of islands is partly connected by a series of causeways. Orkney's low lying character will mean that the impacts could also be significant. Coastal historic sites, settlements and ferry terminals are also likely to be affected by sea level rise. Within the Western Isles, milder and wetter winters will support increased peat formation, but also increase the risk of damage from erosion.

4.89. **Adaptation** responses are likely to focus on addressing the risk of coastal flooding. This may result in the upgrading of flood defences protecting settlements and measures to make road and ferry communications more resilient. Although very remote, better summer weather could lead to an increase in recreation activity.

4.90. **Mitigation** responses are likely to include continued pressure for windfarm development where electricity transmission grid infrastructure allows.

4.91. Taken together, it is likely that sea level rise and the risk of coastal flooding will have the most profound effect on **quality of life** in the outer islands. These changes present a significant threat to physical and mental health and well being. They also threaten the cultural environment, both in terms of historic sites and traditional coastal settlements. Responses to these threats are likely to have adverse implications for other aspects of quality of life by impacting on inspirational and aesthetic values. Increases in recreation activity could bring benefits.

Table 4.2 Summary of degree of change of mapped changes by Natural Heritage Zone

Key to H, M, L: H: likely to experience a high degree of change over a large proportion of the area; M: likely to experience a high degree of change over approximately half of their area; L: likely to experience a high degree of change over a small proportion of their area

					Natural Heritage Zone																				
Topic	**Figure reference**	**Change reference**	**Landscape change**	**Type of change**	**1 Shetland**	**2 N Caithness and Orkney**	**3 Western Isles**	**4 NW Seaboard**	**5 Peatlands of Caithness and Sutherland**	**6 Western Seaboard**	**7 Northern Highlands**	**8 Western Highlands**	**9 NE Coastal Plain**	**10 Central Highlands**	**11 Cairngorm Massif**	**12 North East Glens**	**13 Lochaber**	**14 Argyll West and Islands**	**15 Breadalbane and East Argyll**	**16 Eastern Lowlands**	**17 West Central Belt**	**18 Wigtown Machairs and Outer Solway**	**19 W. Southern Uplands and Inner Solway**	**20 Border Hills**	**21 Moray Firth**
Forests and Woodlands	4.2	62	Mixed broadleaved change	adaptation	L	L	L	H	M	H	H	H	H	H	H	H	H	H	H	H	H	H	H	M	H
	4.3	63	Woodland damage drought	direct	L	L	L	L	M	L	H	L	L	L	L	H	L	H	M	M	M	L	H	H	H
	4.4	64	Woodland flood damage	direct	L	L	L	L	M	L	M	L	L	L	L	H	L	H	M	M	M	L	H	H	H
	4.5	65	woodland damage winds	direct	L	L	L	L	M	H	L	L	L	L	M	H	M	H	M	M	M	L	H	H	H
	4.6	66	woodland fire risk	direct	-	-	-	-	-	-	M	-	L	M	L	H	-	L	H	M	M	L	H	H	H
	4.7	48	Riparian woodland	adaptation	L	L	L	L	L	L	L	L	H	L	L	M	L	L	M	H	H	L	H	M	H
Freshwater systems	4.8	1	flood management	mitigation	L	L	L	L	M	L	L	L	L	L	M	M	L	M	M	M	H	L	L	H	L

					Natural Heritage Zone																				
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	4.9	5	fluvial flooding	direct	L	L	L	L	M	L	L	L	H	L	L	H	L	M	M	H	H	M	H	H	H
	4.10	6	flood damage	direct	L	M	M	L	L	L	L	L	M	L	L	L	L	L	L	H	H	L	H	M	H
Coasts, estuaries and sea	4.11	n/a	Sea level rise	direct	H	H	H	M	M	M	-	L	L	-	-	-	L	L	-	L	L	L	L	-	L
	4.12	n/a	Surge risk	direct	L	L	L	L	L	M	-	L	M	-	-	-	M	H	-	H	H	L	H	-	H
	4.13	n/a	Wave fetch (data too detailed to extract at NHZ scale)	direct	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4.14	n/a	Combined risk	direct	M	M	M	L	M	L	L	L	L	-	-	-	L	M	-	M	M	L	M	-	M
	4.15	3	Coastal flooding	direct	-	-	-	-	-	-	-	-	L	-	-	-	-	M	-	H	M	-	H	-	H
Urban and peri urban	4.16	9	Stress on green infrastructure caused by summer	direct	-	-	-	-	-	-	L	-	M	L	-	L	-	L	L	H	H	M	H	M	M

					Natural Heritage Zone																			
Topic	**Figure reference**	**Change reference**	**Landscape change**	**Type of change**	**1 Shetland**	**2 N Caithness and Orkney**	**3 Western Isles**	**4 NW Seaboard**	**5 Peatlands of Caithness and Sutherland**	**6 Western Seaboard**	**7 Northern Highlands**	**8 Western Highlands**	**9 NE Coastal Plain**	**10 Central Highlands**	**11 Cairngorm Massif**	**12 North East Glens**	**13 Lochaber**	**14 Argyll West and Islands**	**15 Breadalbane and East Argyll**	**16 Eastern Lowlands**	**17 West Central Belt**	**18 Wigtown Machairs and Outer Solway**	**19 W. Southern Uplands and Inner Solway**	**20 Border Hills**	**21 Moray Firth**
			drought and high temperatures, winter rainfall, pests and disease and increased use																						
Tourism and recreation	4.17	14	Changing tourism and recreation products, destinations	adaptation	-	-	-	-	-	-	M	-	H	M	L	H	-	L	M	H	H	H	H	H	M
Urban and peri urban	4.18	8	Increased demand and use of green and blue infrastructure in urban and peri urban areas	adaptation	-	-	-	-	-	-	-	-	M	L	-	L	-	-	L	H	H	M	M	M	M
Infrastructure	4.19	n/a	Further development of wind energy at domestic and	mitigation	L	L	H	-	M	L	M	-	L	H	-	L	-	M	L	L	H	L	H	H	L

					Natural Heritage Zone																			
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			commercial scales																						
	4.20	18	Increase in water infrastructure associated with export	mitigation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-	M	M	-
	4.21	21	Biomass power plants	mitigation	-	-	-	L	L	L	M	L	H	L	L	M	L	M	M	H	L	L	M	M	H
Habitats (natural and semi natural)	4.22	72	Damage to peatland – quicker erosion, gullying and bogbursts	direct	M	M	H	M	H	M	L	L	L	M	H	L	M	M	M	L	L	L	L	L	L
	4.23	39	Changes in peat accumulations – growth where temp and rainfall increase, decay where	direct	M	L	H	H	H	M	H	M	L	H	H	M	H	M	H	L	L	L	L	L	L

					Natural Heritage Zone																			
Topic	**Figure reference**	**Change reference**	**Landscape change**	**Type of change**	**1 Shetland**	**2 N Caithness and Orkney**	**3 Western Isles**	**4 NW Seaboard**	**5 Peatlands of Caithness and Sutherland**	**6 Western Seaboard**	**7 Northern Highlands**	**8 Western Highlands**	**9 NE Coastal Plain**	**10 Central Highlands**	**11 Cairngorm Massif**	**12 North East Glens**	**13 Lochaber**	**14 Argyll West and Islands**	**15 Breadalbane and East Argyll**	**16 Eastern Lowlands**	**17 West Central Belt**	**18 Wigtown Machairs and Outer Solway**	**19 W. Southern Uplands and Inner Solway**	**20 Border Hills**	**21 Moray Firth**
			rainfall decreases																					
	4.24	36	Biodiversity – more rapid decomposition and nutrient recycling – affecting nutrient status of some Habitats (natural and semi-natural) – montane and moorland – invasion of grasses	direct	L	L	M	H	H	M	H	H	L	H	H	M	H	M	H	L	L	L	M	M	L
	4.25	31	Loss of arctic-alpine species / change in upland plant communities	direct	-	-	L	L	L	L	H	M	-	H	H	L	H	L	H	L	-	-	L	L	-
	4.26	27	Impact on heather	direct	L	L	M	H	M	M	H	H	L	H	H	M	H	M	M	L	L	L	L	M	L

					Natural Heritage Zone																				
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			moorlands																						
Agriculture	4.27	41	Shelter belts to shade and shelter livestock and crops	adaptation	-	-	-	-	-	-	M	-	H	-	-	M	-	M	M	H	H	M	M	L	M
	4.28	43	Loss of field boundary and other farmland trees due to storm damage and stress	direct	-	-	-	-	-	-	M	-	H	-	-	M	-	M	L	H	H	M	M	-	M
	4.29	75	Flood damage to agricultural crops – from rainfall, sea and flood storage projects	direct	-	-	-	-	-	-	L	-	M	-	-	L	-	L	L	H	H	L	H	-	H
	4.30	87	Arable – potential increase in productivity if	direct	-	-	-	-	-	-	M	-	H	-	-	M	-	-	M	H	L	-	-	L	H

					Natural Heritage Zone																			
Topic	**Figure reference**	**Change reference**	**Landscape change**	**Type of change**	**1 Shetland**	**2 N Caithness and Orkney**	**3 Western Isles**	**4 NW Seaboard**	**5 Peatlands of Caithness and Sutherland**	**6 Western Seaboard**	**7 Northern Highlands**	**8 Western Highlands**	**9 NE Coastal Plain**	**10 Central Highlands**	**11 Cairngorm Massif**	**12 North East Glens**	**13 Lochaber**	**14 Argyll West and Islands**	**15 Breadalbane and East Argyll**	**16 Eastern Lowlands**	**17 West Central Belt**	**18 Wigtown Machairs and Outer Solway**	**19 W. Southern Uplands and Inner Solway**	**20 Border Hills**	**21 Moray Firth**
			nitrogen and soil moisture – requirement for greater on-farm storage of crops																						
	4.31	88	Increased requirement for irrigation of arable	adaptation	-	-	-	-	-	-	M	-	H	-	-	M	-	-	M	H	L	-	-	-	M
	4.32	94	Sowing and harvesting affected by wetter winters – poss shift from autumn to spring sowing	adaptation	-	-	-	-	-	-	L	-	H	-	-	M	-	-	M	H	L	-	-	-	M
	4.33	98	New or novel crops	adaptation	-	-	-	-	-	-	M	-	H	-	-	H	-	-	M	H	M	-	-	-	H

Population and Multiple Deprivation

4.92. Scotland's population[7] is spread unevenly, (see Figure 4.35) with the most significant concentrations in the cities of Glasgow, Edinburgh, Aberdeen and Dundee (accounting for more than a quarter of the entire population) and across central Scotland (comprising North Ayrshire, Glasgow and the Clyde Valley, the Lothians, Falkirk, Stirling, Clackmannanshire and Fife and accounting for around 45% of the entire population). The lowest population density is found in the Highlands and Western Isles (Eilean Siar).

4.93. As might be expected, the Scottish Index of Multiple Deprivation (SIMD)[8], which is based on analysis of a combination of factors including income, employment, health, access to services and education, shows a similar, though more concentrated, geographic pattern (see Figure 4.34). The most significant concentration of multiple deprivation is found in Glasgow, which has over half of Scotland's 5% most deprived areas. Other local authority areas with notable concentrations include North Lanarkshire, City of Edinburgh, South Lanarkshire, Dundee, Fife, Inverclyde, West Dunbartonshire, and Clackmannanshire. By contrast, the Western Isles (Eilean Siar), Moray, Orkney Islands and Shetland Islands have the lowest levels of deprivation.

4.94. The concentration of population and multiple deprivation means that most people's everyday lives will be affected by a particular combination of climate related landscape changes. In cities and larger towns, changes will focus on measures to manage the flood risk from a combination of fluvial flows, increased run-off and sea level rise. The built environment is likely to experience change with greater use of air conditioning and small scale renewables, and building designs which respond to the opportunity presented by warmer, drier summers but also wetter winters. Greenspaces in and around towns and cities are likely to be improved to create habitat networks and contribute to SUDS projects, while their use is likely to increase particularly during the better summer months. It is possible that warmer summers, and an increase in the urban heat island effect, will prompt people to move to cooler rural and coastal locations.

4.95. The wider population of central Scotland is likely to experience a similar combination of changes, together with the more extensive development of habitat networks, catchment wide approaches to flood management and the development of renewable energy projects and associated infrastructure. The pattern of agricultural production may change with more intense use of better land, the possible expansion of cultivation into areas that are currently pastoral or marginal in character, the loss of some field boundary trees and the increased use of irrigation equipment, particularly in the east of the country. Recreation activity is likely to increase throughout the rural parts of central Scotland, with increased use of Regional Parks, Country Parks and Loch Lomond and the Trossachs National Park, together with access networks and longer distance routes.

4.96. It is perhaps worth noting some of the changes that, while significant elsewhere in Scotland, are less likely to have a significant effect on most people's every day lives. These include the combinations of changes which are likely to affect highland areas such as the modification of moorland, subarctic and peatland plant communities, re-wilding measures designed to reduce the risk of flooding and maintain or enhance the role of soil in carbon sequestration. Areas served by the national grid are likely to

[7] http://www.gro-scotland.gov.uk/statistics/council-areas-map/index.html
[8] http://www.scotland.gov.uk/Topics/Statistics/SIMD/

come under continued pressure for renewable energy development while in some areas it will be necessary to upgrade or protect transport infrastructure to respond to higher rainfall and the risk of landslides. More heavily wooded and forested areas are likely to experience direct impacts (invasion of other species, damage from storms, drought, pests and diseases) and changes in management including the use of different species and moves towards continuous cover forestry. Some rural areas are likely to see a significant expansion of woodland to contribute to flood management, carbon sequestration and habitat networks. Large parts of the east coast, in particular, will experience an intensification of agricultural activity which could alter some characteristic landscapes. On the west coast and the Scottish Islands it is likely that a combination of more severe storms, increases in winter rainfall and sea level rise could have a significant impact on coastal communities and communications.

4.97. Although it is beyond the scope of this report to undertake detailed analysis of issues relating to landscape change, population distribution and deprivation, this is an area which should be further examined through future studies.

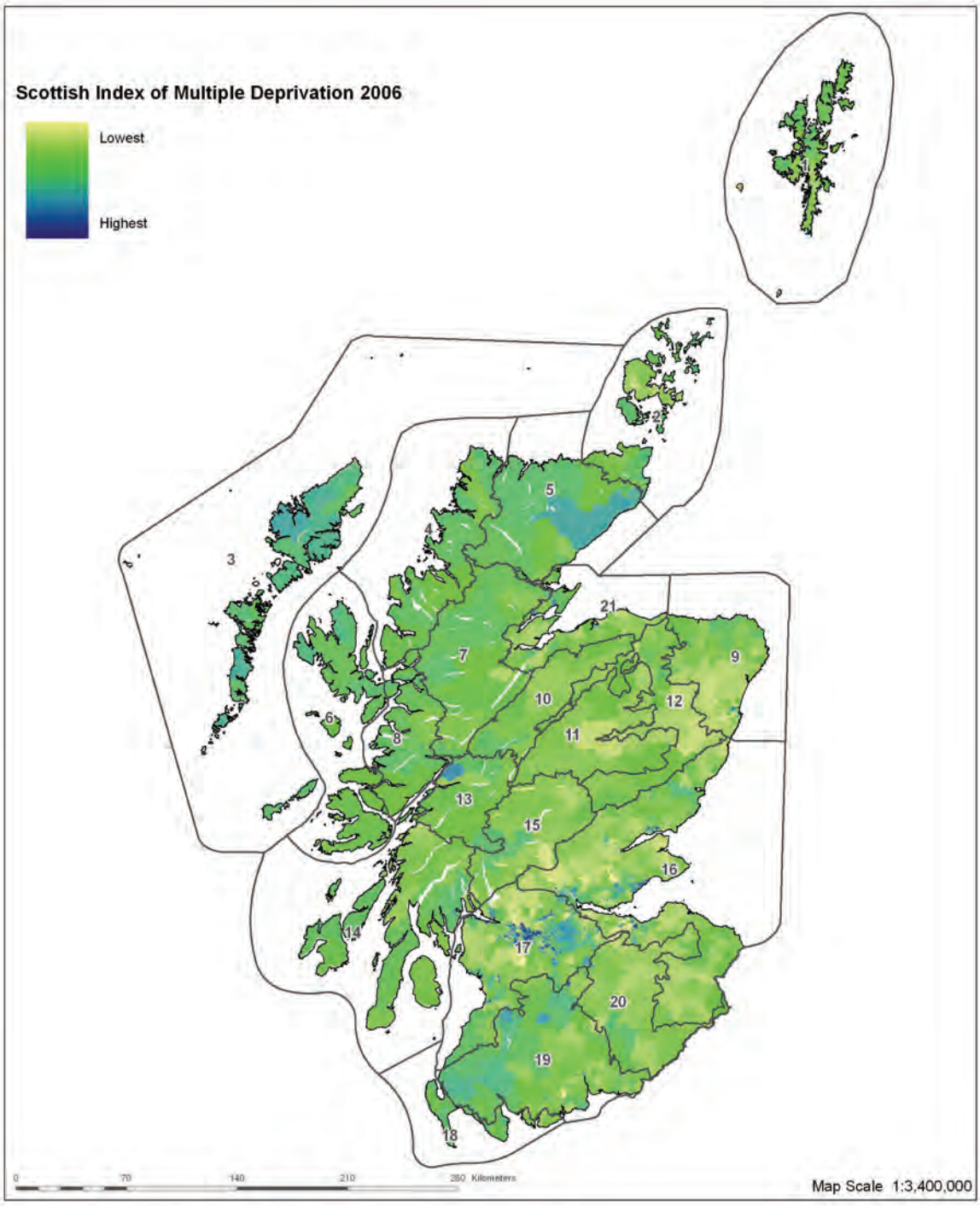


Figure 4.34, Scottish Index of Multiple Deprivation 2006

Key

Natural Heritage Zone

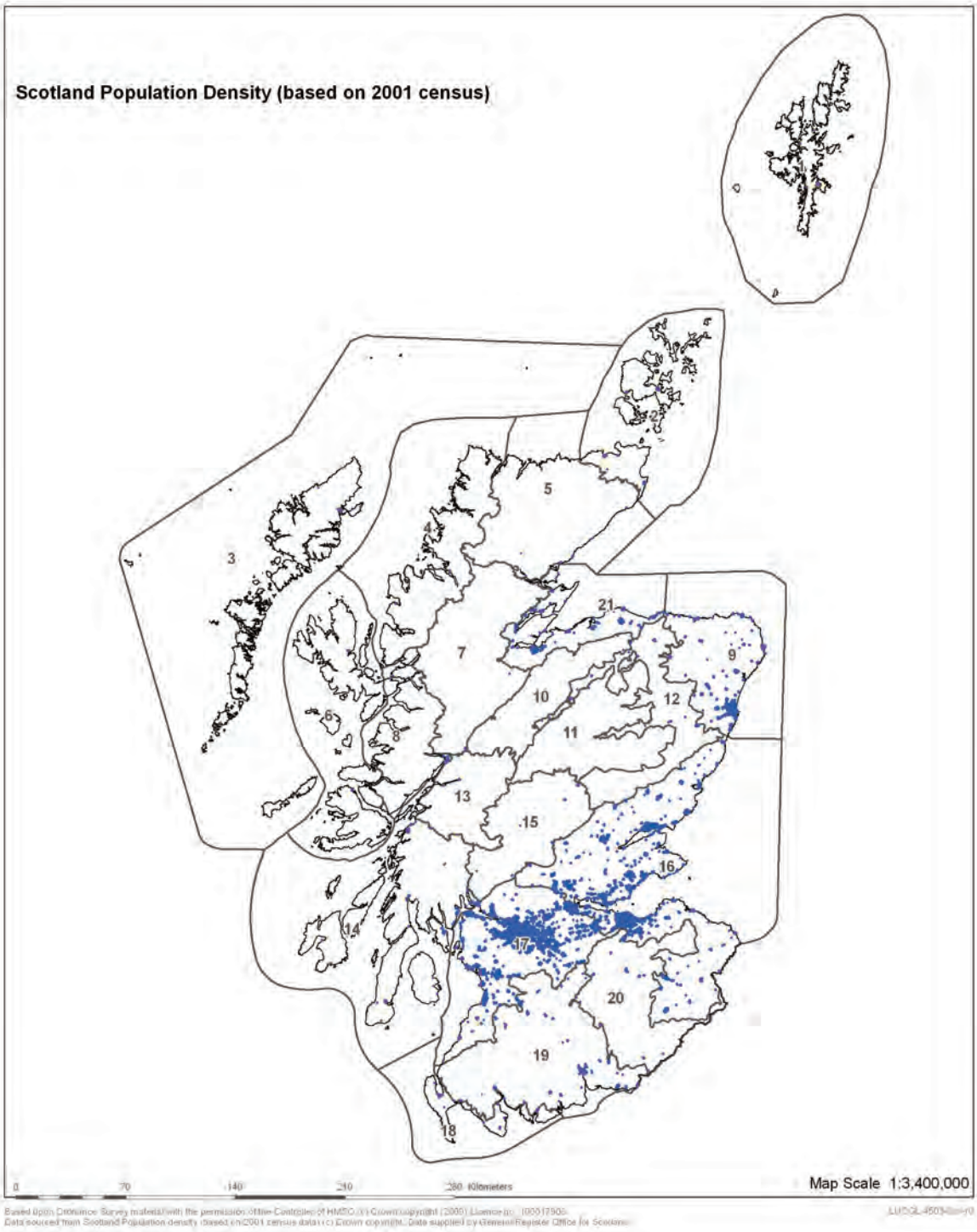


Figure 4.35, Population Density

Key

Natural Heritage Zone

1 Dot = 5,000 people

Designated Landscapes and their Special Qualities

4.98. Climate related landscape change could also have significant influences on National Scenic Areas (NSAs) and National Parks (NPs) and the qualities which make them special and distinctive[9]. Figure 4.36 shows NSA and NP boundaries overlaid on Natural Heritage Zones. It shows that NSA designations are concentrated away from the more densely settled areas of central Scotland and the intensively farmed and forested parts of the east coast, Ayrshire and Dumfries and Galloway in favour of highland, coastal and island areas. The national parks are in more accessible locations, but also include remote areas.

4.99. This suggests that one group of designated areas (including the two National Parks and NSAs ranging from North Arran through Ben Nevis and Glen Coe to Assynt Coigach) are likely to experience a combination of changes focused on the direct impacts of climate change on upland habitats including sub-alpine plant communities, heather moorland, peatland and native woodland. In winter the reduction in snow lie will adversely affect these areas' recreational role, while drier and warmer summers could have the opposite effect. While larger renewable energy developments within these areas are likely to be resisted, windfarms in surrounding areas could affect perceptions of these areas. There may also be a requirement to upgrade electricity and transport infrastructure. These changes could have an influence on the special qualities of designations in these areas.

4.100. A second group of designated areas is focused around coastal and island landscapes along the west coast. Many of these include mountainous areas along the coast. Areas include Knapdale, Jura and Scarba, Lunga and the Garvellachs NSAs in Argyll and Bute, the Small Isles, South Uist Machair, South Lewis, Harris and North Uist NSAs in the inner and Outer Hebrides, extensive areas in the Wester Ross, Assynt-Coigach and North West Sutherland NSAs and parts of Orkney and Shetland. The longer term impact of sea level rise and coastal flooding is likely to be a key issue for many of these areas, particularly where settlements and transport infrastructure are placed at risk. Woodlands are a distinctive feature of some of these areas and could be affected by storm damage, colonisation by alien species and the spread of pests and diseases. Remoteness and wildland qualities are important aspects of many of these landscapes and any significant increase in recreational pressure could have an impact on visitors' and residents' perception of these areas.

4.101. A third group of NSAs is made up of a series of coastal areas along the Solway Firth (Fleet Valley, East Stewartry and Nith Estuary), where a combination of sea level rise and agricultural changes could affect their landscape character and its contribution to special qualities.

4.102. The final group of NSAs is made up of dramatic valley landscapes, often with neighbouring hills. Included in this group are the River Earn (Comrie to St Fillans), River Tay (Dunkeld), Upper Tweeddale and Eildon and Leaderfoot NSAs. These are small areas, but there is potential for changes in the structure and composition of woodland, an increase in the risk of flooding and changes in river morphology, and a significant growth in recreation activity. Again, these changes could combine to influence these areas' special qualities.

4.103. While it has not been possible to review each NSA and National Park within the scope of this research, it is likely that some of the impacts of climate change and human adaptation and mitigation responses will have implications for such areas'

[9] http://www.snh.org.uk/pdfs/nsa/NSAspecialqualityproject.pdf

special qualities. This is explored in greater depth in relation to the Loch Tummel National Scenic Area in Section 5 of this report. It is also important to recognise that climate related landscape change will have implications for the values and qualities that underpin a number of different types of designated area. These include Historic Gardens and Designed Landscapes, World Heritage Sites, local landscape designations, Conservation Areas and international, national and more local nature conservation designations where climate related changes in management could have landscape implications.

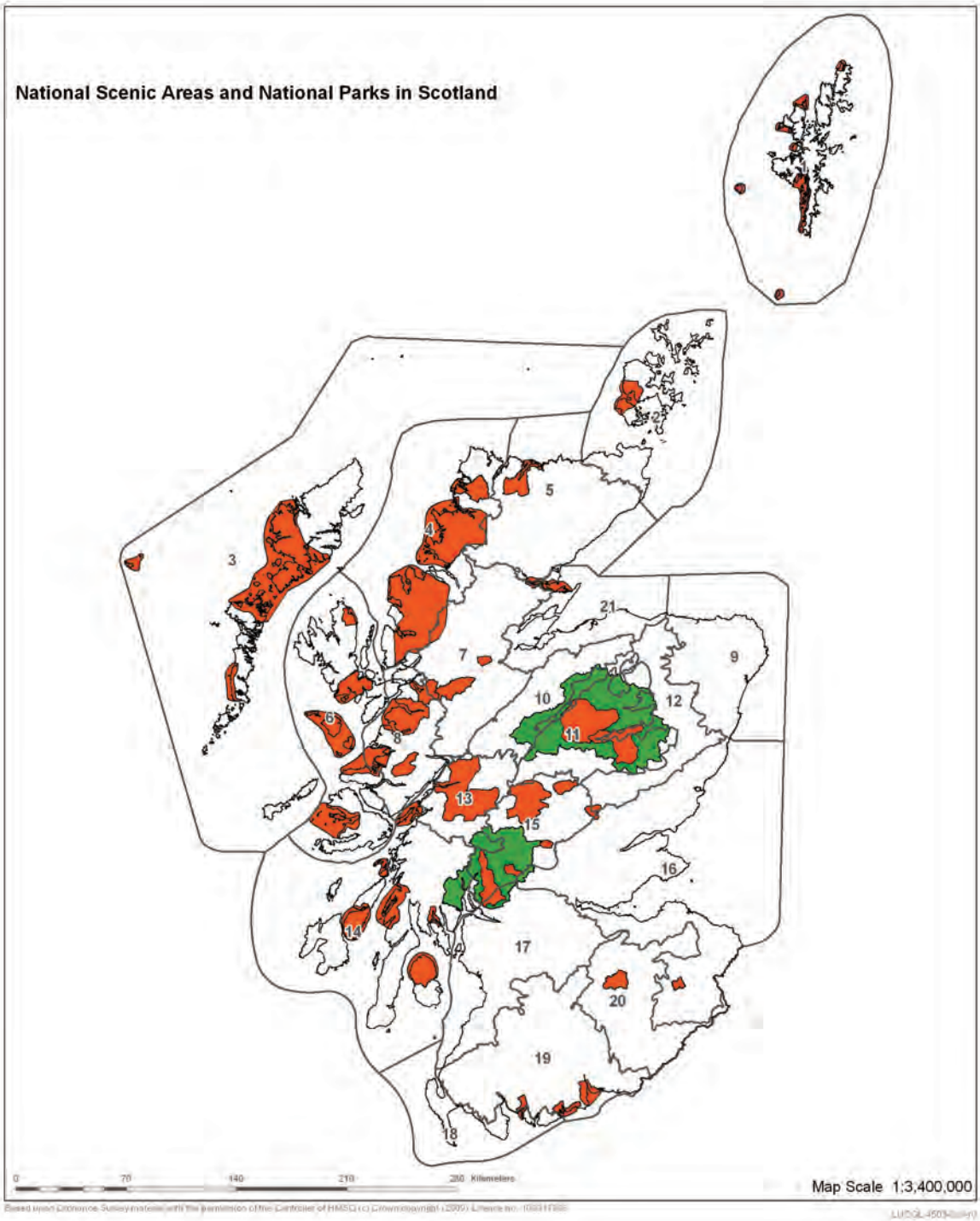


Figure 4.36, National Scenic Areas and National Parks

Key

- Natural Heritage Zone
- National Scenic Area
- National Park

Impacts on SNH Wildland Search Areas

4.104. Scotland's wild landscapes are valuable to society and form a distinctive part of Scotland's natural heritage. Wildland makes a number of different contributions to people's experience of the landscape[10]:

- engagement with the physical world. Enjoyment of wildness links people with the physical elements of a natural world, from which society is now more distant, as an outcome of modern styles of living;

- solitude and sanctuary. The experience of wild places invokes a sense of solitude and sanctuary which is important to many people. Protecting places where solitude can be enjoyed to the full helps to secure a full range of recreation opportunities for society;

- closeness to nature. The wild areas of Scotland contain the most extensive areas of near or semi-natural habitat in Britain, with a distinctive wildlife, some of which depends on the same qualities of sanctuary or lack of disturbance also valued by people;

- wildness as a quality valued in its own right. People value many different aesthetic qualities, for their own sake and for the social benefits they provide. Such qualities can lie in our cultural or historic heritage, or in the natural world, as in the case of wildness.

4.105. There are clear links which can be drawn between the values described above and the ecosystem services provided by landscape. Climate related landscape change may impact on the quality of wild land and the associated ecosystem services.

4.106. Public perceptions of wild land were explored in the SNH report Market Research Partners, Edinburgh. (2008). Public Perceptions of Wild Places and Landscapes in Scotland. Commissioned Report No.291(ROAME No. F06NC03). The report identified that

- areas of wildland are perceived as important for a wide range of reasons, most commonly because they are part of Scotland's culture / heritage and for tourism. Additionally, they are seen of benefit to wildlife and nature, the environment and the local economy. Respondents indicated that wild places contributed to their own health and wellbeing;

- key threats and detractors from wild places tended to be modern and human interference, such as buildings and masts, rather than old buildings or low impact changes such as forest plantations or footpaths. Residents were of the opinion that masts and wind turbines would decrease the wildness of an area most significantly.

4.107. Respondents to the survey were asked to state which features or characteristics make an area wild. The following four classifications were identified to allow categorisation of survey answers:

1. Naturalness of land cover: included wildlife and perceived land cover (e.g. trees, hills, untouched, uncultivated).

2. Lack of modern artefacts: included lack of pylons, masts, turbines, buildings and built up areas.

[10] SNH Policy Statement No. 02/03 Wildness in Scotland's Countryside http://www.snh.org.uk/strategy/pd02c.htm

3. Ruggedness: rugged, harsh or physically challenging terrain.

4. Remoteness: a sense of being alone and to an extent removed from other people or 'developed' amenities. Remoteness is not just a question of distance and included 'lack of people', 'unpopulated, 'quiet', 'peaceful' and 'open spaces'.

4.108. These findings suggest that it is the introduction of new built features within rugged and remote landscapes which would have the greatest impact on perceptions of 'wildness' under potential future climate related landscape change. This could include windfarms other constructed features such as electricity, drainage or water infrastructure. Loss or damage to natural land cover would also reduce the 'naturalness' of the landscape, though this would only affect the experience of wildness if it resulted in the introduction of obviously 'unnatural' patterns of vegetation.

4.109. The findings also suggest that wildness is a function of remoteness and factors such as a 'lack of people'. It is possible that improved summer weather conditions could increase demand for recreation in currently more remote parts of Scotland. In some areas, a relatively small increase in the number of visitors could have a significant impact on perceptions of wildness.

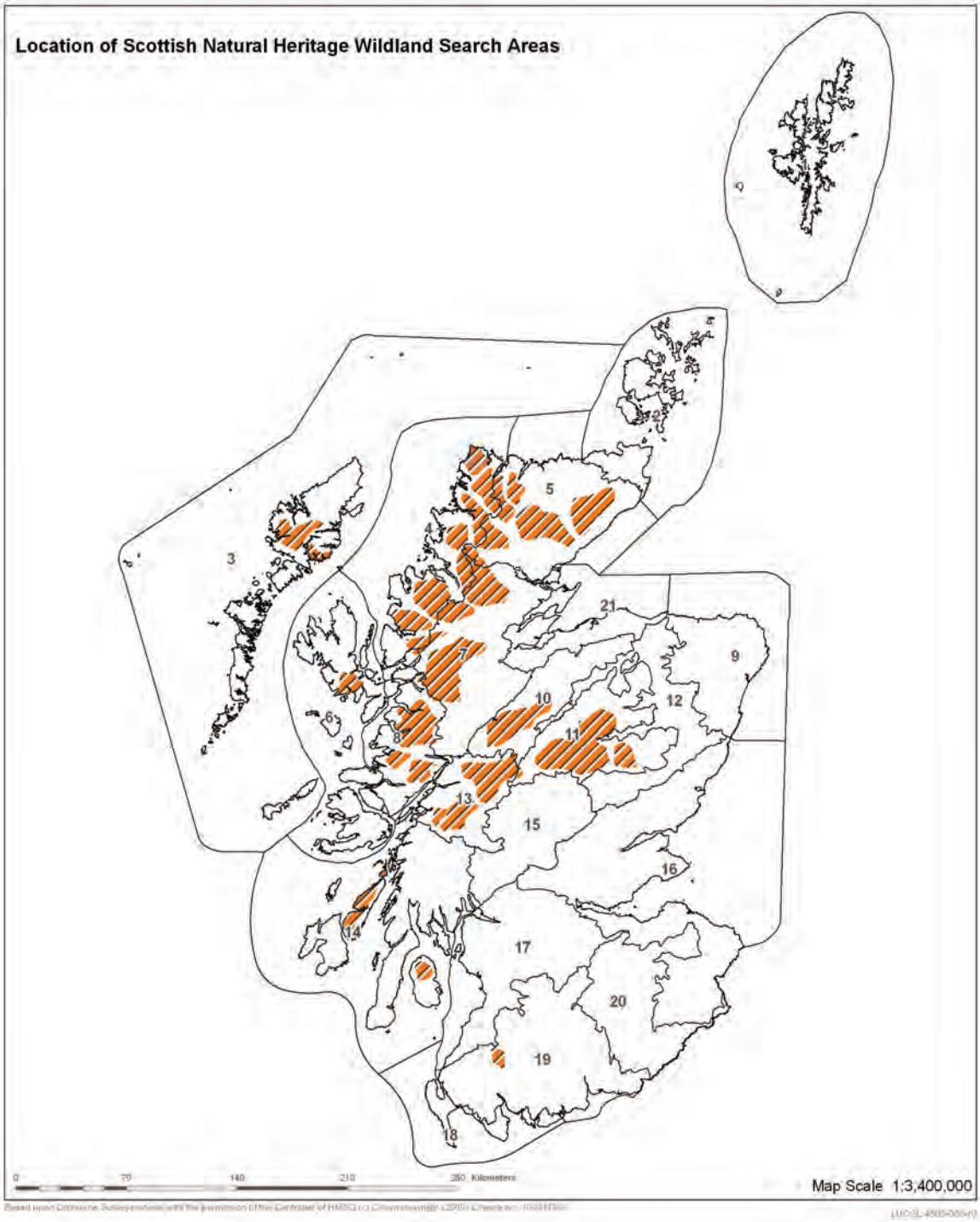


Figure 4.37 SNH Wildland search areas

Key

Natural Heritage Zones

Wildland search areas

5. TAYSIDE DETAILED STUDY AREA

5.1. This section of the report focuses on Tayside to provide a more detailed analysis of the implications of climate change for the landscape and the cultural ecosystem services it provides. The Tayside area combines uplands and glens, lowland agricultural areas, sections of estuary and coast and larger settlements such as Perth and Dundee. The area also has a diverse climate with a range of impacts from the central uplands to the eastern coast.

5.2. The landscape implications of climate change are considered at two scales. The first analyses change at a broad level, describing the three regional landscape character areas identified within the Tayside Landscape Character Assessment and exploring how they could be affected by climate change. The second focuses in on four sample locations to provide a much more detailed analysis of how landscape character, and the cultural ecosystem services it provides, could be affected by climate change. Tayside's location within Scotland is shown below on Figure 5.1 below and it comprises the local authorities of Perth and Kinross, Angus and the City of Dundee.

Figure 5.1 Location of Tayside in Scotland

CLIMATE CHANGE AND REGIONAL LANDSCAPE CHARACTER

5.3. This section describes the key effects of climate change as they may affect the broad pattern of landscape character within Tayside. It draws on the SNH Tayside Landscape Character Assessment descriptions of Regional Character Areas[1], to consider how landscape character might change within these broad areas. The three Regional Character Areas provide a broad representation of the main landscape types found across Scotland and are illustrated below in Figure 5.2:

[1] Areas recognisable as distinct landscape regions at a broad scale, based upon general characteristics such as landform, geology, soils, land use, ecological associations, historical associations and urban and industrial activity.

Figure 5.2 Regional Character Areas
(source: Tayside Landscape Character Assessment)

TAYSIDE LOWLANDS AND THE FIRTH OF TAY

Existing Landscape Character

5.4. The Tayside Lowlands regional character area is located in the south-east part of the Tayside region. The area is characterised by lowland landform with the low hills of the Sidlaws, mostly below 500 metres (m) in elevation. The eastern edge of the region is bound by the North Sea coast. The estuarine environment of the Firth of Tay is located in the south of this region connecting to the North Sea. Areas which have been subject to glacial deposition and subsequent fluvial and marine erosion are evident across this region with features such as eskers, kames and kettle holes[2]. Soils are relatively fertile and hence the landscape is characterised by a range of crops including cereals, ley grassland and root crops. Fields are regularly bounded by trees. Occasional areas of higher ground within the region are covered by less fertile soil where land cover is predominantly woodland or open grass moorland. There are a number of landed estates and inventory listed designed landscapes across the Tayside Lowlands and a high density of historic features and structures. The lowland nature of the region has resulted in a number of communication routes passing through the area.

5.5. A combination of coastal terraces and hills are parallel to the south of the Firth of Tay (within Fife). The landform creates a distinct raised edge above the estuary. Coastal flats near Newburgh provide an inter-tidal habitat of reed beds, including Mugdrum Island within the Firth of Tay.

[2] Landforms resulting from glacial retreat including sinuous ridges of gravel and sediment (eskers), mounds of gravel and sand (kames) and holes in the ground, sometimes filled with water resulting from melting blocks of ice (kettle holes)

Possible Changes to Landscape Character resulting from Climate Change

Forests and Woodlands

Direct Impacts

5.6. There is potential for an increase in **loss of field boundary trees** resulting from storm damage and the stresses resulting from increases in winter rainfall and decreases in summer rainfall. **Damage to** areas of **woodland** resulting from winter flooding or water-logging is most likely to occur where soils are poor draining. Summer drought in the region would exacerbate this damage. **Increased recreation** resulting from longer warmer summers and accessibility of the region may result in an increased risk of fire damage to woodland.

Adaptation Responses

5.7. The limited occurrence of **wet woodland** across lowland areas may increase in extent and frequency as their establishment is seen as a flood management technique. Woodlands may be planted with a broader species and genetic mix in order to improve their resilience to climate and pests. The region's deep fertile soils are suitable for high quality broadleaf trees and it is expected that **new woodland species** would be planted.

Mitigation Activities

5.8. The suitability of the Tayside Lowlands region may result in **woodland expansion** to increase carbon sequestration. This could take the form of new or expanded woods in the hillier parts of the area, together with networks of farm woodlands and shelterbelts.

Freshwater Systems

Direct Impacts

5.9. The frequency and severity of **river flooding** is expected to increase within this region, including along rivers such as the Tay. One of the effects of this flooding may be increased erosion of river banks. **Flood plains**, and other land may be more frequently inundated with water with impacts on their use resulting from increased water flows and hard flood defences. The **physical erosion of river courses** may result in effects on natural and semi-natural river habitats. River courses may also change. There may also be changes in **groundwater** resulting in flooding.

Adaptation Responses

5.10. Flood management may comprise **upland land management** (closing drains, woodland establishment), temporary flood storage within floodplains upstream of Perth and other settlements, engineering measures to divert flood flows away from urban areas and a range of measures within urban areas to slow run-off and manage flood flows. It is possible that the more valuable agricultural land would be subject to increased protection, potentially creating a tension where there is need for increased flood storage.

Mitigation Activities

5.11. Rivers may be developed for small scale run of river hydro electric power schemes.

Coasts, Estuaries and Sea

Direct Impacts

5.12. Changing patterns of **coastal deposition** along the east coast of the region may alter the range of species suited to this habitat. Flood damage to agricultural crops is likely and coastal wetlands, such as Tay reed beds could reduce or be lost as a result of being caught between rising seawaters and hard coastal defences. Increased coastal flooding resulting from sea level rise and increased frequency and severity of storms could overtop, bypass and breach coastal defences.

5.13. Longer term effects of coastal erosion resulting from climate change on the region could affect cliffs (e.g. Auchmithie and Usan) and low - lying coasts and dunes (e.g. Barry links, Lunan Bay, Montrose). **Sea level rise** may be a significant contributor to changing coastal morphology with implications for a wide range of low lying coastal landscapes, land uses and habitats.

Adaptation Responses

5.14. Managed **coastal realignment** may be used to maintain 'natural' flood defences and intertidal habitats, though this in turn may result in the loss of existing land uses and landscapes along the Firth of Tay. In some areas, '**harder' flood defences** may be deployed to protect property and possibly areas of more valuable farmland. In these areas, the intertidal landscapes of mudflats and reedbeds may be lost.

Mitigation Activities

5.15. Coastal and estuarine landscapes are also likely to be affected by **renewable energy** schemes designed to provide cleaner sources of electricity. This may include **offshore windfarms**, which would be most visible from the outer part of the Firth, and from areas of higher ground, and possibly some form of tidal energy scheme based on either the construction of a tidal barrage across the Tay or the use of a series of tidal lagoons located throughout the estuary. A barrage would have a significant impact on the pattern of tidal flows in the upper Firth, with implications for habitats and estuarine landscapes. It could, however, offer some protection from surge tides, reducing the need for coastal flood defences. It is acknowledged that the tidal range in this area may not be sufficient for such development to take place. Both technologies would have significant implications for nature conservation interests which in turn may affect the area's recreational value.

Urban and Peri-Urban

Direct Impacts

5.16. Urban centres, including Perth, Dundee and smaller settlements such as Blairgowrie, and Coupar Angus may experience increased **stress on green infrastructure** and water and sewerage infrastructure caused by summer drought and high temperatures, increases in winter rainfall, pests and disease and increased use.

Adaptation Responses

5.17. Green spaces may be a focus for **sustainable urban drainage** initiatives. Habitat enhancements may be carried out to create **habitat network** links across urban areas.

5.18. As a result of these pressures due to climate change, new building design would seek to maximise shading, passive ventilation, use of reflective and insulating materials. The use of **green roofs** will also contribute toward a reduction in the

urban heat island[3] effect, contributing more widely to attenuation of storm water run-off, absorption of air pollutants and dust. Features such as **shading** and **air conditioning units** may be retrofitted to existing buildings. There may be an increase in provision of networks of open water and water features (although there may be competition for water availability), and green infrastructure at larger urban centres such as Perth, Dundee and Arbroath. Gardens will also become more important for absorbing run off, providing greenery and contributing to well being. This may be reflected in the layout and design of existing gardens and gardens associated with new development.

Mitigation Activities

5.19. The installation of **micro-renewables** such as wind turbines, solar panels and passive water heating may be fitted to buildings within the urban area.

Tourism and Recreation

Direct Impacts

5.20. Climate change may alter the **distribution and number of facilities and pattern of pressure** on tourism and recreation destinations within the region. The easy accessibility of the rural areas of this region and its plentiful historic and coastal tourist destinations may experience the greatest pressure. Climate change may result in changes in the character of coastal areas for formal and informal recreation through changes in erosion and deposition. Increased use of coastal areas may also impact on the nature conservation value of these areas.

Adaptation Responses

5.21. In some locations the construction of hard coastal defences may affect the tourism and recreation use of a coastal area through access restrictions and changes to the character of an area.

Mitigation Activities

5.22. The construction of on-shore and off-shore wind energy developments may affect the recreation and enjoyment value of upland and coastal landscapes.

Infrastructure

Direct Impacts

5.23. Direct impacts may include **flooding**, with associated effects on road and rail infrastructure.

Adaptation Responses

5.24. Adaptation to the effects of climate change would see **road drainage infrastructure** upgraded in terms of its capacity and storage, this would notably occur where there are existing issues of flooding such as along the Tay, Earn and around Coupar Angus, but also along main transport routes including the A9 and A90 corridors, the M90 at Milnathort, and the Edinburgh and Glasgow to Inverness and Aberdeen railway lines.

[3] See glossary.

Mitigation Activities

5.25. The further development of **wind energy** at domestic and commercial scales is expected to continue in the region, especially with the planned reinforcements to the Beauly to Denny and East Coast electricity transmission connections which pass through the Tayside Lowlands. Locations within this area may be suitable for small - medium scale wind farm development. The Firth of Tay may have potential for the development of **tidal power** schemes and off shore wind. Smaller communities in rural areas could see the development of small or medium sized **biomass plants** and combined heat and power plants.

Natural and Semi-Natural Habitats

Direct Impacts

5.26. Climate change could result in a more rapid decomposition and nutrient cycle within the region. This could affect the nutrient status of some natural and semi-natural habitats. This could alter the **composition** of **heather moorland** on higher ground within the region, with a possible increase in the **spread of grasses**.

Adaptation Responses

5.27. Climate change may result in impacts on the limited areas of **heather moorland** within the region (generally higher slopes such as the Sidlaws) as **management** may alter (such as the abandonment of muirburn due to dry autumns making this activity potentially dangerous) and there may be an **increase risk of fire** as a consequence of lower summer rainfall. It is expected that habitat networks would be developed and adapted in lowland agricultural areas and urban areas, for example there could be an increase in woodland cover. Climate change may result in active **rewilding of flood plain** areas, such as that surrounding the Tay, where flood defences are not implemented, and other smaller river networks. Rewilding is only likely to occur where there is low competition for other uses of the land, and land of higher value for agriculture may be retained for productive use.

Mitigation Activities

5.28. The development of **wind energy**, **biomass crops** and **tidal or hydro electric schemes** could result in loss and damage to natural and semi-natural habitats.

Agriculture

Direct Impacts

5.29. **Flooding** and **drought** events will result in direct impacts on **crops** and **vegetation** with associated landscape impacts.

Adaptation Responses

5.30. **Sowing and harvesting** of crops across the region would be affected by wetter winters, resulting in a possible shift from autumn to spring sowing, and possibly an increase in the use of ground cover crops to minimise soil erosion during the winter. A reduction in summer rainfall could result in more **on-farm water management** such as water storage and greater use of irrigation equipment across this arable and horticultural region.

5.31. There are limited areas of sheep/cattle grazing in the region, however the few lowland hills may provide opportunities for **expansion of grazing**. Similarly, better quality land around the fringes of these higher areas may become suitable for arable production and horticulture.

Mitigation Activities

5.32. Across this arable region there may be an increase in the production of **biomass and bioenergy crops** such as oilseed rape, wheat, sugar, beet, miscanthus and for Short Rotation Coppice (SRC). Willow is the most suitable species for SRC in Scotland and the best yields are achieved on sheltered, fertile sites which can be readily cultivated, although it will grow on a wide range of soils.

5.33. Energy crops could compete with conventional and novel arable and horticultural cultivation, which may intensify as Scotland's climatic competitive advantage over other parts of the UK and overseas areas increases. This could encourage the further **intensification of farming activity** in areas such as Strathmore, Strathearn and the Carse of Gowrie, and the potential for expansion into currently less intensively farmed areas.

5.34. Greater productivity could lead to an increase, or change in demand for **on-farm storage of crops** (and therefore increase in the number of farm buildings). Dairy and cattle farms may increase the development of **anaerobic digestion** (AD) to reduce the levels of methane production from farm waste.

Historic Environment

Direct Impacts

5.35. **Veteran trees**, including those associated with the historic tourist destinations and historic gardens and designed landscapes across this area may experience increased stress and increased potential loss. Woodlands within these historic locations may similarly be affected whilst also being subject to an increased presence of **disease and pests**. This could affect Perthshire's brand as Big Tree Country and more widely gardens such as Drummond Castle Gardens, Glamis Castle and specific features such as the Meikleour beech hedge.

5.36. Coastal heritage areas, such as Barry Buddon, may suffer from changing sea levels, an increased incidence of coastal flooding and changing patterns of erosion and deposition.

Adaptation Responses

5.37. Perceptual changes in the character of the surrounding landscapes may become evident from historic areas and therefore affect their setting. This could include crop changes, **loss of field boundaries**. Woodland expansion for habitat networks and shelter for crops could have a physical and perceptual effect on historic rural landscapes such as the mixed policy woodland of the Tayside straths. Increased use of hard coastal defences and riparian flood defences to combat the effects of climate change may in turn affect nearby coastal heritage areas and coastal settlements such as Montrose.

Mitigation Activities

5.38. The development of **renewable energy projects**, including woodland expansion for carbon sequestration, could impact on the setting and context of the wider historic environment. The addition of micro renewables, solar panels, air conditioning units

and passive water heating may impact on the character and setting of historic buildings and conservation areas.

UPLANDS (WEST HIGHLANDS AND MOUNTH HIGHLANDS)

Existing Landscape Character

5.39. The West Highlands Regional Landscape Character Area is located in the north-west of Tayside. The landform within this region is largely influenced by glacial erosion and comprises large, sharp, craggy mountains and deep, long glens which run east to west. Large lochs such as Loch Tay and Loch Earn occupy some of these glens. Several main communication routes pass through the West Highlands region linking to the west of Scotland. Small settlements are limited to principal glens and lower areas which historically provided cultivable land. Lower sections of some glens are also home to a number of large estates and parklands with associated policy planting e.g. Blair Castle, Dunkeld House and Taymouth Castle. Some lower valley sides are covered by extensive plantations of coniferous woodland. Upland areas are covered by heather and grass.

5.40. The Mounth Highland Regional Character Area is located in the north-east of the Tayside region and is characterised by a mountainous ridge. The region is influenced by glacial erosion of landform into distinctive glaciated valleys and deposited moraines in glens. The mountainous landform is generally more rounded and less craggy than those in the West Highlands Regional Character Area. Glens are orientated north-west to south-east and are comparatively shorter and smaller scale than those to the west. A number of castles and fortified houses are scattered throughout the glens. Commercial forestry covers much of the middle and lower parts of glens. Expanses of upland areas are covered by heather moorland.

Possible Changes to Landscape Character resulting from Climate Change

Forests and Woodlands

Direct Impacts

5.41. Summer drought and winter flooding are expected to result in **damage to the woodlands** which are generally located on glen slopes within this region. Woodlands located on poorly draining soils would experience the greatest level of damage. Increased recreation resulting from longer warmer summers and accessibility of the area may result in an **increased risk of fire damage to woodland**.

Adaptation Responses

5.42. Areas within this region with ‘droughty’ soils may become **unsuitable for Sitka spruce** and other drought sensitive species, therefore impacting on the large areas covered by this species. Deep fertile soils within the region may then become more suitable for high quality broadleaved trees. A broader species mix and genetic mix may be developed to improve resilience to climate and pests. **New woodland species**, such as Monterey pine, maritime pine, southern beech and walnut may become established in this region, particularly in more sheltered and lower lying areas. In more low lying areas there may be a shift to ‘**low impact silvicultural systems**’ (LISS) based on continuous tree cover. This may reduce the landscape impact of clear fell operations, as well as reducing the risk of soil erosion and wind damage.

5.43. As a flood management solution, woodland on glen slopes and along river corridors may increase.

Mitigation Activities

5.44. **Woodland** areas may be **expanded** in order to increase carbon sequestration and contribute to habitat networks. Birchwoods are expected to increase in extent to provide shade and shelter of pasture within this area.

Freshwater Systems

Direct Impacts

5.45. **Flood damage** to river banks and flood plains may increase, including physical erosion of river courses with a knock on effect for associated natural and semi natural habitats.

Adaptation Responses

5.46. There may be a greater number of **flood management activities** as the frequency and severity of flooding increases. Catchment-scale flood management measures may be introduced comprising a variety of upland management techniques (rewilding of upland bogs, woodland establishment), and increases in flood storage within the glens. **Flood defences** protecting settlements, better farmland and transport infrastructure within the glens may also be improved.

Mitigation Activities

5.47. Rivers may be developed for small scale run of river hydro electric power schemes.

Coasts, Estuaries and Sea

Direct Impacts and Adaptation Responses

5.48. The highland region does not include coastline and no direct impacts would affect this landscape.

Mitigation Activities

5.49. Effects of climate change on coasts, estuaries and the sea would have limited effects on this highland region. Perceptual changes may be noted where elevated locations provide views of the distant coastline and sea, and therefore possible **offshore wind farms** or tidal barrage schemes within the Firth of Tay. It is acknowledged that the tidal range in this area may not be sufficient for such development to take place.

Urban and Peri-Urban

Direct Impacts

5.50. Settlement in this area comprises relatively small rural communities concentrated within glens, however there are still likely to be perceptible changes within them. There may be an increased **stress**, **demand** and **use** of green and blue infrastructure[4] and **countryside areas** close to and within the settlements areas caused by summer drought and high temperatures, winter rainfall, pests and disease and increased use.

Adaptation Responses

[4] See glossary.

5.51. **New building design** will maximise shading, passive ventilation, use of reflective and insulating materials. There may be an increase in the use of green roofs. There is also likely to be an increased provision of network of open water and water features, and green infrastructure.

Mitigation Activities

5.52. The installation of **micro-renewables** such as wind turbines, solar panels and passive water heating may be fitted to buildings within the urban area.

Tourism and Recreation

Direct Impacts

5.53. Climate change (such as the longer, drier and warmer summers) may alter the pattern and pressure of tourism and recreation activities and destinations within the region. The relative ease of accessibility of this **upland region** and the plentiful opportunities for recreational activities (such as walking, climbing and cycling activities) could result in **increased pressure** on tourist attractions within this region and a possible expansion in the range of formal and informal recreation opportunities such as trails and visitor centres. The area includes a number of Munros[5] which are a draw for walkers and climbers. Similarly the numerous **historic tourist destinations**, such as castles and fortified houses located in glens may experience **increased pressure** from tourism. However, during the winter, reductions in snow lie, and increases in rainfall and cloud cover could reduce the pattern of recreation activity, changing the way in which people experience and enjoy the highlands.

Adaptation Responses

5.54. Changes in the management of woodlands and woodland creation may create benefits for tourism and recreation. This may result from reduced landscape impacts from less clear fell and more continuous cover, and recreation opportunities associated with new woodland creation.

Mitigation Activities

5.55. No relevant mitigation activities are identified.

Infrastructure

Direct Impacts

5.56. Direct impacts may include **flooding** and **landslides**, with associated effects on road and rail infrastructure.

Adaptation Responses

5.57. Adapting to the effects of climate change may see **road drainage infrastructure** upgraded in terms of its capacity and storage, this would notably occur where there are existing issues of flooding such as Weem and Aberfeldy. Along the A9 corridor north of Dunkeld there may be further engineering works, allied to protective woodland planting, to reduce the risk of land slips.

Mitigation Activities

[5] Mountains in Scotland over 3000ft (914m). They are named after Sir Hugh Munro (1856–1919), who produced the first compilation of a catalogue of such hills, known as *Munro's Tables*, in 1891.

5.58. The further development of **wind energy** at **domestic** and **commercial** scales is expected to continue in the region. Current wind farms proposals have been mostly limited to the east and south edge of this region considering the proximity of the Cairngorms National Park to the north, and the extension of the National Park to Killiecrankie in the south will potentially further concentrate development. This pattern of wind farm development is expected to continue.

5.59. There is potential for commercial forestry within the area to be developed for **biomass plants/cropping**.

Natural and Semi-Natural Habitats

Direct Impacts

5.60. The **pattern of peat accumulations** could **change** as a result of climate change, areas of growth may occur where rainfall increases and areas of decay may occur where rainfall decreases. There is also potential for **damage** where increases in total rainfall, or in the intensity of rainfall events, results in peat erosion. Active habitat management may result in rewilding of blanket bog, moorland, upland woods and a managed realignment of flood plain areas.

5.61. Changes in biodiversity may alter species' range and composition within the area resulting in a movement of species north and to higher altitudes within the area. Elevated areas of the West Highlands region (above 600m Above Ordnance Datum (AOD)) may experience a **loss of arctic-alpine species / change in upland plant communities**. Climate change may result in a more rapid decomposition and nutrient cycle; this could have a knock on effect to the nutrient status of some of the region's habitats. Changing patterns of freeze-thaw action could result in the loss of characteristic upland features such as stone stripes and solifluction terraces[6].

Adaptation Responses

5.62. Climate change may result in impacts on **heather moorland** which covers much of this upland region (including areas such as Glen Clova, Glen Shee and Isla). This is likely to include **management** changes (such as the likely abandonment of muirburn to minimise carbon emissions, and changing grazing patterns), and there is an increased risk of fire as rainfall patterns change. It is possible that **grassland habitats** will **expand** at the expense of heather moorland. Habitat networks may be developed and adapted in lowland glens including within settlements, for example there may be an increase in woodland cover.

Mitigation Activities

5.63. The development of **wind energy**, **biomass crops** and **tidal or hydro electric schemes** could result in loss and damage to natural and semi-natural habitats.

Agriculture

Direct Impacts

5.64. **Flooding** and **drought** events will result in direct impacts on **crops** and **vegetation** with associated landscape impacts.

Adaptation Responses

[6] Patterns of stones and sediment resulting from freeze-thaw action.

5.65. A reduction in summer rainfall could result in an increase in **on-farm water management** such as water storage and greater use of irrigation equipment in cultivated lower glens.

5.66. Lower glens are mostly grazed by sheep, however climate change may allow the **expansion of arable and horticultural activity** on lower ground, with sheep and cattle grazing moving uphill and into currently wilder, core mountain areas. The expansion of farming may result in an **increase in the number of new farm buildings** in the lower glens where farming is concentrated. Dairy and cattle farms may increase the development of anaerobic digestion to reduce the levels of methane production from farm waste.

Mitigation Activities

5.67. Farmland may be used for wind energy development, there may be some production of short rotation coppice on the more productive land. Re-wilding of peatland may occur in order to secure carbon sequestration.

Historic Environment

Direct Impacts

5.68. **Veteran trees** are important features of many of the historic tourist destinations, and trees in the parkland estates in the glens may experience increased **stress** and increased potential **loss**. **Policy woodlands** within these historic areas may similarly be affected whilst also being subject to an increased presence of **disease and pests**. These changes could be particularly significant in areas such as Dunkeld and Loch Tummel where the history and culture of woodland and forestry is closely linked to the landscape and people's enjoyment of it. There may also be loss of historic features on the coast, due to sea level rise and changes in patterns of erosion.

Adaptation Responses

5.69. Loss of field boundaries and changes in land management practices such as moorland management will affect the character and setting of historic features such as veteran trees and historic buildings and features.

Mitigation Activities

5.70. Perceptual changes in the character of the surrounding landscape may become evident from historic areas and therefore affect their setting, for example the **loss of field boundaries** and **introduction of wind farms**. However **woodland expansion** for carbon sequestration, habitat networks and shelter for livestock, could have a physical or perceptual effect on historic rural/wooded landscapes as their character alters.

Overview

5.71. Within the lowland landscapes of Tayside, the most significant climate related changes may include the following:

- **Direct impacts of climate change** may be most noticeable along the coastline and the Firth of Tay where a combination of rising sea-level, changing patterns of erosion and deposition, and the incidence of surge tides, could result in the loss or change of low-lying landscapes including dunes, beaches, links golf courses and intertidal habitats. Elsewhere, direct impacts of climate change may include

an increase in the incidence of fluvial flooding (with localised changes in erosion, deposition and river morphology), changes in the composition of natural and semi-natural habitats in higher parts of the Sidlaw Hills and other higher areas, and an acceleration in the loss of field boundary trees that are characteristics of the agricultural landscapes of areas such as Strathmore and Strathearn.

- **Human adaptation to climate change** could have a moderate impact on the agricultural landscapes that are typical of lowland Tayside. It is likely that agricultural activity will intensify, particularly within areas that are currently most productive, though it is possible that activity will also expand into more marginal areas. The potential range of crops may increase. Intensification could result in further field amalgamation, the loss of field boundary trees, hedges and dykes, the development of larger farm buildings and the wider use of irrigation equipment. The use of poly-tunnels and agricultural plastics could increase to reduce the risk of damage from severe weather events. Flood management may be a further influence on the landscape, particularly along the coast where managed realignment may be combined with harder flood defences to protect settlements, historic sites, transport routes and the most productive farmland. Taken together, these changes could have a marked influence on the lowland landscape, reflecting the dominance of land management and land use in shaping character, in contrast to the uplands, where the landform is a dominant factor.

- **Human mitigation of climate change** could include a range of renewable energy schemes including wind farm development, biomass cultivation and associated heat and power plants, micro-renewables and tidal energy schemes. Wind and tidal energy schemes have the potential for significant landscape change across quite large parts of the lowlands. There is also potential for the expansion of woodland cover within the lowlands to contribute to carbon sequestration, as well as providing shelter/shade for stock and crops and contributing to habitat networks. The extent of new woodland in these areas may depend on the degree of agricultural intensification. Carefully designed woodland networks could complement the existing pattern of policy and farm woodlands in the lowlands, but could create a different landscape comprising ‘open’ parcels of farmland within networks of woods.

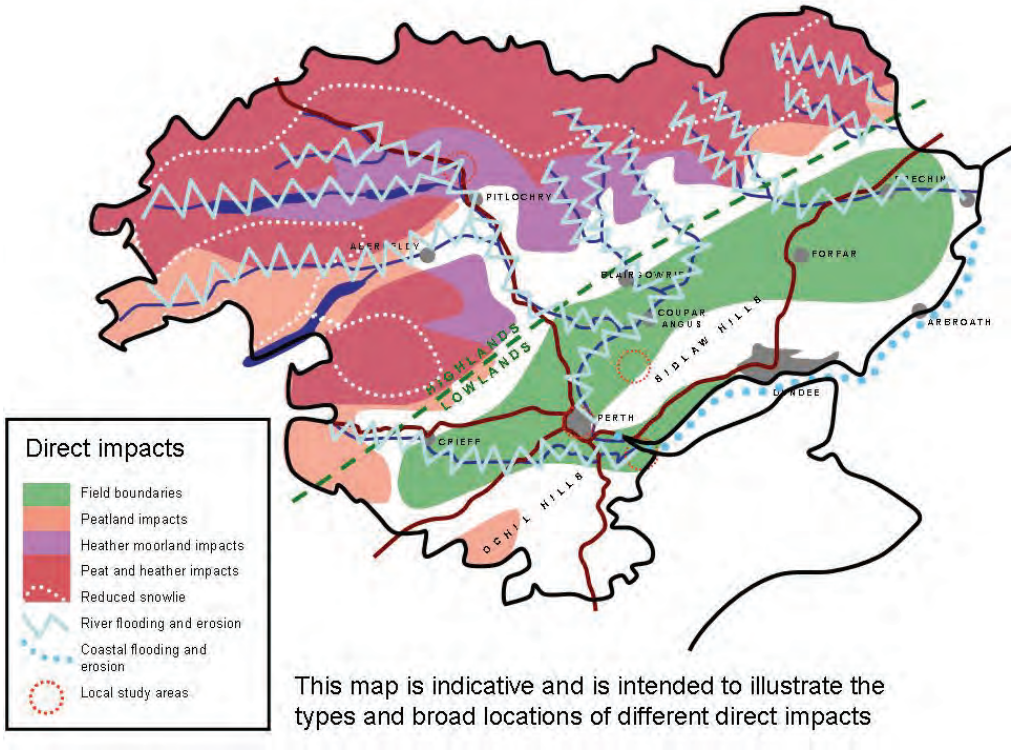


Figure 5.3 Direct Impacts

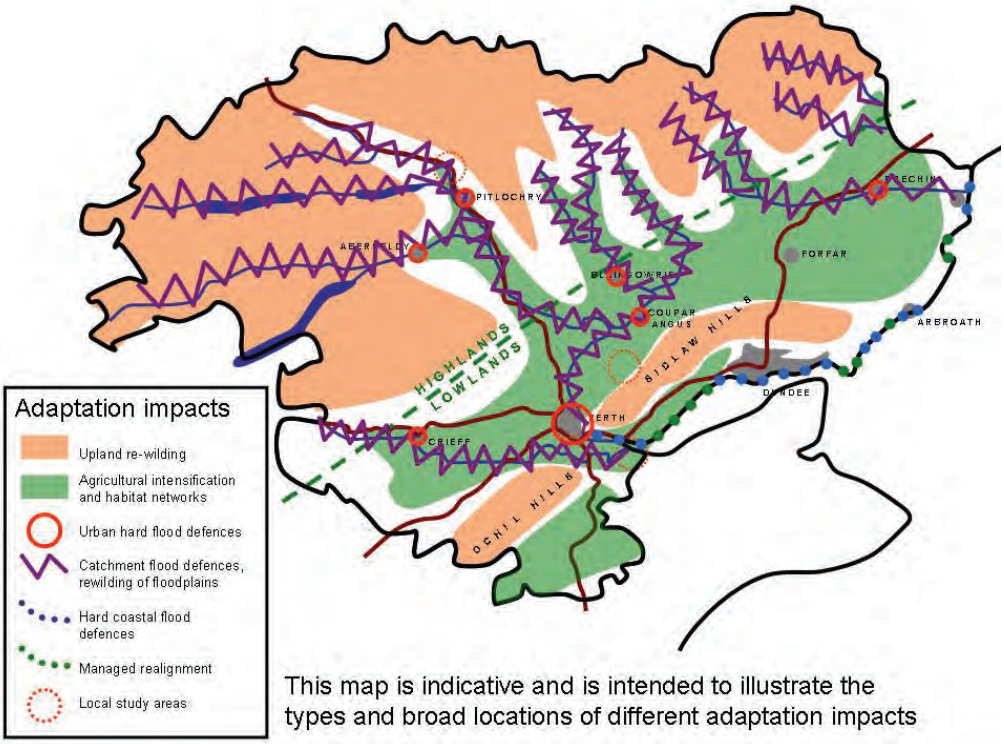


Figure 5.4 Adaptation Impacts

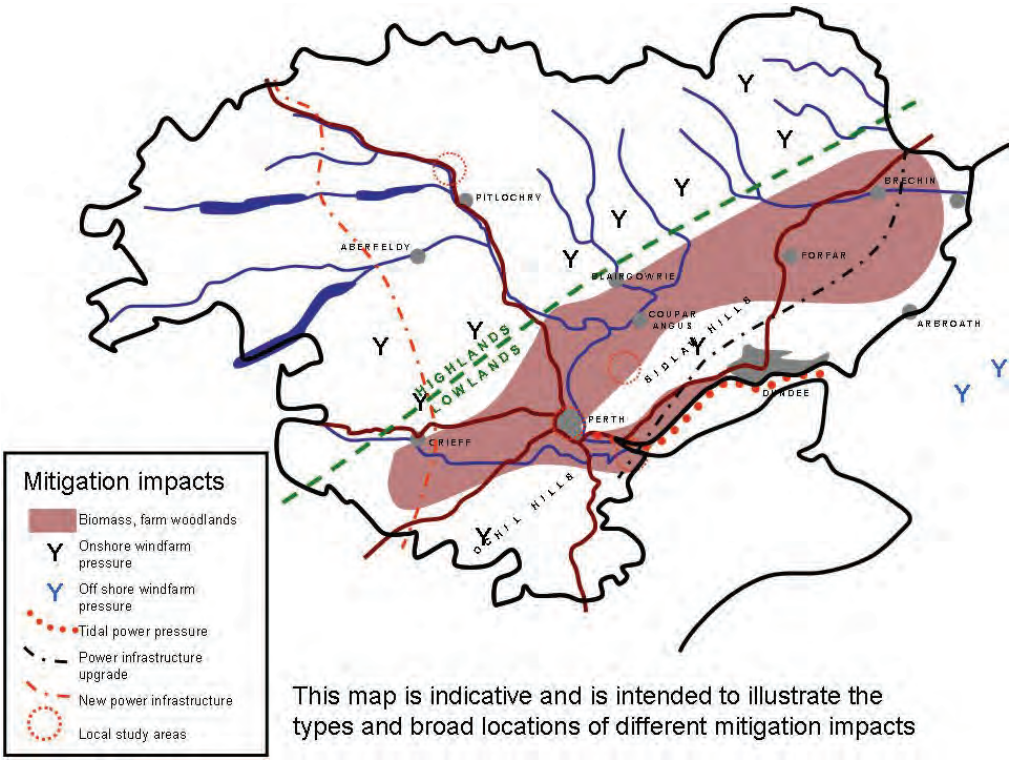


Figure 5.5 Mitigation Impacts

5.72. This analysis suggests that the most significant climate related changes affecting upland landscapes in Tayside may include the following:

- **Direct impacts of climate change** may affect characteristic upland landscapes of heather moorland (possible reduction) and peatbogs (possible expansion in areas experiencing the greatest increases in winter rainfall, but possible losses where drier summers result in significant drying). The local landscape of the highest mountain tops may change as patterns of the freeze thaw cycle change, altering rock weathering and soil features formed by this action. Within upland glens, higher rainfall may result in an increase in flooding, soil erosion and deposition and changes in river morphology. Some slopes may become less stable as winter rainfall totals, and the intensity of individual events, increases. The pattern of snow fall and lie may change, with reduced extent and duration of snow lie, affecting in particular those areas between 600 and 900 metres AOD. All these changes will have a gradual effect on landscape character, although many will be very localised. It is likely that the underlying character of these upland areas will not be significantly changed by these changes.

- **Human adaptation to climate change** may include the re-wilding of upland landscapes to deliver a range of benefits including catchment wide flood management and increases in the resilience and connectivity of natural habitats. Key changes may include an expansion in the extent of plantation, native, and riparian woodlands, the expansion of natural tree lines to higher altitudes, the provision of 'natural' flood storage within floodplains to protect settlements down stream, and the re-wetting of bogs and moorland to slow the speed of water run-off. These measures may result in a moderate degree of landscape change, though with sensitive design of schemes, the net effect on the landscape may be positive. Other adaptation responses may include upgrading of transport

infrastructure to cope with increased rainfall and the risks associated with slope instability. Similar issues may apply to forest and estate road infrastructure and windfarm access tracks. Upland recreation may change, with reductions in snow fall and snow lie severely affecting businesses which rely on the viability of the Glenshee ski area. Agriculture may respond to warmer and drier summers and warmer but wetter winters by expanding stock grazing and arable and horticultural production within the glens, though it is possible that wider trends within the sector, such as economic pressures, will counteract these changes.

- **Human mitigation of climate change** may focus on the continued development of wind power, particularly in upland areas outwith the National Parks and National Scenic Areas. This may require upgrading of electricity infrastructure, with the development of long distance, high voltage lines, including underground connections and shorter connections to individual windfarms. Both these effects would introduce further built elements into the highland landscape and could result in significant landscape change. Within the glens, existing forestry and woodland are likely to be increasingly managed as a source of biomass for power generation, resulting in changes in the age, species and structure of woodlands. There may also be an expansion in woodland and other biomass crops grown specifically as a source of energy. This could have a significant local landscape effect, particularly where new 'crops' such as short rotation coppice are introduced to the smaller scale, pastoral landscapes typical of the glens.

5.73. Figures 5.3, 5.4, and 5.5 provide schematic illustration of the locations and cumulative impacts of the identified changes described above, for direct, adaptation and mitigation impacts. Higher degrees of certainty can be attributed to impacts of climate change resulting from weather changes associated with temperature increases, temperature extremes, increased winter precipitation changes, decreased summer precipitation, and precipitation intensity overall.

5.74. Direct impacts resulting from the climate changes listed above have a high level of certainty, however there may be variations in the human responses to manage these impacts.

5.75. There is a greater degree of uncertainty related to adaptation responses, which are subject to a greater number of potential influences in how people adapt and may be influenced by a wide range of matters from policy to economic considerations.

5.76. Mitigation impacts, some of which are already underway as a result of the existing policy framework, such as renewable energy development, have a higher level of certainty attached to their landscape change implications.

LOCAL AREA ANALYSIS

Introduction

5.77. This part of the analysis focuses on four locations within Tayside to provide a more detailed analysis of the implications of climate change for the local landscape character and for the ecosystem services provided. The descriptions explore landscape change based on the assumption that government policies, patterns of economic growth and societal values will remain largely as they have been over the past decade ('business as usual'). In order to take account of this assumption the four socio-economic scenarios developed by UKCIP to accompany the UKCIP02 scenarios are used to explore the potential landscape and quality of life implications of different development pathways.

Uncertainty

5.78. All the changes described for local area analyses are based on scenario work and are therefore subject to a degree of uncertainty.

5.79. High levels of confidence are associated with the key climate changes affecting this area (changes in rainfall and temperature). Lower levels of confidence apply to changes in storminess, cloud cover and snow lie. Considerable uncertainty relates to sea level changes, with, for example, suggestions expressed during the project workshop that current scenarios may be significant underestimates of the rate and extent of change.

5.80. Several of the key changes described in the 'business as usual' scenario are already supported by UK or Scottish Government policy and are therefore judged to be more certain. These include woodland expansion, renewable energy development, river basin management, management of transport infrastructure, improvement of urban greenspaces, development of habitat networks and SUDS schemes and growth in the take up on micro-renewables.

5.81. The responses of the agricultural sector are less certain reflecting the influence of wider economic trends, patterns of land ownership, tenure and succession, and potential changes in farming techniques and technology. There is also potential competition between conventional, new and energy crops, and other sectors including forestry and development pressure.

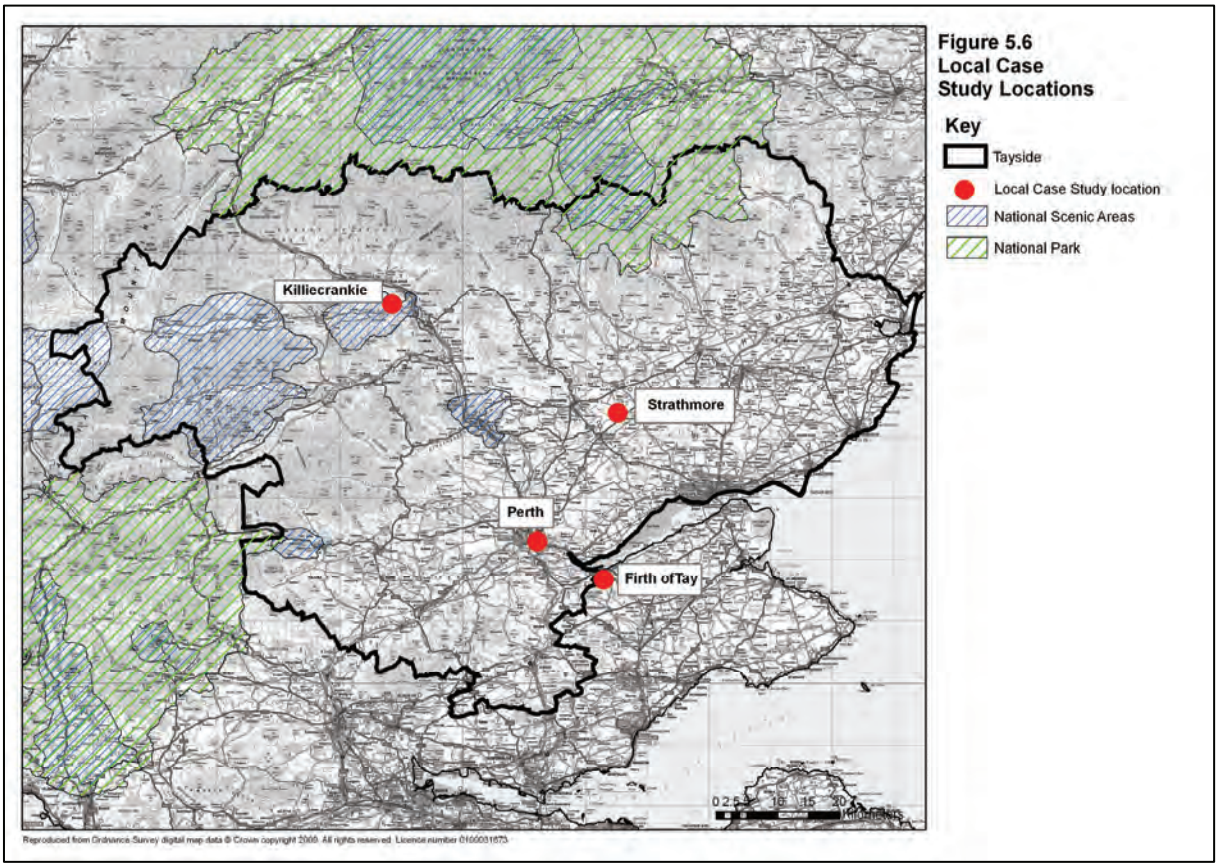
5.82. The analysis of socio-economic scenarios highlights a number of important uncertainties associated with the future development of society and policy. These include the relative importance attached to large and small scale renewable energy development, the weight attached to designated areas and wider patterns of sustainable land use and management, and the scale and nature of recreation and tourism development, the differing levels of household development, different strategies for accommodating such growth, different approaches to urban transport and, perhaps critically, differing approaches to environmental quality, including the role of greenspaces, walking and cycling.

Case Studies

5.83. The four case study locations, which are shown on Figure 5.6, are:

- Killiecrankie;
- Strathmore;
- The inner Firth of Tay
- Perth.

Figure 5.6 Local case study locations



Killiecrankie

5.84. This area is located adjacent to the A9 corridor and lies just within the eastern part of Loch Tummel National Scenic Area and comprises a combination of moorlands and summits with mid and lower altitude highland glens.

5.85. Table 5.1 below provides a comparison of the key characteristics of the upland and glen landscapes under the current climate, and with the landscape impacts of climate change. The analysis of climate related landscape changes is based on the continuation of existing policies ('business as usual'). The potential for different outcomes reflecting different socio-economic conditions is explored in later sections.

Table 5.1 Killiecrankie: Description of climate change influenced landscape change

Current landscape	With climate change
Topography and Geology: Extensive upland area with spurs orientated south, separating main glens. Hills are generally more rounded than to the west and rocky outcrops are fewer. Hill summits range from 400 to 1000m AOD. Glens with wide floodplains (around 0.5-1km across). Valley floor is around 50-200m AOD and valley sides are elevated to around 500m AOD. Harder rock has created a number of gorges and falls. A number of glacial deposition features.	**Topography and Geology:** The physical structure of this landscape may remain largely unchanged, though the localised patterns of erosion and deposition may change.
Forests and woodlands: In the uplands there are a few areas of semi-natural broadleaf woodland up to 600m AOD. Small areas of coniferous plantation are generally limited to below 450m AOD. Within the glens, extensive broad-leaf woodland (semi-natural on steeper slopes and managed estate woodland), mixed and coniferous woodland on valley sides, much of it associated with estates.	**Forests and woodlands:** The uplands may see some expansion of semi-natural woodland reflecting the improved climatic conditions.
Freshwater Systems: Large rivers meander across the floodplain and flows down incised narrow channels, most notably the pass of Killiecrankie. Networks of smaller burns and tributaries draining upland areas.	**Freshwater Systems:** Within the main glen, flood management includes the rewilding of some areas of floodplain to provide storage for flood water, and the use of engineered measures to protect property and infrastructure, particularly around settlements such as the village of Killiecrankie. In the upland area, some rewilding has been undertaken to reduce the speed of run-off, but there is evidence of increased erosion along stream corridors and the loss of some peat where damage has occurred as a result of summer drying and winter erosion.
Urban and Peri-Urban: Within the glens, well settled villages, large estates and some planned villages. Some uniform style and layout settlements. Small estates of distinctive landscape and architecture. General traditional use of building materials including granite, schist, slate and some sandstone.	**Urban and Peri-Urban:** Small settlements within the glen may make increased use of small scale renewables.

Current landscape	With climate change
Tourism and Recreation: Historically the area has attracted tourists from 19th Century onwards. Estates, castles and settlements are popular tourist destinations. The Pass of Killiecrankie itself is an important attraction, and the landscape of the Loch Tummel NSA an important recreation resource. Upland paths provide opportunities for informal recreation, walking and climbing. Appreciated for its panoramic scenic and wild views. Landscape used for game and stalking. Some cross-country skiing opportunities.	**Tourism and Recreation:** Better summer weather may mean the uplands are increasingly used for informal recreation.
Infrastructure: The glen provides important communication routes through the Highlands (A9(T) and railway). Several telecommunication masts. Electricity transmission lines pass along the glen.	**Infrastructure:** Further measures are likely to be implemented along both the A9 and the railway corridors to minimise the risk of disruption through landslides, including slope engineering and debris shelters.
Natural and semi-natural habitats: Within the uplands, below 600m AOD, heather moorland of dry and wet heath is the dominant habitat. Above 600m AOD montane heaths and grasslands predominate, with some areas of rich arctic-alpine flora. Gentle slopes tend to have blanket bog, with the peat at least 1m deep. Vegetation patterns closely reflect altitude, exposure and underlying geology, and the area is managed for grouse shooting, red deer and sheep grazing. Native ancient and semi-natural woodland is concentrated within the glens, particularly on steeper and less accessible slopes. Some gorge vegetation is found within the Pass of Killiecrankie.	**Natural and semi-natural habitats:** Likely enhancement of woodland based habitats within the glens and expanding onto middle hill slopes. Below 600AOD, the amount of heather within the moorland vegetation declines as soil conditions change, and tree planting also causes some loss of heather moorland. Above 600 AOD the rich arctic-alpine flora has disappeared or is much reduced with grasses invading these habitats. There is a noticeable movement of flora and fauna to elevations and latitudes not previously tolerated. However there is uncertainty relating to the interaction of direct and adaptation responses on habitats.
Agriculture: Some arable farming on lower/mid valley sides and drained valley floor. Pasture on glen floor and upper slopes. Large and rectilinear fields occupy glen floor. Medium and rectilinear fields occupy gentler glen slopes. Shelterbelts and post-and-wire fences act as field boundaries on the floodplain. Hedges, trees and walls are used as field boundaries on glen slopes. The general structure of field boundary trees is in decline. Upland areas are characterised by rough and unimproved pasture giving way to heather moorland	**Agriculture:** Farming is not likely to be significantly changed.

Current landscape	With climate change
managed for grouse, deer and sheep.	
Historic Environment: Within the glens there are numerous historic features including castles, fortified manor lodges and estate features e.g. Blair Castle and Blair Atholl and the associated gardens and designed landscapes. There are traces of General Wade's Military Road and, within the upland areas, evidence of historic routeways, former shielings and historic field patterns.	**Historic Environment:** The expansion of woodland may have an impact on the historic structure of the landscape and, potentially, on historic sites such as shielings, trackways and other remains. The introduction of wind turbines and electricity transmission lines will impact on the setting of historic structures, buildings and landscapes.
Protected Landscapes: The landscape includes part of the Loch Tummel National Scenic Area.	**Protected Landscapes:** The impacts on the identified 'special qualities' of the Loch Tummel NSA are explored in more detail at the end of this section. The conclusions of this exercise identified that although there will be some changes to the landscape character; diversity is one of the qualities of the landscape which also makes it more resilient to potential climate related landscape change.

Climate related Landscape Change

5.86. Figure 5.7a shows a typical landscape, comprising a view east across the main glen to the north of the Pass of Killiecrankie.

5.87. Figure 5.7b highlights the changes illustrated in Figure 5.8c, identifying direct impacts, and those due to adaptation and mitigation measures.

5.88. Figure 5.7c illustrates the kinds of climate related landscape change that could occur within this landscape.

Figure 5.7a Killiekrankie baseline

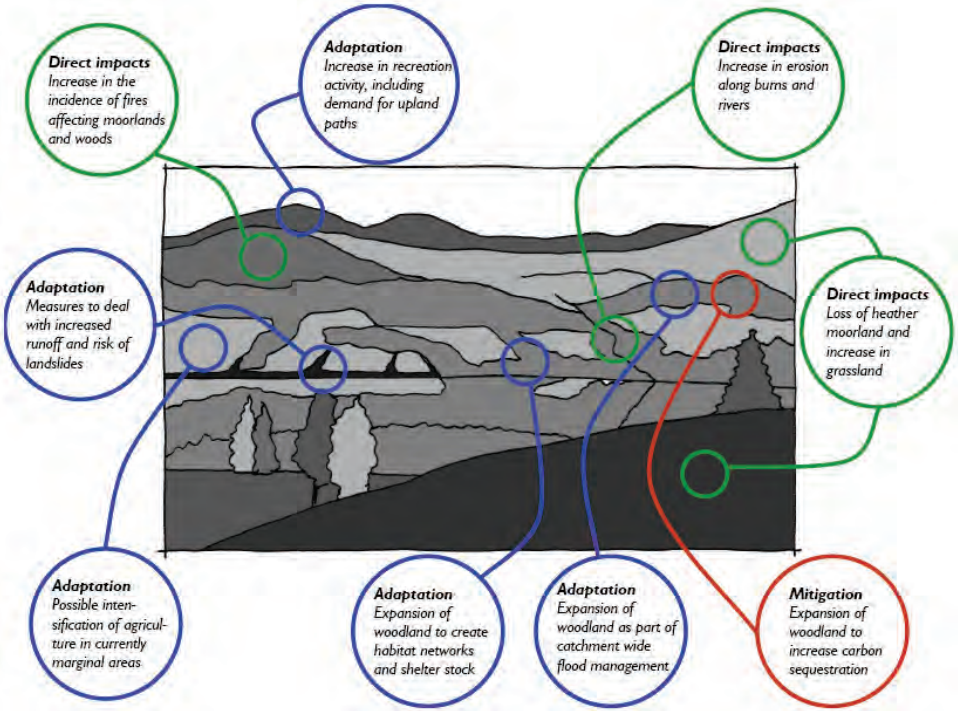


Figure 5.7b Killiekrankie: Diagram of landscape changes

Figure 5.7c Killiekrankie under landscape change scenario
It should be noted that this photomontage illustrates possible combinations of landscape change from a selected view point within a broad timeframe over the next 40 years, and should not be interpreted as planned or predicted change at this location

Overview

5.89. These descriptions suggest that the most significant climate related landscape changes would be associated with:

- the extent, composition and form of woodland (direct, adaptation and mitigation);
- the extent and appearance of heather moorland (direct, mitigation) as a consequence of woodland expansion and colonisation by grasses.

Changes in Ecosystem Services

5.90. These changes could affect the range of cultural ecosystem services provided by this landscape:

Table 5.2 Killiecrankie: Impact of climate related landscape change on cultural ecosystem services

Ecosystem services	Current	With climate change
Inspiration and enrichment	This is an inspirational landscape, reflecting the combination of highland summits, extensive heather moorland, rich broadleaf and mixed woodlands and forests, pastures on the slopes of the glen and of course the distinctive gorge and settlement at Killiecrankie. The steeply rising slopes dominate the landscape, and enclosure of the landform enhances the sense of scale. It is a wild, rugged and diverse landscape which provides an inspirational setting for local communities, and inspires and enriches visitors and travellers along road, rail, cycle and walking routes. The area also has important historic associations with the Battle of Killiecrankie.	This is likely to remain an inspirational landscape, with a changing balance of farmland and woodland.

Ecosystem services	Current	With climate change
Health and wellbeing	The landscape accommodates a range of low level walking routes, together with hill walking, horseriding and cycling opportunities, all opportunities for physical health. The landscape also provides for broader mental and wellbeing benefits – comprising a high quality, accessible landscape, that is within reach of urban populations to the south.	Some of the infrastructure changes for drainage, and water extraction could have a negative impact on recreation activity and indirectly on physical activity and health benefits provided by the landscape.
Aesthetic values	The combination of landscape elements, features and qualities means this landscape is high in aesthetic value.	Drainage and water extraction infrastructure could alter this landscape's aesthetic value.
Sense of place	While many of the individual landscape elements are found in other parts of the south east highlands, the particular combination, and specific features such as Pass of Killicrankie, make this a highly distinctive landscape.	This is likely to remain a highly distinctive landscape.
Cultural heritage values	Many will view this landscape as timeless even though the last century saw considerable change in terms of power generating infrastructure, forestry and transport infrastructure. The historic pattern of settlement and land management is, however, still evident throughout this landscape.	It is possible that expansion of woodland could affect the historic structure and appearance of field systems on the middle slopes of the glen.
Recreation and tourism	The landscape accommodates a range of low level walking routes, together with hill walking, horseriding and cycling opportunities. In addition, many people travelling north and south along main road and rail links will experience this landscape.	It is likely that infrastructure development such as drainage and water extraction infrastructure could have a negative impact on recreation activity and on perceptions of visitors.

Socio-Economic Scenarios

5.91. The above descriptions are based on the assumption that government policies, patterns of economic growth and societal values will remain largely as they have been over the past decade. The following section, which is provided for each of the four case study locations, explores possible future socio-economic approaches, given that it is unlikely that the 'business as usual' scenario will continue. The four socio-economic scenarios developed by UKCIP to accompany the UKCIP02 scenarios are used to explore the implications of different development pathways. It should be noted that these are extreme pictures of future change, but are useful in considering issues of uncertainty associated with human responses to climate change, as well as broader patterns of societal change. The socio-economic scenarios are described in more detail in Appendix 2.

World Markets

5.92. The World Markets scenario could result in the following outcomes:

- the decline of upland farming could result in the expansion of native and semi-natural woodland on the slopes of the glen;
- recreation pressure could be reflected in the development of caravan sites or timber lodge developments on gentler slopes, though overall the area receives some landscape protection reflecting its status as a National Scenic Area, and its accessibility to consumers;
- the village of Killiecrankie could become a holiday home and commuting settlement, with new houses built beyond the existing edge of the village. There could also be development of prestigious houses on the middle slopes of the valley, on new sites and replacing existing farm buildings;
- stalking and shooting remain at current levels or expand in popularity, with resulting pressures to maintain heather moorlands in their current condition;
- the A9 would be upgraded to dual-carriageway with few concerns for its environmental impact and significant visual and aural impacts on the landscape as a result.

5.93. It is likely that the World Markets scenario would result in greater landscape change than the 'business as usual' model. This would generally result in a loss of existing landscape character.

National Enterprise

5.94. The National Enterprise scenario could result in the following outcomes:

- an intensification of agricultural activity on the middle slopes of the glen, with a loss of trees and woodland, improvement of pastures and some field amalgamation. It is possible that agricultural activity could push uphill, particularly if heather moorlands are increasingly replaced by grass moorland. There could be new farm buildings;
- the intensification of farming would result in further loss and fragmentation of natural and semi-natural habitats, with woodland being confined to steeper terraces along the main river valley and along the course of the tributary;

- farm amalgamation could be reflected in the conversion of older buildings where they have become redundant;

- it is likely that there would be some additional housing development on the edge of Killiecrankie;

- renewable energy, including windfarms, biomass and solar would not be developed.

5.95. It is likely that the National Enterprise scenario would result in slightly greater landscape change than the 'business as usual' model. This would have a moderate effect on landscape character.

Global Sustainability

5.96. The Global Sustainability scenario could result in the following outcomes:

- the emphasis on environmental protection and habitat enhancement, together with contraction of animal husbandry in more marginal areas could result in the conversion of large areas of farmland to semi-natural habitats including low input pastures and woodlands, particularly on the valley slopes;

- there would be increased demand for informal recreation, reflecting the accessibility of the area and its status as a National Scenic Area;

- it is likely that inefficient buildings would be replaced, but otherwise new development would be strictly restrained;

- the A9 would be upgraded to dual carriageway, but it is likely that there would be an emphasis on limiting environmental impacts and maximising the landscape 'fit';

- the policy emphasis of conserving wild areas would discourage the development of upland windfarms within or close to the National Scenic Area, though the wider emphasis on developing renewable energy could see the development of biomass sources, particularly those associated with woodland and forestry. It is likely that woodland expansion would also be used as a means of increasing carbon sequestration and catchment scale flood management.

5.97. It is likely that the Global Sustainability scenario would result in a similar degree of landscape change as the 'business as usual' model. This would have an influence on landscape character, with a change in the balance of managed and 'unmanaged' areas.

Local Stewardship

5.98. The Local Stewardship scenario could result in the following outcomes:

- a reduction in agricultural activity reflecting the decreased demand for meat products. Possible conversion of some farmland to cultivation, with fruit and vegetable growing, particularly on the more fertile lower slopes and glen floor;

- an increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks, particularly on the middle slopes of the glen, and an expansion of native woodland and scrub on some of the upper hills slopes;

- the positive management of landscape features including field boundary trees and hedges;
- an increase in the network of footpaths and cycleways and no upgrading of the A9;
- little or no housing development;
- expansion of locally based renewables including biomass and small scale wind turbines

5.99. It is likely that the Local Stewardship scenario would result in a reinforcement of the existing landscape character and would be less damaging than the 'business as usual' example.

Strathmore

5.100. This area is located within the broad, arable landscape of Strathmore, bounded by the Sidlaw Hills to the south and the Angus Glens and Mounth uplands to the north.

5.101. The table overleaf provides a comparison of the key characteristics of the lowland agricultural landscape under the current climate, and with the landscape impacts of climate change. The analysis of climate related landscape changes is based on the continuation of existing policies ('business as usual'). The potential for different outcomes reflecting different socio-economic conditions is explored in later sections.

Table 5.3 Strathmore: Description of climate change influenced landscape change

Current landscape	With climate change
Topography and Geology: Glacial erosion has formed broad straths and a complex landscape of glacial deposition including outwash terraces, eskers and dry valleys. Strathmore is up to 10km wide.	**Topography and Geology:** The physical structure of this landscape may remain largely unchanged.
Forests and woodlands: Overall there is a limited extent of woodland. Broad-leaf woodland is limited to inner policy woodland and a few areas of unimproved land. Coniferous plantations can be found on areas of poorer land, especially glen sides. Native birch woodland is located on pockets of unimproved land. Existing policy and estate woodland. There is a trend of tree loss due to lack of management and replacement planting.	**Forests and woodlands:** Strathmore could experience an accelerated loss of its characteristic field boundary trees as a result of the stress caused by drier and warmer summers and wetter winters. They could also be lost as a result of agricultural intensification, particularly if it results in further field amalgamation. On the other hand, the area could see the development of shelterbelts and forest habitat links, designed to connect habitats across the intensively farmed strath, and provide shading and shelter for crops and stock. The choice of tree species may change with an increasing use of beech and sycamore. Where productive forestry occurs it is less likely to comprise sitka spruce. The overall effect may change from a well treed arable landscape, to a landscape comprising contrasting areas of open arable farmland and more wooded corridors or belts.

Current landscape	With climate change
Freshwater Systems: Undersized glacial misfit rivers occupy the glen floor. Existing flood defences are located along rivers.	**Freshwater Systems:** The risk of flooding along key river corridors, particularly those draining upland areas to the north, may increase, leading to a combination of hard flood defences around settlements and rewilding of river floodplains where this is compatible with intensive agriculture. Patterns of erosion and deposition, together with localised river alignments, may change. In summer, low flow conditions may be more common, with increasing levels of pollution, and implications for fisheries and other freshwater habitats and species as a consequence.
Urban and Peri-Urban: Settlements are small, often planned villages, and some small market/processing towns and larger market towns. The 19th century saw a growth in market towns, e.g. Coupar Angus, Forfar. Some recent modern house building expansions are found on settlement edges. Outside settlements, development is limited to scattered farmsteads and agricultural buildings. Vernacular building materials are predominantly red sandstone.	**Urban and Peri-Urban**: Settlements are generally small and rural, so measures to improve urban liveability in the face of rising temperatures may be limited. There may be an increase in the use of micro-renewables throughout the area, most visibly taking the form of roof-top solar collectors and small scale wind turbines. The use of solar collectors could have a local impact on the character of traditional buildings within the landscape. Small turbines would increase the area's 'developed' character. The emphasis on energy efficiency may result in novel building styles or materials, especially outwith Conservation Areas.
Tourism and Recreation: Generally limited opportunities for tourism and recreation reflecting intensive agriculture, although some use for golf. Occasional historic features provide tourist destinations.	**Tourism and Recreation:** Strathmore is not a major recreation area, though improved summer weather conditions could lead to an increase in local informal recreation activity and creation of local access routes. New recreation facilities may be created inland to replace resources such as golf courses lost as a result of sea level rise and coastal erosion. However, issues such as competition for land for agricultural production may affect recreation provision.
Infrastructure: Some important road connections, e.g. A94, pass through this landscape. There is a network of relatively long straight minor roads between fields. Roads are relatively visible within this flat, open agricultural landscape. Electricity transmission lines are present.	**Infrastructure:** The area could see the development of single turbine or small to medium size windfarms and the upgrading of electricity transmission lines. Close to settlements there is also potential for small or medium sized biomass plants, food processing centres, and combined heat and power plants. However, there is uncertainty surrounding the energy mix in 2050.

Current landscape	With climate change
Natural and semi-natural habitats: Habitat interest is limited to a few unimproved areas. Most land is cultivated for arable production with some field boundary trees and hedgerows.	**Natural and semi-natural habitats:** The creation of woodland belts would contribute to habitat networks, though the biodiversity of this intensively farmed area could remain comparatively low.
Agriculture: Arable agriculture dominates this landscape – cereals, potatoes and oil seed rape. Some arable cultivation has occurred on floodplains. There is limited pasture (mostly of pig farming). Fields are medium sized and regular, some enlarged, most dating back to parliamentary enclosure. Field boundaries are characteristically hedges with a high density of mature hedgerows, however intensification of farming has led to some removal. Agriculture has led to large modern agricultural buildings (especially potato stores) which are often light in colour.	**Agriculture:** the existing pattern of arable and horticultural cultivation is intensified. It is possible that there is a changing composition of crops, with heavily water dependent crops such as potatoes, moving away from drier areas, and a wider range of crops, including oil seed rape and energy crops such as miscanthus grass, increasing in extent. Market conditions, and the levels of incentive for biomass and bioenergy crops will influence the relative balance of crops. It is likely that productivity will increase, leading to a requirement for new, larger storage and processing buildings. Warmer, drier summers may result in the wider use of irrigation equipment including mobile booms. Demand for water may exacerbate low flow conditions in water courses in summer.
Historic Environment: Limited number of landscape features due to intensity of agriculture. Some historic houses, estates and surviving Pictish standing stones and other monuments, also historic villages. The structure of this landscape dates back to the enclosure and agricultural improvement movements of the eighteenth and nineteenth centuries.	**Historic Environment:** Agricultural intensification could result in the weakening of the historic structure of this landscape as field boundaries and trees are lost. Modern infrastructure and buildings would underline the intensive, almost industrial nature of this landscape. There may also be changes to the fabric of historic buildings resulting from management of rainwater, increased salt contamination and accelerated decay of vulnerable stone, and increased biological growth on stone.

Climate related Landscape Change

5.102. Figure 5.8a shows a typical view north across the Strathmore landscape, comprising a small village, areas of arable farmland and estate woodlands.

5.103. Figure 5.8b provides the key to changes illustrated in Figure 5.8c, identifying direct impacts, and those due to adaptation and mitigation measures.

5.104. Figure 5.8c illustrates the kinds of climate related landscape change that could occur within this landscape.

Figure 5.8a Strathmore baseline

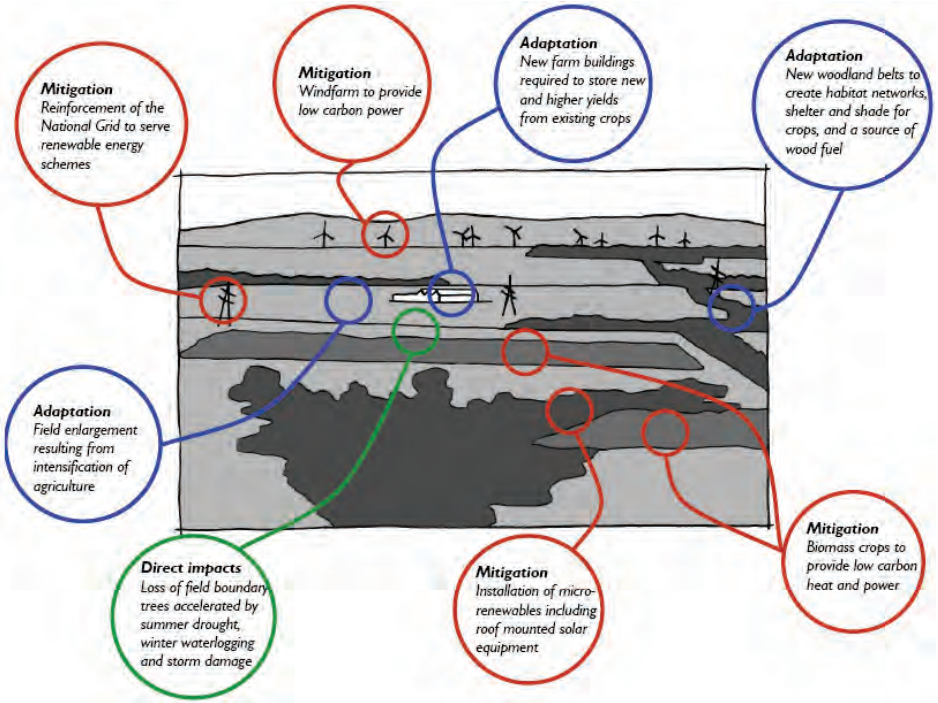


Figure 5.8b Strathmore: Diagram of landscape changes

Figure 5.8c Strathmore under landscape change scenario
It should be noted that this photomontage illustrates possible combinations of landscape change from a selected view point within a broad timeframe over the next 40 years, and should not be interpreted as planned or predicted change at this location.

Overview

5.105. These descriptions suggest that the most significant climate related landscape changes would be associated with:

- the intensification of agricultural activity in response to a combination of improved climatic conditions and an enhanced position relative to other areas which would be more seriously impacted by climate change. This could result in the accelerated loss of field boundaries and field boundary trees, the introduction of new crops, changing patterns of cultivation, the development of new agricultural and processing buildings and the wider use of crop irrigation equipment;

- the development of renewable energy, including small or medium scale windfarms and related infrastructure and, at a more local level, biomass production, processing and use.

Changes in Ecosystem Services

5.106. These changes could affect the range of cultural ecosystem services provided by this landscape:

Table 5.4 Strathmore: Impact of climate related landscape change on cultural ecosystem services

Ecosystem services	Current	With climate change
Inspiration and enrichment	Strathmore is a distinctive working rural landscape which is broadly typical of central and eastern parts of Scotland. While the scale and productivity of agriculture, and the structure of fields, boundary trees, settlement and historic landscapes can be impressive, this landscape does not have the naturalistic qualities associated with what some may regard as more highly inspirational landscapes. The landscape has important historical associations provided by the importance of the area as a Pictish centre, and the presence of Pictish stones.	When the landscape implications of climate change are taken into account, it is likely that the inspirational and enrichment value of this landscape is likely to be reduced. This reflects the introduction of new structures such as biomass plants, new large farm buildings, an upgraded electricity transmission line and a modern windfarm (though the latter element could be seen as inspirational by some).
Health and wellbeing	The countryside of Strathmore provides some recreation opportunities, and an attractive landscape providing mental and physical benefits to local communities, residents of Dundee and the wider population.	It is likely that the range of recreational opportunities might change affecting the area's attraction for informal recreation so health benefits for the wider population could be reduced.

Ecosystem services	Current	With climate change
Aesthetic values	This landscape has a distinctive structure of rectilinear arable fields, repeating lines of field boundary trees, shelter belts, farm woodland and policy woods associated with designed landscapes, and small agricultural villages. The aesthetic value of this landscape has been weakened by trends such as field enlargement, the progressive loss of field boundary trees, the development of large farm buildings, and the influence of infrastructure such as A94 trunk road.	The aesthetic values of this landscape may be adversely affected. The continued loss of field boundary trees, amalgamation of fields and introduction of quite different crops (including biomass) would make this a larger scale and more open landscape. The introduction of large modern structures including pylons, turbines, farm buildings and even a smaller scale biomass plant, would also undermine its distinctive rural and almost timeless character.
Sense of place	This is a distinctively Scottish, east coast landscape. Key identifiers include the arable fields, boundary trees, building styles and materials. The scale of the landscape and its relationship with the Mounth mountains to the north, define this landscape as Strathmore.	Some of these changes may weaken the sense of place, though it is likely that the landscape would still be easily identified as a coherent landscape, in part because of the field patterns and arable crops, in part because of the relationship with adjoining hill masses.
Cultural heritage values	This landscape has a number of distinctive historic and cultural elements, including the eighteenth and nineteenth century pattern field patterns, the policy and wider woodland influence of landed estates, and villages of single storey, sandstone and pantile farm workers cottages.	The cultural heritage values of the landscape are likely to be adversely affected by the further weakening of the field structure, and by the introduction of large scale, modern structures and buildings. Historic cottages may be upgraded and retrofitted with renewable energy equipment.
Recreation and tourism	Strathmore supports local access and recreation networks, country parks together with a number of visitor attractions including Glamis Castle. Many visitors to the north east and eastern Cairngorms, together with the Angus Glens experience this landscape.	It is likely that the informal recreational value of this landscape would change, though particular attractions, together with managed areas such as Country Parks would be largely unaffected, although there may be loss and damage to veteran trees. There may be loss of paths due to changes in land management, but new recreation opportunities created by woodland planting. For travellers, the contrast with protected areas would be more distinct.

Socio-Economic Scenarios

World Markets

5.107. The World Markets scenario could result in the following outcomes:

- an accelerated loss of natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges. It is likely that some fields would be enlarged;
- the emphasis on arable production would remain, though it is likely that there would be an increase in the use of GM based crops. It is likely that irrigation will be increasingly common;
- farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant. There could be additional pressure for new, large farm buildings for crop storage;
- some of the land that is currently being farmed would be taken out of agricultural production, with a conversion to leisure uses, including golf courses which would be particularly prominent in this otherwise open and arable landscape, and contrast with the existing field pattern;
- it is likely that there would be additional housing development, with some new houses replacing traditional cottages, some expanding the overall size of the settlement, and some occupying isolated locations in the wider countryside;
- this would result in a much more open, arable landscape;
- it is likely that minor roads would be widened, adding to the loss of trees and hedges;
- renewable energy, including windfarms, biomass and solar would not be developed.

5.108. It is likely that the World Markets scenario would result in a greater degree of landscape change than the 'business as usual' model. This would result in a significant weakening of existing landscape character, or even the creation of a new, more open and developed character.

National Enterprise

5.109. The National Enterprise scenario could result in the following outcomes:

- a further loss and fragmentation of natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges. It is likely that some fields would be enlarged;
- the emphasis on arable production would remain, with greater use of chemical pesticides and fertilisers and some use of GM based crops. It is likely that irrigation will be increasingly common;

- farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant;

- it is likely that there would be additional housing development, with some new houses replacing the traditional cottages in the foreground, some expanding the overall size of the settlement, and some occupying isolated locations in the wider countryside. This would result in a much more open, arable landscape;

- renewable energy, including windfarms, biomass and solar would not be developed.

5.110. It is likely that the National Enterprise scenario would result in a greater degree of landscape change than the 'business as usual' model. This would result in a significant weakening of existing landscape character, or even the creation of a new, more open and developed character.

Global Sustainability

5.111. The Global Sustainability scenario could result in the following outcomes:

- an increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks;
- the positive management of landscape features including field boundary trees and hedges;
- a reduction overall in the extent of farmland, and an increasing emphasis on arable as opposed to pastoral production;
- the replacement of less energy efficient properties with modern, energy efficient dwellings, with integrated micro-renewables such as solar power, solar hot water, biomass and small scale wind power;
- the possible development of some form of commercial scale solar collector, reflecting the trend towards sunnier summers and, in the longer term, a hydrogen fuel network (temporary landscape effect);
- no further expansion of the settlement;
- an increase in the network of footpaths used for informal recreation.

5.112. It is likely that the Global Sustainability scenario would result in a slightly greater degree of landscape change than the 'business as usual' model, though key elements of the landscape would be managed positively. The overall character of the landscape would therefore be maintained or enhanced.

Local Stewardship

5.113. The Local Stewardship scenario could result in the following outcomes:

- an increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks;

- the positive management of landscape features including field boundary trees and hedges;

- a reduction overall in the extent of farmland, and a further emphasis on arable as opposed to pastoral production, with a possible reduction in the size of some fields;
- the development of horticulture and market gardens around the village, with allotments, polytunnels and small fields;
- the development of a local biomass plant serving the settlement, together with other forms of small scale renewable energy development
- no further expansion of the settlement;
- an increase in the network of footpaths and cycleways.

5.114. It is likely that the Local Stewardship scenario would result in a greater degree of landscape change than the 'business as usual' model described above, largely as a result of the move to smaller scale agricultural production and the development of small scale renewables. This could change the character of this currently arable, medium scale landscape.

Firth of Tay

5.115. This area is located within the inner Firth of Tay to the east of Perth. It includes the tidal firth itself, including reedbeds and mudflats, the productive farmland of the Carse of Gowrie and the southern slopes of the Sidlaw Hills to the north.

5.116. Table 5.5 provides a comparison of the key characteristics of the Firth of Tay lowland landscape under the current climate, and with the landscape impacts of climate change. The analysis of climate related landscape changes is based on the continuation of existing policies ('business as usual'). The potential for different outcomes reflecting different socio-economic conditions is explored in later sections.

Table 5.5 Firth of Tay: Description of climate change influenced landscape change

Current landscape	With climate change
Topography and geology: The Carse of Gowrie is predominantly flat with a bank marking the south edge before the Firth of Tay. Landform is around 10-50m AOD. The Sidlaws beyond comprise hard volcanic rocks and form a line of smooth rounded hills up to 300m AOD. The southern hills are most distinctive, where the vertical scarp of Braes of the Carse face south-east. To the north the hills subside to farmland plateau.	**Topography and geology:** The overall structure of this landscape would remain unchanged, but sea-level rise, particularly if more extreme scenarios are accurate, could have a significant influence on the balance of land and water, depending on the nature of human responses to flood management.
Forests and woodlands: There is limited tree cover on the Carse. Broad-leaf trees are limited to field boundaries, shelterbelts and policy woodlands. Very limited areas of coniferous policy woodland. History of orchards means some apple trees still remain. The Sidlaw hills are more wooded, with a combination of broadleaf and	**Forests and woodlands:** On the Carse it is possible that traditional orchards would be reinstated or expanded. It is likely that the current pattern of gappy and outgrown hedges further deteriorates in response to agricultural intensification and stress from higher winter rainfall and drier summers. This could also affect woodland around

Current landscape	With climate change
productive coniferous forestry.	Carseland settlements and designed landscapes. Woodland on the Sidlaws is diversified, with an expansion of native woodland and the management of coniferous plantations on a continuous cover basis but with increased evidence of damage from storms, summer fires, summer drought and pests and diseases. The high value of agricultural land on the Carse may preclude the expansion of wet woodland in this location.
Freshwater Systems: A series of short burns drain the southern slopes of the Sidlaws and the Carse of Gowrie.	**Freshwater Systems:** An increase in flood protection along streams and burns where there is a risk that increased storm flows from the Sidlaws could flood settlement on the Carse, particularly with high or surge tides. Within the Sidlaws there is some evidence of increased erosion, but the expansion of woodland helps to mitigate run-off.
Coast, estuaries and sea: The tidal Tay dominates the landscape of the Firth area, particularly when viewed from higher ground. The river turns through a series of meanders before broadening and straightening to the east of its confluence with the River Earn. The river is fringed with intertidal mudflats and reedbeds, though it is likely that these are already more limited in extent due to existing flood protection embankments along its northern side.	**Coasts, estuaries and seas**: The effects of climate change on the Tay Estuary would depend upon human adaptation and mitigation responses. Sea level rise and the increase risk of storm surge tides suggest that the estuary, like many others on the east coast of Scotland, will be at increased risk of flooding. Existing flood defences mean that rising sea level in particular would result in coastal 'squeeze' and the loss of intertidal mudflats and reedbeds which are of ecological, landscape and cultural significance. It is likely that existing flood defences would be upgraded in some areas in response to the increased risk to properties, settlement and possibly the most productive farmland. Alternatively, a process of managed realignment could see the removal or repositioning of flood defences to allow the migration of intertidal areas as sea levels rise. This would result in loss of farmland and would also change the landscape of the Firth. It is also possible that the tidal based renewable energy developments are brought forward in the form of a tidal barrage or a series of tidal lagoons, although it is acknowledged that the tidal range in this area may not be sufficiently large. The former would significantly modify the pattern of tides, with knock-on implications for upstream habitats and

Current landscape	With climate change
	landscapes.
Urban and Peri-Urban: On the Carse, settlement tends to be located on slightly raised ground, or along the foot of the Sidlaws' slopes. A scatter of large farmsteads and hamlets are located on tracks leading from principal roads. Recent housing demand has led to settlement expansion and some ribbon and dispersed development. Traditional building materials include red sandstone, harder igneous rocks from the Sidlaws, and also brick around Errol.	**Urban and Peri-Urban**: There may be an increase in the use of micro-renewables throughout the area, most visibly taking the form of roof-top solar collectors and small scale wind turbines. Solar collectors could have a local impact on the contribution of traditional buildings within the landscape. Small turbines would increase the area's 'developed' character. The emphasis on energy efficiency may result in novel building styles or materials, especially outwith conservation areas.
Tourism and Recreation: Generally limited opportunities for tourism and recreation, although the hills are more popular recreational areas. Occasional historic features provide tourist destinations.	**Tourism and Recreation:** Improved summer weather conditions could lead to an increase in local recreation activity along the Carse and more particularly in the Sidlaws and hills to the south of Newburgh.
Infrastructure: The Carse is a communication corridor (A90 (T) and the Perth to Aberdeen railway line). There is a geometric pattern of roads and railways. Several transmission lines cross this landscape. A disused airfield is located at Errol.	**Infrastructure:** The area could see the development of small or medium size windfarms and the upgrading of national grid transmission lines. There is also potential for small or medium sized biomass plants and close to settlements, or food processing centres, combined heat and power plants. However, there is uncertainty surrounding the energy mix in 2050.
Natural and semi-natural habitats: Ecological interest is concentrated within the intertidal mudflats and reedbeds, and along some of the Tay's tributaries. Grass and heather moorland is found in some higher parts of the Sidlaws.	**Natural and semi-natural habitats:** Sea level rise and the increase risk of storm surges, together with human responses, could have a significant impact on natural and semi-natural habitats along the Tay and its tributaries. The creation of woodland belts would contribute to habitat networks on the Carse and into the Sidlaws, though the biodiversity of this intensively farmed area could remain comparatively low. There may also be loss of heather moorland to grassland on the upper slopes and summits of the Sidlaws as a result of changes in moorland management.
Agriculture: On the Carse extensive arable land and limited pasture occupy large rectilinear fields. Field boundaries comprise gappy hedges, post-and-wire fences and wet ditches. There is a decaying structure of hedgerow trees. Recent years have seen a significant expansion in the use of polytunnels to provide controlled conditions	**Agriculture:** the existing pattern of arable and horticultural cultivation is intensified. It is possible that there is a changing composition of crops, with a wider range of crops, including oil seed rape and energy crops such as miscanthus grass, increasing in extent. Alternatively, the area could further specialise in fruit growing, with re-

Current landscape	With climate change
for fruit cultivation.	establishment of orchards and other fruit trees, and expansion of polytunnel growing[7]. Market conditions, and the levels of incentive for biomass and bio-energy crops will influence the relative balance of crops. It is likely that productivity will increase, leading to a requirement for new, larger storage and processing buildings. Warmer, drier summers may result in the wider use of irrigation equipment including mobile booms.
Historic Environment: On the Carse, historic features are limited due to the intensity of agriculture but include castles, historic houses and designed landscapes. The Sidlaws include some historic field systems, burial sites, hill-forts and castle sites.	**Historic Environment:** Agricultural intensification could result in the further weakening of the historic structure of this landscape as field boundaries and trees are lost. Modern infrastructure and buildings would underline the intensive, almost industrial character of this landscape. There may also be changes to the fabric of historic buildings resulting from management of rainwater, increased salt contamination and accelerated decay of vulnerable stone, increased biological growth on stone, impacts on and potential loss of unique coastal historic sites due to sea level rise or the risk of subsidence to historic structures.

[7] Note that Figure 5.9c shows the landscape in the winter months, when the plastic is removed from the polytunnel supports.

Climate related Landscape Change

5.117. Figure 5.9a shows a view north across the inner Firth of Tay from the south bank of the river. Visible in the photograph are the estuarine river with reedbeds and island, the productive agricultural landscape of the Carse of Gowrie and the partially wooded Sidlaw slopes beyond.

5.118. Figure 5.9b provides the key to the changes illustrated in the image, identifying direct impacts, those relating to adaptation and mitigation measures.

5.119. Figure 5.9c illustrates the kinds of climate related landscape change that could occur within this landscape.

Figure 5.9a Firth of Tay baseline

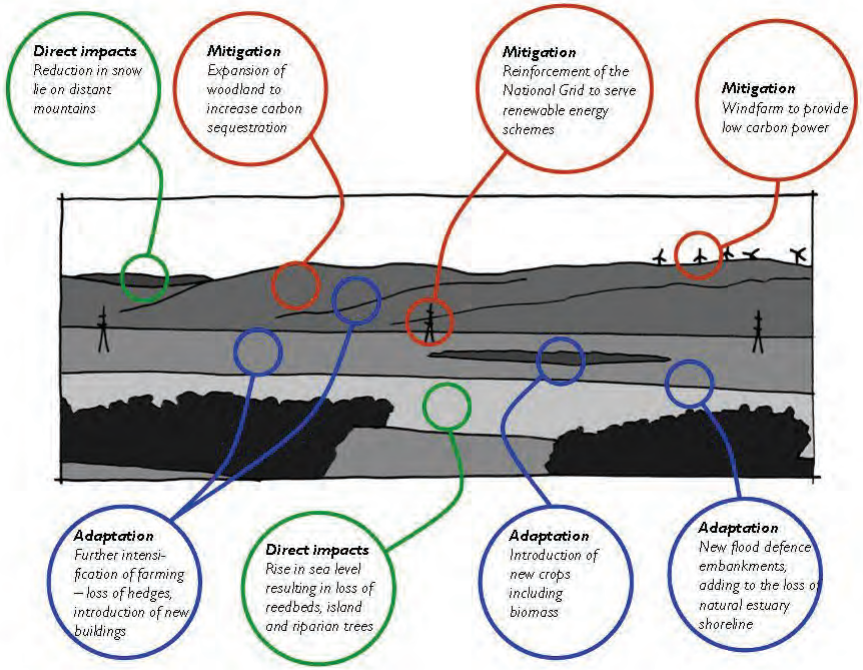


Figure 5.9b Firth of Tay: Diagram of landscape changes

Figure 5.9c Firth of Tay under landscape change scenario
It should be noted that this photomontage illustrates possible combinations of landscape change from a selected view point within a broad timeframe over the next 40 years, and should not be interpreted as planned or predicted change at this location.

Overview

5.120. These descriptions suggest that the most significant climate related landscape changes would be associated with:

- sea level rise and storm surges, and human responses to the increased risk of flooding;
- further intensification and specialisation of agriculture;
- expansion of woodland in Sidlaws to reduce run-off and flood risk;
- the development of renewable energy infrastructure and grid connections.

Changes in Ecosystem Services

5.121. These changes could affect the range of cultural ecosystem services provided by this landscape:

Table 5.6 Firth of Tay: Impact of climate related landscape change on cultural ecosystem services

Ecosystem services	Current	With climate change
Inspiration and enrichment	The juxtaposition of steeply enclosing hills to the north and south, the flat Carselands and the meandering course of the tidal Tay, together with a series of historic settlements and influences, create a rich and varied landscape, though its inspirational value is perhaps reduced by modern road infrastructure, pylon lines and the spread of polytunnels associated with intensive fruit cultivation.	It is likely that the inspirational and enrichment roles would be further reduced by the introduction of pylons, turbines, new farm buildings and estuarine flood defences and the loss of field boundaries and trees.
Health and wellbeing	The hills enclosing the estuary are reasonably popular with walkers and cyclists, though the estuary itself is largely inaccessible from land.	It is likely that the area would see an increase in recreation activity as a resource for local people resulting from increased opportunities provided by new woodland planting and summer weather.
Aesthetic values	The inner Firth of Tay is a high quality landscape, where the influence of the landform, woodland, river, settlements and wetlands overcome the effects of transport infrastructure, electricity pylons and intensive horticulture. Downstream, the human influences are greater, and the enclosure and influence of landform reduced.	The balance between human and naturalistic influences would change with the introduction of turbines and larger pylons, tidal barrages and lagoons, and the loss of intertidal habitats. This would weaken its aesthetic value.

Ecosystem services	Current	With climate change
Sense of place	This is a distinctive landscape with the intensively cultivated flat Carseland adjacent to the river, and rising hills behind.	The Firth of Tay would remain a distinctive landscape, reflecting its landform, the river and the interaction with land use and land cover.
Cultural heritage values	While the influence of landform, woodland cover and the tidal river dominate, the pattern of settlement ('coastal' villages such as Newburgh, defensive sites such as at Rhynd, estates and follies such as on Kinnoull Hill), together with the pattern of agricultural fields, contribute to the character of this landscape.	There could be impacts on the character of historic settlements immediately adjacent to the river where improved flood defences would be required to deal with sea level rise and the risk of tidal surges. The loss of field boundary trees, reedbeds and the potential amalgamation of fields would have an impact on the historic structure of the wider landscape.
Recreation and tourism	The hills enclosing the estuary are reasonably popular with walkers and cyclists, though the estuary itself is largely inaccessible from land.	The loss of estuarine landscape character and historic landscape features combined with the introduction of renewable energy infrastructure and introduction of new farm buildings may reduce the aesthetic value of the landscape and attraction for visitors.

Socio-Economic Scenarios

World Markets

5.122. The World Markets scenario could result in the following outcomes (which are similar to the outcomes identified for Strathmore, reflecting the influence of agriculture in this landscape):

- the loss of coastal reedbeds and mudflats as sea levels rise and flood defences are improved around private properties and also more productive farmland;
- an accelerated loss of natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges;
- the emphasis on arable and fruit production may remain, though it is likely that there would be an increase in the use of GM based crops. It is likely that irrigation will be increasingly common;
- farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant. There could be additional pressure for new, large farmbuildings for crop storage;
- some of the land that is currently being farmed may be taken out of agricultural production, with a conversion to leisure uses, including golf courses and caravan parks which would be visible on the open Carselands, and on the southern slopes of the Sidlaw hills;
- it is likely that there would be additional housing development, with some new houses built on the Carse itself, and in positions on rising ground to the south;

- renewable energy, including windfarms, biomass and solar are unlikely to be developed.

5.123. With the exception of windfarm development, which would not occur, it is likely that the World Markets scenario would result in a greater degree of landscape change than the 'business as usual' model. This would result in a significant weakening of existing landscape character, or even the creation of a new, more open and developed character.

National Enterprise

5.124. The **National Enterprise** scenario could result in the following outcomes:

- a significant upgrading of flood defences along the northern side of the River Tay in order to protect farmland, property and transport infrastructure on the Carse of Gowrie. The implementation of these defences, and the impacts of rising sea levels may result in the loss of distinctive riverside landscapes and habitats including mudflats and areas of reedbed;

- a further loss and fragmentation of other natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges. It is likely that some fields could be enlarged;

- the emphasis on arable and fruit production is likely to remain, with greater use of chemical pesticides and fertilisers and some use of GM based crops. Irrigation may become increasingly common;

- farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant;

- it is likely that there would be some additional housing development, including on the Carse where they would be protected by the upgraded flood defences;

- renewable energy, including windfarms, biomass and solar are not likely to be developed.

5.125. With the exception of renewable energy development, which would not occur, it is likely that the National Enterprise scenario would result in a greater degree of landscape change than the 'business as usual' model. This would result in a significant weakening of existing landscape character, or even the creation of a new, more open and developed character.

Global Sustainability

5.126. The **Global Sustainability** scenario could result in the following outcomes:

- the use of managed realignment to create soft flood defences. This could result in creation of new wetlands and reedbeds in areas of the Carse that are currently farmed;

- an increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks;

- the positive management of landscape features including field boundary trees and hedges;

- a reduction overall in the extent of farmland, and a further emphasis on arable as opposed to pastoral production;

- the replacement of traditional buildings with modern, energy efficient dwellings, with integrated micro-renewables such as solar power, solar hot water, biomass and small scale wind power;

- the possible development of a tidal barrage renewable energy project, altering or removing the pattern of tides along the Firth, with further implications for habitats and species, although it is acknowledged that the tidal range in this area may not be sufficient for such development;

- the possible development of some form of commercial scale solar collector, reflecting the trend towards sunnier summers and, in the longer term, a hydrogen fuel network (temporary landscape effect);

- an increase in the network of footpaths used for informal recreation.

5.127. It is likely that the Global Sustainability scenario would result in more positive landscape change than the 'business as usual' model. Some of these changes are likely to result in a reinforcement of existing landscape character; however the development of renewable energy could have a significant adverse effect.

Local Stewardship

5.128. The **Local Stewardship** scenario could result in the following outcomes:

- an increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks;

- the positive management of landscape features including field boundary trees and hedges;

- a carefully balanced approach to coastal flood defence which aims to protect some areas of productive farmland, but which uses managed realignment elsewhere as a means of conserving or enhancing estuarine habitats including reedbeds and mudflats;

- a reduction overall in the extent of farmland, and a further emphasis on arable as opposed to pastoral production;

- an increase in the network of footpaths and cycleways.

5.129. It is likely that the Local Stewardship scenario would result in a greater degree of positive landscape change than the 'business as usual' model. This could result in the reinforcement of existing landscape character.

Perth

5.130. This part of the detailed analysis focuses on the City of Perth and explores the likely implications of climate change on the character of the settlement, including the provision and management of open space. The analysis is based on an overview of the city's key characteristics and the implications of climate change, since the Tayside landscape character assessment does not include detailed analysis of the city.

Existing Townscape Character

5.131. Perth is located close to the tidal limit of the Firth of Tay and at what was historically the lowest bridging point. The city sits on the River Tay where it cuts through the ridge of high ground (Sidlaw Hills to the east, Gask Ridge to the west) that separates Strathmore and land to the south of the Highland Boundary Fault from the Firth of Tay. The historic significance of the settlement is reflected in its medieval street layout, its proximity to the Scone Palace, and the legacy of Victorian commercial and industrial buildings, railway infrastructure and villas. In the city centre sandstone buildings and details provide architectural variety and interest. The city centre is quite compact and bounded by the two large parks of North Inch and South Inch. The Perth Conservation Area Appraisal notes that the North and South Inches, the River Tay, Norie Miller Riverside Walk and Kinnoull Hill are essential to the character of the central area. The city saw extensive growth during the twentieth century, with extensive residential suburbs and commercial and light industrial areas extending west and north. In addition to the River Tay, which passes close to the city centre, Perth has a range of open spaces, including riverside spaces, local parks, allotments and semi-natural areas (including Kinnoull Hill) on the fringes of the city. Perth is now bypassed by the A9 (to the west) and A90 (to the south east).

Climate related Landscape Change

5.132. The following table summarises the key characteristics of the City of Perth urban area, and describes possible future change scenarios in relation to these. The following map illustrates the potential spatial distribution of the described changes.

Table 5.7 Perth: Description of climate change influenced landscape change

Key characteristics	Possible future change scenario
Flood risk associated with low lying riverside greenspace and urban area, areas already used for flood water storage e.g. South Insch	Use of riverside greenspace for riparian woodland planting and water storage
Existing flood embankments	Reduced maintenance and retreat from flood embankments protecting marginal areas
Existing hard flood defences	New and improved hard flood defences around core areas
River islands and banks	Changes to the extent and character of river islands and unprotected riverbanks
Important recreational spaces including Kinnoull Hill, North and South Inch	Significant increased recreational pressure on Kinnoull Hill and open spaces of North Insch and South Inch.

Key characteristics	Possible future change scenario
	Changes in character and accessibility due to hard flood defences and role of recreational spaces for flood water storage.
Major road and rail infrastructure, close to river including links to Stirling, Inverness, Dundee, Edinburgh and Glasgow	New hard flood defences to protect road and rail infrastructure from increased flood risk
Policy trees associated with Scone Palace	Loss of policy trees on areas of land prone to waterlogging
Historic core with Georgian and Victorian buildings	Increased damage to historic buildings resulting from storm damage, water penetration and bio-deterioration from fungal and algal growth
Mature gardens with trees	Changes in tree species composition within urban area

5.133. Figure 5.10 illustrates the kinds of climate related changes that could occur within this landscape.

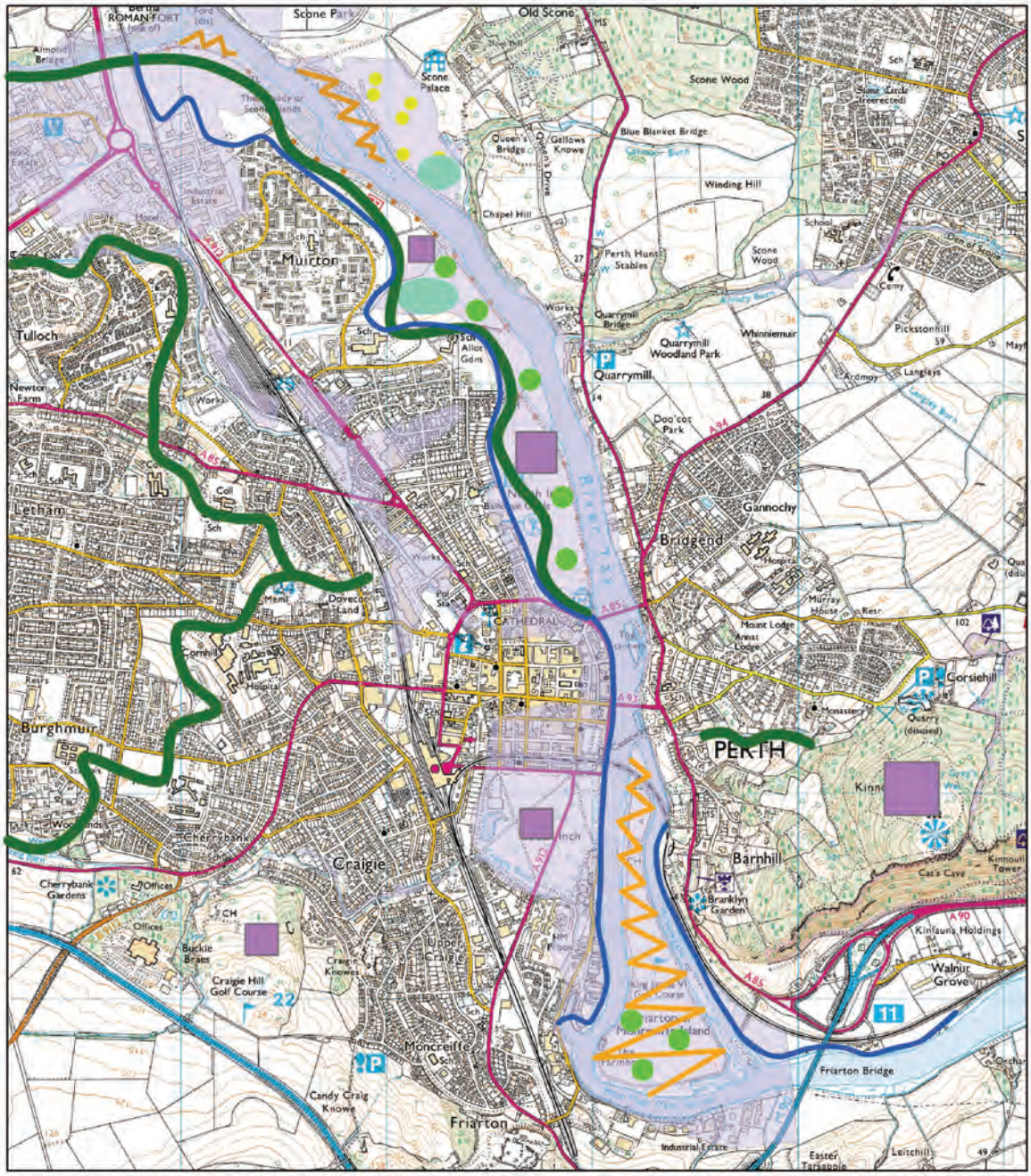


Figure 5.10: Perth 2050 climate related possible landscape change scenario

- Changes in erosion and deposition
- Flood water storage
- Riparian woodland planting
- Habitat corridor creation
- Loss of policy trees
- Increased recreational pressure
- Hard flood defences

Changes in Ecosystem Services

5.134. These changes could affect the range of cultural ecosystem services provided by Perth:

Table 5.8 Perth: Impact of climate related landscape change on cultural ecosystem services

Ecosystem services	Current	With climate change
Inspiration and enrichment	The contribution of Perth's urban environment to inspiration and enrichment is based on a combination of its historic character, stock of historic buildings, relationship with the River Tay, the range of open spaces including civic spaces, formal parks (including the North and South Inches), historic gardens (notably Scone Palace) and semi-natural greenspaces and the landscape setting provided by enclosing hills, narrow valley of the River Tay and more open landscapes to the north. These resources provide opportunities for enjoyment of the urban and natural environment, appreciation of their historic associations and the inspiration and enrichment provided by this experience.	Key aspects that could be affected by climate change include, a possible weakening of the relationship with the River Tay, due to further hard flood defences, changes in the use of existing open spaces (e.g. to accommodate SUDS), stress on urban vegetation caused by summer drought, winter rainfall, increased summer use, the development of habitat networks based upon, and linking open spaces, the effects of retrofitting micro-renewables onto existing building stock (e.g. south facing solar panels) and the use of energy efficient (e.g. passive solar) and environmentally friendly (e.g. green roofs) design and materials. There may be restrictions on the retrofitting of micro-renewables on listed buildings and in conservation areas which could reduce the impact in these areas. It is likely that these changes could alter, though not significantly reduce the overall contribution to inspiration and enrichment.

Ecosystem services	Current	With climate change
Health and wellbeing	Open spaces in particular have an existing and potential role to play in facilitating active recreation, walking and cycling. They include informal recreation areas, semi-natural areas (particularly on steeper ground on the edges of the city) and formal provision such as golf courses. It is likely that the natural setting of the city, the role of the river corridor, and the network of open spaces also contribute to mental health and well being.	It is likely that measures to increase the role of open spaces in contributing to flood management and habitat networks, together with mitigation measures designed to encourage sustainable travel could increase the overall contribution to health and well being. Increased provision of open spaces and access to the river could provide additional opportunities for reducing the heat island effect. An increase in flood risk from fluvial, pluvial or estuarine events could have a significant influence on people living or working in areas affected.
Aesthetic values	Perth's contribution to aesthetic values is based on the city's historic core, its relationship with the River Tay, key city centre open spaces and the influence of surrounding hills. These qualities are less prominent in extensive areas of twentieth century development to the north, west and south of the centre.	Some of these values could be adversely affected, for example as a result of the need for increased flood defences along the river corridor, though the recent works in this area demonstrates how this can be undertaken in a manner sensitive to the wider townscape. The need for measures in the city centre could be reduced by catchment scale measures, and by more radical options such as a tidal barrage. It is likely that new types of development would be concentrated away from the historic core of the city, though an extensive uptake of solar power equipment could have an impact on the appearance of the historic core and adjoining Victorian neighbourhoods. Habitat enhancement and other greenspace enhancements could increase the contribution of open spaces to aesthetic values.

Ecosystem services	Current	With climate change
Sense of place	The historic structure of the city centre, its relationship with the River Tay (including bridging points), city centre open spaces, and relationship with the surrounding landscape (including landmarks such as Kinnoull Hill) mean that much of the city has a distinctive sense of place, though this is significantly weakened in suburban areas to the west and north where commercial expansion detracts from this.	It is possible that Perth's sense of place could be marginally affected by new building styles, the take up of micro-renewables, and any additional flood protection measures along the River Tay.
Cultural heritage values	The city has a rich historic character reflecting its location at the lowest bridging point on the River Tay, its medieval street layout, the relationship with Scone Palace, the Victorian heritage of villas, shopping streets, railway and industrial infrastructure.	The principal impacts on the city's contribution to cultural heritage values could result from new building styles, the take up of micro-renewables, any additional flood protection measures along the River Tay and changes in the management or use of historic open spaces such as the North and South Inches.
Recreation and tourism	The network of open spaces within and around Perth provides a local resource for recreation. Specific sites, including Scone Palace, Kinnoull Hill, Branklyn Gardens and the River Tay play a wider role. Many visitors to the Highlands pass through or close to Perth, though road travellers in particular largely by-pass the city. The River Tay is also popular for water based activities such as canoeing.	It is likely that the local recreation resource would be enhanced as the network of open spaces and greenspaces is improved to provide walking and cycling routes. Use of the rivers for activities such as canoeing and rafting may be more frequently affected by issues such as low water flow, resulting from higher levels of extraction and hydro electric power generation.

Socio-Economic Scenarios

World Markets

5.135. The World Markets scenario could result in the following outcomes:

- development pressure on urban greenspaces and surrounding countryside with impacts on amenity, health, recreation, biodiversity and sustainable flood management;
- deterioration of conditions for pedestrians and cyclists;

- increased risk of flooding associated with higher winter rainfall, loss of greenspaces within the settlement and an increased risk of estuarine flooding;

- modernisation of the building stock;

- management of retained greenspaces and habitats in and around the town for recreation.

5.136. It is likely that the World Markets scenario could result in a significant deterioration of the quality of the environment in Perth and would therefore compare poorly with the 'business as usual' scenario.

National Enterprise

5.137. The key changes associated with this socio-economic scenario could include:

- deterioration of environmental quality within the urban area, and a further loss and fragmentation of urban greenspaces;

- a disparate pattern of flood protection, with greater protection in affluent areas and lesser protection in poorer areas, responding to affluence and political influence;

- no significant expansion of the urban area, upgrading the existing building stock or regeneration of former industrial areas;

- declining water quality but an ongoing commitment to flood protection.

5.138. It is likely that the National Enterprise scenario would also result in the deterioration of the quality of the environment in Perth and would be more negative than the 'business as usual' scenario.

Global Sustainability

5.139. The key changes associated with this socio-economic scenario could include:

- an emphasis on environmental quality which may be reflected in high quality greenspaces, public realm, walking and cycling networks;

- an increase in the density of urban development, with new housing on brownfield, former industrial and other urban sites;

- conservation and enhancement of biodiversity within and around the urban area, but also an increasing demand for recreation in accessible countryside around Perth;

- replacement of the existing stock of older buildings, with an increase in the use of sustainable design, construction and materials, and the take up of solar energy;

- investment in transport infrastructure.

5.140. It is likely that the Global Sustainability scenario would result in an improvement in environmental quality within Perth and therefore compares favourably with the 'business as usual' scenario.

Local Stewardship

5.141. The key changes associated with this socio-economic scenario include:

- a reinforcement of the existing urban form, but redevelopment to create a denser and less homogeneous structure;

- an increased emphasis on the role of greenspaces within the city, particularly in terms of providing habitat networks, accommodating walking and cycling routes and providing land for allotments and community gardens;

- an increase in the take up of urban renewables including district combined heat and power and the retrofitting of solar energy equipment;

- an increased risk of flooding, and a withdrawal from areas at risk of inundation.

5.142. It is likely that the Local Stewardship scenario would result in a general improvement in environmental quality within Perth, though some areas could be affected by an increased risk of flooding. It compares favourably with the 'business as usual' scenario.

National Scenic Areas

5.143. Tayside includes the four National Scenic Areas (NSA) of Loch Tummel, River Earn, River Tay, and Loch Rannoch and Glen Lyon, and a part of the Ben Nevis and Glen Coe NSA. As part of the local level analysis, closer consideration is given to the potential impacts of the identified landscape changes on the Loch Tummel National Scenic Area. SNH have recently review the Special Qualities of each NSA, including Loch Tummel. The following section explores the identified landscape changes which are set out in Table 5.1.

Loch Tummel National Scenic Area – Special Qualities

5.144. This section of the report summarises the potential impacts of climate related landscape change on the 'Special Qualities' of the Loch Tummel National Scenic Area. The review of impacts on this designated landscape was carried out in order to identify if the climate related landscape changes would significantly alter the features for which the area is designated. The conclusions can inform the future management of designated landscapes.

5.145. The following table summarises the key landscape features identified as the Draft Special Qualities of Loch Tummel National Scenic Area, within includes the Killiecrankie local case study on Figure 5.6. The landscape we see today is the product of quite significant past change, principally relating to the construction of the hydro electric schemes. This includes the increased length of Loch Tummel, the reduction of the Linn of Tummel rapids, the construction of the Pitlochry Dam and the creation of Loch Faskally. In addition a number of recreation and visitor facilities have been incorporated into the landscape including the planning and expansion of Tummel Forest Park, boating on Loch Faskally and creation of visitor centres. In relation to transport links the railway and the upgrading of the A9 have also introduced new features into the landscape. The description highlights that in spite of these past changes, the scenic qualities persist in being of national value.

5.146. Current detractors are identified as:

- a line of pylons running along the lower slopes on the south shore links the Tummel hydro scheme but forms corridors through woodland;

- the Scottish hydro-electric amenity/visitor site at Cluny Dam needs reappraisal and attention.

5.147. Table 5.9 below identifies the key landscape features identified as contributing to the special qualities of Loch Tummel and the potential future changes to these features resulting from mitigation and adaptation to climate change.

5.148. In summary, the key characteristics of the landscape remain essentially unchanged as a result of the potential climate change impacts. This may reflect the strength of character provided by the varied landform and the diversity of the landscape itself. The landscape is already influenced by hydro electricity generation and has been subject to significant change in the past. There may be changes in the species composition and extent of woodland, however the existing diversity of this resource will absorb these changes. The main impacts may include damage to the policy woodlands, loss of heather moorland and potential increases in recreation pressure.

Table 5.9 Special Qualities of Loch Tummel and potential change resulting from future climate change

Loch Tummel NSA Special Qualities	**Potential scenario resulting from future climate change**
• **Rich and varied woodlands** Extensive woodlands of unusual richness and variety frame the low lying loch and lochside farms and ensure constant but changing colour throughout the seasons. The wood provide a restful transition between the loch waters and the heathery upper hills and bare rocky summits. Ancient oakwoods frame the western flanks of the Pass of Killiecrankie.	Increased use of Low Impact Silvicultural Systems(LISS) reduces landscape impacts of timber extraction. Broad species mix provides resilience to climate change and pests, new woodland species contribute to the mosaic of colour provided by variety of species, however there is some change in existing species composition. Some evidence of damage to woodlands caused by summer drought. Change in species composition of flora within SSSI.
• **A breathtakingly beautiful landscape, both lowland and upland** The Tummel valley dramatically from the stern straths of the north and the wild glens of the west. It is a breathtakingly beautiful wooded landscape containing a sparkling river and stunning loch. It is a fertile, lowland strath with a long history of settlement and prosperous-looking houses and farms; and on the higher slopes there is a wilder landscape of rocky crags and bare, heather-clad summits	Wind energy development, and further development of electricity transmission network. Increase in woodland and scrub above current tree line. Increased sheep and cattle grazing higher up slope. Loss of heather moorland vegetation. Loss of policy trees due to storms and waterlogging resulting from increased flooding. Increased recreational pressure and associated infrastructure, and fire risk.
• **Spectacular and famous mountain gorge – the Pass of Killiecrankie**	Increased river erosion. Change in

Loch Tummel NSA **Special Qualities**	**Potential scenario resulting from future climate change**
The deep wooded gorge of the River Garry in the Pass of Killiecrankie, famous for its historical associations, is spectacular. Its deep pools and narrow rapids are dramatic when viewed from the surrounding woodland walks or briefly glimpsed from a window of a train. Above the gorge, the view from Craigower Hill provides a stunning panorama westwards over the whole NSA; and the main A9 road, as it exits the narrow pass, presents a grand vista northwards into the Vale of Atholl, a 'gateway to the Highlands'.	woodland composition. Upgrading and engineering on road and railway to improve drainage.
• **Loch Tummel, the heart of the NSA** The long and narrow Loch Tummel, beneath its rocky hills and wooded slopes, fills most of the floor of the strath. Presenting a tranquil aspect, the peaceful waters are the heart of the NSA. The loch was extended by hydro-electric schemes in the 1930's and 1950's and *'enlargement of Loch Tummel itself has created one of the most beautiful sheets of water in the country.'* Sylvia Crowe (1958)	Physical erosion of river courses, however opportunities for controlling flow through dams. Increase in river flooding severity. Upgrading of existing hydro electricity infrastructure.
• **The picturesque Linn of Tummel** The picturesque rapids of the Linn of Tummel provide an exciting spectacle of sound and vision, contrasting with the peacefulness of Loch Tummel above and Loch Faskally below.	Physical erosion of river courses, however opportunities for controlling flow through dams.

6. CONCLUSIONS

6.1. This section of the report summarises the areas of most significant climate related landscape change and explores the spatial and topic based variations in relation to direct impacts, human adaptation and mitigation activities at a national level. These summaries are based on the changes identified as having the most significant landscape impacts through the research process. It also draws out a number of key conclusions before recommending ways of taking the work forward in Phase 2 of the study. This study is the first piece of work of its type that seeks to integrate a range of sectoral climate change impacts and translate it into potential landscape and human impacts. The conclusions highlight the importance of a holistic approach to climate change adaptation and mitigation, and the interactions between different sectors.

Climate related Landscape Change

6.2. The four main areas of greatest change have been identified in relation to lowland landscapes (including agricultural change), upland landscapes (including agricultural and forestry related change), river flooding and flood management, and coastal change. The following paragraphs summarise the main issues in these landscapes.

Lowland Landscapes

6.3. Lowland agricultural landscapes may be subject to a range of changes as a result of climate change and associated policy measures. This includes, most notably, the Climate Change (Scotland) Bill 2008 which outlines a target of reducing Scotland's greenhouse gas emissions by 50 per cent by 2030 and 80 per cent by 2050 and which includes a focus on renewable energy sources, and the draft Scottish Climate Change Adaptation Framework (2009). A key outcome of the Climate Change Bill may be the production of biomass crops in line with the Biomass Action Plan for Scotland (Scottish Executive, March 2007). Other policy areas include EU targets in energy efficiency, emission reductions and renewable energy development.

6.4. Further changes may include developments in agricultural production, irrigation, farm woodland and habitat networks, and new farm buildings. The impact of new buildings within the landscape will have a potentially significant effect on landscape character. New buildings may be erected for agricultural purposes, for storage, to provide additional tourism and recreational facilities, or for energy generation, such as biomass power plants. In addition to the scale of change in the number of new buildings, decisions on the siting and design of each will have implications for landscape change.

6.5. Changes in the type of agricultural production, new crop types and associated infrastructure such as irrigation are likely to have notable impacts. There is some uncertainty about the future balance between existing crops, new food crops and the development of energy and biomass crops, including short rotation coppice and other tall crops such as Miscanthus which could have a significant effect on both views and landscape character. These trends are likely to be compounded by changes in the pattern of farm woodland with loss of field trees, the creation of new shelterbelts and enlargement of fields. Changes in farm woodland should be informed by Forestry Commission Scotland guidance on the ‘Creation of Small Woodlands on Farms’ to help ensure a coherent landscape structure and fit.

6.6. The agricultural changes described above may reflect the different patterns of farm type in east and west with the most profound changes in the east. Areas subject to

greatest change include the north east coastal plain, north east glens, the eastern lowlands, the west central belt, west southern uplands and inner Solway Firth and Moray Firth. Non-agriculture related changes are also likely to affect the lowland agricultural landscapes reflecting changes in flood management and energy distribution and generation. In particular, areas at greatest risk of flooding will be subject to the new extensive range of flood risk management measures (such as flood warning systems and natural flood management measures) which are outlined within the Flood Risk Management (Scotland) Bill 2008.

6.7. Economic drivers may be significant in influencing agriculture-related adaptation, and the rate of change could be potentially rapid.

Upland Landscapes

6.8. Upland landscapes may be subject to a range of changes which partially reflect their role in providing a number of ecosystem services from water storage and regulation, forestry production, energy generation, recreation, and natural and semi-natural habitats. Transitional landscapes which lie between the lowlands and the uplands may experience the greatest degree of change, with the more remote upland landscapes experiencing more subtle, localised or gradual changes.

6.9. In relation to natural and semi-natural habitats, where the majority of changes are direct but likely to occur gradually, the areas identified as likely to experience the greatest degree of change include the north west seaboard, the peatlands of Caithness and Sutherland, the Western Highlands, Central Highlands and Cairngorms Massif, Lochaber, Breadalbane and East Argyll. These are also the areas with the highest concentrations of wildland, and these changes will affect the qualities and experience of the landscape.

6.10. Energy generation and distribution may result in some of the most significant and large scale landscape impacts. The continued policy focus on renewable energy and the targets set out within the Climate Change (Scotland) Bill 2008 to reduce greenhouse gas emissions will contribute to a continued demand for wind power in upland areas. Landscapes under the greatest pressure include the upland fringes around the northern and eastern coast, and central and southern Scotland.

6.11. Changes in forestry and woodland in upland landscapes is also a key area of change. These may include changes in the distribution of species suited to the changing climate. Areas most likely to experience change include the northern highlands, north east glens, Argyll west and islands, Breadalbane and East Argyll, West Southern Uplands and inner Solway Firth, the Border Hills and the Moray Firth. Active management to maintain particular species distributions may be resource intensive and unsustainable in the long term. Suitability to local climate and economic viability may be the main determining factors in species choice. The main opportunities may relate to research and guidance on managing change and addressing issues such as disease control.

6.12. Changes in the extent of woodland may occur in many areas, particularly those areas with currently lower levels of existing woodland and forestry cover. At a national level the Scottish Forestry Strategy (2006) sets out a target of increasing woodland cover from 17.1% of Scotland's land area to 25% by the second half of the 21st century with recognition of the role of forestry in mitigating the impacts of climate change. New woodland may reflect roles related to flood management which will be focused upstream of main settlements. A new generation of Indicative Forestry Strategies are currently being prepared to reflect the changing priorities for woodland and forests

and Forestry Commission Scotland is in the process of preparing a revised suite of Forest Guidelines which will complement an updated UK Forestry Standard.

6.13. Direct impacts on woodland through events such as flood, wind and fire damage may also have notable but localised landscape impacts. The areas expected to experience a potentially higher degree of flood damage include the south (West Southern Uplands and Inner Solway and Border Hills), north-east (Moray Firth and North East Glens) and west (Argyll West and Islands) of Scotland. The potential distribution of fire risk is similar to that for wind damage and includes the West Southern Uplands and Inner Solway, Border Hills, West Central Belt, Breadalbane and East Argyll, North East Glens, Central Highlands, Moray Firth and Northern Highlands.

River Flooding and Flood Management

6.14. The effects of flooding have a significant direct impact on the landscape, and where these effects impact on populations and transport routes mitigation measures will be implemented to reduce these effects. Scottish Ministers, SEPA and responsible authorities (including local authorities) have a duty to promote sustainable flood management (SFM) under the Water Environment and Water Services (Scotland) Act 2003. In addition, the Flood Risk Management (Scotland) Bill 2008 outlines detailed measures to address flood risk incorporating climate change adaptation. Direct impacts of flooding relating to freshwater systems are greatest in the eastern lowlands, west central belt, southern uplands and inner Solway Firth, and the Moray Firth. Actions to adapt and mitigate the impacts of flooding will be concentrated within areas surrounding Glasgow, Edinburgh, Perth, Dundee, Inverness and Aberdeen in order to reduce the effects of flooding on these settled areas.

Coastal Change

6.15. Changes in the coastal environment will result from direct impacts resulting from sea level rise and the increased risk of flooding from surge events, together with the impacts of adaptation responses such as coastal defence. These will result in changes in the nature and distribution of coastal habitats, erosion and deposition, changing morphology, loss of land, increased flood defences (hard and soft), increased risk of flooding and implications for land use. Rising sea levels have a greater impact on the island communities of Orkney, Shetland and the Western Isles, however the combined risk resulting from changes in sea levels, surge risk and wave fetch include the areas around Inverness and the Black Isle, the Firth of Tay, the Firth of Forth and the Solway Firth. The proximity to settlement, transport infrastructure or valuable farmland will influence the areas of greatest change where defence mechanisms are implemented.

6.16. Additional changes within the coastal landscape may include offshore energy generation in order to help attain the Scottish Government's greenhouse gas emission targets set out within the Climate Change (Scotland) Bill 2008 and the Government's Economic Strategy (2007). The Scottish Marine Bill Consultation Document (2008) outlines the potential of the tidal and offshore wind resource in Scotland and notes the Scottish Government target of deploying 10MW of wave and tidal power by 2010. Future development of wind turbines may be concentrated in the shallower waters off the east coast[8], with further development in the Solway Firth,

[8] Crown Estate Press Release 16th February 2009 confirms 10 locations for exclusivity agreements for offshore wind locations including the Solway Firth, Moray Firth, coast of Argyll and islands, and four locations to the east of Angus, Dundee, Fife and East Lothian.

coast of Argyll and islands. Tidal energy generation in the east coast firths could result in significant landscape and other environmental change.

Summary

6.17. This research has explored the potential for a wide range of climate related landscape changes, each of which may affect different areas in different ways and over different timescales. Uncertainties associated with the climate change information and the way that natural and human systems will respond to these changes mean that the research has necessarily focused on a potential direction of change rather than firm predictions.

6.18. The research suggests that, overall, human mitigation and adaptation measures may have a more significant influence on landscape character than the direct effects of climate change. This is an important finding, since there may be opportunities to influence the development and implementation of climate change mitigation and adaptation responses to ensure that landscape implications are taken fully into account. Some of these opportunities are identified in the following paragraphs (see *Responding to Change*). A review of four socio-economic scenarios also suggests the finding that wider human influences (including policies on adaptation and mitigation) may be as important as the direct effects of climate change.

6.19. The research also suggests that the combined influence of these direct, mitigation and adaptation changes may be greatest in lowland and coastal landscapes reflecting the dominance of land management, settlement and land use in shaping landscape character and the likely impact of changing sea levels. This is in contrast to the uplands where landform is a more dominant factor and where, with the exception of developments such as windfarms and related infrastructure, change may be more gradual and subtle.

6.20. This conclusion has implications for designated landscapes such as National Scenic Areas and National Parks. Relatively few of these are located in lowland landscapes, so many will be largely unaffected by the range of climate related landscape changes which are likely to occur in these areas. Many are found in the highlands where most changes are likely to be slower and less dramatic, with the exception of further energy related developments. A significant number of nationally important landscapes include mainland or island coastlines. These could experience particular pressures associated with sea level rise and the effects on coastal settlements and transport infrastructure.

6.21. The patterns of change are also likely to impact upon wildland qualities. While the greatest changes may be experienced in more settled lowland areas, it is possible that relatively minor changes to infrastructure, or a small increase in recreation activity, for example, could have a disproportionate effect on people's perception and enjoyment of remoter upland and coastal areas.

6.22. All of this has implications for the way in which the landscape contributes to our quality of life. Using the framework of ecosystem services to consider the effects on inspiration and enrichment, health and well being, sense of place, cultural heritage values and recreation tourism reveal a mixed pattern of change which reflects the study's wider findings. On the basis of the four detailed study areas in Section 5, the research found that ecosystem services may change the least in upland areas and most in more intensively managed and densely populated lowland areas. Perhaps reflecting the scale of possible changes associated with climate related landscape change, the work found that cultural heritage values were likely to be affected in all four locations. Inspiration and enrichment services were slightly reduced or altered in

the upland and settlement examples but reduced in the case of lowland and coastal locations. Most other services recorded a mix of positive, neutral or negative changes for these areas.

6.23. The significance of this finding is underlined when it is considered that Scotland's population is concentrated in urban areas, particularly within the central lowlands. Even in remoter areas, settlement tends to be concentrated in lower lying and coastal locations where impacts of sea level are most likely to be felt. This suggests that climate related landscape change will have some of the greatest impacts in those areas where people live and work. While continued management of upland landscapes will continue to be important in order to minimise the impacts of climate change wherever possible, this finding does suggest this should be accompanied by measures to maintain the contribution of lowland and undesignated landscapes and townscapes to quality of life.

6.24. The urban environment has not been identified as an area likely to be subject to the most significant landscape change. Changes in relation to settlements largely reflect a continuation of current trends and policies through greater development of multi-functional green networks, modernisation of building stock through the introduction of energy efficiency and micro renewables, opportunities for walking cycling and public transport and increased flood defences. Changes which affect the historic environment are intrinsically linked to the landscape character of many of the lowland agricultural landscapes as reflected in patterns such as field size, enclosure and woodlands. Within urban areas impacts on the historic environment may have greater impact as a result of actions such as flood defence and direct impacts on stone structures. These changes may have a positive effect on the ecosystem services provided by greenspaces in urban areas as they are improved through adaptation.

Responding to Change

6.25. This research identifies the need for an integrated approach to managing change across lowland agricultural, upland and coastal landscapes. This approach will need to take account of landscape character and qualities and the ecosystem services they provide. Approaches to influencing landscape change must take a long term perspective, but must also recognise the role of wider economic trends in influencing the rate and type of change.

6.26. Lowland **agricultural landscapes**, and transitional agricultural landscapes between lowland and upland areas, particularly those which are in close proximity to the main urban centres, are identified as likely to undergo the most significant level of landscape change. These changes will result primarily from adaptation actions and it is therefore a priority to inform policies guiding key areas of change. Key policies for implementing these changes include mechanisms such as the Scotland Rural Development Programme (SRDP). Issues such as agricultural flood damage have no direct policy or strategy responses, however mitigation responses as set out under 'freshwater systems' may reduce the extent of damage. Economic impacts of damage may result in responses to reduce productive use of areas vulnerable to flooding, which may result in alternative crops or conversion to pasture.

6.27. In relation to the loss of field boundary trees, policy and strategy responses should include 'future proofing' the agricultural landscape through choice of species used in planting in farmland areas, and the creation of diverse and robust habitat networks.

6.28. Policy and strategy responses may require a higher level of planning control over agricultural buildings and greater guidance on their scale, location and landscaping.

6.29. There are currently limited policy or strategy responses to the impacts **on natural and semi natural habitats** such as changes to peatland and invasion of grasses onto montane and moorland habitat. Changes in alpine and sub arctic vegetation and patterns of snow lie are focused on the highest hills, and again, there are limited opportunities for policy or strategy response. Changes in species composition may result in changes in the key habitats and species for which areas are subject to nature conservation designations.

6.30. Review should be undertaken to identify additional activities which increase vulnerability of habitats, such as access and recreation and opportunities for reducing this damage.

6.31. Additional guidance may be required to inform management responses to habitat and species loss as a result of climate change, and the landscape implications of altered management activities.

6.32. Policy is well established in relation to **onshore wind**, however opportunities to provide further guidance to address the issues of cumulative impacts of development, and development within the context of a changing landscape may be required..

6.33. The main demand in relation to **forestry** may relate to research and guidance on managing change and addressing issues such as disease control.

6.34. Action to reduce fire risk include education of the visiting public, increased ranger presence within woodlands and areas identified at risk, increased management of woodlands to reduce fire risk through removal of dead wood, and adequate fire breaks.

6.35. There are a range of tools to help foresters manage the risk of wind damage to forests and these will assist in adapting forestry practice as the climate changes. Forestry practices are already changing to avoid more exposed locations. Similarly in relation to flood damage, future planting can avoid areas at known flood risk and support the planting of appropriate species.

6.36. There are limited policy and strategy responses available to manage **fluvial flooding** in areas where flood management has not already been implemented. Action can only be concentrated on reducing the effects of flooding through flood management measures. However mitigation of the effects of fluvial flooding includes the implementation of further flood management measures, which have landscape impacts. There may be a need for policy guidance on the implementation of flood defences, and their impacts in relation to urban and historic features. Further development of sustainable flood management within settlements (SUDS measures), and upstream of settlements, needs to be supported as a means of minimising the requirement for such defences.

6.37. The **coastal environment** is likely to be subject to a range of changes in both urban and rural environments. Sea level rise, surge risk, wave fetch, and the combined effects of these, changes in coastal erosion, and loss of coastal habitats can be addressed through further mitigation measures such as coastal defences, managed retreat, and habitat creation. Clear policy guidance to inform decision making in relation to the coastal environment will be required. This may include tools to assist in decision making over retreat and defence and the nature of these actions. The landscape impacts of coastal developments and offshore developments should be considered through both land use planning, and marine planning. The visual impacts of the cumulative impacts of offshore and coastal development change should be

adequately addressed through policy guidance in order to provide clear guidance and direction for the location of such changes.

6.38. There is also a need to inform policies guiding mitigation activities such as woodland expansion, rewilding uplands, renewables development, and to ensure consideration of the cumulative landscape and quality of life impacts of the changes across different sectors.

6.39. Opportunities to influence change vary, but it is important to identify where a change is also being driven by existing policy trends and the opportunities to influence these trends. There is also a need to identify those changes where there is no existing policy framework in order to provide a positive agenda to guide future change.

COMMUNICATING LANDSCAPE CHANGE

6.40. Phase 2 of this project will focus on communicating the findings from the Phase 1 Report and exploring the options for influencing policy and practice with these findings. It will explore ways of using and developing the approach used in this study. The aim should be to raise awareness of the implications of climate change, and our responses to it, for the character of the landscape and the way in which it contributes to quality of life. Communicating these findings effectively will be important if the work is to inform policy formulation and key decision making processes. It will also be important in order to increase wider understanding of the landscape changes that may take place over coming decades, the reasons for such changes, and the range of individual and collective choices that could influence the scale and nature of change. It is recommended that Phase 2 of the study explores the existing policy framework and identifies gaps and opportunities to guide future landscape change. The research has identified undesignated, lowland landscapes as an area where particular attention may be warranted.

6.41. A first step will be to define the audience more precisely. This may include:

- policy and decision makers including Scottish Government, Government Agencies and Non Departmental Public Bodies, local authorities and National Park Authorities and Non Governmental Organisations;
- professions whose work has an influence on responses to climate change and the landscape, including engineers, planners, landscape architects, ecologists, urban designers and architects;
- land managers and land management representatives covering agriculture, forests, woodland, water and moorland management;
- representatives from key industry sectors including power, water and tourism;
- communities and the wider public.

6.42. These different audiences will require different forms of engagement and communication which could include:

- policy area summaries and briefings, based on an analysis of the existing policy framework relating to mitigation and adaptation, including the identification of key gaps or missing links. A key aim should be to link the findings back to Scottish Government objectives and remit of agencies and local authorities (e.g. in relation to Single Outcome Agreements);
- stakeholder seminars and dissemination events to debate and explore the findings and the implications for different policy areas and areas of activity. Where possible these could link into existing policy or topic areas;

- written and visual communication including the preparation of a well illustrated and easy read summary for non-technical audiences, the development of display materials for seminars and conferences drawing on material in this report, and web based presentation;

- publication of journal articles in professional publications and landscape related press.

Recommendations for further work

6.43. In addition to taking forward Phase 2 of this project, the study has identified a number of areas which could be explored in greater detail through future work. These include:

- More detailed study of the impacts of landscape change on quality of life and provision of ecosystem services;

- Investigation of the opportunities for integrating issues of landscape change with Historic Land Use Assessment data;

- Exploring perceptions of change through public consultations, identifying which changes are most significant and the reasons for this;

- Taking forward the findings at a local level through Local Climate Impact Profiles (LCIP), where these are developed;

- Raising awareness of the landscape implications of climate change through the implementation of Scotland's Climate Change Adaptation Framework.

References

Agriculture and Climate Change Stakeholder Group (ACCSG) (2008) Climate change and Scottish agriculture, report to government, *Scottish Government.*

BRANCH partnership (2007), 'Planning for biodiversity in a changing climate – BRANCH project Final Report', *Natural England*, UK.

Brown, I., Towers, W Mike Rivington, Helaina Black, Philippa Booth and Donald Barrie(2008) The Implications of Climate Change on Land Capability for Agriculture, *Macaulay Institute.*

CABE Space (2008) Public Space Lessons Adapting public space to climate change.

Centre for Marine and Climate Research, Hamburg University; the International Institute of Applied Systems Analysis; the Flood Hazard Research Centre, Middlesex University; the Stockholm Environment Institute and its Oxford Office; the Institute for Environmental Studies, Vrije Universiteit Amsterdam; and Institut Symlog de France (2002) Atlantis Policy Makers Summary – Atlantic Sea Level Rise: Adaptation to imaginable Worst Case Climate Change.

Climate Research Unit, University of East Anglia (2006) Climate Change and the European Countryside: Impacts on land management and response strategies. Scientific report of the CLIO project.

Country Land and Business Association (nd) Climate Change and the Rural Economy http://www.cla.org.uk/Policy_Work/Policy_Reports/Environment/Climate_Change/2555.htm/.

Crown Estate Press Release 16th February 2009 The Crown Estate announce awards for offshore windfarms within Scottish territorial waters.

David Tyldesley and Associates (1999) Fife Landscape Character Assessment, *Scottish Natural Heritage.*

Dawson, A., Smith, D.E. & Dawson, S. (2001) Potential impacts of climate change on sea levels around Scotland. Scottish Natural Heritage Research. Survey and Monitoring Report No 178.

Defra (2003) Climate Change Impacts and Adaptations Research Programme (CC03) Project Summaries Report, *Defra.*

English Heritage (2008) Climate change and the historic environment, *English Heritage.*

Farming Futures (nd) Fact sheets (http://www.farmingfutures.org.uk/x360.xml).

Halcrow Group (2002) UK Future Coast, *Defra.*

Foresight Programme (2003-04) Flood and Coastal Defence research project (http://www.foresight.gov.uk/OurWork/CompletedProjects/Flood/index.asp).

Forestry Commission Scotland (2009) Climate Change Action Plan 2009 – 2011, *Forestry Commission Scotland.*

Forestry Commission Scotland (2008) Impacts of Climate change on forestry in Scotland – a synopsis of spatial modelling research, *Forestry Commission Scotland.*

Forestry Commission Scotland (2008) Climate change action plan 2009-2011 Draft for Consultation, *Forestry Commission Scotland.*

Forestry Commission Scotland (2008) Discussion paper on Woodland expansion in Scotland, *Forestry Commission Scotland.*

Forestry Commission Scotland (2008) Impacts of climate change on forests and forestry in Scotland, *Forestry Commission Scotland.*

Forestry Commission Scotland (2006) The Scottish Forestry Strategy, *Forestry Commission Scotland.*

Forestry Commission (2005) Climate Change and British Woodland, *Forestry Commission.*

Henley Centre (2005) Demand for Outdoor Recreation: A Report for Natural England's Outdoor Recreation Study. Paper 2, *Natural England.*

Isle of Wight Centre for the Coastal Environment, (nd) Coastal Processes and Climate Change Predictions in the Coastal Study Areas, Life Environment Project 2003-2006.

Jackson, J. (2007) Applying the principles of landscape ecology to green infrastructure planning.

Kerr, A et al (1999) Climate Change: Scottish Implications Scoping Study, *Scottish Executive Central Research Unit.*

Land Use Consultants (1999) Tayside Landscape Character Assessment, *Scottish Natural Heritage.*

MACIS project (2008) Climate Change Impacts on European biodiversity – observations and future projections.

The Macaulay Institute (2006) Possible Opportunities for Future Forest Development in Scotland: A Scoping Study Executive Report.

McEvoy et al (2008) Changes to Climate and Visitor behaviour: implications for vulnerable landscapes in North West Region of England, Journal of Sustainable Tourism, Vol 16, No1.

McEvoy, D., Handley, J. F., Cavan, G., Aylen, J., Lindley, S., McMorrow, J. and Glynn, S. (2006). Climate Change and the Visitor Economy: the challenges and opportunities for England's Northwest, *Sustainability Northwest* (Manchester) and *UKCIP* (Oxford).

Ray, Duncan et al (2008) Impacts of Climate Change on forests and forestry in Scotland, *Forestry Commission Scotland.*

Rothero, G., Grytnes,JA., Birks, J., and Genney, D. (2007) Effects of climate change on bryophyte-dominated snowbed vegetation Part 1: Cairngorms (Interim report with work continuing into 2008).

RSPB and Birdlife International (nd) Birds on the Move Introducing a Climatic Atlas of European Breeding Birds, *RSPB and Birdlife International.*

Scottish Executive (2005) Scottish Road Network Climate Change Study, *Scottish Executive.*

Scottish Executive Central Research Unit (1999) Climate Change: Scottish Implications Scoping Study, *Scottish Executive.*

Werrity, A. Black, A., Duck, R. University of Dundee, and Finlinson, B., Thurston, N., Shackley, S., and Crichton, D., Entec UK Limited (2002) Review of flooding occurrences *Scottish Executive Central Research Unit*.

Scottish Government (2008) Adapting Our Ways: Managing Scotland's Climate Risk Consultation to inform Scotland's Climate Change Adaptation Framework, *Scottish Government.*

Scottish Government (2008) The Scottish Soil Framework A Consultation Document June 2008, *Scottish Government.*

Shaw, R., Colley, M., and Connell, R. (2007) Climate Change Adaptation by Design – a guide for sustainable communities *TCPA.*

SNH (2007) Guidance Advice Note – Climate change issues at the coast: Adapting to a dynamic Landscape, *Scottish Natural Heritage.*

Smith C. and G Levermore, (2008) Designing urban spaces and buildings to improve sustainability and quality of life in a warmer world, Energy Policy.

UK Biodiversity Partnership (2007) Conserving biodiversity in a changing climate: guidance on building capacity to adapt, *Defra.*

UK Climate Impacts Programme (UKCIP) (2001) Modelling Natural Resource Responses to Climate Change (MONARCH), *UKCIP.*

SNH/Countryside Agency (nd) Landscape Character Assessment Guidance for England and Scotland – Topic paper 9 Climate changes and natural forces – the consequences for landscape character, *SNH and Countryside Agency.*

SNH (undated) Policy Statement No. 02/03 Wildness in Scotland's Countryside, *Scottish Natural Heritage.*

SNH report Market Research Partners, Edinburgh. (2008). Public Perceptions of Wild Places and Landscapes in Scotland. Commissioned Report No.291(ROAME No. F06NC03)

Sniffer CC02 (2005) Business Risks of Climate Change to Public Sector Organisations in Scotland, *SNIFFER.*

Sniffer CC03 (2006) A handbook of climate trends across Scotland, *SNIFFER.*

Sniffer CC03 (2006) Patterns of Climate Change across Scotland: Technical report, *SNIFFER.*

Sniffer CC05 (2005) A survey of Scottish Local Authority Activities on Climate Change, *SNIFFER.*

Sniffer CC06 (2007) Climate Change Tools for Local Authorities, *SNIFFER.*

SNIFFER UKCC13 (2007) Preparing for a Changing Climate in Northern Ireland, *SNIFFER.*

SNIFFER (2008) FRM10 Coastal Flooding in Scotland: A Scoping Study, *SNIFFER.*

SNIFFER (in progress) Adapting to the differential social impacts of climate change, *SNIFFER.*

School of Social and Environmental Sciences at the University of Dundee (2008) Coastal Flooding in Scotland: A scoping study, *SNIFFER.*

Sustainability Northwest (Manchester) and the UKCIP (Oxford), (2006) Climate Change and the Visitor Economy: the Challenges and Opportunities for England's Northwest; and Changes to Climate and Visitor Behaviour, *Sustainability Northwest (Manchester) and the UKCIP.*

Transport Scotland (2008) Scottish Road Network landslides study: Implementation, *Scottish Government.*

Tyndall Centre North (2003) Spatial implications of climate change for the North West, Manchester: University of Manchester/North West Regional Assembly.

UK Biodiversity Partnership (2007) Conserving biodiversity in a changing climate: guidance on building capacity to adapt, *Defra.*

UK Climate Impacts Programme (nd) A changing climate for business : business planning for the impacts of climate change (http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=293&Itemid=389).

UKCIP (nd) Climate Change and Nature Conservation in Britain and Ireland, MONARCH.

Urban Design Group (2007) Urban Design – special issue on climate change.

Weldon, S., Bailey, C. and O'Brien, L. (2007) New Pathways for Health and Well-being in Scotland: Research to understand and overcome barriers to accessing woodlands *Forestry Commission Scotland.*

APPENDICES CONTENTS

1. ECOSYSTEM SERVICES

Introduction

1.1. The study brief suggested that research into climate related landscape change should include consideration of the effects in terms of ecosystem services - the benefits that people obtain from ecosystems. These include provisioning, regulating and cultural services that directly affect people and the supporting services needed to maintain other services. The scope of the inclusion of ecosystem services was refined to focus in particular on cultural services (e.g. sense of place, recreation and eco-tourism). However, the following paragraphs describe the range of services, based on work carried out by Defra[1]. Many of the services listed are highly interlinked (primary production, photosynthesis, nutrient cycling and water cycling, for example, all involve different aspects of the same biological processes).

Provisioning Services

1.2. These are the products obtained from ecosystems, including:

- **food**. This encompasses the vast range of food products derived from plants, animals and microbes;
- **fibre**. This is derived from materials such as wood, jute, cotton, hemp, silk and wool;
- **fuel**. Wood, dung and other biological materials serve as sources of energy;
- **genetic resources**. This covers the genes and genetic information used for animal and plant breeding and biotechnology;
- **biochemicals, natural medicines, and pharmaceuticals**. Many medicines, biocides, food additives such as alginates and biological materials are derived from ecosystems;
- **ornamental resources**. Animal and plant products, such as skins, shells and flowers are used as ornaments, and whole plants are used for landscaping and as ornaments;
- **fresh water**. People obtain freshwater from ecosystems and therefore the supply of freshwater can be considered a provisioning service. Fresh water in rivers is also a source of energy. Because water is required for other life to exist, however, it could also be considered a supporting service.

Regulating Services

1.3. These are the benefits obtained from the regulation of ecosystem processes, including:

- **air quality regulation**. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality;

[1] Source: Defra (2007). Securing a healthy natural environment: An action plan for embedding an ecosystems approach. PB12853. *(Adapted from Millennium Ecosystem Assessment Ecosystems and Human Wellbeing: General Synthesis)*

- **climate regulation**. Ecosystems influence climate both locally and globally. For example, at the local level, changes in land cover can affect both temperature and precipitation. At the global level, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases;

- **water regulation**. The timing and magnitude of run-off, flooding and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water-storage potential of the system such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas;

- **erosion regulation**. Vegetative cover plays an important role in soil retention and the prevention of landslides;

- **water purification and waste treatment**. Ecosystems can be a source of impurities (e.g. in fresh water). However, they can help in the filtering out and decomposition of organic wastes introduced into inland waters and coastal and marine ecosystems and can also assimilate and detoxify compounds through soil and sub-soil processes;

- **disease regulation**. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes;

- **pest regulation**. Ecosystem changes affect the prevalence of crop and livestock pests and diseases;

- **pollination**. Ecosystem changes affect the distribution, abundance and effectiveness of pollinators;

- **natural hazard regulation**. The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves.

Cultural Services

1.4. These are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences, including:

- **cultural diversity**. The diversity of ecosystems is one factor influencing the diversity of cultures;

- **spiritual and religious values**. Many religions attach spiritual and religious values to ecosystems or their components;

- **knowledge systems** (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures;

- **educational values**. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies;

- **inspiration**. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture and advertising;

- **aesthetic values**. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks and scenic drives and in the selection of housing locations;
- **social relations**. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies;
- **sense of place**. Many people value the 'sense of place' that is associated with recognised features of their environment, including aspects of the ecosystem;
- **cultural heritage values**. Many societies place high value on the maintenance of either historically important landscapes ('cultural landscapes') or culturally significant species;
- **recreation and tourism**. People often choose where to spend their leisure time based, in part, on the characteristics of the natural or cultivated landscapes in a particular area.

1.5. The list of cultural services above has been refined for the application within this study to include the following:

- **inspiration and enrichment**;
- **health and wellbeing**;
- **aesthetic values**;
- **sense of place**;
- **cultural heritage values**;
- **recreation and tourism**.

Supporting Services

1.6. Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorised as both a supporting and a regulating service, depending on the timescale and immediacy of their impact on people):

- **soil formation**. Because many provisioning services depend on soil fertility, the rate of soil formation influences human wellbeing in many ways;
- **photosynthesis**. This process produces oxygen, which is necessary for most living organisms;
- **primary production**. The assimilation or accumulation of energy and nutrients by organisms;
- **nutrient cycling**. Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems;
- **water cycling**. Water cycles through ecosystems and is essential for living organisms.

2. UKCIP SOCIO-ECONOMIC SCENARIOS

2.1. UKCIP has recognised the importance of uncertainties about the adaptation and mitigation responses of humans, particularly over the medium to longer terms, and has developed four alternative socio-economic scenarios to illustrate the different directions in which society might develop. These are not predictions but provide a useful framework to test the relevance of adaptation and mitigation responses to climate change.

2.2. This Appendix provides a detailed description of the four socio-economic scenarios, based on information drawn from UKCIP's report[2]. The following table provides a quick summary of the scenarios, drawing out the key differences.

Scenario	Description
World Markets	**Very rapid economic growth; population peaks mid-century; social, cultural and economic convergence among regions; market mechanisms dominate.**
National Enterprise	**Self reliance; preservation of local identities; continuously increasing population; economic growth on regional scales**
Global sustainability	**Clean and efficient technologies; reduction in material use; global solutions to economic, social and environmental sustainability; improved equity; population peaks mid-century**
Local Stewardship	**Local solutions to sustainability; continuously increasing population at a lower rate than in 'national enterprise'; less rapid technological change than in 'global sustainability' and 'world markets'.**

2.3. There is not scope within the programme and resources available to model these different scenarios for each of the climate related landscape changes identified in this project. However, **the pilot area work (Section 5 of main report) describes how the possible future outcomes might differ under each of the four scenarios, using the scenarios to 'confidence test' the results**.

INTRODUCTION TO SOCIO-ECONOMIC SCENARIOS

2.4. Studies to assess climate change impacts suffer from serious weakness if by default they merely assume that the projected future climates will take place in a world with a society and economy similar to today.

2.5. While most aspects of climate projection are based on well-understood physical processes, there is less understanding of the interactions of factors operating in socio-economic systems, which can change very rapidly.

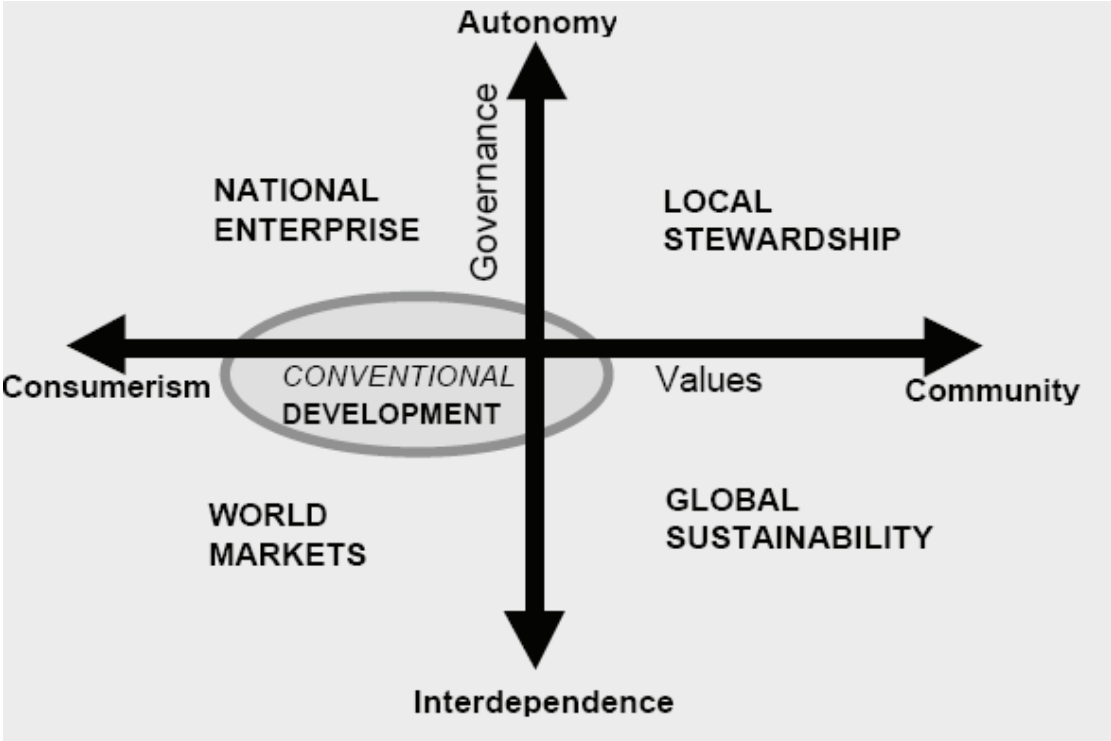
2.6. Scenarios are coherent, internally consistent and plausible descriptions of possible future states of the world, used to inform future trends, potential decisions, or

[2] UK Climate Impacts Programme, (2000), *Socio-economic scenarios for climate change impact assessment: a guide to their use in the UK Climate Impacts Programme.* UKCIP, Oxford.

consequences. They can be considered as a convenient way of visioning a range of possible futures, constructing worlds outside the normal timespans and processes covering the public policy environment. The futures socio-economic scenarios are a tool for visioning the future; they are not a set of prescriptions of how the future will evolve.

2.7. Four socio-economic scenarios have been developed for the UK. They are based on a review of the large global futures literature which identified five main dimensions of change highlighted:

- the composition and rate of economic growth;
- the rate and direction of technological change;
- the nature of governance; and
- social and political values.



National Enterprise

Summary of Climate Vulnerability

2.8. Under this scenario, biodiversity is under pressure from habitat fragmentation, industrial/housing development and weak environmental controls. Ecosystems are therefore vulnerable to climate impacts. The policy drive to combat biodiversity loss is also unambitious. The capacity to adapt to climate change in the agricultural sector is constrained by poor economic conditions in the sector and low levels of investment. Water systems are stressed, especially in the South East, because of a failure to curb demand and constraints on the financial resources available for investment in water supply. Water quality is poor. The economic and organisational capacity to protect coastal zones, where there is continued investment, is also weak. In the latter part of this scenario, in the 2050s, the climate signal is also strong because of a failure to curb greenhouse gas emissions.

Values and Policy

Social/Political Values

2.9. Prevailing social and political values are such that people concentrate on meeting their own needs through private consumption. There is little concern about social equity or protection of the environment, other than where it meets people's recreational needs.

Role of the State

2.10. The state broadly allows markets to determine social and economic outcomes, but intervenes to protect prevailing interests at the national and regional level. The transfer of sovereignty to global and European institutions is resisted and government at the UK level continues to play an important role. The pace of devolution within the UK is slow, but assemblies at the Scottish, Welsh and regional levels in England act to protect economic activity at the local level.

Policy Style

2.11. Economic and political power is consolidated in traditionally strong interest groups - the law, the City, the professions. The 'top-down' policy-style leaves little room for local democracy and more open policy processes.

Welfare and Health

2.12. State provision of healthcare and education declines and access becomes uneven. Social service provision also declines with relatively low concern about social inequities. Income disparities grow.

Education

2.13. Those who can afford it increasingly make use of private education as the quality of state education declines. The focus is very much on teaching basic skills that will fit people for an economically-oriented society. The education system does little to impart concern about social inequities or the environment. Those at the lower end of the social scale generally have low educational attainment.

Environmental Policy

2.14. Environmental policy measures which are seen to impede economic development or restrict personal freedom do not succeed. There is little concern about global environmental issues. People support measures which enhance their immediate local environment, especially those relating to clean air, the built environment and the provision of recreational opportunities. Policies which benefit affluent groups and those with access to political power are more often successful.

Economic Development

Economic Policy and Economic Development

2.15. Growth is a political priority under this scenario but falls below the long-run UK average as a result of protectionist policies at the national and regional level. Export-oriented sectors grow relatively slowly, while businesses focused on meeting domestic consumer demand fare better. In general there is little state intervention in the economy, except in relation to key industries (utilities, banks, defence) where national industries are supported against foreign competition. The UK remains outside European Monetary Union (EMU), but continues to trade extensively with the EU.

Regional Trends

2.16. There are considerable variations in economic development at the regional level. London and South East England experience the highest growth rates. Scotland, Wales and the rest of England suffer from relative underdevelopment through the continued drift of economic activities towards the South East. The peripheral regions continue to rely on traditional activities, especially manufacturing, and there is a lack of investment in new industries.

2.17. Regions heavily dependent on international airports and shipping ports face lower growth prospects due to the relatively slower growth of international trade. Generally, regional policies are determined by decisions at the UK level. Economic, political and cultural development continue to vary from one region to another.

Manufacturing

2.18. The relative decline in overall manufacturing activity ceases and there is more intensive exploitation of agricultural resources, with greater diversification of output to meet local demands. Sectors operating in global markets (banking and finance, chemicals, pharmaceuticals, metals, automobiles, electronics) face slower growth rates. The rate of innovation is generally low due to low investment in research and technological development and restricted international competition.

Services

2.19. In the service sector, demand for private education and healthcare rises. On the other hand, concentrated sectors operating in global markets (specialised services, banking and finance) grow more slowly.

Construction

2.20. The construction sector struggles because of lack of investment in new housing and infrastructure. Construction and refurbishment activity within existing urban areas is an important market. Maintenance and conversion of existing buildings and infrastructures is the primary activity. Traditional UK construction techniques continue

to play a major role. Much of the sector remains labour intensive with low skill micro-enterprises predominating.

Energy

2.21. The energy sector is based on plentiful supplies of fossil fuels. There is a strong tendency to preserve existing sources of energy including indigenous coal and nuclear power by extending the lives of existing stations. Prices for final consumers of energy are relatively high because some higher cost forms of generation are maintained. The pursuit of energy efficiency is limited in this scenario despite higher prices, due to a lack of available capital and the low priority attached to environmental investments. Renewables do not develop under this scenario, although there is some further development of combined heat and power plants.

Settlement and Planning

Population

2.22. Population numbers increase slowly as there is little inward migration and birth-rates are relatively low. Average household size is stable due to medium economic growth and low social provision.

Planning

2.23. Planning controls at the local level are weakened in an effort to encourage economic development. There is a presumption in favour of new housing, industrial and infrastructure developments. Regional-level decision making is heavily steered by national guidance.

Housing Development

2.24. New housing development generally takes the form of additions to existing towns and villages. As fewer planning barriers exist for high income housing, new developments are established in green belts and in the countryside, including in areas which are environmentally sensitive.

Transport

2.25. There is a continuing reliance on private transport with little additional provision for public transport. Moderate GDP growth limits the spread of car ownership and use, and the car fleet grows rather slowly. Due to a lack of investment, many roads operate at full capacity and congestion and accidents increase. New technologies, such as informatics, are introduced at the very top end of the car market. With a relatively slow growth in international trade, air traffic increases no more quickly than other transport modes. Without new developments in the rail system, freight continues to be moved mainly by road.

Agriculture

Agricultural Policy

2.26. Agricultural policy aims to protect the British agricultural and food industry and to ensure the availability of high-quality food at modest prices. There is little concern about the rural environment.

Support Measures

2.27. Public support for agricultural production continues through a modified Common Agricultural Policy (CAP) and national subsidies. As a result, consumer prices remain relatively low. There is almost no link between public support and environmental objectives.

Agricultural Trade and Consumer Demand

2.28. Self-sufficiency in food supply increases slightly because of trade barriers and subsidies. Diets do not change radically, meat consumption remains high. Trade in food commodities continues but there is less development of global markets for seasonal and high-quality food inputs. Retailers have a strong influence over farmers, but this is manifested in requirements for uniform, high quality products rather than for sustainable farming practices.

Farming Practices

2.29. Current agricultural practices intensify with high inputs of pesticides and fertilisers. The uptake of genetically modified organisms is patchy, drawing on the UK science and industrial supply base. There is a moderate trend towards large farms.

Agricultural Production

2.30. Agricultural productivity increases within the limits of conventional technologies which leads to a further decrease in the area devoted to UK agriculture. Productivity growth slows gradually.

Water

Water Demand

2.31. Water demand increases because capital investment in water efficiency is low and demand-side management remains a marginal activity. Leakage levels are high. On the other hand, price mechanisms limit the increase of water demand in both the industrial and household sectors. Metering systems are installed in the majority of private houses and tradable abstraction permits are used in industry.

Water Supply

2.32. Supply strategies are based on the ‘predict and provide’ principle. Increased demand is met by extending traditional water sources.

Water Quality

2.33. There are new and enlarged reservoirs, inter-regional transfers and additional groundwater development. Supply difficulties arise in the South and East of England. The quality of river and groundwater deteriorates as a result of the intensification of agriculture, low investment in sewage treatment and the weak control of industrial pollution.

Biodiversity

Nature Conservation Policy

2.34. There is little public concern about biodiversity. Nature conservation policy is not sufficiently strong to restrict development pressures on the natural environment. The current level of protection for many conservation areas declines.

Agricultural Impacts

2.35. Although the total area in agricultural use is smaller than today, biodiversity is under very significant pressures from agriculture. Intensified farming practices and the trend towards larger farms leads to biodiversity loss and fragmentation of habitats.

Housing and Industrial Impacts

2.36. Changes in land use resulting from housing and industrial developments also have detrimental effects on biodiversity. Environmental pollution and the depletion of water resources also put stress on animal and plant species.

Coastal Zone Management

Coastal Zone Development

2.37. Housing development in coastal zones takes place but is limited by the generally low rate of investment in new housing.

Coastal Protection

2.38. Coastal defence aims to protect all coastal areas, environmental, housing, commercial, industrial and infrastructure assets as well as agricultural areas. Withdrawal from formerly protected areas occurs only in small areas where the costs of protection exceed the derived benefits. Coastal defence investment is significantly higher than today but still within the range of economically justified spending. Built environment

Housing and Transport Infrastructure

2.39. The quality of public infrastructures is poor because of low public investment. Innovation in the construction sector remains at a low level. Housing and other buildings in poorer areas declines while high quality buildings are developed close to centres of economic activity.

Local Stewardship

Summary of Climate Vulnerability

2.40. Under this scenario, there is both the will and the capacity to protect biodiversity from the impacts of climate change. Economic development is controlled so that fragile ecosystems are protected, although there is some threat from the expansion of agricultural areas. Housing developments on the edges of smaller towns may also have local impacts on the countryside. Extensive agriculture focused on small-scale, diversified and organic production provides an alternative route to high adaptive capacity in the sector. There is less pressure on water resources due to lower demand, but local difficulties continue where there is resistance to the development of new water resources. The vulnerability of coastal zones will be decreased because

resources are made available for protection. There is a willingness to contemplate 'managed retreat' where protection is too expensive.

Values and Policy

Social/Political Values

2.41. Social values are community-oriented encouraging cooperative self-reliance and regional development. Economic growth is not an absolute political priority. Instead, there is a strong emphasis on equity, social inclusion and democratic values. The conservation of resources and the protection of the natural environment are strong political objectives. Cultural and political variations across the UK regions, and in Europe more generally, lead to a stronger regional flavour in policy making, with diverse socio-economic outcomes. The EU develops as a 'Europe of Regions'.

Role of the State and Policy Style

2.42. The promotion of these social values becomes the most important task of public institutions which successfully turn community values into practice through purposeful social and economic planning. Decision-making power is devolved downwards in a more federal system of government. Political systems are transparent, participatory and democratic at the local level. Traditional 'regulation' is replaced by a more diffused structure of governance involving stakeholders throughout society.

Welfare and Health

2.43. There is a high level of public provision for health and social services which are open to all.

Education

2.44. The publicly funded educational system aims to ensure equal and broad access. The educational system affirms a strong degree of citizenship and promotes concern about social equity and environmental protection.

Environmental Policy

2.45. The conservation of resources and the natural environment are strong political objectives. Environmental policy succeeds as a result of structural and behavioural changes as much as on technological change and innovation.

Economic Development

Economic Policy and Economic Development

2.46. Economic growth is slow relative to the long-term average. Smaller-scale production of goods and services is encouraged. Small and medium-sized enterprises in the manufacturing sector, co-operatives, and locally-based financial and other services prosper. Agricultural production stabilises as a proportion of economic activity. International trade plays a relatively less important role in economic growth. Even more so than in the National Enterprise scenario, sectors heavily dependent on international trade face difficult growth prospects. National champions re-emerge in key industries such as energy and communications.

Regional Trends

2.47. Economic growth is more evenly spread across the regions, with London and the South East of England ceasing to be the main pole of economic development. Greater importance is placed on regional development and the local economy as a way of achieving sustainable social and environmental benefits. Wales, Scotland, Northern Ireland and the English regions are able to pursue their own economic development more autonomously. Given this level of local economic autonomy, specific outcomes of development are more firmly determined by regional resources and the capabilities of local government, businesses and people.

Manufacturing

2.48. Rates of investment and innovation in manufacturing industry are generally low. Major changes occur in industrial structure, since the scale of markets is restricted. Small and medium size enterprises, along with technologies adapted to small-scale sustainable production are favoured. Innovative new applications of information technology and biotechnology enable smaller production units to remain economic. There is a stress on eco-efficiency, quality and durability in consumer goods.

Construction

2.49. In construction, a conservationist ethic and low levels of investment leads to the survival of traditional housing, and a relatively slow uptake of new styles and technologies. The industry continues to be dominated by small firms, but the skill base is greatly enhanced, leading to efficiency gains and higher quality.

Energy

2.50. The exploitation of local energy resources is a particular feature of this scenario. A wide range of renewable energy technologies is exploited, facilitated by a willingness to invest in technologies with low rates of return. Some local coal resources are also exploited in this scenario, but with high standards of environmental control. Locally based combined heat and power schemes flourish. Green tariffs are taken up by environmentally conscious consumers and reinforce more formal regulatory controls. High energy prices lead to the large scale adoption of energy efficiency measures.

Settlement and Planning

Population

2.51. The UK population is stable and the trend towards smaller households is reversed due to lower growth in household incomes, strong planning controls on new housing development and the revival of more collective social values. Household numbers decline slightly and urbanisation stops.

Planning and Housing Development

2.52. Tight planning control over the countryside and the need to preserve land for agricultural production leads to denser urban development. Growth is concentrated within existing towns and smaller cities. Government policy encourages the conversion of urban land to natural vegetation.

2.53. There is general migration away from the larger cities and a corresponding growth of small and medium-sized towns more suited to a smaller-scale local development path. The distinction between countryside and towns is preserved. Planning favours

mixed residential and commercial development and decentralisation. As a result, overall transport volume decreases.

Transport

2.54. The transportation sector is affected by a major slowdown in the growth of trade and the demand for mobility. Transport costs rise sharply due to high energy prices and policies which internalise environmental costs. Passenger transport is still dominated by private cars but public road and rail transport structures are extended. Alternatives such as car sharing, cycling and walking increase. Cars based on low emission technology (fuel cells, electricity, hybrids) are commonly used.

Agriculture

Agricultural Policy

2.55. The main goal of agricultural policy is to support a broader social desire for local self-sufficiency and what are seen as traditional farming practices. Research and technical support increases the productivity of low-input farming systems. Large scale farming is not encouraged.

Support Measures

2.56. Agriculture is heavily subsidised to protect food security, local landscapes and to reduce environmental impacts.

Agricultural Trade

2.57. Retailers and consumers place considerable emphasis on procurement of local supplies while sales of exotic fruits and out-of-season vegetables decline.

Consumer Demand

2.58. Demand for meat continues to fall, and broader support for animal rights brings an end to the transport of live animals over long distances.

Farming Practices

2.59. There is a rapid growth in organic and low input farming. Farm size declines and the use of fertilisers and pesticides decreases. Genetically modified crops are banned.

Agricultural Production and Agricultural Area

2.60. The shift to extensive farming practices decreases productivity and the total agricultural area is extended. Production of arable increases slowly, while livestock production decreases.

Water

Water Demand

2.61. Water demand falls as a result of low growth and effective demand-side management measures. Consumers install water conservation technologies, grey water systems and radically reduce the use of public supply water in gardens.

Water Supply

2.62. There is an increasing consciousness that water resources have to be protected. Exchange of water resources between regions in the UK becomes more difficult. High water-using activities either innovate in regions with shortages (like the South East) or relocate to other regions. Major investments are made to reduce water leakage. Few new supply-side investments are needed.

Water Quality

2.63. Water quality improves dramatically as a result of acute concerns about the quality of the local environment, reduced pesticide use and changes in industrial structure. Dry waste systems are increasingly adopted resulting in a decline in demand for waste water treatment.

Biodiversity

Nature Conservation Policy

2.64. There are strenuous efforts to preserve wildlife at the local level, both in rural and urban areas.

Agricultural Impacts

2.65. Some pressures arise from increased land use associated with agriculture. On the other hand, the shift away from high input and large-scale livestock agriculture to extensive and more diverse agricultural areas has positive effects on biodiversity.

Housing and Industrial Impacts

2.66. Planning controls ensure that land is set aside for nature conservation and that habitats are protected from housing and industrial development. Some tensions arise because demands for public access to conservation areas puts pressure in ecologically vulnerable areas.

Coastal Zone Management

Coastal Zone Development

2.67. Planning controls are consciously used to limit economic development in coastal zones, especially in environmentally sensitive areas.

Coastal Protection

2.68. 'Managed retreat' becomes an increasingly important policy option, especially where artificial sea defences are costly. Major areas of productive agricultural land and areas already developed tend to be protected by publicly funded sea defences. As public bodies try to keep maintenance investments at a low level, the quality of defence structures is relatively poor. There is a significant increase in risks of economic loss through defence failure.

Built Environment

Housing and Transport Infrastructure

2.69. Improving the quality of housing is a political priority for social as well as environmental reasons (energy efficiency). However, efforts are limited by budget

constraints. Investments in transport infrastructure are low as the demand for mobility remains stable.

World Markets

Summary of Climate Vulnerability

2.70. This is a scenario in which biodiversity is vulnerable as a result of fragmented habitats, particularly under pressure from housing development, high-intensity farming and leisure industry uses of the countryside. There is little public concern about biodiversity loss. Conversely, the capacity to adapt in the agriculture sector is high because technology offers the opportunity to introduce new varieties and techniques in response to climatic changes. Pressure on water resources is very high, especially in the South East, but prices provide incentives to use water efficiently and cut leakage. The vulnerability of coastal regions increases because of continued investment in housing and infrastructure. There is a demand to protect these investments from coastal flooding.

Values and Policy

Social/Political Values

2.71. People are primarily concerned with personal consumption and their material well-being. The market, as opposed to state institutions, is presumed to best deliver these goals. There is a strong desire for mobility. People are less tied to locality and are more concerned with creating personal objectives and identities in a post-modern culture.

Role of the State

2.72. There is a continued reshaping of governance, with the retreat of the nation state. Political responsibilities are more disparate than today. On the one hand, fiscal, trade and defence policy is increasingly transferred to the EU level. On the other, attempts to improve the efficiency of regional and local decision-making lead to further, though limited, devolution.

Policy Style

2.73. Governments experiment to some extent with more open and deliberative decision-making. Private sector, non-governmental agencies and international organisations have an increasingly strong influence on public policy. Regional governments also have a growing role, but their primary goal is to attract inward investment to secure jobs through investment in transport and other infrastructures.

Welfare and Health

2.74. There is a declining role for governments in the provision of healthcare, education and other public services. Private sector provision becomes the norm. Privatisation leads to increasing inequalities in access and quality of social services, creating significant new social tensions.

Education

2.75. Access to high quality education becomes very uneven, with the wealthier enjoying high standards and the quality of public education declining. The education system

emphasises basic skills, information technology and personal fulfilment. It does not promote interest in local culture, social equity or environmental issues.

Environmental Policy

2.76. Environmental policy is aligned to meeting competitiveness goals and protecting local amenity and environmental quality. It relies heavily on economic instruments and focuses on problems which immediately affect the population, e.g. noise and air quality. Areas which are easily accessible to wealthier people with high levels of mobility for recreational purposes tend to enjoy higher levels of protection. Longer-term, global issues such as climate change tend to be neglected.

Economic Development

Economic Policy and Economic Development

2.77. This scenario is characterised by liberalised national and international markets, the dismantling of trade barriers and the retreat of the state, leaving a greater role for the private sector. Income distribution widens in this scenario more than in any other. By historical standards, economic growth is rapid under the World Market scenario. Globalisation proceeds rapidly with growing trade in goods and services, and the further integration and growth of financial markets. The development and pervasive application of World Trade Organisation rules leads to the removal of trade barriers. Much of UK goods and services are produced for an EU market expanded to include new members in eastern and central Europe. Global markets, including China, Latin America and other emerging markets, are important for a growing number of firms. This scenario is compatible with early UK entry into EMU.

2.78. Structural change in the economy is rapid. The service sector, including financial services, healthcare and education, leisure, distribution and transportation, dominates overall economic activity. Mining, manufacturing and agriculture all decline.

Regional Trends

2.79. All regions benefit from rapid economic growth through ‘spillover’ effects, although regions heavily dependent on manufacturing face rapid change. Regions and localities offering world-class knowledge-based services will tend to grow fastest, wherever they are. This leads to high levels of local and regional specialisation in sectors where UK industry has a comparative advantage. Those sectors which do not perform at a world-class level do not survive. London grows rapidly as a world financial and service centre, and has a positive economic influence on neighbouring regions. Areas close to airports and ports will benefit from the growing volume of trade.

Manufacturing

2.80. Rates of innovation and growth are high in many manufacturing sectors, with information technology and biotechnology being the main technological drivers of change. Traditional manufacturing in primary industries declines as a result of competition from newly industrialising countries in South Asia and the Middle East. However, resource extraction grows in order to meet energy and infrastructure construction needs. Small-scale, agile assembly industries linked to complex, global supply chains continue to grow. There is local and regional specialisation in high value-added industries. Pharmaceuticals benefit from the rapid growth in demand for health care.

Construction

2.81. The construction industry experiences high rates of growth and there is rapid innovation in technologies for the built environment. New towns and communities are constructed on ‘greenfield’ sites. New technologies, materials and construction processes are adopted and the UK becomes more open to non-traditional building techniques. There are major advances in training and skills within the construction sector. Modular buildings are assembled from units pre-fabricated off-site. There is a greater willingness to scrap the existing building stock and a lower priority is attached to the preservation of existing buildings.

Energy

2.82. Energy markets are dominated by fossil fuels, particularly natural gas. Exploitation of alternatives to conventional oil begins. Demand for electricity and transportation fuels continues to grow. Electricity supply investments are generally in modular, distributed power systems. Energy prices remain low, and there is little concern for energy efficiency, although most of the easy energy efficiency opportunities have been realised. High discount rates and the low priority attached to global environmental problems preclude the widespread adoption of renewable energy. Neither is there a revival of nuclear power because of high discount rates and low fossil fuel prices.

Settlement and Planning

Population

2.83. The UK population grows slowly but the labour force becomes increasingly mobile. There is not only a higher rate of immigration from outside Europe but also a significant migration within the UK. Net out-migration continues in regions such as the North East, the North West, Yorkshire and Humberside, while the population of Scotland, Wales and Northern Ireland remains relatively stable. Population grows in London, the South East and East Anglia.

Households

2.84. High incomes and individualist values reinforce the existing trend towards smaller households. Rising demand for housing causes urban land use to increase significantly across all regions, especially around larger towns and cities. Renting and buying property will become increasingly expensive in the London area, causing housing demand to be particularly high in the South East.

Planning

2.85. The planning system is weak and is not used to counter-act wider social and economic trends.

Housing Development

2.86. New housing development will take place along the main transport lines leading to London, in the Midlands, the North West and the South of England.

Transport

2.87. Housing development creates a need for new investments in infrastructure, especially in transport. New roads are built to meet the increased demand for passenger transport. Traffic is efficiently managed using new control systems. The quality of water, energy and communication infrastructure will improve significantly.

Agriculture

Agricultural Policy

2.88. Agricultural policy becomes much less interventionist and subsidies are reduced to a comparably low level.

Support Measures

2.89. The CAP plays only a minor role and lower food prices prompt farmers to search for improved productivity.

Agricultural Trade and Consumer Demand

2.90. Food markets are increasingly dominated by the large retailers. There is a growing differentiation between staple 'engineered' foods, and higher value unadulterated food produced using traditional methods. More processed food is consumed, and a greater proportion of food is eaten outside the home.

Farming Practices

2.91. Agriculture becomes increasingly concentrated, industrialised and global in scope. Farms increase in size, accelerating the adoption of technological approaches such as 'precision farming'. The use of genetically modified crops becomes pervasive, and has a major impact, raising productivity. Fears about the environmental impact of genetically modified crops on biodiversity are demonstrated, but are primarily of concern to environmentalists who have little influence in this scenario.

Agricultural Production and Agricultural Area

2.92. The total agricultural production rises because of higher productivity. Substantial tracts of land are converted from agricultural to recreational uses, or are sold for development.

Water

Water Demand

2.93. Water demand increases significantly due to economic growth, higher living standards, small household sizes, minimal environmental concern and the development of more distributed communities. Metering is universally adopted and water prices are high. This encourages the adoption of low-cost efficiency measures.

Water Supply

2.94. High water prices encourage a significant reduction in water leakage and the development of new sources of supply. There is little resistance to the development of new reservoirs except where significant recreational opportunities are threatened.

Water Quality

2.95. Water quality is mixed: agricultural and road run-off are a severe problem; river quality improves in recreational areas; and groundwater quality declines.

Biodiversity

Nature Conservation Policy

2.96. Conservation sites are maintained and slowly expanded but are designed with access in mind, to provide space for tourism and leisure activities rather than in order to protect biodiversity.

Agricultural Impacts

2.97. Habitats are under high pressure from large-scale farming. The wide use of genetically modified crops creates new problems for biodiversity.

Housing and Industrial Impacts

2.98. Urban sprawl and the demand for ‘managed landscapes’ (as opposed to habitat preservation) put pressure on biodiversity.

Coastal Zone Management

Coastal Zone Development

2.99. High housing demand coupled with high income levels and the demand for an attractive living environment enhances pressure for housing development in coastal zones. Areas at high risk from flooding will be developed by high income groups, even if insurance for these areas is refused.

Coastal Protection

2.100. The state withdraws partly from coastal defence which becomes to a larger extent privately funded. The high value of coastal assets economically justifies the increasingly high investments. Sea defences protect almost all coastal areas making use of advanced technology but they will involve significant costs. Modern early warning systems based on satellite and other remotely sensed data are installed to minimise the risk of human casualty. New construction techniques applied in coastal areas reduce the damage from flooding events.

Built Environment

Housing and Transport Infrastructure

2.101. High investment in the built environment drastically improves the quality of the housing and transport infrastructure. The turnover of office and residential buildings increases. There is more rapid adoption of innovative technologies (e.g. information technologies).

Global Sustainability

Summary of Climate Vulnerability

2.102. In this scenario, natural ecosystems are considerably less vulnerable than in the World Markets scenario but are less well protected than under Local Stewardship. Demand for access to the countryside increases while, on the other hand, pollution levels are lower. Technology allows agriculture to adapt to climate change, but there are tighter controls on the use of genetically modified crops for example than under the World Markets scenario. More efficient end use means that there is less pressure on water resources. Existing coastal infrastructure continues to be vulnerable to sea-level rise but new developments are strictly controlled.

Values and Policy

Social/Political Values and the Role of the State

2.103. Social values are communitarian and internationalist. There is broad consensus on the need to maintain and enhance social equity and environmental quality. Low discount rates reflect a concern about long-term development issues. There is a belief that these objectives are best achieved through international co-operation within the EU and in global organisations, such as a strong international climate regime. This leads to the loss of some power over monetary, defence, social and environmental policy at the UK level. Governance becomes more globalised. The main task of regional governments is to implement standards agreed at the EU and global levels. There is less scope for regional autonomy in this scenario, which follows the 'One Europe' model of harmonised standards across international boundaries. Politically strong regions co-operate and integrate horizontally. The accountability and legitimacy of global decisions implemented at the local level is stressed.

Policy Style

2.104. Consensus about sustainable development is transmitted through participative, open democracies with a growing role for local governments within more federal political systems. The policy style is characterised by a strong partnership between government, industry and non-governmental organisations (NGOs).

Welfare and Health

2.105. Policy aims to reconcile social values with economic development and the expenditure of public funds reflects this. The welfare system provides an adequate safety net for disadvantaged groups. There is a shift from care for the sick to high-technology health promotion and preventive care.

Education

2.106. There is equal access to high quality public education which reinforces social and environmental values throughout the taught curriculum.

Environmental Policy

2.107. Working towards sustainable development is a political priority. Larger ideas such as the maintenance of biodiversity, the protection of the 'global commons' (the atmosphere, the oceans, wilderness areas) and resource efficiency drive environmental policy. Strong concerns are reflected in the development of *external* regulation and *internal* environmental management. Environmental policy is based on a mix of market-based and regulatory instruments.

Economic Development

Economic Policy and Economic Development

2.108. Economic growth continues at long-term average rates. Growth is achieved by balancing commercial and social/environmental objectives. Innovation is promoted by high investments in research and technology development, and private-public partnerships. International co-operation and regulation reduces the tensions between social and environmental objectives on the one hand and competitiveness on the other. There is a growth in the role of services in the economy, at the expense of production and agriculture. Resource intensive agriculture and manufacturing tend to decline. The economy is increasingly export-oriented, with mobile, highly skilled labour force. In most markets competitiveness is achieved through encouraging higher quality and emphasis on non-price value added (branding and functional) differentiation.

Regional Trends

2.109. Regional development is evenly distributed through planning controls and transfer payments. Development prospects are shaped by the existence of a highly skilled labour force, the ‘pleasantness’ of towns and cities, and the provision of infrastructure which encourage sustainable economic development. In some more industrialised regions this will necessitate significant structural change. The management of this economic transition is an important task for national and regional policy.

Manufacturing

2.110. Manufacturing industry is transformed by a combination of high investment and the drive towards a low input, ‘small footprint’ economy. Highest growth is experienced in sectors providing eco-efficient goods and services. High levels of investment are associated with the re-structuring and/or phasing out of inefficient and heavily polluting industries. Innovation focuses on radical improvements in eco-efficiency across the board. This has major implications for the market structure of many industries, with returns to scale being replaced by returns to scope and specialisation.

Construction

2.111. The built environment is transformed with the rapid replacement of old and inefficient buildings and infrastructures. Due to strict development controls, housing construction is concentrated in existing urban centres and in brown field sites. There is significant innovation in biotechnological and other advanced land reclamation techniques. New, energy efficient buildings are engineered products with relatively short lives. There is heavy investment in new infrastructure in the UK. There is a particular emphasis on training and the acquisition of skills in this scenario, as UK firms seek to learn advanced construction techniques employed in other European countries.

Energy

2.112. Natural gas is the dominant energy source up to 2010 in this scenario, but renewable energy sources gain a large market share thereafter. A large global market for solar energy builds up with economies of scale driving down costs, forcing market concentration and making solar the dominant renewable energy form. Encouraged by regulatory incentives, energy suppliers move towards the provision of integrated services, greatly enhancing the take-up of energy efficiency measures. Investment in higher cost energy forms and environmental controls mean that the price of energy for the final consumer is high. With the growing importance of non-fossil energy, hydrogen becomes a significant energy carrier beyond 2020 and there is major infrastructure investment associated with its production, storage and distribution.

Settlement and Planning

Population

2.113. Rising incomes tend to reduce average household size but this factor is balanced by the strengthening of community values. Household size therefore declines slowly and household numbers grow at past rates. More even economic development reduces migration within the UK. London and the South East continue to be attractive due to the proximity to European markets, but regional development elsewhere is supported at a European level. The aesthetic, social, cultural and environmental benefits of living in Scotland, Wales and northern England are valued more.

Planning and Housing Development

2.114. Strong planning controls prevent development in the green belt. Most new housing demand is met by dense low-rise development mainly on existing urban land. There is little conversion to urban land on the fringes of smaller towns and villages.

Government policy encourages energy efficiency investments in the housing stock. There is a higher turnover of the housing stock, with a general emphasis on modern, high quality housing for socially disadvantaged groups.

Transport

2.115. The modernisation and restructuring of freight and passenger transport is started, with the longer-term aim of building an integrated system with an increased proportion of public road and rail transport. Although eco-efficient cars reduce the negative impacts of traffic, a tension between the transport demands of a mobile society and environmental concerns persist. Major new investments are made in telematics as a way of substituting for travel. New roads, rail and airport infrastructures are developed, but with a high priority given to minimising environmental impacts. As a result, the cost of transport rises substantially.

Agriculture

Agricultural Policy

2.116. The aim of agriculture policy is to balance high agricultural yields with low environmental impacts.

Support Measures

2.117. Support payments for farmers are tied to the sustainable management of rural landscapes. Some existing agricultural land is converted to promote nature conservation.

Agricultural Trade and Consumer Demand

2.118. Retailers transmit consumer concerns to farmers through purchasing policies. Common environmental, animal welfare and ethical standards are accepted and implemented through the food supply chain in the UK and EU. There is a widespread desire to eat high-quality, nutritious food supplied mainly by major brands and retail chains. More people switch to vegetarianism and meat consumption declines more widely.

Farming Practices

2.119. Approaches such as integrated crop management are adopted resulting in lower pesticide inputs. There is a gradual uptake of genetically modified crops around which there is considerable controversy. Introduction takes place very slowly, with tight regulatory controls in place to screen for adverse environmental and biodiversity impacts. Large-scale livestock farming declines.

Agricultural Production

2.120. The increase in agricultural productivity and production slows down and substantial areas of land are taken out of production. This area is used to support nature conservation rather than recreation.

Water

Water Demand

2.121. Forces tending to increase water demand, such as an improved standard of living, are balanced by demand-side management and the adoption of clean technology.

Water Supply

2.122. As a result of improved efficiency of water end-use, there is little need to develop new sources of water supply.

Water Quality

2.123. Water quality improves in this scenario due to reduced pesticide use and the shift to cleaner production in industry.

Biodiversity

Nature Conservation

2.124. Despite the high priority assigned to the protection of the countryside, landscape and key habitats, this scenario has a mixed impact. Growing demand for access to a clean, quiet rural environment creates pressures which must be consciously managed.

Agricultural Impacts

2.125. Low input farming and the promotion of sustainable landscape management helps to protect biodiversity. The decline in animal husbandry in marginal upland areas results in radical changes in land use. Rapid changes in agricultural practice across the rest of the UK also result in significant changes in the appearance of the countryside.

Housing and Industrial Impacts

2.126. Tight planning controls prevent the fragmentation and loss of important habitats. The control of industrial pollution improves the quality of air, soil and water.

Coastal Zone Management

Coastal Zone Development

2.127. The pressure for the development of coastal areas is high but tight planning controls restrict further development, especially in vulnerable areas.

Coastal Protection

2.128. Coastal zone management follows a twofold strategy leading to diverse regional outcomes. Developed areas and high value assets are protected through artificial engineering structures. These will also be used to experiment with alternative energy technologies such as wave energy. There will be 'managed retreat' in areas where ecological conditions are favourable to the development of biologically diverse habitats. The majority of investments in coastal defence are public. New technological solutions, for example in the construction of houses in areas at risk from flooding, are adopted.

Built Environment

Housing and Transport Infrastructure

2.129. High investment is made in public infrastructures and new building stock. Emphasis is given to energy and resource efficient housing and transport projects. The benefits of the better built environment are more fairly distributed.

3. WORKSHOP

3.1. An internal workshop took place on 7th January for SNH staff. The purpose of the Workshop was:

- to explore initial responses to the changes identified and spatial extent of these;
- to explore the issue of uncertainty associated with the changes identified including the influences of different socio-economic scenarios.

3.2. The workshop presented the key landscape issues identified from the literature review and held discussion on these issues.

3.3. The results of the workshop were used as a checklist to confirm the impacts as identified in Appendix 5, and to identify additional issues. The workshop also highlighted key issues of uncertainty relating to the way in which certain climate changes may impact on the landscape, particularly in light of differing policy and economic pressures.

3.4. The following bullet points identify those additional landscape impacts identified by workshop attendees.

WORKSHOP NOTES

Forests and woodlands

- pest damage including deer;
- species choice in woodland planting;
- competition for woodland expansion land with agriculture and built development;
- rate of regeneration of tree species;
- felling rotation;
- growth of wood for woodfuel;
- impact of SFS woodland expansion targets.

Freshwater systems

- river morphology and impacts on river systems;
- natural flood defences and naturalisation;
- planned movement of infrastructure in response to increased flood risk;
- landslides;
- low river flow and conflict between hydro power and water abstraction;
- water export.

Coasts, estuaries and seas

- softer defences, use of e.g. groynes;
- abandonment of existing defences;
- salinisation resulting from sea water inundation;
- viability of coastal settlements;
- changes in populations of seabirds;
- shorelook Coastal SSSI project.

Urban and peri-urban

- urban growth – competition for land;
- use of brownfield land;
- impact of redevelopment on settlement identity;
- loss of Vernacular e.g. sandstone erosion;
- allotments – what are the drivers? Is this social change or can it be attributed to climate change?
- key issue is the role of external impacts on these areas.

Tourism and recreation

- coastal erosion – loss of footpaths, golf courses;
- fire hazard;
- increase in local tourism – type and infrastructure required;
- a complex area where there is significant uncertainty;
- also the issue of people's perceptions and experience of the landscape to changes which may result from impacts which have a more limited physical impact;
- conflicts between users;
- accessibility of wild land – increased use may affect the perception of this resource;
- what are people's expectations and perceptions of the countryside?

Infrastructure

- realignment of roads/railways;
- rail expansion – Strategic transport projects review;
- carbon storage infrastructure.

Habitats

- coastal habitats;
- soil (work as part of Scottish soil framework);
- erosion and debris flow;
- pests and diseases;
- grazing pressure impact on habitats;
- resistance of different habitats to climate change;
- resilience of habitat networks;
- potential interactions with other topics – more research required;
- forest habitat network;
- opportunity maps of forest expansion.

Agriculture

- biofuel crops;
- waste management;
- disease – affecting the distribution of livestock;
- livestock – potential movement off hill;
- intensification of production on productive land;
- role of technology;
- impact on viability of smaller farm units – potential introduction of a ranch landscape;
- loss of cattle from the landscape.

Historic environment

- vegetation impacts on sub surface remains;
- erosion exposing previously hidden resources.

TOP OVERALL SIGNIFICANT IMPACTS ON LANDSCAPE/QUALITY OF LIFE

3.5. Workshop attendees were asked to identify the top three overall significant impacts on landscape and quality of life, and the following responses are grouped by topic area.

Forests and woodlands

- the most cited landscape change for forestry was woodland and forestry expansion including for carbon sequestration and woodfuel;

- changes in forestry planting, including woodland restructuring and changing planting species, management practices and clear felling and the impact on local distinctiveness due to these changing patterns;

- competition/pressure on land by different interests/sectors and associated changes in land use.

Agriculture

- nearly half of respondents identified changes in relation to agriculture. These changes included the influence of climate led/climate change policy drivers on agricultural change. This is related to the issue of food security and expansion of agricultural production areas, and also competition/pressure on land by different interests;

- direct impacts include changes in boundary patterns, and a loss of local distinctiveness associated with these changes. Additional issues identified include flooding impact on crops and fruit and vegetable growing.

Habitats

- Just over a quarter of attendees identified landscape changes relating to habitats. This included general changes to habitats and more specific changes including alien invasive species threatening current vegetation patterns, consequences of pests and diseases, and peat formation slowing down/ceasing and changes to bogs and moorlands. Further threats to habitats were identified as competition for land by different interests/sectors.

Freshwater

- Under a quarter of attendees identified freshwater issues including direct and adaptation responses of increased construction of hard defence structures (River and coastal defences, culverts and road protection), and flooding and storms.

Coast

- Nearly half of attendees identified coastal issues which included direct and adaptation impacts including coastal erosion, flooding, inundation and new coastal defences. Coastal changes were also categorised in relation to their impacts on habitats, agriculture and settlement patterns.

Tourism and recreation

- No issues raised.

Urban and peri-urban

- Issues identified included development changes – transport and housing, inappropriate development, competition/pressure on land by different interests/sectors and the impacts of competition for land as a result of climate related pressures on how it is used.

Historic environment

- A limited number of issues were identified and included loss of sites by erosion, changes to buildings to adapt to increases in temperature and rainfall and the impact of mitigation works e.g. flood defences.

Infrastructure

- The most significant issue was identified by nearly half the attendees as windfarms, other renewable energy infrastructure and changes in the electricity distribution network.
- Other issues identified included transport changes to a lower carbon footprint.

TOP SIGNIFICANT IMPACTS ON LANDSCAPE, IN YOUR SPECIALIST SUBJECT AREA

3.6. Workshop attendees were asked to identify the top three overall significant impacts on landscape and quality of life, within their subject area and the following responses are grouped by topic area.

Forests and woodlands

- changes in forestry planting and clear felling and expansion of woodland network;
- increase in productive forestry for carbon sequestration;
- more productive forestry in the lowlands/low slopes and consequent changes in the spatial distribution and extent of forests and woodlands;
- woodland expansion (identified three times) up slopes with elevated treelines and scrub habitat development.

Agriculture

- lack of livestock grazing;
- age structure in farming;
- intensification of production on better land;
- change from agriculture to forestry on marginal land;
- further abandonment of marginal land (only partly attributable to climate change);
- loss of agricultural diversity, intensification.

Habitats

- coastal habitat change e.g. saltmarsh – mudflat;
- disease impact on trees/shrubs from dieback and change in dominant species;
- invasive species expansion replacing dominant species e.g. bracken, sycamore, beech and other frost limited species;

- species composition and management systems as a response to climate change for forests and woodlands;
- development of forest habitat networks and riparian habitat and design for habitat networks.

Freshwater

- increase in rainfall;
- changes in river corridors/floodplains;
- changes in magnitude and frequency of hazardous events including floods;
- flood management/catchment management.

Coast

- more rapid erosion and coastal flooding leading to coastal habitat loss and landscape change (identified twice);
- changes in magnitude and frequency of hazardous events including coastal erosion;
- increased construction of hard (and some soft) coastal defences;
- growth in offshore renewables;
- cumulative effects of offshore and inshore/offshore wind energy generation.

Tourism and recreation

- No issues raised.

Urban and peri-urban

- development changes – transport and housing;
- impact of micro renewables;
- increase in pressure and need for greenspace;
- potential flooding in built up areas;
- wider implementation of SUDS.

Historic environment

- changes to buildings to adapt to increased temperature and rainfall;
- impact of mitigation works e.g. flood protection;
- loss of sites due to erosion.

Infrastructure

- windfarms (identified twice), hydro schemes and electricity distribution network;

- cumulative impacts of onshore wind energy development;
- increased adaptation/mitigation responses through infrastructure windfarms, grid, buildings, etc.

Soil

- soil erosion;
- suitability of soil for land use changes/habitat changes;
- loss of soil for planning and development.

Other

- Concentration of cumulative change.

Workshop Attendees

The following are SNH staff except where otherwise specified, and their work area is listed:

Bill Band	Head of Strategic Direction
Cathy Tilbrook	Coastal and Marine Manager
Catriona Morrison	Communities and Greenspace Officer
Deborah Munro	Group Manager, Landscape
Duncan Blake	Geographic Information Analyst
Ian Angus	Group Manager, Communities and Greenspace
James Fenton	Policy and Advice Officer, Landscape
Joanna Duncan	Landscape Adviser, Renewables
John Gordon	Group Manager, Earth Sciences
Mary Christie	Strategy and Communications Manager
Marion Mulholland	Policy and Advice Officer, Climate Change
Patricia Bruneau	Soil Science Adviser
Peter Pitkin	Land Use Programme Manager
Phil Baarda	Land Use, Woodlands Officer
Richard Ferguson	Planning Group Manager
Sarah Hutcheon	Policy and Advice Officer, Landscape
Matthew Hawkins	Cairngorms National Park Authority
Gordon McConachie	Cairngorms National Park Authority
Nicholas Shepherd	Forestry Commission Scotland
Noel Fojut	Historic Scotland

4. LITERATURE REVIEW

INTRODUCTION

4.1. This part of the report provides an overview of the literature under the following headings:

- climate change in Scotland;
- climate change literature;
- climate change and landscape – examples from elsewhere.

CLIMATE CHANGE LITERATURE – CROSS CUTTING RESEARCH

Climate Change: Scottish Implications Scoping Study, 1999

4.2. The Scottish Executive Central Research Unit commissioned Climate Change: Scottish Implications Scoping Study, published in 1999.

4.3. The study comprised three parts.

- identifying the key stakeholders and reviewing existing information concerning climate change issues within Scotland;
- interviewing experts from a wide range of public and private organisations affected by climate change issues;
- synthesising this expert knowledge into an analysis of the Scottish implications of climate change, together with an assessment of the implications for future work.

4.4. The study explored direct and indirect impacts of climate change and explored the implications of climate change across a number of key sectors including energy, transport, domestic, public services, business and agriculture, forestry and fisheries. The study identified priorities for future work including the need for higher resolution climate data and impacts studies in Scotland. The second priority was identified for exploring the linkages between the main driving forces on each sector, the likely impacts of emissions strategies, and climate impacts.

Adapting Our Ways: Managing Scotland's Climate Risk, 2008

4.5. Scottish Government produced a consultation document in summer 2008 *Adapting Our Ways: Managing Scotland's Climate Risk* Consultation to inform Scotland's Climate Change Adaptation Framework.

4.6. The document proposes to identify strategic principles and priority actions in the forthcoming Scotland's Climate Change Adaptation Framework as a means of providing leadership, guidance and consistency of approach to government and non-government decision-makers.

4.7. Scotland's Climate Change Adaptation Framework will also identify roles and responsibilities for public and private decision makers across Scotland. Finally, it will draw links with Government action on mitigating future impacts of climate change, through efforts to reduce emissions.

4.8. The document identifies a number of strategic principles for climate adaptation:

- adaptation should be through actions that build resilience;
- adaptation should be continuous and responsive to new information;
- adaptation should be integrated into normal development and implementation practices;
- adaptation should be integrated at an appropriate scale and involve relevant levels of decision making;
- adaptation must be addressed alongside actions to reduce emissions;
- adaptation by one sector should not restrict adaptation by other sectors.

4.9. The document also identifies strategic priority actions for climate adaptation:

- where possible act now;
- provide leadership and coordination;
- built adaptive capacity;
- reduce and manage uncertainty;
- educate the public and other sectors on the nature of climate risks and how they can be managed.

4.10. These principles and actions will inform the future shape of climate change adaptation within Scotland.

Preparing for a Changing Climate in Northern Ireland, 2007

4.11. The SNIFFER report UKCC13: Preparing for a Changing Climate in Northern Ireland (2007) identified a series of potential impacts, including the following which have implications for the landscape and could also be relevant in a Scottish context.

Conservation, Biodiversity and Habitats:

- change in distribution and species composition of habitats;
- increase in the range of invasive non-native species;
- threats to intertidal habitats including salt marshes and mudflats;
- loss of coastal grazing marsh;
- impacts on estuarine and river ecology;
- decline in sand eel populations adversely affecting seabirds.

Agriculture

- field drainage to cope with wetter weather;
- impacts on crop yields and animal health;
- potential for new crops;

- reduced frost damage and requirement for indoor rearing.

Forestry

- hotter, drier summers could increase water uptake by woodlands, creating restrictions in areas with limited water availability;
- increasing frequency of forest fires;
- changing incidence of pest and disease outbreaks;
- increased tree mortality due to summer drought;
- increased productivity due to higher temperatures and CO2 levels;
- increased commercial planting as part of a mitigation strategy;
- expansion of woodland to offset soil erosion, fluvial flooding and providing shade for fish and leisure activity.

Water Resources

- low flows with impacts on ecology and recreation;
- water quality implications for rivers and reservoirs;
- sewer overflows due to storm flows;
- soil erosion, leaching of agricultural chemicals and wastes;
- reductions in water quantity and quality in waterbodies with implications for marginal habitats;
- high pollutant loads associated with intense summer storms.

Built Environment

- impact of winter flooding on settlements, farms and agricultural land, natural heritage, transport infrastructure, economy and health;
- increase in flooding with impacts on urban infrastructure, buildings, utilities and transport, economy and health;
- increase in flooding and erosion at the coast, with impacts on coastal habitats, coastal settlements, coastal transport infrastructure and agricultural land;
- increase in summer temperatures and drought with impacts on buildings and settlements, infrastructure, greenspaces and soil moisture, construction, urban heat island and waste management.

Transport

- infrastructure damage, roads, railways, related infrastructure;
- risk of fire and subsidence due to warmer drier summers;
- increases in walking and cycling.

Tourism, Recreation and Sport

- wetter winters affecting outdoor tourism and sport;

- coastal changes affecting beaches and coastal recreation;
- dry summers resulting in water shortages and impacts on natural heritage;
- drier warmer summers benefiting tourism and outdoor recreation.

Energy

- increased demand for summer cooling, reduced demand for winter warming.

Adapting to the Differential Social Impacts of Climate Change (ongoing)

4.12. Work commissioned by SNIFFER is currently being carried out to explore the differential social impacts of climate change.

4.13. The project aims to:

- to identify the social impacts in the UK which are forecast to increase under climate change projections;
- to identify the differential impacts, for example, based on exposure and sensitivity and the capacity to adapt;
- to identify adaptation measures that will need to consider these differential social impacts.

4.14. Information from a literature review undertaken as part of the project process identified the following key issues relating to the differential social impacts of climate change, under the UKCIP02 climate change scenarios:

- **Location:** High temperatures are more likely to affect southern England and south Wales. All regions are likely to get wetter winters, but those living in floodplains and coastal areas will be particularly at risk from flooding, while winter depressions and storms are likely to increase, particularly in southern England.
- **Type & frequency:** Flooding will affect people differently to heat, and the type of flood, its speeds, timing, duration and other factors will affect the effects of a flood.
- **Health:** People who are already ill are likely to be particularly sensitive, particularly those with heart and lung-disease, cardiovascular and respiratory problems, cerebrovascular conditions, diabetes and severe mental illness.
- **Finance:** Money can often buy you out of risk, risk resistance (e.g. flood protection measures), or insurance against the risk. The ABI estimate that 35% of people in very low income households do not have any insurance, and 44% only have contents insurance.
- **Access to services and social networks:** can significantly protect your health, as well as providing wider support through friends, family and neighbours.
- **Access to personal or public transport:** can help you reach safety, but also put you at risk.

AGRICULTURE

Farming Futures, 2008

Outline

4.15. Farming Futures is a communications collaboration between the National Farmers' Union, the Country Land and Business Association and the Agricultural, the Horticultural Research Forum, the Agricultural Industries Confederation, Forum for the Future and DEFRA. During 2008 it has issued a series of guidance notes outlining potential effects, mitigation and adaptation strategies for relating to aspects of farming practice. The 'factsheets' provide advice tailored to the likely concerns of farmers and agricultural suppliers and include the following subjects:

- basic information on climate change and its general effects on agriculture;
- opportunities and challenges presented by climate change;
- suggestions on how best to adapt agricultural businesses to climate change;
- suggested general mitigation measures;
- livestock (in four separate factsheets);
- dairying;
- arable crops;
- root vegetables and legumes;
- horticulture;
- forestry;
- anaerobic digestion;
- water management;
- biomass;
- soil management; and
- nutrient management.

Analysis

4.16. Climate change has the potential to significantly affect the agricultural landscapes of Scotland. Warmer, drier summer weather in eastern Scotland may extend the growing season for arable crops and expand the range of species that can be productively grown. Similarly, there is the potential for cultivation to extend into formerly marginal areas. Increased prevalence of summer drought is likely to pressurise growers of water-intensive crops, such as potatoes, possibly resulting in increased private abstraction to meet demand.

4.17. For livestock farmers, increased summer temperatures are likely to be a significant factor, possibly resulting in heat stress effects on animals, such as low fertility, reduced dairy yields, and increased mortality. (This will be particularly significant for

intensively reared species, such as pigs and poultry, as effective and efficient cooling systems will be vital to stock health.) The additional costs and difficulties may cause farms in traditionally pastoral areas to consider larger-scale arable farming as an alternative, particularly given the depressed stock and milk prices of recent years. This could have a major effect on landscape character as such a shift could result in large-scale amalgamation of fields and a change in farm infrastructure and buildings to accommodate machinery and plant, in addition to the obvious changes in appearance of the agricultural landscape.

Key Areas of risk and uncertainty

4.18. While the Farming Futures factsheets do not focus specifically on areas of uncertainty (since their primary function is to reassure farmers and land managers that successful adaptation to climate change is possible), a number of issues are apparent.

4.19. The majority of the adaptation measures proposed could be characterised as 'technical fixes,' many of which have significant cost implications. For farmers that may already be struggling financially, particularly in the livestock sector, the additional investment in energy efficient or advanced plant may render their businesses unviable. This may add to the trend of amalgamation of farms into ever larger businesses. Similarly, the potential effects on hill farming are significant for large areas of Scotland from the Borders to Sutherland. In addition to the physical effects of climate change (summer drought, unpredictable winter and spring weather, flash floods), farms in more marginal locations may find it harder to diversify. This has the potential to result in relatively large-scale abandonment of upland farms that have characterised many rural areas of Scotland since the early 19th century.

Climate Change and the Rural Economy, 2001

Outline

4.20. This report, commissioned and researched by the **Country Land and Business Association** (with assistance from a range of professionals), outlines the agricultural industry's view of the challenges, opportunities and policy needs created by climate change. It sets out a vision for supporting the transition of farming to a robust, climate adapted industry at the heart of the UK economy. However, the paper relates specifically to England and Wales, therefore conclusions drawn for the Scottish context should be seen as indicative.

4.21. Aimed at European, national and regional policymakers and the industry itself, the paper was designed to stimulate debate and attempt to put agriculture, and the potential impact of climate change in rural areas, at the forefront of the policy response.

Analysis

4.22. The report examines the effects of climate change on a range of cross-cutting rural themes including: water resources, soil, arable farming, livestock, energy, forestry, rural business, flooding and biodiversity; proposing adaptation and mitigation strategies for each.

4.23. Given the age of the report, many of the explicit policy recommendations have been addressed through the Stern Review (2005) and through the forthcoming UK and Scottish Climate Change Bills. Similarly, recommendations in relation to flooding are largely addressed by the Flood Risk Management Bill currently before the Scottish

Parliament. The principal requirement of the report was to propagate 'joined up thinking' by government in relation to climate change. To what extent this has been meaningfully accomplished remains to be seen but, on the surface at least, there has been a relatively significant focus on the issue (particularly through the creation of the Office of Climate Change).

4.24. In terms of the potential for landscape impacts, the report largely covers topics addressed above, suggesting the scope for the adoption of more resilient, condition-appropriate cultivars and breeds of animal.

4.25. An interesting topic raised is the role of agricultural land in carbon sequestration. Several cogent suggestions for reducing the amount of tillage to which land is subjected, including increasing the amount of winter crop cover to reduce erosion, are proposed. This could have an impact on landscapes by limiting the prevalence of bare ground during the winter months (although this is often necessary as a ground preparation technique for planting particular crops). Similarly, the potential of converting marginal land to forestry specifically to sequester carbon is also proposed.

Key areas of risk and uncertainty

4.26. As the report is now rather dated, particularly in its references to policy frameworks and climate projections, a significant proportion of the 'wish list' has been addressed. However, there have been notable failures – particularly the abortive European Soil Framework Directive – which would have played an important role in improving rural stewardship and land management.

4.27. Perhaps the most significant element of the report is that its many recommendations are largely focussed on the development of policy frameworks and support for the industry, rather than on reshaping the industry itself to mitigate and adapt to climate change.

Climate Change and the European Countryside: Impacts on Land Management and Response Strategies – 'CLIO', 2006

Outline

4.28. Produced as a result of collaboration between the **European Landowners Association** and the **Climatic Research Unit at the University of East Anglia**, the report focussed on the challenges presented by climate change to landowners across Europe. Through 21 case studies spread throughout the climatic zones of Europe, the paper presents a thorough, science-based, range of recommendations for mitigation and adaptation.

4.29. The study represents a major attempt by European landowners to educate themselves to the potential effects and concurrent threats and opportunities created by mitigating and adapting to climate change.

4.30. A central theme of the study is the fact that land-based industries (in this context, agriculture, forestry and sporting estates) are placed in a unique position in relation to climate change, and the environment in general. Where other industries only have a responsibility for reducing pollution, land-based industries are obliged to provide and maintain a comprehensive range of societal and environmental benefits. However, this responsibility is presented as a strength of the sector and a key asset, rather than an unwelcome externality.

Analysis

4.31. One of the case study estates – Invercauld, near Braemar – is conveniently located in some of Scotland's most treasured landscapes (the Cairngorms National Park) and is therefore ideally suited to present a general impression of the potential landscape effects of climate change on upland Scotland.

4.32. As sporting pursuits comprise around 65% of the estate's income (which is broadly typical for upland Scottish estates) the effect of climate change on deer, grouse and salmonid fish populations is critical to its economic survival. Milder spring weather has the potential to boost grouse breeding success through more vigorous insect populations (a critical food source for juvenile red grouse), potentially enhancing the viability of shooting[3]. It may also result in more vigorous heather growth, which is the grouse's principal source of food in adulthood.

4.33. Increased temperatures may also have a significant negative effect on salmon and sea trout numbers as heat stress on shallow rivers, raising the temperature to a point where successful spawning is not possible. Similarly, sudden changes in river level and flash flooding – both increasingly likely as a result of more frequent severe weather events – can wash away eggs or open redds (spawning sites) to predation. Equally, increased sedimentation is a threat to salmonid eggs, depriving them of oxygen and killing the embryonic fry.

4.34. As skiing is of significant economic importance in this area of the Cairngorms (both downhill at the Cairngorm and Glenshee centres and cross-country throughout the area), estates stand to lose significant revenues from property lettings.

4.35. In terms of landscape impact, management for grouse is a fundamental creator of the current open moorland landscape character. Increased summer temperatures may result in drying of peat cover, making extensive muirburning potentially dangerous in dry autumns. Similarly, the significant reserves of carbon stored in the peat may gradually begin to escape through drying or aerobic decay processes.

4.36. The loss of the downhill ski industry, which could occur relatively rapidly as climate change drastically reduces snowfall, would leave a legacy of scarred landscapes and redundant infrastructure which would require considerable investment to remediate (where a sustainable reuse was not forthcoming). Equally, the lack of snow in the mountains will fundamentally alter the character of the Cairngorms and reduce the impression of 'wildness' conveyed by the virtual year-round presence of snow in the north-facing corries.

4.37. As a solution to the release of soil carbon, the report proposes significantly increasing forest cover to mitigate this and to increase the viability of the forestry aspect of the estate's business. Although commercial crops are not currently considered viable above around 480m (Forestry Commission Scotland), warming of the climate may significantly expand the available 'climate space' for Scots pine and larch plantations. This has the potential to make a significant impact on the landscape, reducing the area of open moorland and, visually at least, pressurising the montane landscapes beyond.

4.38. A key strength of the report is in stressing locally specific sustainability solutions to the challenges of climate change, enhancing existing strategies and assets rather than trying to impose a general solution on landowners. This has the dual benefit of

[3] Although this may also increase the prevalence of parasites, particularly ticks carrying 'louping ill' which can increase chick mortality by up to 80%

enabling estates to play to their strengths and increasing the potential for a diversity of uses across Scotland's upland landscapes.

Key areas of risk and uncertainty

4.39. In terms of landscape impacts of changing estate management practice, the critical area of uncertainty relates largely to the potential for highly localised changes in weather patterns as a result of climate change. Given that the resolution of climate predictions is not sufficient to enable estates to plan with any degree of certainty, there may have to be an element of 'adaptation on the fly' which may result in cyclical landscape change.

4.40. The report also suggests a greater application of biofuels to reduce emission produced by the estate, although it makes no suggestion as to how this may be achieved or sourced.

Climate Change and Scottish Agriculture, 2008

Outline

4.41. This study represents the report to the Scottish Government of the Agriculture and Climate Change Stakeholder Group (ACCSG), an advisory panel composed of representatives from a range of public bodies and industry organisations which has met since 2006. Based on a range of evidence, it outlines the group's findings regarding the implications of climate change for farming in Scotland and offers a number of recommendations.

Analysis

4.42. The report lays out a number of required actions in line with the following themes:

- research and development needs;
- policy design needs;
- industry actions; and
- communication needs.

4.43. By so structuring their response, the ACCSG offers a coherent programme for an integrated response to the challenges faced by the agricultural industry from climate change.

4.44. The recommendations are comprehensive and extremely detailed and therefore create a valuable opportunity to assess the potential effects on landscapes. The topics dealt with below should not therefore be considered an exhaustive list of the subjects covered in the report.

4.45. In addition to relatively straightforward, farm-level adaptation measures such as altering sowing and harvesting operation timing, longer term proposals, such as the adoption of more robust cultivars or livestock breeds is suggested. While these are unlikely to have a significant landscape effect, the suggestion of widespread adoption of irrigation and associated on-farm water storage measures has the potential to alter landscape character. Similarly, the proposed expansion or short rotation coppice has the potential to have a major effect on former arable or pastoral areas. Equally, the proposals to increase woodland cover and management for biodiversity and flood

management could, if appropriately planned, enhance landscape character. Increased opportunities for farm diversification are identified as an important dimension to mitigating and adapting to the effects of climate change by introducing lower emissions land uses and concentrating on value-added products or services. Depending on the infrastructure required to support diversification activities (e.g. holiday chalets, ancillary campsite buildings, foodstuff processing facilities), there is scope for limited landscape effects. However, as many of these uses (being non-agricultural in the strictest sense) would require planning consent and therefore any negative effects could be successfully mitigated.

4.46. The paper also suggests a raft of institutional support mechanisms to aid the 'climate proofing' of the industry. These focus largely on the provision of accurate, accessible and relevant information (e.g. localised weather and climate projections and their potential effects on animal diseases and pest species). This strategic guidance role may have significant potential to ensure that diversification, adaptation and mitigation responses have minimal impacts on the landscape.

Key areas of risk and uncertainty

4.47. Perhaps the principal area of uncertainty is in relation to emissions from the agricultural sector. Scientific uncertainty and the lack of appropriate data hinder precise measurements of the impact of Scottish agriculture on the climate system, and therefore make developing mitigation strategies difficult. This is particularly significant for emissions from soils as, although an assessment of current land use can give a useful indication of rates of release, there is likely to be significant variation due to soil type etc. Similarly, aspects of agricultural practice, such as feed type, can have a major effect on emissions from livestock (and can dramatically reduce the amount of CH_4 produced in digestion). While this may provide significant carbon saving, an alternate strategy of shifting production to non-ruminant livestock (namely poultry and pigs) may reduce emissions; such a move would have major landscape impacts. Equally, reducing overall numbers of livestock would have a similar effect, but could radically alter the character of rural Scotland, as livestock play a major part in creating landscape character through their physical presence, the traditional structure required to manage herds/flocks and the effect they have on vegetation – particularly in upland areas.

4.48. It is possible that the pastoral sector will be disproportionately affected by mitigating climate change. Since such farms are often smaller entities than lowland arable holdings (which are often large conglomerates) and have suffered considerably more from falling commodity prices, they may be less able to adapt without help.

4.49. Given the range of approaches to the problem, it is likely that no one strategy will dominate, possibly limiting the effects on the landscape. However, the introduction of a more ambitious 'set-aside' type programme, removing land from cultivation, may be increasingly attractive to both the industry and government. Measures such as blocking land drains in peat-covered areas and creating woodland for biodiversity may allow controlled contraction of parts of the industry (if necessary) while ensuring parallel landscape benefits – rather than a wholesale abandonment of hill farms.

The Implications of Climate Change on Land Capability for Agriculture, 2008[4]

Outline

4.50. Conducted by climate change, ecology and agricultural specialists at the Macaulay Institute, this report presents the highlights from a pilot study investigating the potential effects on land capability for agriculture from climate change. The report intended to promote dialogue between stakeholders and to inform the Scottish Government's Land Use Summit in 2009.

4.51. The existing land capability classification was developed in the 1970s and early 1980s, and is based on climate data from 1958-1978. Analysis of more recent climate data has shown some changes in land capability, particularly in eastern Scotland, and the likely effects of climate change have the potential to significantly affect existing patterns of cultivation. The study examines the potential climatic effects of the most recent climate projections for the UK (UKCIP02) and assesses the likely effect on the distribution of the various classes of land capability.

Analysis

4.52. The study proposes an updated model for assessing land capability for agriculture using modern GIS technology (as opposed to the manual mapping used for the original study), interpolating climate, soils, and topographic datasets. They following datasets were analysed to produce the updated Land Capability for Agriculture (LCA) model:

- Met Office climate observations from 1961-2005;
- future climate projections derived from the UKCIP02 climate change scenarios;
- Soils of Scotland map data (1:250,000); and
- OS topographic map data (1:50,000).

4.53. Particular emphasis was placed upon the potential changes in the distribution of 'prime' agricultural land, therefore the dataset was filtered using a further set of criteria to ensure a more accurate result:

- slopes over 7°, which impose restrictions on machinery use;
- soil depth: soils with an effective rooting depth less than 45cm were excluded;
- soil wetness;
- soil pattern: as some area are inherently variable in quality (e.g. in areas of fluvioglacial geology, where intricate patterns of freely and poorly draining soils may occur) which make management difficult; and
- soil stoniness: a 35% maximum was applied.

4.54. The increasing warm and dry conditions projected to occur in eastern Scotland by the 2050s significantly expand the area of prime quality agricultural land[5] available for cultivation. Mapping indicates that the capability of the coastal plain of Moray and

[4] See Brown, I. et al in references section of this report.

[5] Categorised as classes 1, 2 and 3 of the Land Capability for Agriculture.

Banffshire, Aberdeenshire, the carselands of Angus and Perthshire, much of Fife and the Lothians improve substantially under both the 'low' and 'medium-high' UKCIP02 emissions scenarios.

4.55. It should be noted that the LCA system is based on long-term climate averages, but yearly variations are just as important for land managers. The model therefore screens out the extremes of both good and bad years to theoretically produce a more useful average.

4.56. The landscape implications of increased availability of prime agricultural land are potentially significant. As changes in climate increase pressure on agricultural land further south, perhaps restricting the range of traditional crops that can be grown in southern England, there may be a national strategic need to utilise as much of Scotland's agricultural resource. However, the areas that are improved due to the warming climate are already Scotland's centres of arable production. It is likely that cultivation would expand into current areas of pasture or poorer quality arable land, rather than resulting in a wholesale taking in of currently uncultivated ground. Rather, further intensification of agricultural practice – possibly resulting in the loss of field boundaries and hedgerows – may have more significant effects on landscape character.

4.57. In currently marginal areas, there will be the potential for improving areas of moorland or poor quality grassland for grazing or even cropping. The projections suggest that this will be particularly significant in Strathspey and upland Perthshire. As these areas contain some of Scotland's most treasured landscapes, such a transition would have to be carefully planned and managed to limit negative effects.

4.58. Stakeholder consultation undertaken as part of the study highlighted the potential for integration of the land capability data with other spatial datasets, such as the Landscape Character Assessment or Historic Landuse Assessment, to allow the effects from a possible expansion of intensive agriculture on environmental assets to be predicted and effectively planned.

Key areas of risk and uncertainty

4.59. The effect of updated climate projections on the distribution of land capability types is a major area of uncertainty. Although the release of UKCIP08 has been delayed, initial reports suggest that warming may be more severe than presented by UKCIP02 which may make recalculation of the LCA model advisable.

4.60. This introduces considerable uncertainty in terms of landscape impact, as the physical effects of climate change may be more severe. Similarly, this may increase the strategic importance of agriculture in Scotland, which would require a fundamental reassessment of patterns of development and the management of land.

4.61. Key points were also identified by a farm manager in relation to the future of farming about additional influencing factors. Moderation of the climate will not reverse the trend of land extensification and reversion to rough grazing, because:

i. Artificial inputs are likely to continue to increase in price; and
ii. It will always be more worthwhile to focus costly inputs on more productive land.
iii. As energy costs rise and labour costs fall (relatively), livestock systems will recruit more labour and use less energy, therefore:

iv. Extensive systems will become more profitable than energy-intensive middle ground systems; and
v. Middle ground livestock systems could extensify due to rising input costs.
vi. High quality arable land will be used for the production of bulk commodity staple crops.
vii. Marginal hill land will benefit from a moderated climate and will be valued as a source of cheaply produced meat and wool.
viii. Middle ground will also benefit from a moderated climate but the level of output will no longer justify the level of inputs required to achieve economic crop yields.
ix. Economic constraints will tend to outweigh the benefits which accrue from climate moderation.

Scottish Soil Framework, 2008

Outline

4.62. Prepared by The Scottish Government and published in June 2008, the Scottish Soil Framework consultation document highlights the importance of soil in relation to all aspects of life, providing a range of environmental, economic and societal benefits. According to recently published research, climate change and loss of organic matter are the most significant threats to Scottish Soils.

4.63. Soil functions:

- providing the basis for food and biomass production;
- controlling and regulating environmental interactions – regulating water flow and quality;
- storing carbon and maintaining the balance of gases in the air;
- providing valued habitats and sustaining biodiversity;
- preserving cultural and archaeological heritage;
- providing raw material;
- providing a platform for buildings and roads.

4.64. The consultation document specifically explores the issue of soils in the context of climate change.

Analysis

4.65. In the exploration of the impact of climate change on soils, the consultation document identifies that a changing climate with prolonged periods of dry weather followed by intense rainfall could be a severe threat to Scotland's soil resource. The climatic conditions anticipated for Scotland over the next decades are likely to stimulate the desiccation and decomposition of peat. Desiccated peats are vulnerable to erosion and bare peats are susceptible to landslides or bog bursts during periods of intense rainfall.

Key areas of risk and uncertainty

4.66. Climate change could impact on the workability of mineral soils, and soils in the north and east could be at increased risk of wind erosion given their use for arable farming.

There is a potential increased loss of carbon from peat soils, where these are suited to wind farm development.

4.67. The potential future need for increased food production in Scotland may result in additional pressures on soils, which will also be under pressure for sustainable economic development.

FORESTS AND WOODLANDS

Impacts of Climate Change on Forests and Forestry in Scotland, 2008

Outline

4.68. Commissioned and conducted by Forest Research ecology staff from the Forestry Commission Scotland, this report outlines the potential effects of climate change on the native and commercial planted forests of Scotland.

4.69. The research examines the possible implications of climate change on:

- growing conditions across Scotland;
- species choice for plantation forests – choosing varieties with appropriate characteristics and provenance to enable adaptation;
- the quality of the timber resource, and potential applications of standing and future forests;
- the prevalence of pest and diseases in light of changing conditions (and changing tree species distribution);
- the potential for marine inundation of coastal forests;
- silvicultural practice; and the
- distribution, condition and levels of risk to the main types of native woodland.

4.70. Although the report necessarily has an initial focus on the potential effects on the forestry industry, it provides useful insights – albeit indirectly – for the potential landscape impacts through changing woodland structure and species distribution.

Analysis

4.71. The changing weather patterns anticipated by current climate models suggest the potential for a range of landscape effects through their impact on woodland and forestry. Increased frequency of severe weather events – particularly winter gales and summer droughts – may result increased tree death where existing plantations are either in exposed locations, inappropriately structured to reduce windthrow, or planted on drought-prone soils (particularly with drought intolerant species). While the potential for negative effects through large-scale wind damage represents a significant threat, the need to restructure plantations and foster a more widespread adoption of Lower Impact Silvicultural Systems (where appropriate) could have net positive effects on landscape quality, as even-aged monoculture plantations are gradually restructured to aid adaptation to climate change.

4.72. Increased frequency and unpredictability of severe weather events also highlights the need for better site and operations planning to mitigate the potential effects of forest operations on the environment. The application of techniques to limit soil damage through rutting and erosion may also result in positive effects on landscape quality, as lower impact operations could assist in speeding the recovery time of vegetation.

4.73. The increased prevalence of warmer, wetter winters may have an effect on the landscape as tree species react differently to a general lack of intense winter chilling. For instance, although oak trees show a linear flushing response to warmer springs

(i.e. coming into leaf earlier with successive mild winters and warm springs), the lack of chilling actually inhibits early flushing in ash trees. Modelling undertaken for the report suggests that Scotland's native woodlands are more sensitive to temperature cues than in any other part of Europe, with a 1°C increase predicted to advance flushing date by around 11 days (current projections suggest a 3°C temperature rise for Scotland). The landscape is therefore likely to spend around a month less without woodland canopy cover, considerably altering the appearance of the winter landscape.

4.74. For native species, warmer summers may encourage broadleaf colonisation of pinewoods and promote vascular plant communities that are not currently associated with pinewoods, significantly changing the character of these most 'Scottish' of landscapes. Similarly, where grazing pressure allows, there may be natural expansion of scrub habitats above the current treeline, with juniper and montane willow possibly establishing at higher elevations in the complex and fragile montane soil mosaic[6]. This has the potential to radically change some of Scotland's more treasured and characteristic upland landscapes.

4.75. There is also an increased threat from fire in woodlands, and the ability of both beech and sycamore to increasingly outcompete the seeds of native broadleaves in regenerating forest cover.

Key areas of risk and uncertainty

4.76. Woodland management is a long-term process, with rotation periods reaching up to 200 years for hardwood species. Therefore the effects of decisions being made now will not be felt for many decades. There is considerable potential for decisions made using particular projections – e.g. UKCIP02 – to have disastrous consequences should these projections prove inaccurate or overly conservative. The introduction of more 'climate change adapted' species, such as *Pinus pinaster* (Maritime pine), *Pinus radiate* (Monterey pine) or *Castanea sativa* (sweet chestnut) that are currently less frequently used in Scotland, could have a significant effect on landscape character.

4.77. In addition to the direct effects of climate change on tree populations, the potential effects of a range of pathogens, fungi and insect pest species, while extensively modelled, remains somewhat uncertain. When combined with a new range of tree species, the potential landscape effects are unclear.

4.78. As the predictions of Scotland's climate in the (relative) short term remains uncertain, suggesting that perhaps 2 or more rotations of commercial forestry may be planted based on predictions with a high degree of built-in uncertainty. The paper outlines the need to move towards forestry practice that actively spreads risk and effectively plans for contingencies, while moving towards a diverse species mix of a 'no regrets' planting regime to minimise the potential for total loss.

Impacts of Climate Change on Forestry in Scotland – a Synopsis of Spatial Modelling Research, 2008

Outline

4.79. Conducted by the same Forest Research staff as the report above, this Forestry Commission Scotland Research Note outlines the preliminary findings of ongoing

[6] This assertion is borne out by research from across Europe, summarised in Grace, J., Berninger, F., and Nagy, L. 2002 'Impacts of climate change on the tree line,' *Annals of Botany* **90**: 537-544

research into the potential effects on Scotland's woodland and forests. The spatial models generated highlight the potential effects of the UKCIP02 scenarios on the soil resource and the indicative changes likely in suitability for particular indicator tree species (Sitka spruce, Scots pine, ash and pedunculate oak).

Analysis

4.80. This paper's conclusions are essentially a synopsis of the full Forest Research report above. However, its explicitly spatial focus is highly instructive in terms of drawing outline conclusions in terms of the regional effects on woodland and forestry and hence the landscape.

4.81. The anticipated changes in climate by 2080 render most of eastern Scotland unsuitable for Sitka spruce (the dominant species in contemporary commercial forests) and also reduce the suitability of much of the area for Scots pine. However, more marginal areas of eastern Scotland increase in suitability for both oak and ash, suggesting that significant restructuring of plantation forests is advisable from both an ecological and economic perspective (since native broadleaves also produce higher value timber). In the west of the country, certain provenances of Sitka spruce will become increasingly suitable, with the exception of Ayrshire and the Firth of Clyde which will go from being very suitable to unsuitable for the species.

4.82. The enhancement of Forest Habitat Networks through reforestation is highlighted as a key component in addressing the potential for increased woodland fragmentation precipitated by the effects of climate change. As this initiative focuses on linking habitats at a landscape scale, there is considerable potential for safeguarding landscape character in wooded areas.

4.83. The potential for woodland to contribute to flood and water management is also touched upon. The efficacy of wet woodland in flood attenuate is as yet unproven, although the results of initial research are encouraging. However, there is clear potential for floodplain woodland to make a significant contribution to landscape character, as well as providing some protection against the erosive force of flooding.

Key areas of risk and uncertainty

4.84. As noted in relation to the previous paper, uncertainty is a major factor in planning for the sustainable future of Scotland's woodlands and forests. This report stresses the need for FCS and other forestry operators to effectively plan to address the increased potential for severe weather and other natural phenomena likely to impact on woodlands. Whether or not Scotland's landscapes face significant landscape impacts as a result of changes to woodland and forestry is therefore partly contingent on forest managers adopting the correct strategies to cope with the likely localised effects of climate change.

Climate Change and British Woodland, 2005

Outline

4.85. Although based on somewhat older climate projections, this Forestry Commission information note (again produced by Forest Research staff) comes to the same broad conclusions as the previous two papers. However, it does include a UK-wide interpretation of the effects of climate change on forestry, and also a brief account of the role of woodlands in the wider landscape as affected by climate change.

Analysis

4.86. The most useful aspect of this paper is the highlighting of the wider potential role of trees and woodland in adapting to the effects of climate change. The need to ensure habitat robustness through the creation of habitat networks is again stressed, along with the imperatives of preserving biogenetic reserves of particular native species in key locations. Similarly, the value of trees and greenspace in limiting the 'urban heat island' effect and mitigating air pollution are identified as significant benefits to expanding woodland cover.

4.87. The role of woodlands and forests as potential sources of renewable energy, in the form of biomass, to mitigate future carbon emissions is also stressed. In terms of landscape impact, there is the potential for short rotation woodlands to have an effect on landscape character, particularly in the case of relation to densely planted monoculture coppice plantations.

Key areas of risk and uncertainty

4.88. The long timescales involved in forestry practice are again raised as the principal source of risk for the sector. Similarly, the report notes that the effects of climate change that are likely to occur within the coming 30-40 years will largely result from historical rather than current emissions, and explains the need for realism in terms of forestry's potential to 'offset' emissions from other sectors. Indeed, the report states that the total carbon stock associated with above ground woody biomass (approximately 130MtC) in the UK is less than the total of fossil fuel emissions for a single year. However, it does note that, in relation to the national emissions reduction commitments under the Kyoto protocol (20MtC per year), the net uptake of carbon by UK woodlands (approximately 2.5MtC per year) is significant and may play an important role in buying time to allow other mitigation strategies to take effect.

Forestry Commission Scotland Discussion Paper on Woodland Expansion in Scotland, 2008

Outline

4.89. Forestry Commission Scotland published a Discussion paper on Woodland expansion in Scotland, in 2008 which explored the role of woodland expansion in Scotland as set out in the Scottish Forestry Strategy. The Scottish Forestry Strategy, published in 2006, sets a vision for Scottish forestry in the second half of the 21st century. It lays out the range of economic, social and environmental benefits forestry can deliver within the context of sustainable forest management

4.90. The Strategy identifies a number of woodland creation priorities for Scotland:

- **Helping to tackle greenhouse gas emissions.** Carbon sequestration, timber and fuel production (climate change theme).
- **Restoring lost habitats and adapting to climate change**. Forest habitat networks (climate change theme) and new native woodlands (biodiversity theme).
- **Helping to manage ecosystem services**. Sustainable flood management, and protection of soil and water resources (environmental quality theme).
- **Underpinning a sustainable forest products industry**. Consistent and reliable timber supply for timber processing and wood fuel investments (timber theme).

- **Supporting rural development**. Supporting local businesses and farm diversification (business development theme).
- **Providing community benefits**. Provision of welcoming and well-managed woodlands in and around communities (community development theme) and where health and community need is greatest (access and health).
- **Enhancing urban areas and improving landscapes**. Improving derelict, underused and neglected land (community development theme), improving degraded or unsightly environments and diversifying farmed landscapes (environmental quality theme).

4.91. The study illustrates some indicative links between land use and woodland types, and this can be used to interpret some of the potential land use changes which may occur as a result of climate change:

Land type	Woodland type			
	Native woodlands	Mixed woodlands	Softwood production forests	Energy forests
Built up	✓	✓✓		
Arable and temporary grassland	✓	✓		✓✓
Permanent improved grassland	✓	✓	✓✓	✓
Semi-natural grassland/ bracken	✓		✓✓	
Shrub heath	✓✓			

4.92. The delivery mechanisms available to achieve the woodland expansion benefits are identified as:

- natural regeneration;
- un-aided tree planting (individuals and organisations acting without government support);
- carbon trading and offsetting;
- woodland creation grants;
- woodland creation on the National Forest Estate;
- woodland creation as a condition of planning permission.

Analysis

4.93. The potential landscape impact of the identified changes include an increase in native woodlands and mixed woodlands within built up areas. Arable and temporary grassland areas will also experience a high degree of change with a large increase in energy forests and also native woodland and mixed woodland planting. Areas of permanent improved grassland are likely to be subject to the broadest extent of

landscape change with potential increases in native woodlands, mixed woodlands, softwood production and energy forests. Semi natural grassland areas area also likely to experience change through increased native woodland cover, and also softwood production. Shrub heath landscapes will experience the lowest degree of landscape change through an increase in native woodland cover.

Possible Opportunities for Future Forest Development in Scotland, 2006

Outline

4.94. The Macaulay Institute undertook a scoping study which examined possible opportunities for future forest development in Scotland. This study explored application of the current Scottish Forestry Strategy which states that "our objective should be to increase Scotland's forests and woodlands towards one quarter of our land area by the middle of this century". The underlying assumptions concerning the biological, economic and social feasibility of achieving this objective have never been rigorously examined and the study aims to provide a solid foundation for assumptions about the proportion of Scotland that might reasonably be afforested over the next 40-50 years. The study aims to complement the development of the Scottish Forestry Strategy by:

1. Determining the practical constraints on the expansion and distribution of woodland cover.

2. Assessing the potential for expansion and distribution relative to a range of policy objectives and factors that might influence uptake.

Analysis

4.95. The study examined the physical and biological constraints for a wide range of tree species and identified that some 84% of Scotland has the biological potential for tree cover. However not all of the land area identified as having the biological potential is suitable for woodland. This is due to constraints such as designations, and 33% of Scotland is identified as being suitable for trees from both a biological and land use planning perspective. The study also identified further factors which might influence the future woodland expansion. These include:

- owner-occupier and tenant farmers;
- sporting estates, the MoD, Investment groups and other large landowners (e.g. mineral companies);
- community land managers including Community Woodland Trusts, crofting communities, and local authorities;
- conservation and environmental NGOs including the National Trust for Scotland, RSPB, Woodland Trust, John Muir Trust, etc.;
- Forestry Commission.

4.96. The study identified that the largest proportion of the land area potentially available for new woodland development is on land currently used for agricultural purposes. In order to reach the target of 25% of "woodland" cover by 2050, an annual rate of 14,000ha of new woodland would need to be created. The study suggests that

because of the generally-held negative view of forestry amongst the Scottish farming community, this rate of new woodland creation is unlikely to happen.

4.97. The study concluded that whilst the target of 25% is feasible from a biological and land use planning perspective, it is unlikely to be achievable by 2050 without significant changes in the economic attractiveness of woodlands relative to agriculture.

INFRASTRUCTURE

Scottish Road Network Landslides Study: Implementation, 2008

Outline

4.98. Produced by a range of geotechnical and engineering consultants for Transport Scotland, this report outlines recommendations for planning for and coping with the effects of landslides on the Scottish road network. Although the topography and geology of Scotland has long presented a risk of landslides, the intense rainfall and severe landslide events of August 2004 focussed attention on a likely increase in such phenomena as a result of climate change.

4.99. The study presents a range of proposals to manage the flow of debris on the trunk road network and introduces a management and mitigation strategy for landslides and represents the implementation phase of a research project undertaken in 2005.

Analysis

4.100. The hazard assessment process involved extensive GIS modelling of zones of susceptibility on the trunk road network. The subsequent hazard ranking process involved the development of exposure scores predicated primarily upon the risk to life and limb, but also taking some account of the socio-economic impact of debris flow events.

4.101. The report then outlines an approach for managing and mitigating debris flow hazards, taking the form of:

- exposure reduction: educating the public to the risks, warning systems, signage and road closure (cf. snow gates);
- hazard reduction: including engineering measures to protect the road, reduction of the opportunity for debris flow to occur or realignment of roads.

4.102. It should be noted that the report prioritises reducing exposure of road users to risks, due to lower costs and significantly lower environmental impact. However, in instances where hard engineering solutions are necessary, significant landscape impacts are likely to occur. The construction of spillways, debris basins and barriers are intrinsically high impact, but can be designed to minimise their effects.

4.103. The report also highlights the potential for liaison with the Forestry Commission to explore the potential of woodland as a preventative measure, creating greater soil integrity and also disrupting the destructive force of debris flow events.

Key areas of risk and uncertainty

4.104. Up-to-date climate predictions will be vital in maintaining up to date models of landslide susceptibility for the Scottish road network. Similarly, Government

approaches to risk may change through time, perhaps shifting from exposure reduction to hazard reduction in response to political pressure from key stakeholders. This would be a key area that could increase landscape impact, potentially where strictly unnecessary.

Scottish Road Network Climate Change Study, 2005

Outline

4.105. Produced for the then Scottish Executive by Jacobs Babtie and the Met Office, this study considers the potential trends in climate change in Scotland and how these may affect the road network. It is designed to be read in tandem with an accompanying landslides study. (The report outlined above is the implementation phase of said study).

4.106. Scotland's road network is potentially vulnerable to a range of climate change effects, ranging from dealing with increased volumes of stormwater to more frequent high winds affecting bridges in particular.

Analysis

4.107. The general conclusions of the report are that the climatic changes expected in Scotland in the near future (e.g. up to the 2020s) are relatively small. However, even these relatively small changes may have sufficiently significant effects to warrant changes to current practice. While the report notes that these changes are likely to become more marked over time, the degree of uncertainty associated with these predictions increases.

4.108. Precipitation and stormwater management is a significant cause for concern, and the report highlights the potential for failure of the existing standards of drainage systems in the near future. The study recommends:

- revision of the storm parameters used to design drainage infrastructure to allow for future increases;
- revision of the storm parameters used in the design of culverts and river bridges to allow for future increases;
- locations where flooding of the road network has occurred are identified and potential solutions evaluated on a cost/benefit basis, with priority for those areas where repeated flooding occurs;
- pre-emptive clearance of detritus from drainage channels / watercourses should be carried out in known areas of flooding risk in response to anticipated heavy rainfall;
- undertake further research to determine parameters used in the estimation of catchment runoff and absorption to enable the development of guidance on risk-based design approaches;
- development of a high winds strategy

4.109. The majority of measures suggested are unlikely to have a major effect on the landscape as they focus on the development of predictive tools to enable the design process for new infrastructure.

4.110. There may be limited scope for impacts where Transport Scotland or the local roads authority decide to experiment with alternative surface dressings for roads if localised conditions are found to be increasingly damaging, for example: more extreme freeze-thaw action or increased summer temperatures causing surface melting (although this is relatively unlikely in most of Scotland in the short term).

4.111. Perhaps the most likely area where the landscape will be influenced is through the extended growing season experienced by trees and shrubs planted as part of the landscaping measures undertaken as part of roads development. There may be a need for landscape architects to specify slow-growing species in areas where this is likely to be a particular problem.

4.112. There may be limited scope for landscape impacts through the extended roll-out of 'Variable Message Sign' network (large overhead or roadside digital message systems used to display warnings or advice for motorists), although these are only likely to be deployed on the trunk road network and would therefore form part of the wider language of infrastructure architecture within the road corridor. Similarly, the development of more robust hard drainage infrastructure may have limited scope for landscape effects – although this is likely to be restricted to reinforcing culverts and bridges that may be susceptible to scour.

Key Areas of risk and uncertainty

4.113. Again, the availability of up to date climate projection scenarios are vital to allow transport planners to effectively adapt the road network to the effects of climate change.

4.114. A significant uncertainty factor relates to the government approach to road transport and network expansion/upgrading over the coming decades, as the Scottish and UK governments attempts to curb carbon emission and the price of oil rises inexorably as supplies peak and subsequently dwindle. Bearing in mind that much of Scotland is entirely reliant on the road network, it is likely that these decisions will be influenced in the short term at least as much by rural *realpolitik*[7] as by climate commitments.

URBAN AND PERI-URBAN

Public Space Lessons: Adapting Public Space to Climate Change, 2008

4.115. Published by CABE Space in 2008, this document explores the need to adapt to climate change through making towns and cities more resilient.

4.116. Green spaces will have a role to play in rainwater harvesting and storage, with measures to address the challenge of flooding. Street trees play an important role in cooling the air and shading and need to be protected and planted. The need for a green space strategy or green infrastructure plan can lead a more holistic approach to green space planning, design and management.

4.117. Developing spaces which adapt to climate change can also bring wider benefits through creating additional open space and improving the quality of the environment.

[7] Policy based on practical rather than ideological objectives

Climate Change: Adaptation by Design, 2007

Outline

4.118. Published by the Town and Country Planning Association, with support from CABE, RICS, the Environment Agency and English Partnerships, 'Adaptation by Design' highlights the need to build climate resilience into the built environment to enhance the future quality of life in Britain's urban areas.

4.119. Climate change presents a major challenge to planners, architects, urban designers and developers in that the design life of most projects is between 40 and 100 years – meaning that the environments which today's projects will have to cope with are essentially unknowable (although predictions are obviously highly valuable). It is therefore imperative to design in appropriate feature to provide, for example appropriate temperature control and water management while making use of low energy, sustainable, materials.

4.120. The report proposes a framework for delivering adaptation action at the regional and local levels, together with guidance for local authorities and stakeholders to create local adaptation strategies. It also outlines best practice in delivering adaptation measures through the design and development process.

Analysis

4.121. The built environment, whether in cities or in rural areas, plays a major part in creating landscape character. However, traditional British building forms and street design may become increasingly unsuitable for the changing climate; therefore a suitable sustainable design ethos must be developed for new development.

4.122. The study suggests that UK designers should learn from the vernacular architecture of areas with climatic conditions comparable to those we are likely to experience in coming decades. In the interests of sustainability, the report prioritises passive design features, such as solar orientation, urban form and building envelope insulation to buffer the effects of increased temperatures; similarly, the use of high quality greenspace, permeable hard surfaces, SUDS and green roofs to buffer the effects of severe rainfall and alleviate flood effects.

4.123. In terms of landscape impact, it is unlikely that areas allocated for housing in development plans will change radically. Apart from the increased risks from flooding, settlement location will be broadly similar. However, the urban form of new developments is likely to be far better designed (or should be) to make the most of natural ventilation and temperature control and feature better designed green/blue space. It is the design details of individual buildings that are likely to change, but it will still largely be the choice of site and the interaction of buildings with their context that will govern their impact on the landscape. In fact, the need to incorporate adaptation measures in design may in fact result in an improvement of the general standard of urban and architectural design.

Key areas of risk and uncertainty

4.124. If previous rates of change in the mass house-building and construction industries are any indicator, the most serious area of uncertainty is likely to be the willingness and ability of companies to meaningfully adopt appropriate design measures within the required timeframe. (This can be viewed in comparison to the Scottish Government's

ongoing attempts to improve the general standard of design in Scotland, with mixed results.)

4.125. A key threat is clearly that from flooding, against which the precautionary principle must be applied in a far more stringent manner than is currently the case. Development affecting the functional capability of floodplains, or proximal to flood-prone areas should be more effectively discouraged in tandem with the development of more effective predictive tools. This should also preserve landscape quality in such areas, and enable the development of floodplain woodland or wetland environments to more effectively buffer the effects of flooding.

4.126. Although planning authorities have to balance a variety of objectives, they should be encouraged to seek 'no-regrets' options for land use in risk-prone areas. However this may raise conflicts between low risk development locations and landscape quality and character.

Urban Design – Adapting to Climate Change, 2007

Outline

4.127. Comprising several articles by various specialist authors, this climate change-focussed edition of Urban Design magazine, published by the Urban Design Group, centres on applying principles of good quality sustainable design to 'future proofing' the built environment.

4.128. The articles deal with a range of subjects, including:

- location of development and urban form;
- transport planning for climate change;
- progress to date in designing for climate change;
- greenspace, landscaping and planting;
- use of urban characterisation in understanding the challenges and opportunities presented by climate change;
- designing to 'beat the heat' through passive cooling;
- urban drainage;
- planning policy and climate change; and
- Local Climate Impacts Profiling (LCLIP);

4.129. Drawing on the UKCIP02 scenarios, and the main messages for urban design therein (changing conditions across the lifespan of buildings; location of development; summer overheating; increased frequency of severe weather events) the articles attempt to present design options and solutions for these primary challenges.

Analysis

4.130. Broadly, the conclusions of the various papers are very similar to those of the TCPA study outlined above. The key consideration of this collection of articles is the incorporation of climate change into spatial planning policy.

4.131. While individual components, such as SUDS and greenspace, have featured in the common lexicon of planning for some time, the 'joining up' of these components is a relatively recent phenomenon. However, as buildings are replaced fairly infrequently and whole neighbourhoods even less so, even the best policy framework can only really affect the course of new development. By integrating the design of buildings, open/green space, sustainable drainage infrastructure, hard surfaces and street trees more robust developments can be created with a range of 'climate proofing' measures built in. It will inevitably take time for such measures to be implemented in relation to existing developments and urban areas as retro-fitting such infrastructure is inherently more problematic than in a new-build context.

4.132. Again, the potential for landscape impacts is relatively low as such large-scale development are likely to be in urban areas or in areas otherwise allocated for development through relevant spatial plans. Where planning authorities adopt decision-support tools such as Local Climate Impacts Profile (LCLIP), the improved understanding of climate-related issues should result in higher quality design of settlements and proposals as authorities are able to specify appropriate infrastructure and urban design measures.

4.133. At the local level, there is the potential for changes to the character of settlements through the use of more sustainable construction materials may present a contrast between traditional or prevalent materials. However, if good design principles are applied by designers, developers and planning authorities, this can readily respect context while providing an interesting and stimulating counterpoint to existing built forms.

Key areas of risk and uncertainty

4.134. The nature of planning policy development – particularly through the development plan process – means that there is limited scope for rapid reaction to emergent issues. As local development / local plans are the principal material consideration for planning applications in Scotland it is imperative that relevant provisions relating to 'climate friendly design' are incorporated at the earliest possible opportunity. However, the five year cycle of development plan production does not readily lend itself to such spontaneity. In practice, the use of supplementary guidance (SG), approved by the Scottish Ministers, is perhaps the most suitable vehicle for instituting standards of design for adaptation measures that ensure a suitable level of protection of landscape quality.

Applying the Principles of Landscape Ecology to Green Infrastructure Planning, 2007

Outline

4.135. Published as a discussion paper by Dr. Janet Jackson, this study attempts to reconcile the process of designing green infrastructure (GI) into development with established ecological principles.

4.136. The paper highlights the fact that, although individual developments may be subject to Environmental Impact Assessment, the actual long term cumulative effects of development are rarely monitored or understood. Jackson proposes the adoption of landscape ecology as the discipline that can provide a spatial and temporal perspective on land use, biodiversity and the strategic planning of ecosystem services.

Analysis

4.137. The paper outlines recent work that has examined the effects of urbanisation on species and habitats, and how behaviour in certain instances has adapted to take account of the human landscape. Jackson suggests that the current 'urban growth agenda,' which focuses on regeneration and high density development, is not conducive to the incorporation of bio-diverse and ecologically functioning greenspace within new urban environments. However, this would seem to deny recent developments in national and regional policy across the UK which is prioritising the development of green networks in parallel with more traditional development goals. Habitat connectivity has become a key factor in assessing the environmental impact of proposals, and SNH has been instrumental in this.

4.138. The author also makes a limited argument in favour of 'eco-towns' that, she argues, provide space for 'permaculture, community farms, and orchards, collection of rainwater and control of surface drainage...' which, while true, displays a limited appreciation of trends in urban design and sustainable planning that have developed across Europe during the last decade.

4.139. However, the fact that landscape ecology principles have a valuable application in planning new developments cannot be denied. As the effects of climate change take hold, creating robust habitat networks that can facilitate the adaptation of species to emerging conditions will be fundamental.

4.140. In terms of landscape impact, the development of functional and resilient networks of appropriate greenspace should have positive effects on landscape quality, particular where development focuses on the regeneration of derelict sites that may currently present a barrier to biodiversity.

Key areas of risk and uncertainty

4.141. As noted in relation to the previous paper, the speed at which the policy process moves may be the most significant barrier to progress. Climate projections are, in this respect, less significant as the development of habitat networks should theoretically be a 'no-regrets' adaptation measure.

Climate Change and the Historic Environment, 2008

Outline

4.142. Published as national-level policy statement by English Heritage, 'Climate Change and the Historic Environment' represents the latest thinking in relation to the effects of climate change, and mitigation and adaptation responses, on built heritage. It is intended to provide guidance to stakeholders in the historic environment as well as those involved in the wider scientific and technical aspects of climate change.

Analysis

4.143. The historic environment is particularly vulnerable to a range of factors resulting from climate change. Given the nature of much of the nation's heritage, it cannot be relocated on common-sense grounds and also because context is often vital in informing the significance of a site or monument. Indeed, landscapes themselves are artefacts of human activity and are often highly significant. Much of the archaeological record lies beneath the topsoil and, although invisible, is vulnerable to erosion or shifts in agricultural practice. Similarly, many assets are located in

vulnerable locations – such as flood plains, river valleys and the coastal zone – as these were the most accessible areas for much of the past.

4.144. The potential effects on the historic environment can be summarised thus:

- **Direct Effects:**
  - rising sea levels and increased storminess threatens historic landscapes, structures, buildings and archaeology in the coastal zone;
  - increased extremes of wetting and drying heighten the risk of ground subsidence and accelerated decay of stonework;
  - more frequent intense rainfall, causing increased erosion on archaeological sites and damaging flooding in historic settlements – often making historic buildings difficult to insure (thus threatening their long-term survival);
  - changes in hydrology that threaten buried archaeological remains, including well-preserved wetland archaeology, at risk;
  - changes in vegetation patterns that threaten visibility and integrity of archaeological remains and historic landscapes;

- **Adaptation Impacts:**
  - 'managed realignment/retreat' on undeveloped coast threatens archaeology, buildings and landscapes;
  - 'hard' flood defences, particularly in historic towns, can cause major archaeological damage and impair historic character;
  - loss of design integrity of historic buildings and landscapes as a result of stormwater storage or disposal systems, or flood protection features;
  - alteration of agricultural practice could pose a threat to buried archaeology and vernacular farm buildings and historic landscapes;

- **Mitigation Impacts:**
  - renewable energy infrastructure may have direct effects on archaeological remains;
  - renewable energy may compromise the setting of sites, monuments or designed landscapes;
  - biomass crops may pose a threat to buried archaeology through deeper ploughing and lowered water tables, or may radically alter the appearance of historically significant landscapes;
  - micro-generation technology must be sensitively sited to avoid impacts on the integrity or setting of historic assets;
  - poorly designed or inappropriate energy-efficiency measures could severely detract from the value of historic buildings.

4.145. As the historic environment plays a fundamental part in informing landscape character, great care must be taken to ensure that adaptation and mitigation measures preserve the integrity and setting of assets. Direct effects on archaeology may be harder to mitigate, and may be a question of preserving sites and landscapes by record in advance of their inevitably inundation or erosion by the sea, or destruction through other climate-driven processes.

4.146. As protection of the historic environment is relatively well incorporated into the planning framework, the impact of development proposals will be effectively considered – particularly through consultation with Historic Scotland where particularly significant sites are threatened.

Key areas of risk and uncertainty

4.147. The nature of the likely effects of climate change will disproportionately affect particular types of site and monument. It should therefore be a national priority to conduct rigorous analysis of the potential effects of climate change on the historic environment with an eye to conducting extensive research into sites that are likely to be lost. It may be advisable to also focus attention on archaeological landscapes as, given the greater scales involved, the potential for loss is increased. The Historic Land Use Assessment dataset may provide an interesting route into assessing vulnerability at a landscape scale when interpolated with climate and topographic data.

4.148. The historic environment also has the potential to make a significant contribution to emissions reductions and energy efficiency targets, as a large proportion of Britain's building stock is over 100 years old and, as such, represents a significant investment of embodied energy that should be preserved.

TOURISM AND RECREATION

Climate Change and the Visitor Economy: the Challenges and Opportunities for England's Northwest; and Changes to Climate and Visitor Behaviour, 2006

Outline

4.149. This Climate Change and the Visitor Economy (CCVE) research was undertaken by Sustainability Northwest (Manchester) and the UKCIP (Oxford), in 2006, to examine the impacts of climate change on the visitor economy in England's North West. This literature review also draws from an article in the Journal of Sustainable Tourism (McEvoy et al, 2008) which also outlines the findings of the research. The work was commissioned as the pilot project for the Department for Environment, Food and Rural Affairs (Defra) Cross-Regional Research Programme on Climate Change Impacts and Adaptation. The study was the first in the UK to assess the interaction between climate change, visitor behaviour and environmental capacity. Both the findings and methodologies, although focused on England's Northwest, are transferable to other regions of the UK and internationally.

Analysis

4.150. Based on the UK Climate Impacts Programme (UKCIP) risk and decision-making framework the research programme was set out as a series of eight interlinked issues, as follows:

- understanding climate-related visitor response;

- exploring visitor response to climate change;
- changes in visitor demand under differing socio-economic scenarios;
- interaction of climate change and socio-economic change on regional visitor behaviour;
- influence of climate change on environmental capacity;
- case study analysis of costed adaptation responses in 'vulnerable' locations;
- case study analysis of capacity building in 'less-vulnerable' locations;
- interaction with related sectors especially farming, forestry, health and transport.

4.151. The first regional scoping of climate change impacts in the UK was undertaken in the Northwest of England due to the geographical diversity of the region which provides a 'microcosm of the English landscapes'. In the Northwest there are 30 landscape character areas, many of which are key visitor attractions. The region has 32 NNRs, four AONBs, three National Parks and one Heritage Coast. The visitor economy in the region currently generates £7bn of expenditure with a large proportion of the visitor market being based on day trips. A key aim of the regional tourism strategy is to increase visitor numbers, however this will lead to further pressure on the facilities and, in particular, the landscapes on which the visitor economy depends. The CCVE includes case studies of tourism within climate sensitive landscapes (the coast and the uplands) the content of which were gained through a series of workshops. A summary of the findings are outlined below:

1. **Integrity of the Sefton Dune System:** The Sefton Dune System is a landscape of international significance for biodiversity; it is also the setting for recreation activity including a number of golf courses. Impacts of climate change are anticipated to be an influx of visitors to the cooler coastal areas when temperatures in urban areas increase. The coastal protection function of the dunes will also become more important due to a rise in sea level but this may be compromised by increased visitor numbers. The Sefton Coast Management Scheme is currently an example of best practice in controlling visitor flows and protecting the dune habitats but it is likely that the Scheme will now have to also consider future climate change impacts.

2. **Moorland Wildfires in the Peak District National Park:** The Peak District is a popular destination for outdoor activities such as hill walking and mountain biking and visitor pressure can adversely affect biodiversity despite management schemes. A further issue is that of fire risk which will be exacerbated by the warmer, drier, summer conditions anticipated in relation to climate change. Preventative measures to reduce the risk include reseeding to create less vulnerable habitats and gully blocking to raise the water table. Other strategies include access restrictions during periods of high risk.

3. **Footpath Erosion in the Lake District National Park:** The Lake District is a key recreation area for day visitors. Climate change impacts are likely to include the loss of protective snow cover and greater winter rainfall levels which will both result in further erosion of upland footpaths. The research also notes that future climate conditions will result in more all year round access to the Fells, particularly due to the availability of increasingly sophisticated outdoor clothing and

equipment. Several adaptation strategies are outlined to tackle this including footpath repair and visitor management.

Key areas of risk and uncertainty

4.152. The findings are replicable in the Scottish context as both the coastal and upland landscapes studied are comparable with a Scottish equivalent. The research findings have illustrated that climate change, far from enhancing the opportunities for tourism, will reduce the carrying capacity of valued rural landscapes on which tourism within the Northwest depends. The study has also highlighted that socio-economic factors will also influence the landscape through differing recreation patterns. The findings illustrate that effective adaptation will require a number of changes to current landscape and tourism management including greater monitoring and data collection alongside modelling techniques. Management systems are outlined including the Limits of Acceptable Change (LAC) model which is used in the Cairngorm ski area and the Sustainable Visitor Management System both of which can be used to control adverse landscape impacts. Several implications for policy are also outlined including the need to consider climate change to a greater extent within tourism policy which should take into account the vulnerability of the landscape resource.

Demand for Outdoor Recreation: A Report for Natural England's Outdoor Recreation Study. Paper 2, 2005

Outline

4.153. The Henley Centre was commissioned, in 2005, to undertake a study of the future demand for outdoor recreation (to 2020) by the Outdoor Recreation Strategy Project Board. The Board comprises representatives from the Countryside Agency, English Nature and the Rural Development Service. The research examines a number of factors which will influence demand for outdoor recreation, known as 'drivers' and the implications of these for Natural England's Outdoor Recreation Strategy. The research was based on a literature review and series of workshops.

Analysis

4.154. The key drivers of demand for outdoor recreation were identified as being:

- an increasingly affluent society – an increase in disposable income and the opportunity to participate in outdoor recreation experiences;
- wellbeing – health promotion and a greater awareness of the benefits of outdoor recreation (both physically and mentally);
- reconfiguring age – larger older population and a more sedentary younger population;
- increased availability of information – availability and quality of information relating to the outdoors;
- social inclusion – a more inclusive society should result in those from a wide variety of backgrounds taking part in outdoor recreation;
- risk averse society – perceived risk (e.g. in relation to health risks, safety risks) of outdoor recreation could either increase or suppress demand;

- convenience culture – how popular outdoor recreation is will depend on how convenient it is due to the nature of the time pressured society.

Key Areas of risk and uncertainty

4.155. These issues comprise areas which must be addressed if participation in outdoor recreation is to be encouraged to a greater extent over the next 20 years. If the reasons for aversion are tackled and those for engagement are supported and enhanced then greater numbers will participate in recreation pursuits. Those drivers with a particular implication for the Scottish landscape include a growing desire to engage with the natural world ('retuned to nature'), a drive towards physical activity and health and a focus on the 'experience' economy. If, as predicted, these factors become more important within society, then numbers of visitors to Scottish outdoor tourism destinations will increase, with associated impacts on the carrying capacity of the landscape.

COAST, ESTUARIES AND SEA

Climate Change Issues at the Coast: Adapting to a Dynamic Landscape, 2007

4.156. SNH produced a Guidance Advice Note on Climate Change Issues at the coast: Adapting to a dynamic landscape in 2007. This document explores coastal specific climate change drivers which include:

- rising mean sea level (which acts like inflation behind all other processes);
- variations in storminess;
- increases in wave height;
- reductions in coastal sediment supply; and
- ever present development pressure.

4.157. In addition to the above, changes to land levels are influenced by isostatic changes resulting from the rebounding of the land following the melting of the ice cap centred on Rannoch Moor.

Potential Impacts of Climate Change on Sea Levels around Scotland, 2001

Outline

4.158. SNH commissioned research which was published in 2001 to explore the potential impacts of climate change on sea levels around Scotland.

4.159. SNH commissioned the study to allow them to quantify potential future changes in sea level along with other impacts such as storm surges around Scotland in order to know how best to manage coastal habitats for nature conservation:

1. to determine the predicted magnitude and geographical variation of sea level rise, and the range of possible scenarios, which will be experienced by coastlines in Scotland over the twenty-first century, taking into account regional variation in isostatic readjustment (i.e. the rebound of the land following the loss of ice after the last Ice Age); and

2. to illustrate the maximum extreme tidal levels which may be experienced around the Scottish coastline in the twenty-first century, taking into account elevations resulting from storm surges.

Analysis

4.160. The report considers the varied factors which influence sea level including rebound of the land following the melting of the ice, thermal expansion of the oceans and the melting of glaciers, ice caps and ice sheets. The report also notes the importance of changes in patterns of storminess in the future on sea levels.

4.161. The report highlights that soft and low-lying intertidal habitats such as mudflats, beaches and saltmarshes are especially sensitive to changes in the marine environment. Where humans have developed the land up to the coastal edge and built defences to protect these developments, the natural erosion and inland progression of coastal features cannot take place.

Foresight Future Flooding, 2004

Outline

4.162. Research was undertaken by the Flood and Coastal Defence project of the Foresight Programme. Foresight is run by the Office of Science and Technology under the direction of the Chief Scientific Adviser to the British Government. The research builds on the Foresight Flood and Coastal Defence project to explore issues within Scotland in greater detail. The research:

- identifies how the drivers of future flooding and coastal erosion operate and interact differently in Scotland;
- assesses the magnitudes of their impacts on flood risk;
- ranks the importance of the drivers for Scotland for four future scenarios over the period 2030 – 2100.

Analysis

4.163. The research highlights the range of morphologies within Scottish rivers which includes a high proportion of active gravel-bed rivers. It identifies that these rivers with steep gradients and coarse bed materials have the ability to rework the valley floors unless constrained by bank reinforcement. The landscape implications of this are highlighted as follows:

'Gravel bed rivers can exhibit significant lateral shifts during flood periods and under future warmer and wetter climate conditions predicted for the 2080s this could potentially shift rivers outwith their indicative floodplain.'

4.164. Further landscape impacts include the implementation of sustainable flood management. This is likely to include restoring wetland habitats and enlarging floodplain storage. It is noted that the recent trend in Scottish flood management schemes has been the combination of upstream storage and downstream flood embankments which looks set to continue and increase. Landscape impacts will also result from the need to provide new or upgraded flood defences for existing urban areas. The EU Water Framework Directive is likely to increase the use of floodplains and wetlands to provide temporary storage of floodwater.

Coastal Flooding

4.165. The research identifies the main economic sectors at risk (in the absence of effective flood defences) in each of the local authority areas. This identifies locations where the most extensive flood defence measures are likely to be implemented:

- *Moray* Residential and commercial properties in Forres and Elgin were severely inundated during the 1997 and 2002 floods. There is also a long history of summer storms inundating prime agricultural land and severing important rail and road links.

- *Aberdeenshire and Aberdeen City.* There is little by way of flood risk in the catchments in and around Aberdeen and this is largely focused on agricultural land and coastal recreational areas.

- *Angus, Perth and Kinross and Fife.* Perth is the largest urban area at risk (severely flooded in 1993 but now with a much higher level of flood defence), although Crieff is also locally vulnerable plus some prime agricultural land in the Carse of Gowrie and Dundee airport. The Bridge of Earn (also flooded in 1993) will soon see its flood risk reduced by new defences. Much of the coastal zone in north-east Fife is vulnerable to sea-level rise and coastal flooding, including Tentsmuir, RAF Leuchars and the St Andrews golf links.

- *Falkirk, West Lothian, Stirling, Edinburgh and East Lothian.* The Grangemouth refinery and the Longannet Power Station are both below the 5m OD contour, as is a significant amount of residential property in Grangemouth and Stenhousemuir and residential and business properties in and around Stirling. Within Edinburgh, flooding severely affected residential properties alongside the Water of Leith in 2000. Commercial properties at Haymarket and Murrayfield are also considered to be at risk. Haddington in East Lothian has a long history of flooding and remains vulnerable to storms over the Lammermuir Hills.

- *Glasgow, East Ayrshire, North Ayrshire, South Ayrshire, West Dunbartonshire, East Renfrewshire and Renfrewshire.* Residential properties are at risk from inland flooding in Kirkintilloch, Paisley and Johnstone – all were inundated in 1994. The White Cart Water in south-west Glasgow has a history of urban flooding. Coastal flooding was especially severe in Helensburgh and Dumbarton in 1991. Coastal surges inundated Saltcoats on the Ayrshire coast in 1990s – the area is now covered by a flood-warning scheme. The River Irvine generates some inland flooding of residential and commercial properties in Kilmarnock.

- *Dumfries and Galloway.* Most of the flooding in this local authority area is on agricultural land, but urban flooding on the River Nith has repeatedly occurred at the Whitesands in Dumfries, involving many commercial properties.

4.166. Significant exposure to flood risk is focused on a relatively small number of local authorities. Glasgow City, Edinburgh and Falkirk account for 38% of the inland fluvial flood risk, while East Dunbartonshire and Argyll and Bute account for 28% of the coastal flood risk. It is also striking that Moray and Falkirk have high levels of both inland and coastal flood risk. This arises, in part, because 10-13% of the area covered by the Moray and Falkirk local authorities falls either within the indicative floodplain or the coastal area below 5m OD.

4.167. This identifies areas where flood defence measures are likely to be implemented in future and where the potential landscape impacts are greatest.

Atlantis Policy Makers Summary – Atlantic Sea Level Rise: Adaptation to imaginable Worst Case Climate Change, 2002

Outline

4.168. The ATLANTIS project was financially supported by CEC DG Research under contract EVK-CT-2002-000138. The project was conducted by the Centre for Marine and Climate Research, Hamburg University; the International Institute of Applied Systems Analysis; the Flood Hazard Research Centre, Middlesex University; the Stockholm Environment Institute and its Oxford Office; the Institute for Environmental Studies, Vrije Universiteit Amsterdam; and Institut Symlog de France.

4.169. The project studied what would happen if the West-Antarctic Ice Sheet (WIAS) were to collapse. The study was based on the worst case scenario of an additional five metre sea level rise within a century. The study used this scenario in order to identify if society can cope with the predicted impacts. The study conducted three case studies in the Rhone delta, the Thames estuary, and the Rhine/Meuse delta.

Analysis

4.170. The study results indicate that 5-6 metre sea level rise in a century would cause severe problems, even in rich, technologically adept and well-organised societies such as France, the Netherlands and the United Kingdom. In particular the study suggests that across the three case study regions there would be abandonment of lower value areas. However should flooding occur prior to the implementation of protective infrastructure, this may lead to even abandonment of higher value areas as people feel unsafe and migrate from poorly protected areas.

Coastal Processes and Climate Change Predictions in the Coastal Study Areas, 2006

Outline

4.171. Research was carried out as part of the LIFE Environment Project 2003-2006 'RESPONSE': LIFE 03 ENV/UK/000611 by the Isle of Wight Centre for the coastal environment. The project aimed to "*develop and test an effective, transferable methodology for coastal evolution studies and risk mapping that can be applied across the EU to allow local authorities and Regions to assess and prepare for the impacts of climate change along their coastline*". The report comprises two sections: an assessment of coastal processes and a review of predicted climate change in the RESPONSE Coastal Study Areas.

4.172. The study aimed to develop a mapping methodology to identify and prioritise coastal hazards, in view of the likely impacts of climate change. The mapping methodology is based on a geomorphological characterisation and sensitivity analysis, integrating the best current climate change predictions. The study examined case studies in five regions Central-South Coast of England, North-east Coast of England (North Yorkshire), Central-East Coast of Italy (Regione Marche), Languedoc-Roussillon Coast of France and The Aquitaine Coast of France.

Analysis

4.173. The study identifies that climate change and sea level rise will result in an increase in the probability of damaging events. The impacts on the landscape relate to the uncertainty of how operating authorities will be able to manage the increased risk. A

potential consequence is that defences that are currently protecting marginally economic and clearly uneconomic sites will either be abandoned or maintained at a lower standard of protection. However there may also be a need to improve standards of protection in high risk urban areas in response to the lower risk tolerance in society.

UK Future Coast, 2002

Outline

4.174. The research was commissioned by the UK government Department for the Environment Food and Rural Affairs (DEFRA) and carried out by a team lead by the Halcrow Group and completed in 2002.

4.175. Coastal dynamics is a complex area influenced by the range of spatial and temporal scales over which coastal changes occur. There is also inter-dependence between the different features which make up the system.

4.176. The FUTURECOAST project identifies the different elements that make up the coastal structure and developed an understanding of how these elements interact on a range of both temporal and spatial scales.

Analysis

1.17. The softer shorelines are most sensitive to changes in environmental conditions such as climate change impacts. However changes in conditions can take decades or centuries to occur and changes taking place at the shoreline over the next century may be a continuation of a response to events that occurred some time in the past.

SNIFFER Coastal Flooding in Scotland: A scoping study, 2008

Outline

4.177. The research was commissioned by SNIFFER, the Scotland and Northern Ireland Forum for Environmental Research, and was undertaken by the School of Social and Environmental Sciences at the University of Dundee, and published in 2008. The study examined the risks posed by coastal flooding. The study was commissioned to provide greater understanding of coastal flood risk. Policy on managing coastal flooding is less well developed than for river based and pluvial flooding in cities. The project scoped the risks posed by coastal flooding in Scotland.

4.178. The study objectives were:

- identify historic coastal flood events – source, scale, impacts and any commonalities or trends;
- identify areas of current flood risk at a generic level;
- identify future trends at a national level using the latest UKCIP scenarios and other recent relevant research;
- make initial and generic (not site specific) recommendations or management options for addressing, minimising and adapting to coastal flood risk in Scotland.

Analysis

4.179. Much of Scotland's coastline has experienced coastal flooding with the Solway Firth, the Moray Firth, Aberdeenshire and the Firth of Clyde reporting the highest number of events. The frequency of flooding in the north west is lower than for other parts of Scotland. This is likely to reflect the variations in coastal characteristics, with a greater proportion of hard cliff coastline and fewer low lying coastal settlements. Additionally the major river systems of Scotland drain to the east,

4.180. The North Atlantic Oscillation is a major driver for storms and coastal floods in the North Atlantic, and positive values of the NAO index are associated with a higher incidence of coastal floods in Scotland. The NAO index is likely to become more positive by 2080, and therefore the frequency of coastal floods may increase throughout the 21st century.

4.181. The study identified that the occurrence of extreme water levels at four tidal gauges (Aberdeen, Millport, Lerwick and Stornoway) is determined by the combination of predictable tides, rising sea level and independent surges drawn from a distribution which shows no evidence of increased storminess.

4.182. Relative surge risk has been mapped and shows the highest threat of surges at the head of estuaries; the Solway Firth, the inner Moray Firth, the Clyde estuary, the Forth and Tay Firths and Loch Linnhe. In the Outer Hebrides there is a strong difference between the exposed western coastline and the more protected eastern coastline.

4.183. Risk involves combining hazard and damage and the number of properties at risk of being inundated by a 1 in 200 year coastal flood has been calculated by the Scottish Government. Falkirk is the local authority with the highest exposure to coastal flood risk, however new coastal flood defence schemes have been brought forward since the survey. Future flood risk depends on a range of factors including:

- global mean sea level rise;
- regional uplift or depression of the land surface;
- tidal changes (reflecting local changes in mean sea level);
- changes in wave heights and the frequency and severity of storm surges.

Managing flood risk and landscape implications

4.184. Current legislation on flood risk management for Scotland includes UK-wide legislation (The Coastal Protection Act 1949), legislation which only applies to Scotland (the Flood Prevention (Scotland) Act 1961 as amended) and the EC Directive on the Assessment and Management of Floods (2007/60/EC) which will be transposed into Scottish law by a new flooding act. Further relevant legislation is anticipated in the draft UK Marine Bill, which proposes a Marine Management Authority with competence to oversee spatial planning in the offshore zone.

4.185. New and enhanced coastal protection schemes often with flood defence functions have been or are being put forward for Bo'ness (Falkirk Council), Rothesay (Argyll and Bute Council), Clyde (Glasgow City Council), and Saltcoats and Largs (North Ayrshire Council). The report notes that managed realignment is not seen as a universal panacea for flood alleviation, although acknowledges that there may be an enhanced role locally for such schemes.

4.186. Landscape implications of managing coastal flood risk will be focused in those areas highlighted above with the highest level of identified risk and urban locations which require protection, and where hard coastal flood defences are likely to be implemented. Managed realignment is likely to only be considered in less urban locations where the value of the resource to be protected does not merit the costs associated with hard defences. Therefore flood defences are likely to be of greatest extent within urban areas, and the protection of other areas of land will be influenced by the relative costs and benefits associated with implementing and maintaining flood defences. Where the coastline is not defended there may be issues with erosion, and inundation by sea water, with impacts on coastal habitats and farmland and changes in vegetation.

FRESHWATER SYSTEMS

Climate Change: Flooding Occurrences Review, 2002

Outline

4.187. Research was commissioned by the Scottish Executive Central Research Unit (2002) to review flooding occurrences. The research was carried out by Werrity, A. Black, A., Duck, R. University of Dundee, and Finlinson, B., Thurston, N., Shackley, S., and Crichton, D., Entec UK Limited.

4.188. Climate change predictions for Scotland's climate are for wetter and more stormy weather and sea level rise. This will result in an increased flood risk both inland and along low-lying coasts.

4.189. The study comprises five parts:

- historic overview of past flooding in Scotland;
- predicted future flooding under climate change scenarios;
- the economic impact of current and future flooding;
- public awareness and concern about flooding;
- recommendations and priorities for further research.

Analysis

4.190. Sea level rise will have a varied impact on the coast of Scotland, with minimal impacts on hard, rocky coasts but widespread impacts on sand/dune machair systems and open beaches. The research identifies that the most profound impacts may be on estuaries where landward migration of estuarine morphology is predicted. The study identified the need for better tools to manage floods and improve public awareness, much of which has been implemented through the SEPA indicative flood maps and more detailed floodplain mapping at a local authority level.

HABITATS AND SPECIES

MONARCH, 2001

Outline

4.191. The study Modelling Natural Resource Responses to Climate Change (MONARCH) was published in 2001 and was commissioned by a consortium of nature conservation organisations in Britain and Ireland, as part of the UK Climate Impacts Programme. The study evaluates the impacts of climate change on wildlife and geomorphological features in Britain and Ireland.

4.192. The study identifies the potential implications for species and habitats in four environments: terrestrial, freshwater, coastal and marine. Winners and losers emerge, including some species threatened with national extinction. The study also indicates gaps in knowledge and the implications of the research findings for policy makers. The study was carried out under the UK Climate Impacts Programme (UKCIP). The impacts of climate change on the distribution of suitable climate space were modelled for 33 plant, four insect, two amphibian, one mammal and 10 bird species associated with 12 habitats of conservation concern. Responses were highly variable, with some of each category losing and some gaining climate space. The ability to move and the ecological suitability of the new climate space will also be vital in determining the future distribution of species in Britain and Ireland.

Analysis

4.193. The following summarises the findings relating to the main habitats of relevance to Scotland:

- **Montane heaths** occur high in the windswept mountains of Scotland, Montane heaths are also the most sensitive to climate change of all the habitats analysed. Under the various climate change scenarios, all montane heath species show a loss of climate space.

- **Upland hay meadows** are found on the better soils in the higher parts of England, Wales and Scotland. Their survival will depend crucially on how farmers respond to climate change and other pressures.

- **Upland oak woodlands** Oak woodlands occupy many of the poorer soils and steeper slopes of the upland north and west of Britain and Ireland. Oaks themselves may grow vigorously enough under warmer conditions, and may colonise mountain sides that are currently too cold for them. But the other vegetation of these woodlands is likely to suffer seriously as soils dry out in summer.

- **Native pine woodland** Native mixed woodland, dominated by pine, used to be found over large areas of the Scottish Highlands, but it has been reduced to about 1% of its former range and is now only found in the Grampians and the northern and western Highlands of Scotland. Climate change could lead to the spread of Scots pine *(Pinus sylvestris)* to higher altitudes, aided by an increased growth rate, but also a reduction in the east. It could, however, be adversely affected by increased windthrow, as the less frozen soils provide less anchorage, loss of biomass and regeneration ability through increased temperatures and competition from less cold tolerant species.

- **Wet heath and acid grassland** While these habitats may cover the same amount of land in the future, they may shift in response to climate change. Wet heaths may expand in Ireland and in some northern and western areas of Britain where increased winter rainfall waterlogs formerly dry heath.

- **Peat bogs** Peat bogs are among Europe's rarest and most threatened habitats. There are several types of peat bog, each with characteristic species. Britain and Ireland hold a significant proportion of the world's total area of certain types of bogs. Suitable climatic conditions will persist for some types of peat bog, but the species composition of the plant communities may well change. The dominant vegetation of most bogs is sphagnum moss, of which there are many species. The study investigated the likely future extent of *Sphagnum papillosum*. Its climate space is likely to remain and possibly enlarge across Britain and Ireland.

- **Coastal ecosystems** can be expected to retreat inland, at least partially compensating for sea level rise. Salt marshes that are inundated at their seaward boundary could reform further up the beach. But along most of the coasts of Britain and Ireland, sea defences designed to protect farmland and human settlements will impede this retreat (commonly termed coastal squeeze). They both block off natural retreat and deprive the coastal waters of the sediment from coastal erosion that is necessary to help create new structures such as salt marshes. The likely resulting loss of salt marshes will damage the populations of many wildfowl and some waders, such as golden plover *(Pluvialis apricaria)* and lapwing *(Vanellus vanellus)*, by depriving them of habitat used for feeding and breeding.

Gaps and future research

4.194. The study identified a number of gaps in the knowledge and data. The climatic variables which will determine the climate space available for species, habitats and geomorphological systems require further study, as do the sensitivities of a wider range of species. In addition more research is needed on the potential for and possible rate of migration of species. Further work is also required on how wildlife communities are likely to change and the future role of non native species.

Conserving Biodiversity in a Changing Climate, 2007

Outline

4.195. Published by Defra on behalf of the UK Biodiversity Partnership (2007), this is a guidance document aimed at those who plan and deliver conservation of terrestrial biodiversity. The document sets out six guiding principles which summarise current thinking on how to reduce the impacts of climate change on biodiversity and how to adapt existing plans and projects in the light of climate change. The document focuses on adaptation responses, but highlights that our ability to predict the way in which biodiversity will be influenced by climate change is limited.

Analysis

4.196. A number of direct key impacts of climate change upon biodiversity have been identified from observational data and models of future trends. They include:

- changes in the timings of seasonal events, leading to loss of synchrony between species and the availability of food, and other resources upon which they depend

shifts in suitable climate conditions for individual species leading to change in abundance and range changes in the habitats which species occupy;

- changes to the composition of plant and animal communities;
- changes to habitats and ecosystems, such as altered water regimes, increased rates of decomposition in bogs and higher growth rates in forest.

4.197. The document also identifies that some of the most dramatic changes may occur on the coast as a result of sea-level rise exacerbated by extreme weather events, which may lead to alterations in the balance between accretion and erosion on saltmarshes, sand dunes and shingle beaches on low-lying coasts. There may also be change to the erosion of cliffs and complex changes in the water regimes and landforms of estuaries and tidal rivers.

4.198. The six guiding principles identified in the document, which have implications for the management of habitats and the landscape include:

- conserve existing biodiversity;
- reduce sources of harm not linked to climate;
- develop ecologically resilient and varied landscapes;
- establish ecological networks through habitat protection, restoration and creation;
- make sound decisions based on analysis;
- integrate adaptation and mitigation measures into conservation management, planning and practice.

4.199. Management of the landscape now based on these principles will promote biodiversity and support resilience in a future changing climate.

MACIS Project – Climate Change Impacts on European Biodiversity, observations and future projections, 2008

Outline

4.200. Minimisation of and Adaptation to Climate change Impacts on biodiversity (MACIS) was a 2 year project which started in November 2006, see www.macis-project.net. The project provides a detailed assessment of observed and potential impacts of climate change on biodiversity. Research was produced in April 2008 which sets out Climate Change Impacts on European biodiversity – observations and future projections.

Analysis

4.201. European species and ecosystems are reported to have responded to climate changes in a wide range of ways including:

- upward shift of species (e.g. tree line and alpine species);
- phenological changes (e.g. advanced timing of flowering, breeding and migration);
- increased productivity and forest carbon sinks;

- invasion of evergreen broad leaved species in Alpine forests;
- disappearance of wetlands and changes in vegetation composition.

4.202. Other changes include bird species which have changed their winter locations or even stopped migrating. The study also highlights the role of climatic conditions in determining suitable regions for certain species. A warming by 1°C in Europe corresponds approximately to a 150km shift northwards in temperature isotherms or a shift upwards in altitude by 150 -180m. European climate zones are generally projected to move from south west towards north east.

Climate Change and its Consequences for Snowbed Vegetation, 2007

Outline

4.203. Effects of climate change on bryophyte-dominated snowbed vegetation Part 1: Cairngorms Gordon Rothero, John-Arvid Grytnes, John Birks and David Genney 2007 (Interim report with work continuing into 2008).

4.204. Snow accumulates on the high Scottish mountains where wind blows snow onto lee slopes, which tend to form in the same places each winter and can persist in large patches into July. The persistent snow cover on these sites has an effect on the vegetation, which tends to be dominated by bryophytes, with a significant lichen element on the drier soils. Bryophyte-dominated snowbed vegetation is rare in the UK, covering only a few hundred hectares and it contains a number of nationally rare and scarce species and so is of considerable conservation interest.

Analysis

4.205. Systematic observation of these long lasting snowbeds which have areas of bryophyte-dominated vegetation, shows that, since the survey in 1989, there has been a general decline in both the duration of snow cover and of the size of patches that persist into the summer months (Watson et al., 2006). It is possible that this trend is a manifestation of global climate change and certainly corresponds to some of the models of change in the Cairngorms that have been proposed (Ellis & McGowan in Shaw & Thompson, 2006). Whatever the cause, the likelihood is that this trend towards smaller and less persistent patches of snow in the summer months will have some effect on the bryophyte-dominated vegetation that currently occurs on these sites.

4.206. The survey aims to look at possible changes in the vegetation first by a resurvey of the vegetation of the Cairngorm sites surveyed in 1989 to try to pick up changes within the various snowbed communities since that date and second by setting up fixed point photographs and permanent plots so that future change across the whole site can be assessed.

Key issues and uncertainty

4.207. A comparison of photographs from the 1989 survey shows some changes, although these changes must be interpreted with caution due to the poor quality of the 1989 photographs and that they were not taken with the view to being used for future comparison. The main finding emerging to date is that although the gross extent of snowbed vegetation is largely unchanged, there have been changes such as a reduction in the areas of gravel with sparse vegetation cover. A large number of other

variables are likely to play a role in snowbed vegetation, and future re-survey is likely to provide further data to inform the findings to date.

Birds on the Move Introducing a Climatic Atlas of European Breeding Birds, undated Summary (undated)

Outline

4.208. RSPB and Birdlife International produced an atlas of the potential future range of the average European bird species. The Atlas identifies that this range will shift by 550km north east by the end of this century and will reduce in size by a fifth.

Analysis

4.209. In order to address these changes the document highlights the need for better stewardship of protected areas to make them more resilient to climate change. In addition much bigger areas of new habitat should be created and the wildlife value of all land should be improved.

Key issues and uncertainty

4.210. The Atlas acknowledges that other factors than climate change may limit the breeding range of species, such as the availability of a limited habitat such as cliffs or human persecution. Additionally there may be delay in the development of suitable conditions, as habitats change.

4.211. The main message from the Atlas is the potential impact of the human response to provide new suitable habitat for species, supported by habitat networks. In addition there will be a future need to adjust the management of nature reserves and protected areas to reflect changes in species' distributions.

Designing Urban Spaces and Buildings to improve Sustainability and Quality of Life in a Warmer World, 2008

Outline

4.212. The article in *Energy Policy* by Smith, C. and G. Levermore. Explores the negative impacts of a warming climate in cities. The urban heat island effect is responsible for temperature differences of up to 7 ^{0}C between cities and the country in the UK. The European summer heatwave in August 2003 was estimated to be responsible for over 2000 fatalities in the UK, and the impacts of this event were most strongly felt in urban areas because of a lack of night time relief from high temperatures. The problem is identified as becoming increasingly heightened under future climate change scenarios and predictions of urbanisation.

Analysis

4.213. More built up or denser cities have a more intense heat island effect. Vegetated areas have a cooling effect as water evaporates. The document notes that on a neighbourhood scale the presence of a vegetated area or water body within a city can have a significant cooling effect on local temperatures.

4.214. Key measures to reduce the heat island effect include actions to reduce solar radiation absorption by buildings, and increasing the rate of heat loss. The greening of urban environments by planting more vegetation to encourage evapotranspiration

and the reduction of solar gains by using high reflectivity materials in urban structures have been cited as measures to reduce thermal discomfort.

4.215. Micro climate modification through the use of vegetation can also be integrated into the building envelope through the use of green roofs or bio shaders. Future planning and development can help to reduce the urban heat island effect considerably by adding to the evapotranspiration of built up areas with green spaces. Green roofs will also contribute to the openness of the urban area, to allow cooling winds to take away the heat. The technology exists, and it is for planning and policy commitments to ensure that it is used.

Planning for Biodiversity in a Changing Climate, 2007

Outline

4.216. The study was carried out by the BRANCH partnership for Natural England in 2007, and explores the issues surrounding planning for biodiversity within the context of climate change.

Analysis

4.217. Europe's fragmented landscape is likely to prevent many species from moving with shifting favourable climate conditions into new areas. How well a species can adapt will depend largely on how easily it can disperse and whether suitable habitat is available to move through and into. Spatial planning can create networks of high-quality, well connected habitats. Prioritising space between internationally important habitats and other requirements may create conflict between different land uses. Biodiversity policy must be integrated into other land use policies and look to longer timescales.

4.218. The study reviewed planning policies across north west Europe and found that planning has been slow to provide for adaptation to climate change because of :

- the low profile of biodiversity;
- uncertainties about the likely impact of climate change and how best to intervene;
- no clear vision, strategy or programme of delivery.

4.219. The study highlights the potential restriction on species movement due to the fragmented nature of wetland ecosystems. The study identifies that with predicted rises in sea level the mix of coastal habitats will change in extent, location and species assemblages. The study explored the potential impacts of climate change through coastal case studies. In the south of England the findings identified that the current loss of habitat in many intertidal areas will be exacerbated by a rise in sea level. In particular, areas of saltmarsh which dissipate wave energy may be lost. As a result of this loss sea walls will require upgrading. Freshwater habitats may also no longer be sustainable in coastal areas in the long term.

4.220. A case study on the Normandy coast of France found that mudflats, dunes, wetlands and freshwater ponds are the most vulnerable coastal habitats to climate change. Saltmarshes were found to be expanding at all the study sites, which contrasts with the findings from the UK case studies.

4.221. The study also explored the role of robust corridors to facilitate species dispersal through the Dutch National Ecological Network and the Natura 2000 sites along the Dutch-German border. The modelling results show that the robust corridor is most effective for ground living and small flying species. The study also identified that the design of robust corridors should focus on the species they are intended to help.

4.222. The main findings from the study stress the importance of long term spatial planning and the development of wildlife networks. The study sets out recommendations for European policy leadership, national spatial planning and policy guidance and recommendations for regional and local spatial planners.

CLIMATE CHANGE AND THE LANDSCAPE – WORK FROM ELSEWHERE IN THE UK AND EUROPE

4.223. This section of the report reviews work that is being carried out elsewhere in the UK and Europe into climate change and the landscape. Perhaps the most significant finding is that most work on climate change is currently conducted on a sectoral basis, with little or no interpretation in terms of the likely impacts on the landscape, is echoed at an international level. For example, work of organisations such as the European Environment Agency has focused on the direct effects of climate change (temperature rise, change in rainfall, glacier retreat) and implications for health, flooding, agriculture, biodiversity etc. While this is not perhaps surprising, it does suggest that a key level of integration is missing and that there is a risk that adaptation and mitigation strategies may neglect individual and cumulative impacts on the landscape. It also has significance in terms of communicating the implications of climate change to a wider audience.

4.224. The review has included a number of projects designed to explore public perceptions of landscape change, and to develop a range of different methods to support this, including GIS mapping, computer generated graphics and photomontages of varying levels of realism. Most of these projects have explored a wide range of drivers of change, with relatively few focusing specifically on climate change. Where climate change is addressed, there is perhaps an emphasis on illustrating mitigation measures (windfarms, biomass cultivation etc) rather than the more ‘speculative’ implications for landscape character.

4.225. Within the academic literature there has been extensive discussion of methods of translating climate change scenario information into computer generated images or photomontages, though some of the outputs have been quite narrow in their scope (perhaps illustrating the loss of single tree in a given view, or the introduction of a biomass power station) and do not always convey the scale and extent of the landscape change that could result from climate change. On the other hand, GIS based approaches illustrate the extent of change, but less often assess the implications for landscape character.

4.226. Sheppard (2005), working at the University of British Colombia in Vancouver has explored the role of landscape visualisations in raising awareness of climate change. Noting the gap between awareness and action on climate change, Sheppard discussed the relative merits of approaches which exaggerate the scale of change, prompting greater responses on the part of viewers, and those which provide a more balanced approach and which may imply that relatively little change is likely to occur.

Land use change and the countryside

4.227. Research for the Countryside Agency (Future Character and Function of England's Landscapes 2006) by LUC, University of Sheffield, University of East Anglia and the University of Reading, reviewed a number of programmes focusing on land use change. Examples include:

- **NELUP (the NERC - ESRC Land Use Programme - University of Newcastle, 1995)** This established a decision support system linking agriculture economics, ecology and hydrology and focused on the environmental impacts of agricultural land use.
- **LUAM (Land Use Allocation Model - University of Reading, 1996)** A mathematical model, based on ITE Land Classes, predicting land use patterns at the national and land class level, designed to show the effects of policy on land use type, intensity and output. **CLUAM (Climate and Land Use Allocation Model)** broadens the scope of the model by allowing the potential effects of climate change to be incorporated.
- **MEILUC (Modelling Environmental Impacts on Land Use Change - Scottish Agricultural College, with University of Newcastle and Macaulay Institute, 1998**) A review of techniques for forecasting the environmental impacts of land use change over a 5 to 20 year, or in some cases a 50 year, timescale, with particular attention to links with LUAM (see above) and Countryside Survey data.
- **Rural Futures:** A scenario project carried out under the Defra/HM Treasury Horizons scanning programme, focusing on social and economic aspects of the future for rural communities.
- **State of the Countryside 2020:** The Countryside Agency's scenarios project, focusing on social and economic aspects of future countryside.
- **SURPLUS:** A scoping study completed under the Defra/HM Treasury Horizons scanning programme, and particularly the outcome of the consultation exercise that explored the ideas of policymakers and researchers about important drivers of change and their impacts.
- **PRELUDE:** The European futures scenarios project by the European Environment Agency.

4.228. The research found that these programmes explored a common range of 'drivers' of change including:

- Governance and planning:
  - Agricultural policy and support
  - Forestry policy
  - Environmental legislation and strategies
  - Housing and wider development policy
  - Transport provision/policy and other infrastructure
  - Rural policy
  - Energy policy

- Demography:
  - Migration trends and population characteristics
  - Societal values and behaviour
  - Life style choices
  - Leisure activities

- Economic and Market trends:
  - Agricultural economy
  - Skills base
  - Land ownership

- Technology:
  - Agricultural technology
  - ICT
  - Energy

- Environmental change:
  - Environmental change
  - Climate change
  - Energy sources
  - Environmental impacts

4.229. A key finding from the research was that there is little, if any, consideration given to the influence that these different drivers have either directly or indirectly in shaping the character, or the quality of future landscapes. The research tends to deal with individual land uses, such as agriculture and forestry, from which landscape effects have to be inferred. The report concludes that this reflects the generally poor understanding or recognition of the concept of landscape character amongst researchers of rural issues and a failure to address the changes in landscape that are ongoing.

4.230. The research did identify three UK projects that had applied the outcome of spatial modelling projects to interpret the landscape implications of the forecast changes, namely:

- University of East Anglia 'Futurescapes' research;

- Environmental Change Institute, Oxford, research;

- Countryside Agency / Ethos work on Visualising Renewable Energy.

4.231. These are considered below.

4.232. In addition, LUC has recently been commissioned by Natural England to carry out the first phase of the South West Future Landscapes project. This study will develop the approach described above, tracing the patterns of past and future landscape change in the South West, in response to key drivers including climate change.

UEA: Futurescapes

4.233. This project is investigating the practicalities of reinterpreting the available climate change impacts information from existing research (frequently at the national scale, or related to specific sectors) at a scale more useful to local stakeholders/policy makers. In this project, the subject is the rural landscape and how climate change will interact with changes in farming practice, and the consequences for water supply and demand, soils and biodiversity.

4.234. The approach taken in the research is the development of landscape-scale 'scenarios' of climate change impacts derived from policy guidance documents and

the climate change impacts literature, expressed as visualisations of potential future landscapes. Visualisations are mainly in the form of digitally-altered photographs but for landscapes in Norfolk and the Humberhead Levels, and computer-generated visualisations derived from a GIS database are also being developed. For these sites producing VRML 'Virtual Reality' models are also being produced which offer the possibility for a user to 'fly through' the landscape or 'visit' particular locations of interest to them. The work is being funded by the Jackson Foundation and the Countryside Agency.

4.235. The research was based on UKCIP02 climate change scenarios and drew on two socio-economic scenarios:

- **world markets** where economic development is prioritised over environmental protection; and
- **local stewardship** where there is a strong emphasis on protecting the landscape.

4.236. It also included some landscape changes unrelated to the climate.

4.237. Under the world markets scenario, the following changes were modelled:

- intensive farming practice, or a switch to leisure landscapes, with no biodiversity enhancements;
- soil erosion, baked-earth, die-back of trees, poor quality stressed vegetation - pretty much the results of a long-drought summer but including flash-flood type damage, and maybe wind damage to trees, etc.

4.238. Under the local stewardship scenario, the following changes were modelled:

- summer drought but in a less extreme way as measures would have been put in place to prepare and lessen the impacts of climate change - e.g. water use efficiency measures, changes in farming practice etc. This scenario also includes introduction of new food crops and also industrial crops - biofuels etc responding to the need for society to decarbonise.

4.239. Visualisations (photomontages and computer generated graphics) were prepared for the 2020s in the following parts of England:

- Norfolk arable;
- Humberhead Levels;
- Severn-Vyrnwy;
- Northumberland;
- High Weald.

4.240. Figure 2.1 shows one of the computer generated images, while Figures 2.2-2.4 show a selection of photomontages. UEA's work focused on a locally defined landscape character areas. Within the Humberhead Levels, for example, it drew on North Lincolnshire Council's landscape character assessment, selecting intensively farmed land alongside the River Trent near the village of West Butterwick.

4.241. While the photomontages illustrate changes in vegetation that might result from summer drought, the most obvious changes illustrated relate to climate change mitigation, in the form of biofuels and wind energy.

Figure 2.1: computer generated image

(a)

(b)

(c)

Figure 2.2: Humberhead Levels (Ref: http://www.uea.ac.uk/~e384/landscapes.htm)

(a) Existing (b) 2020 under world markets with climate change

(c) 2020 under local stewardship with climate change

(a)

(b)

(c)

Figure 2.3: Norfolk Arable (Ref: http://www.uea.ac.uk/~e384/landscapes.htm)

(a) Existing

(b) 2020 under world markets with climate change

(c) 2020 under local stewardship with climate change

(a)

(b)

(c)

Figure 2.4: Northumberland

(a) Existing

(b) 2020 under world markets with climate change

(c) 2020 under local stewardship with climate change Ref: http://www.uea.ac.uk/~e384/landscapes.htm

Northmoor Trust : Wittenham Clumps Project

4.242. The Northmoor Trust is based in South Oxfordshire and manages an estate of 300 hectares, including a nature reserve, a conservation farm and woodland dedicated to forestry research. The purpose of the work reported here was to devise a set of 'future landscape scenarios' over three future time periods for an area around the Trust's estate. The 'future landscape scenarios' comprise narratives and land use maps.

4.243. The 'future landscape scenarios' were developed using UKCIP climate-change and socio-economic change scenarios and used a Geographic Information System (GIS) to characterise the landscape and to encapsulate the land-parcel selection criteria in sets of simple rules, which were then applied to a land use map of the project area. The resulting maps of potential future land cover will be used to generate three-dimensional visualisations showing the landscape under each scenario.

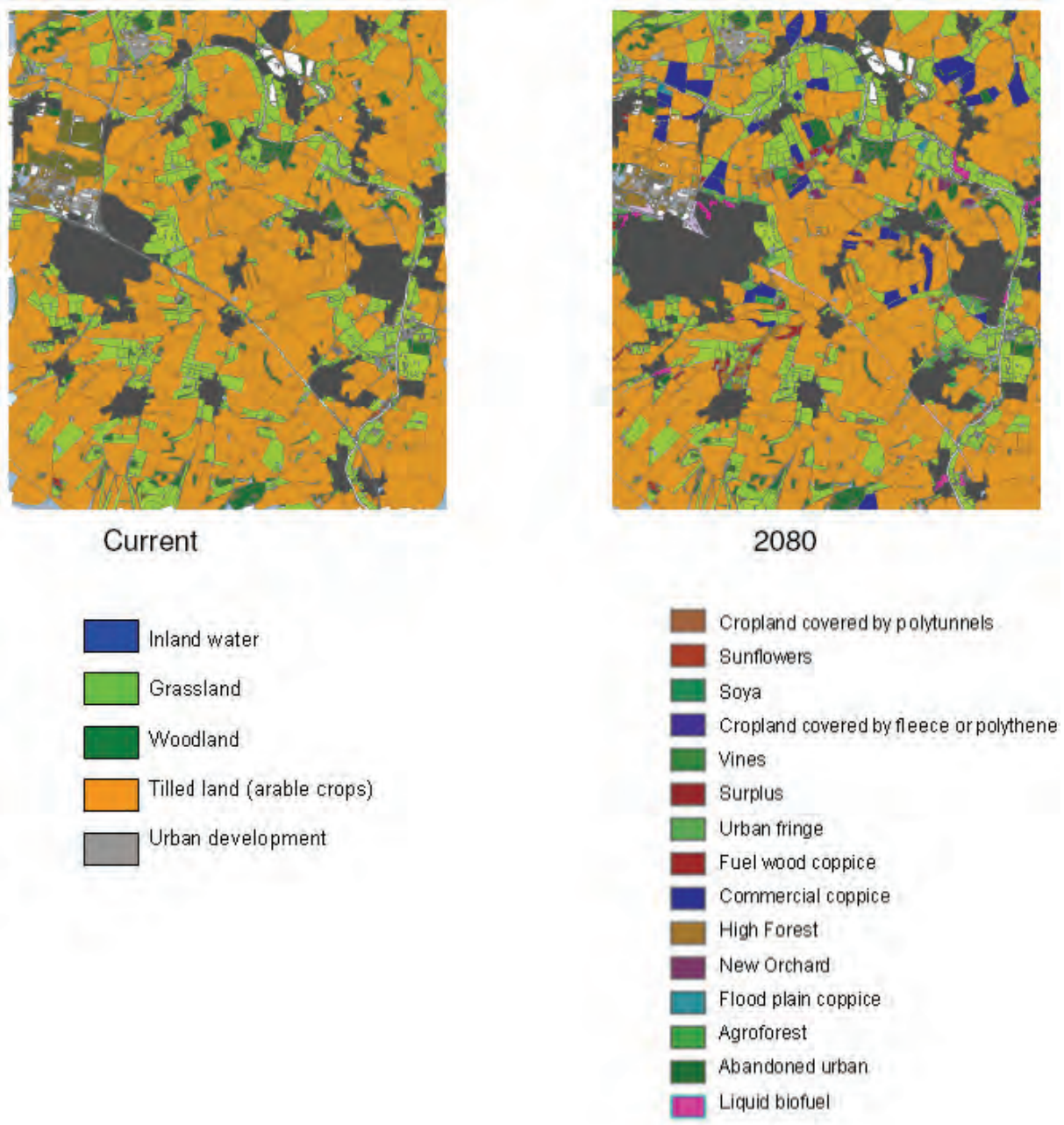


Figure 2.5: Potential changes in land use by 2080 under the Global Economic scenario

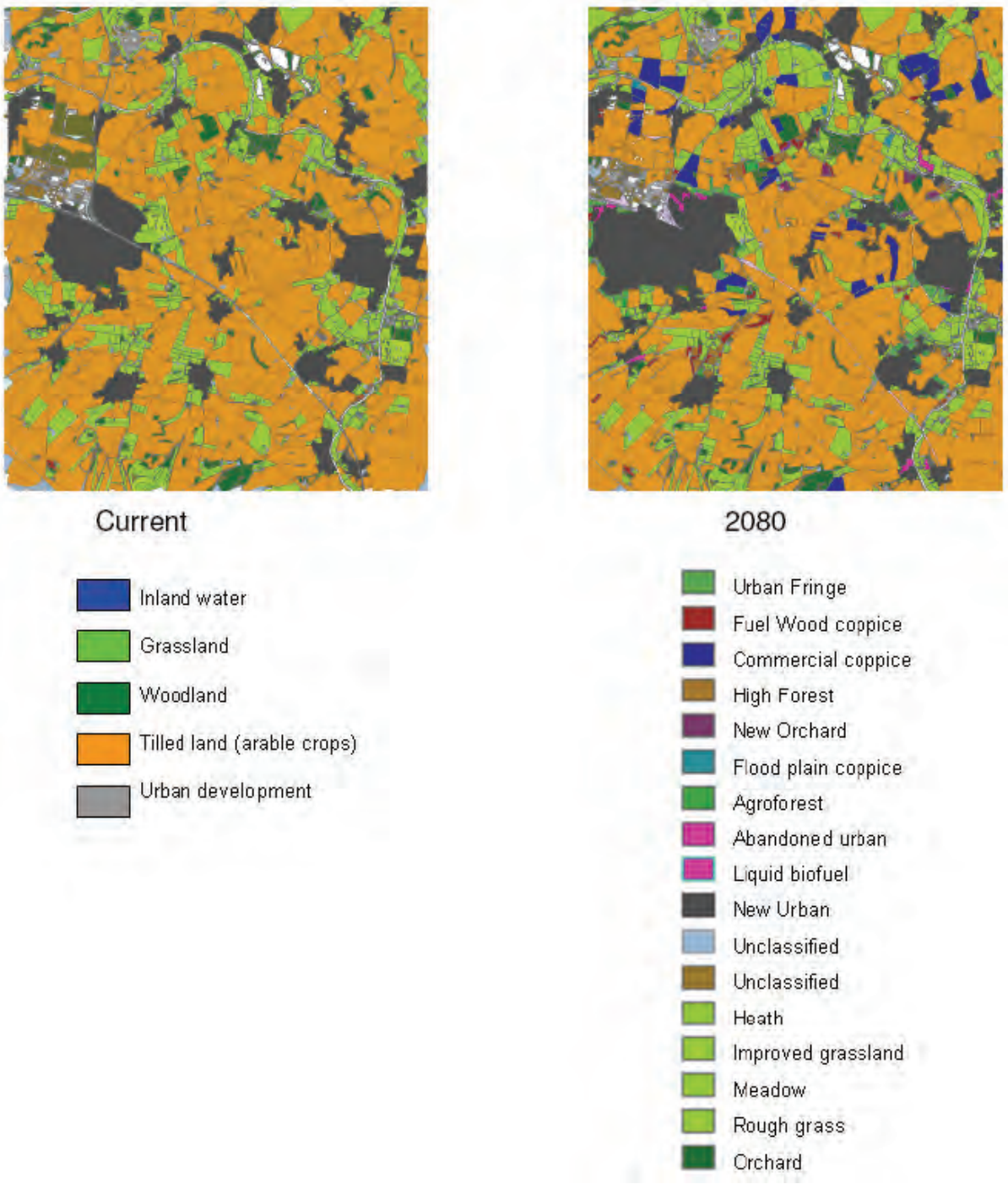


Figure 2.6 : Potential changes in land use by 2080 under the Regional Sustainability scenario

Countryside Agency/Ethos Visualising Renewable Energy in the Landscape of 2050

4.244. Countryside Agency/Ethos work on Visualising Renewable Energy in the Landscape of 2050. Here the visualisations were based on the idea of typical landscape types referred to as the 'eastern' type (flat low-lying coastal areas, typical for example of the Fens, and the 'western' type typified by low rolling hills and mountains and probably intended to represent areas like the Welsh borderlands. Models of these typical landscapes were constructed digitally, allowing different futures to be illustrated. There was, however, no attempt to make these illustrations realistic. They are clearly intended to be broadly representative of both types of landscapes and possible changes and are effective in achieving this, but they have not been used to test public responses and so their effectiveness as a form of communication cannot be judged.

Figure 2.7 : western landscape – present day and 2050

Figure 2.8 : eastern landscape – present day and 2050

ADAS – Headline Indicators on the Impact of Climate Change on South Eastern Protected Landscapes (2006)

4.245. ADAS (2006) carried out a scoping study into the likely impact of climate change on protected landscapes (Areas of Outstanding Natural Beauty and National Parks) in the south east of England. It considered impacts on agricultural, biodiversity, cultural, geological and river features and included both a scientific and a 'journalistic' interpretation of the impacts of climate change in the region. The research concluded that:

- climate change will have a major impact on some important aspects of protected landscapes, as a consequence of changes in biodiversity, agricultural activity, coastal morphology and cultural heritage features;
- climate change will affect both landscape quality and character of protected landscapes but should not affect their function. The research highlighted the need to communicate the reasons for changes, the loss of some features and the creation of others;
- climate change may affect the volume and nature of public use of protected landscapes;
- there are some clear opportunities, particularly in relation to agricultural production and reductions in food miles;
- the management of some key biodiversity features such as beech, ancient woodland and dry heathland will need to change to reflect the incidence of storm damage, drought and increased fire risk. Changes in the timing of the growing season (earlier spring and later autumns) may affect the timing of visitor peaks (e.g. flowering of bluebells, turning of leaf colour in autumn) and hence the public appreciation of these areas;
- cultural features will be affected with elements such as veteran trees being lost, but the focus of management on conservation rather than preservation should help the process of adaptation for historic buildings etc.;
- geological features could see the greatest changes and would be most difficult to address through the management of protected landscapes. The work highlighted the national importance of features such as the White Cliffs in the Kent Downs AONB;
- work is required to ensure that management plan objectives, and in particular the detailed actions, are still relevant and achievable under climate change.

Visualisation Tools for Public Participation in managing Landscape Change (Visulands)

4.246. The principal objective of VISULANDS is to develop and apply of visualisation tools to support public involvement in the assessment of landscape change. It is a European Commission funded project and is being used across a range of landscape changes and is thus not focused specifically on issues relating to climate change. More detailed objectives are:

- to develop visualisation techniques to assess future landscapes;
- to develop quantitative indicators of landscape change;
- to provide a robust set of preference models applicable to European landscapes;
- to test the potential to link assessments of visual qualities and production, socio-economic, ecological, cultural and amenity functions;
- to test the effectiveness of visualisation tools in communicating the outcomes of policy and planning decisions on landscape evolution;
- to exploit the project results and tools through the production of educational materials and outreach schemes for professional training and the public.

4.247. In the UK, three studies are being brought forward under the project:

4.248. Clashindarroch in Aberdeenshire where a native woodland project is being developed around the margins of a large Forestry Commission Scotland productive forest. As part of the Visulands project, a series of visualisations have been prepared showing different stages of woodland development;

4.249. On the Isle of Wight, the Visulands project is being used to explore the development of forest habitat networks to reverse fragmentation of woodlands under a range of different support schemes;

4.250. Clocaenog in North Wales where the Visulands project is being used to explore the visual implications of alternatives to clear felling management, such as Low Impact Silvicultural Systems or continuous cover.

4.251. Figure 2.9a to 2.9c show three of the visualisations prepared as part of the Clashindarroch work.

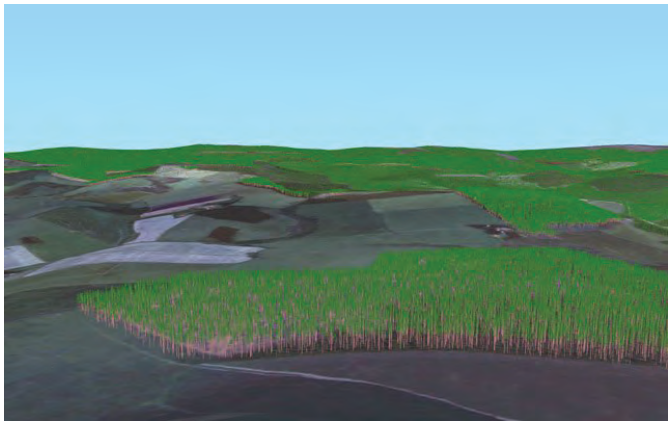


Figure 2.9 a

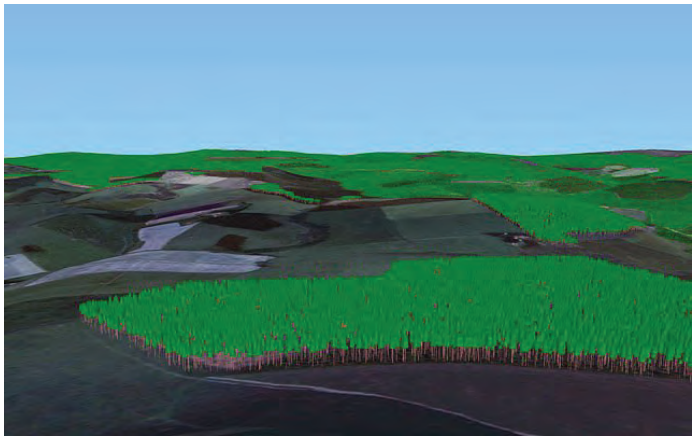


Figure 2.9 b

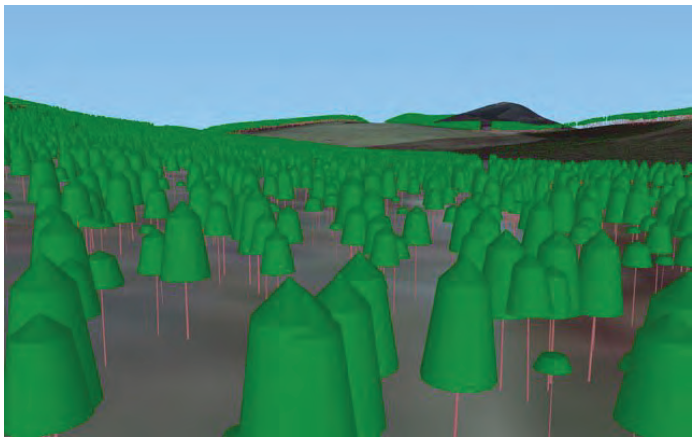
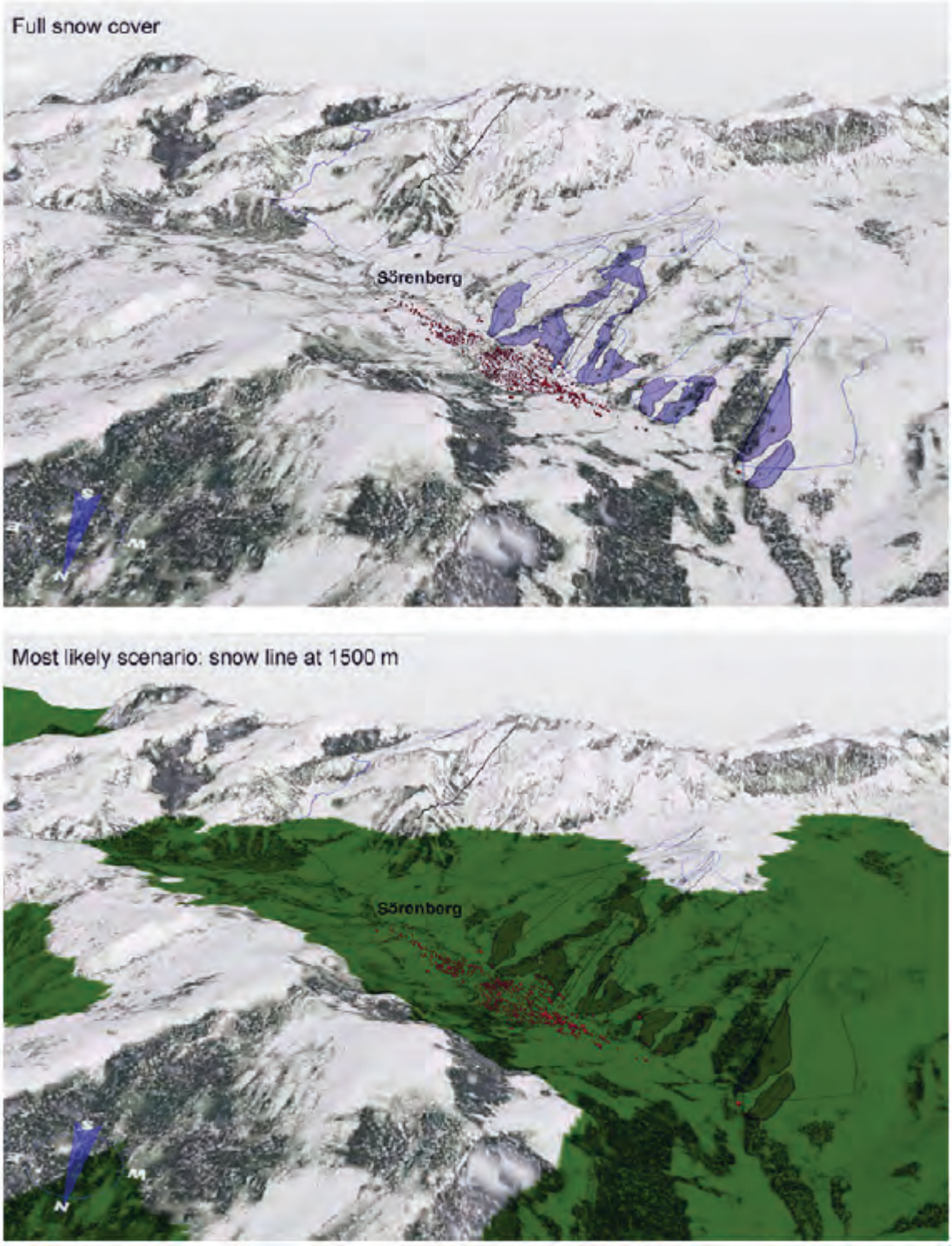


Figure 2.9 c

4.252. Other project partners have used the Visulands project to develop realistic representations of real or typical landscapes, using these to explore the implications of different patterns of land management, the interaction of tourism and biodiversity and the effects of settlement expansion. A project run by the Swiss Federal Institute of Technology focused on the Entlebuch UNESCO Biosphere Reserve and explored range of potential landscape issues as means of stimulating early public debate. Of most relevance to this project is work carried out in relation to the village of Soerenberg where climate change could affect the ski-industry which plays a major role in the local economy. One of the key results of an early workshop was the identification of climate change as a key driver of change because the skiing areas of Soerenberg are lower than those of the competitors and will be one of the first to suffer from global warming. Visualisations (**Figure 2.9 a and 2.9b**) were prepared showing the existing situation and the implications of a rise in the snow-line. Further analysis was used to link these changes to the location of chalets, hotels and other accommodation. Discussion with local stakeholders highlighted the importance of shifting away from the previous narrow focus on winter sports to the diversification of tourist opportunities towards hiking, education and farm holidays, based on a recognition of the landscape as a key asset. There was also a move to improving ski infrastructure at higher elevations.



Average level of sufficient snow conditions for skiing (snow line) in comparison to the existing infrastructure: The green areas are below the average level, black lines represent the ski lifts, the blue areas are covered with artificial snow and the village is shown in red. The second variant represents the most likely climate change scenario (3D visualisation: VisuLands 2005; geodata courtesy of GIS Canton Lucerne).

Figure 2.10 a and b

The Guardian: 2020 Vision

4.253. In 2004 The Guardian newspaper ran a series of supplements illustrating life in the year 2020. The supplement covered a range of different influences including increasing traffic congestion and suburban sprawl. Two of the images related directly to the issue of climate change – the first illustrating the impact of climate change in the Italian Alps, the second on the Dorset town of Shaftesbury. The images do not appear to have been based on climate change scenario information, and adopted a dramatic and eye-catching approach to the issue. As such, they were powerful ways of raising awareness, but perhaps poorer reflections of what is likely to occur within the predicted timescales.

Figure 2.11: The Guardian 2020 Vision, climate change in Shaftesbury, Dorset.

Figure 2.11: The Guardian 2020 Vision, climate change in the Italian Alps.

Analysis of Approaches to Communicating Change

4.254. The examples provided above illustrate a range of approaches to communicating landscape change. The images were produced for a number of different purposes, and the appropriateness and effectiveness of these images depends on a number of considerations. Issues to be considered include:

- the audience to which the change is being communicated;
- the familiarity of the audience with the landscape in question;
- the purpose of illustrating the change: is it intended to invoke a reaction or inform discussion?
- image size: the perceived impact of landscape changes may vary depending on the relative importance of different features within the image;
- the representativeness of the images in reflecting typical viewpoints and experiences of the landscape. An overview image may not illustrate how the landscape experience is affected for example by the introduction of tall crops/hedgerows/woodland/buildings etc. which may limit views in what was previously an open landscape. Aerial viewpoints or mapped illustrations can provide an overview of larger scale landscape changes which may be more relevant to illustrate landscape scale change, but may be less easy for people to relate to in terms of everyday experience.

4.255. As illustrated in the previous examples the Futurescapes project is developing Virtual Reality' models which offer the possibility for a user to 'fly through' the landscape or 'visit' particular locations of interest to them. This approach seeks to provide a more realistic and interactive approach to experiencing landscape change. This indicates that the use of a range of illustrative methods to provide a number of experiences of a particular landscape is likely to provide the most comprehensive understanding of landscape change. The combination of maps, images and text can be used in different ways to support this variety of landscape experiences, however the approach should be tailored to the specific audience and intended purpose of the illustration process.

5. SIGNIFICANT LANDSCAPE CHANGES

5.1. The following pages comprise:

- Table 5.1 which sets out information from the UKCIP02 Scenarios for Scotland – these are the key inputs to the study. The coding in column 1 is used to attribute climate related landscape changes set out in Tables 4 and 5.5 to specific components of climate change;

- Table 5.2 which explains the column headings and provides a key to the classification used in Table 5.4;

- Table 5.3 which provides explanation of the abbreviations used in Table 5.4 and 5.5;

- Table 5.4 which comprises the Climate Change Matrix itself (long matrix);

- Table 5.5 which comprises the prioritised Climate Change Matrix (short matrix, prioritised list).

5.2. This section summarises the analysis based on UKCIP02 projections. Appendix 11 provides a detailed analysis of UKCP09 projections.

Table 5.1: Climate changes: derived from the UKCIP02 predictions for Scotland

	Variable	UKCIP02 high emission scenario for 2080	Confidence level
T1	Temperature	Warming of 0.3 to 0.5 per decade	High
T2		Greatest warming +3.5 to +4.5 in autumn across whole country except far north	High
T3		More marked seasonal difference between summer / autumn and winter	High
P1	Precipitation	Winter precipitation increases by 20-35% in the south, east and north east	High
P2		Summer precipitation decreases by 30-50% in south, central and east Scotland	High
P3		Larger differentiation between drier summer and wetter winter seasons	High
V1	Variability	With regard to temperature, winter and spring become less variable by up to 25%, however inter-annual variability is increased in summer by 25% across south Scotland , and in autumn by 15-25% across almost all of Scotland	High
V2		With regard to precipitation, there is a reduction in the intra annual variation in summer across almost all of Scotland, reaching 30% in south, central and west Scotland	Low
C1	Cloud cover	Slight decrease in summer cloud cover, except in the extreme north and north west. Slight increase in winter cloud cover in some northerly areas	Low
H1	Humidity	Relative humidity decreases across the whole of Scotland in spring and summer and all of Scotland bar the extreme north and north-west in autumn and winter	Medium
SN1	Snowfall	All of Scotland will receive at least 50% less snowfall than at present and over 70% less in the eastern half of the country	Medium
SM1	Soil moisture	The highest changes are in summer and autumn, with a reduction in soil moisture in summer and autumn of 10-40% in all of Scotland bar the Highlands	High
SM2		Soil moisture levels are higher than present in winter with an increase of up to 10% across most of Scotland	Medium
P4	Precipitation intensity	Increases in winter	High
T4	Temperature extremes	Number of very hot days increases, especially in summer and autumn Number of very cold days decreases, especially in winter	High
W1	Wind speed	Daily mean wind speed with a 2 year return period will increase slightly in winter and decrease in summer	Low
T5	Thermal growing season	Increase everywhere	High

	Variable	UKCIP02 high emission scenario for 2080	Confidence level
T6	**Degree days**	**Heating degree days decrease everywhere** **Cooling degree days increase everywhere**	**High**
SL1	**Average sea level**	**Global sea level will continue to rise for centuries**	**High**
SL2		**Melting West Antarctic ice-sheet will contribute relatively little to global sea level rise this century**	**High**
SL3		**Global sea level rise will rise by 9-69 cm by the 2080s**	**Medium**
SL4		**Scottish sea level will be similar to global sea level**	**Medium**
SL5	**Extreme sea level**	**Storm surge return periods will fall and storm surge heights will increase**	**Medium**
ST1	**Marine climate**	**Sea-surface temperature will increase around all Scottish Coasts**	**High**

See Appendix 11 for analysis of UKCP09 data, particularly in relation to winter precipitation and confidence levels for key variables.

Table 5.2 Explanation of column headings in Table 5.4

Reference Number	To facilitate ease of reference
Topic	Categorises the type of change by primary policy grouping, however acknowledges there is some overlap between these. All impacts are grouped into one of eight topic areas: Forests and woodlands Freshwater systems Coast, estuaries and sea Urban Tourism Infrastructure Habitats (natural and semi-natural) Agriculture Hitsoric Environment
Type	Impacts are grouped into one of four types of change identified: Built structure relates to the introduction of new buildings or structures into the landscape e.g.

	buildings, irrigation booms, wind turbines Change in extent – this includes an increase or decrease in the extent of a characteristic of the environment e.g. crop cover or habitat Change in type – this reflects a change in the type of vegetation or landcover e.g. crop type or tree species Event – reflects the landscape impacts of climate related events such as flood, fire or landslide
Change and landscape implications	Describes the identified change and landscape implications
Caused by	Describes the climate variable causing the change. The symbol 09 has been used to indicate which landscape changes were potentially affected by the UKCP09 winter precipitation data (see Appendix 11) which projects different scales, spatial patterns and directions of change to UKCIP02.
Direct, mitigation, adaptation	Identifies if the change is a result of a direct impact, mitigation response or adaptation response
Climate change confidence	Reflects the confidence associated with the climate variable as defined in the UKCIP02 scenarios
Extent	Broad geographical extent of the change (local, regional, national)
Magnitude	The extent to which change will impact on the key characteristics of the landscape (high, medium, low)
Significance	Combination of extent and magnitude, classed as high, medium or low.
Timescale (short, medium and long term)	Outlines the likely timescale for the change
Source	Reference to the document which identified the change
Data source	Data which could be used to inform mapping of the spatial distribution of the change

Table 5.3 List of abbreviations used in Table 5.4

Abbreviation	Explanation
CLIO	Climate Impacts and Options
CMP	Catchment Management Plan
CRU Scoping	Climate change: Scottish Implications Scoping Study (1999)
CP	Coastal Processes and Climate Change Predictions in the Coastal Study Areas
FCS	Forestry Commission Scotland
FF	Farming Futures (topic pages)
IFS	Indicative Forestry Strategies
LCA	Landscape Character Assessment
LFA	Less Favoured Ares
NIWT	National Inventory of Woodlands and Trees
OS	Ordinance Survey
RBMP	River Basin Management Plans
RSPB	Royal Society for the Protection of Birds
SCAPE	Scottish Coastal Archaeology and the Problem of Erosion
SEERAD	Scottish Executive Environment and Rural Affairs Department
SEPA	Scottish Environment Protection Agency
SNIFFER CC02	Scotland and Northern Ireland Forum for Environmental Research (2005) Business Risks of Climate Change to Public Sector Organisations in Scotland
SNH CC AP	SNH Climate Change Action Plan
SRC	Short Rotation Coppice
SRDP	Scottish Rural Development Programme
SRNLS	Scottish Road Network Landslides Study
SUDS	Sustainable Urban Drainage Systems
TCPA	Town and Country Planning Association
TS	Transport Scotland
UDG	Urban Design Group

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
42	Forests and woodlands	Change in extent	Woodland management / expansion to increase on-farm carbon storage through shelterbelts and habitat networks	-	Mitigate	-	N	M	M	M-L	FF4	Lowland agricultural areas
44	Forests and woodlands	Change in extent	Increase in tree growth (2-4m^3 / ha) for conifers where water and nutrients not limited. Biggest increases in growth in southern and eastern Scotland	T2, T5	Adapt	H	N	L	L	M-L	FCS	Woodland types
45	Forests and woodlands	Change in extent	Colonisation by non-native species where compatible with biodiversity changing the woodland species mix	Range of changes	Adaptation	H	N	M	M	M-L	FCS	Woodland types
46	Forests and woodlands	Change in extent	Pinewoods – drier summers favour drier communities in west and central Highlands. Reduction in suitability in east, increase in west and central	P2	Direct	H	L	L	L	S-L	FCS	Woodland cover and types
47	Forests and woodlands	Change in extent Change in type	Increase in scrub above current tree line and upper edge of pinewoods – juniper, montaine willows – where grazing allows resulting in more natural treelines	T1	Direct	H	R	M	M	M-L	FCS	Woodland cover and types
48	Forests and woodlands	Change in extent	Riparian woodlands – more frequent and extensive along river corridors and area at risk of flooding used as a part of flood management	P1	Direct and adapt	H	N	M	M	M-L	FCS	Woodland cover and types. SEPA flood risk maps

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
49	Forests and woodlands	Change in extent	Removal of conifers on peatbog through possible option to ringbark and let woodland die and decay rather than clear fell – less impact on carbon storage – but landscape impacts of decaying trees	-	mitigation	-	R	H	M	M-L	FCS	Woodland on peat maps
50	Forests and woodlands	Change in extent	Woodland expansion to increase carbon sequestration	-	Mitigation	-	N	H	H	M-L	FCS	IFS data (FCS)
51	Forests and woodlands	Change in practice	Expansion of Low Impact Silivicultural Systems (LISS), except on windiest sites resulting in changes in appearance of woodland	-	Adaptation	-	N	H	M	S-L	FCS	Woodland types
52	Forests and woodlands	Change in type	Deep fertile soils in southern and eastern Scotland more suitable for high quality broadleaf trees resulting in change in species composition	T2, T5	Adapt	H	R	H	M	M-L	FCS	Woodland types
53	Forests and woodlands	Change in type	'Droughty' soils in eastern Scotland will become unsuitable for sitka and other drought sensitive species, increased suitability in west (except Ayrshire and Clyde valley). Increased suitability in previous marginal areas of eastern Scotland for oak and ash resulting in species change from sitka to other spruce and pine	T2, P2	Adapt	H	R	L	L	M-L	FCS	Woodland types
54	Forests and woodlands	Change in type	Broader species mix and genetic mix to improve resilience to climate and pests	T1, P1, P2	Adaptation	H	N	M	M	M-L	FCS	Woodland types

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
55	Forests and woodlands	Change in type	New woodland species – Monterey pine, maritime pine, southern beech, walnut	T1	Adaptation	H	R	L	L	M-L	FCS	
56	Forests and woodlands	Change in type	Pinewood colonisation by broadleaves (oak, birch, rowan) resulting in changes in species mix	T2	Direct	H	R	L	L	S-L	FCS	Woodland cover and types
57	Forests and woodlands	Change in type	Altantic oakwoods on western seaboard – milder winters, severe gales, warmer drier summers – loss of epiphytes, storm damage, colonisation by birch, hazel and rowan and non-natives such as beech.	T2, W1, P2	Direct	H/L	R	M	L	S-L	FCS	Woodland cover and types
58	Forests and woodlands	Change in type	Eastern oakwoods – colonisation by sycamore resulting in changes in species mix	T2, P2	Direct	H	R	M	L	S-L	FCS	Woodland cover and types
59	Forests and woodlands	Change in type	Expansion of birch to provide shade and shelter with pasture in central and eastern highlands and eastern Scotland allied to expansion / intensification of woodland in glens and up hill slopes	T2, W1, P2	Adapt	H/L	R	M	M	S-L	FCS	Land cover and farm type maps
60	Forests and woodlands	Change in type	Diversification of recently planted upland birchwoods to make more resilient – oak and hazel	T2, P2	Adapt	H	R	M	L	M	FCS	Woodland cover and types

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
61	Forests and woodlands	Change in type	Storm damage may increase in mixed broadleaves – on heavier soils,– more shrubby regeneration in woodland openings as result	P1, W1	Direct	H/L	L	L	L	M-L	FCS	Woodland cover and types Soil types?
62	Forests and woodlands	Change in type	Mixed broadleaves – species mix – increase in beech and sycamore – outcompeting oak, ash and elm resulting in changing woodland composition – loss of native species, increase in new species	T2	Direct	H	N	M	M	M-L	FCS	Woodland cover and types
63	Forests and woodlands	Event	Damage to woodlands caused by summer drought resulting in early leaf fall and dying trees	P2	Adapt	H	R	M	L	M-L	FCS	Woodland types
64	Forests and woodlands	Event	Damage to woodlands caused by winter flooding resulting in early leaf fall and dying trees especially on poorly draining soils and where linked to summer drought – most evident in eastern Scotland	P1, SM2	Adapt	H	R	M	L	M-L	FCS	Woodland types
65	Forests and woodlands	Event	Wind throw damage to woodland caused by extreme winds, exacerbated by wetter winters	W1, P1, SM2	Adapt	L/H/M	R	H	M	S-L	FCS	Woodland and exposure
66	Forests and woodlands	Event	Fire damage and prevention measures in response to increased risk of fire damage to woodlands (greatest in eastern and southern Scotland), linked to increase in recreation activity	T2, P2, T4	Direct	H	R	H	M	S-L	FCS	Woodland types

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
67	Forests and woodlands	Event	Increase in deer numbers likely due to milder winters, increase in scrub shelter – resulting in damage to new and regenerating woodlands	T2, T5	Direct	H	N	M	M	S-L	FCS	Woodland types
68	Forests and woodlands	Event	Fire damage to pinewoods – natural disturbance by fire more frequent, esp where adjacent to heather moorlands and or pop recreation areas	P2, T2, T4	Direct and adapt	H	L	H	H	S-L	FCS	Woodland cover and types
69	Forests and woodlands	Event	Fire damage to broadleaves	T2, P2, T4	Direct	H	L	H	H	S-L	FCS	Woodland cover and types
125	Forests and woodlands	Change in extent	Increased energy forests, native woodland, mixed woodland and softwood on agricultural land resulting in change in character of agricultural land through increased woodland planting	T1, P1	Adaptation	H	R	M	M	S-L	FCS discussion paper on woodland expansion in Scotland	
134	Forests and woodlands	Change in type	Damage from pathogens, fungi and insects resulting in potential loss and damage to key species however interaction with new species unclear	Range of changes	direct	L	R	M	M	S-L	FCS	
1	Freshwater systems	Built structure	Flood management comprising – upland land management (closing drains, woodland establishment), temporary flood storage, diversion of flood flows away from urban areas, green roofs, SUDS, one way valves, raising floor levels, increasing drain	P1, P4	Direct and adaptation	H	N	M	H	S-L	TCPA	SEPA flood maps, CMP / RBMPs

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			capacity, flood resilient design and materials, doubling flood defences									
2	Freshwater systems	Change in type	Algal blooms in rivers and lakes affected by eutrophication	T1	Direct	H	L	M	L	L	CRU Scoping	Water bodies at risk of eutro-phication
4	Freshwater systems	Event	Increasing flood risk from reservoir over-topping in winter, resulting in erosion	P1	Direct	H	L	L	L	L	Sniffer CCO2 App	SEPA floodmap Landcover
5	Freshwater systems	Event	Increase in river flooding severity and frequency, esp in Western Scotland	P1, P4	Direct	H	R	M	M	S-L	None identified	TS Climate change and roads (ref Black 1996)
6	Freshwater systems	Event	Flood damage to river banks and flood plains	P1, P4	Direct	H	N	M	H	S-L	Foresight Future flooding	SNH
7	Freshwater systems	Event	Physical erosion of river courses with knock on effects for river habitats	P1, P4	Direct	H	N	M	L	S-L	CLIO	SNH
76	Coast, estuaries and sea	Change in extent	Loss of coastal wetlands and intertidal habitats to the sea as they are trapped between rising seawaters and hard coastal defences	SL4 and response	Direct / adaptation	M	L	H	M	S-L	Sniffer CCO2 CP	Land cover and lowlying coastal areas

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
70	Coast, estuaries and sea	Change in extent	Changes in coastal erosion – loss of characteristic coastal features, and or managed realignment affecting cliffs, low - lying coasts and dunes	SL4, SL5, P1, P4 09	Adapt	H/M	R	H	H	S-L	CP	Geology /areas vulnerable to coastal erosion SCAPE information
71	Coast, estuaries and sea	Change in extent	Changes in coastal deposition – changing species	SL4, SL5	Adapt	M	R	M	M	S-L	CP SNH	Geology /areas vulnerable to coastal erosion SCAPE information
77	Coast, estuaries and sea	Change in type	Increased coastal protection through provision of hard and soft coastal defences, including managed realignment	SL4 and response	Adaptation	M	N	H	H	M-L	Sniffer CCO2	OS maps – lowlying coastal areas
78	Coast, estuaries and sea	Change in extent	Managed realignment along low lying coasts and estuaries	SL5, SL4, P1, P4, W1 09	Adapt	H/M/L	L	H	H	M-L	CLIO	Managed realignment projects - SNH
79	Coast, estuaries and	Event	Increased coastal flooding from sea level rise - overtopping, bypassing	SL4	Direct	M	L	H	M	M-L	Sniffer	OS maps – lowlying

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
	sea		and breaching of coastal defences due to sea level rise and increased storminess. Event, but could result in local damage to crops, buildings, habitats Sea level rise - expected to be up to 30cm by 2040-2069, although the Northern Isles and Western Isles could see >71.5cm.								CCO2	coastal areas
136	Coast, estuaries and sea	Change in extent	Abandonment of costal flood defences protecting marginal sites, increased protection of high value sites resulting in change in character of coastal areas with erosion and inundation of land in places, and increased built structures in urban areas	SL1	Adaptation	H	R	H	H	S-L	CP	
80	Coasts, estuaries and sea/ Infrastructure	Built	Increase in offshore windfarm development resulting in changes in character of coastal views. Specific local impacts where infrastructure comes onshore	-	Mitigate	-	N	H	H	S-L	Steering Group	
3	Coasts, estuaries and	Event	Flooding in inner estuaries and erosion of mudflats and shingle banks	SL5, SL4, P1,	Direct	M	L	L	L	M-L	Sniffer CCO2 App	OS maps – lowlying

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
	sea			P4, W1								estuaries
8	Urban and peri-urban	Change in type	Increased demand and use of green and blue infrastructure in urban areas. Increased provision, use and management.	T2, T4	Adapt	H	N	M	M	M	TCPA	Urban greenspace
9	Urban and peri-urban	Change in type	Stress on green infrastructure caused by summer drought and high temperatures, winter rainfall, pests and disease and increased use resulting in damage or modification of urban greenspace	T2, P2, P4	Direct and adapt	H	N	L	L	M	TCPA	Urban greenspace
10	Urban and peri-urban	Change in type	Changing building design to maximise shading, passive ventilation, use of cool materials, reflective and insulating materials	T2, T4	Adapt	H	N	M	L	M-L	TCPA	Urban areas – new communities, regen areas
11	Urban and peri-urban	Change in type	Increased provision of network of open water and water features, and green infrastructure including street trees, including new greenspaces and SUDS	T2, T4	Adapt	H	N	M	M	S-L	TCPA	Urban greenspace
12	Urban and peri-urban	Change in type	Increased and improved green infrastructure to provide shading, cooling, air filtering, linking habitats. Management and maintenance to avoid stress (watering). Link to green roofs and green facades, SUDS	T2, T4, P1, P2	Adapt	H	N	L	L	S-L	UDG	Urban greenspace

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			schemes which can capture winter rainfall for reuse, cooling and recreation									
74	Urban and peri-urban	Event	Subsidence due to changing groundwater with local impacts on buildings and infrastructure	SM1, SM2	Direct	H/M	L	M	L	S-L	TS Climate change and roads	Groundwater resources/ SEPA
123	Urban and peri-urban	Built structure	Increased levels of flood defence in urban areas, affecting urban character	P1 P3	Adaptation	H	R	L	M	S-L	Foresight future flooding	
124	Urban and peri-urban	Change in extent	Increased native woodland and mixed woodland changing character of urban and peri urban areas	T1, P1	Adaptation	H	N	M	M	M-L	FCS discussion paper on woodland expansion	
13	Tourism	Built structure	Impact on skiing industry. Since the late 1970s, there has been a reduction of 12 days with snow lying in the altitude range 100-400m per decade. Decay or removal of infrastructure. Diversification into other recreation activities. Loss of winter landscapes experience	T1, T2, SN1	Direct	H	L	H	L	S-M	Sniffer CCO2	OS map
14	Tourism	Built structure	Changing tourism products, destinations. Increasing provision of outdoor recreation infrastructure and associated facilities. Including	T1, T2, T3, P2, C1, SN1,	Adaptation	M	N	M	M	S-L	Sniffer CCO2	

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			increased erosion in upland areas, and increased pressure on coastal resources	T4, ST1								
15	Tourism	Built structures	Diversification out of snow sports. New infrastructure, decay or removal of existing infrastructure.	SN1	Adapt	M	L	H	L	S-M	CLIO	Tourism locations
16	Infrastructure	Built structure	Upgrade of road drainage infrastructure where existing flooding occurs – capacity, storage .Local effect of bigger drains, culverts, more balancing lagoons etc. See also management of landslides below	P1, P4	Adapt	H	N	M	M	S-L	TS Climate change and roads	Trunk roads and A roads in areas with high and increasing rainfall?
17	Infrastructure	Built structure	Impact on harbours through flooding of harbour facilities. Some may be upgraded, but cost may mean this is not universal.	SL4	Direct	M	L	L	L	M-L	CRU Scoping	Harbours
18	Infrastructure	Built structure	Increase in water infrastructure associated with export resulting in new large reservoirs, aqueducts etc	P1, P2	Adapt	H	L	H	M	M-L	LCA topic Paper 9	Areas of water surplus and areas of water deficiency
19	Infrastructure	Change in extent	Further development of wind energy at domestic and commercial scales. Commercial scale - focus on areas served by current and proposed grid connections with wind resource and lower environmental constraints. Also	-	Mitigation	-	N	H	H	S-M	Steering	Grid network Wind resource

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			offshore wind energy development.									
19b	Infrastructure	Change in extent	Further development of off shore wind energy	-	Mitigation	-	R	M	H	S-M	Steering	Off shore wind energy potential
20	Infrastructure	Change in extent	Further development of small scale hydro resulting in local landscape change	-	Mitigation	-	L	L	L	S-M	Steering	Areas with hydro potential
21	Infrastructure	Change in extent	Biomass power plants resulting in industrial type buildings in rural locations	-	Mitigation	-	L	L	L	S-M	Climate change and British Woodlands	Areas with biomass potential
22	Infrastructure	Change in extent	Tidal power schemes resulting in small scale – lagoons to large scale estuarine barrage projects	-	Mitigation	-	L	H	M-H	M-L	Steering	Areas with tidal potential
23	Infrastructure	Change in extent	Wave power schemes changing views of the sea and shoreline	-	Mitigation	-	N	H	M	M-L	Harnessing Scotland's Marine Energy Potential (2004)	Areas with wave potential
24	Infrastructure	Change in extent	Nuclear power stations expanding or being redeveloped at current sites	-	Mitigation	-	L	H	L	M-L	Steering	Areas with nuclear potential
25	Infrastructure	Change in type	Adaptation of architecture, urban design and landscape design to	T2, T4	Adapt	H	N	L	L	M-L	TCPA	Urban areas

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			increase community resilience to climate change Depends on nature of changes and rate of take up, especially retro-fitting. Character of built environment and spaces changes									
26	Infrastructure	event	Severe storms – damage to urban areas – buildings, infrastructure, and trees. Adaptation in design of infrastructure	W1	Direct	L	R	H	L	S-L	TCPA	Urban areas
40	Infrastructure	Built structure	Changing water treatment infrastructure through redevelopment of waste water treatment works to accommodate storm flows	P1	Adapt	H	L	M	L	M	CRU Scoping	Locations of infrastructure
73	Infrastructure	Event	Increased incidence of slope instability and landslips. Visual/landscape effect of landslip scars. Management to avoid landslips where risk to transport and infrastructure - measures including protective forestry, management of land drainage, construction of debris traps and debris channels, debris basins, stone shelters, catch fences in key locations, or even road realignment	P1, P4, SM2	Direct and adaptation	H/M	N	H	M	S-L	TS Climate change and roads TS SRNLS	See report for location of roads at risk of landslides
72	Habitats	Event	Damage to peatland – quicker	P1, P4	Direct	H	R	H	H	S-L	SNH	Peatland maps

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
	(natural and semi natural)		erosion, gullying and bogbursts									
27	Habitats (natural and semi-natural)	Change in extent	Impact on heather moorlands from damage through fire and change in extent and distribution	T1, T2, T3,	Direct	H	M	R	M	S-L	Sniffer CCO2 App	Landcover
28	Habitats (natural and semi-natural)	Change in extent	Abandonment of muirburn resulting in more uniform appearance, changing use and perceptions	T1, T2, P2	Mitigation	H	M	R	M	S-L	Sniffer CCO2 App	Landcover
29	Habitats (natural and semi-natural)	Change in extent	Loss of biodiversity, reduction in ecosystem productivity	T1-3, P1-3, SN1, SM1, SM2, T4, T5, SL4, ST1	Direct	H	N	H	H	S-L	Sniffer CCO2 App	Land cover
30	Habitats (natural and semi-natural)	Change in extent	Reduction in snow lie resulting in changes in use and perception of winter landscape	SN1	Direct	M	N	M	M	S-L	TS Climate change and roads	Elevation and temp
31	Habitats (natural and semi-natural)	Change in extent	Loss of arctic-alpine species resulting in changing micro character of highest uplands	T2, T5	Direct	H	L	L	L	S-L	SNH	Elevation
32	Habitats (natural and semi-natural)	Change in extent	Restoring peatbog to address overgrazing, burning and drainage	-	Mitigation	-	L	L	L	S-L	RSPB	Peatland maps

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
33	Habitats (natural and semi-natural)	Change in extent Change in type	Creation of habitat networks – woodland, coastal, urban resulting in changing patterns of landcover	Range of changes	Adapt	H	N	M	M-H	S-L	Climate Change and British Woodland, Forestry Commission Scotland Discussion Paper on Woodland Expansion in Scotland	Land cover
34	Habitats (natural and semi-natural)	Change in extent	Rewilding – blanket bogs, moorland, upland woodlands, managed realignment, flood plains resulting in changing patterns of landcover	P1, P3	Adapt	H	N	M	M	S-L	RSPB	Land cover
35	Habitats (natural and semi-natural)	Change in type Change in extent	Biodiversity – change in species range and composition – move north and uphill. With an increase of 1°C in mean annual temperature, there will be accompanying shifts in isotherms by c. 250-400km north and c. 200-275m uphill. This will mean a decline in availability of montane habitat by approximately 90% across Scotland	T2	Direct	H	N	M	M	S-L	SNH CC AP	Land cover
36	Habitats (natural and semi-natural)	Change in type	Biodiversity – more rapid decomposition and nutrient recycling – affecting nutrient status of some habitats – montane and moorland –	T2	Direct	H	R			S-L	SNH	Land cover

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			resulting in invasion of grasses									
37	Habitats (natural and semi-natural)	Change in type	Nutrient recycling and enrichment – with impact on nutrient poor habitats resulting in changing vegetation patterns	T1, P1	Direct	H	L	M	L	S-L	CRU Scoping	Land cover
38	Habitats (natural and semi-natural)	Change in type	Changing upland plant communities resulting from reduction in freeze thaw. Changing upland vegetation – loss of subarctic willows and other arctic alpine plants	T1	Direct	H	L	L	L	S-L	CRU Scoping	Elevation
39	Habitats (natural and semi-natural)	Change in type	Changes in peat accumulations and upland vegetation – growth where temp and rainfall increase, decay where rainfall decreases	T1, P1, P2	Direct	H	L	M	L	S-L	CRU Scoping	Landcover
126	Habitats (natural and semi-natural)	Change in extent	Increased native woodland in areas of former shrub heath resulting in change in character of former shrub heath landscapes through introduction of new woodland planting	T1 P1	Adaptation	H	L	M	M	S-L	FCS discussion paper on woodland expansion in Scotland	
127	Habitats (natural and semi-natural)	Change in extent	Expansion of oak woods and loss of associated vegetation resulting in change in extent and character of oakwoods	T1 P1	Direct	H	R	M	M	M-L	Monarch	
128	Habitats (natural and semi-natural)	Change in extent	Loss of intertidal habitats such as mudflats, beaches and saltmarshes resulting in change in local landscape character	SL1, SL5	Direct	H	R	H	H	S-L	Climate change impacts at the coast	

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
129	Habitats (natural and semi-natural)	Change in extent	Creation of new habitat networks to facilitate habitat shift and links between urban and rural areas	T1, P1, P2, P3	Adaptation	H	N	M	M	S-L	Planning for biodiversity in a changing climate	
130	Habitats (natural and semi-natural)	Change in extent	Loss of montane heath resulting in change in character of upland areas	T1, P1, P2, P3	Direct	H	L	H	M	S-L	Monarch	
41	Agriculture	Change in extent	Shelter belts to shade and shelter livestock and crops in farmed areas – especially those with livestock and with sensitive crops	T2, P1, W1	Adapt	H/L	N	M	M	M-L	FF3	farm types map
43	Agriculture	Change in extent	Loss of field boundary and other farmland trees due to storm damage and stress resulting in more open farmland landscapes	T1, P1, P2, W1	Direct	H/L	N	M	H	S-L	Steering Group	Lowland agricultural areas, glens etc.
75	Agriculture	Event	Flood damage to agricultural crops – from rainfall, sea and flood storage projects	P1, P4, SL5	Direct and adapt	H/M	L	M	M	S-L	FF1	SEPA flood maps, OS maps
81	Agriculture	Built structure	Increase in irrigation and on-farm water storage resulting in on farm	P2, T2, SM1	Adapt	H	R	M	M	M-L	FF1, FF6, FF7	

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			reservoirs and associated infrastructure									
82	Agriculture	Built structure	Increase in groundwater and surface water abstraction for agriculture (limits in coastal areas to prevent salination of ground water) resulting in pipe and pump infrastructure	P2	Adapt	H	L	M	L	M-L	FF3	
83	Agriculture	Built structure	Increased dev of anaerobic digestion to reduce methane from farm waste in dairy, cattle and pig areas	-	Mitigate	-	N	M	M	S-M	FF4	farm types map
84	Agriculture	Built structure	Different buildings – pig arcs etc	T2, T4	Adapt	H	R	M	M	S-M	FF6, FF7 (cattle), FF8 (dairy)	farm types map
85	Agriculture	Built structure	Expansion in poultry farming (prices up, costs down), more free range animals	-	Adapt	-	R	M	M	S-M	FF9	farm types map
86	Agriculture	Built structure	Improved poultry buildings and more free range animals	T2, T4	Adapt	H	R	L	L	S-M	FF9	farm types map
87	Agriculture	Built structure	Arable – potential increase in productivity if nitrogen and soil moisture – requirement for greater on-farm storage of crops resulting in new, larger farm buildings	T2	Adapt	H	R	M	M	M-L	FF10	farm types map

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
88	Agriculture	Built structure	Increased requirement for irrigation of arable resulting in irrigation infrastructure – sprays and booms	T3, P2, SM1	Adapt and adapt	H	R	M	M	M-L	FF10	farm types map
89	Agriculture	Built structure	Increased need for irrigation infrastructure sprays and booms, winter water storage for horticultural production	P2, SM1	Adapt	H	R	M	M	M-L	FF14	farm types map
90	Agriculture	Built structure	Changing livestock building requirements (warmer, wetter) resulting in new or replacement farm buildings	T2, T5	Adapt	H	R	M	M	M-L	FF1	Livestock areas
91	Agriculture	Built structure	Reductions in soil moisture may affect some crops / require irrigation resulting in increase in irrigation infrastructure of sprays and booms	T2, T5	Direct	H	R	M	M	M-L	FF1	Arable, horticultural and fruit areas
92	Agriculture	Built structure	Changing potato storage requirements (size, insulation, refrigeration) resulting in new farm buildings	T2, T4	Adapt	H	L	L	L	M-L	FF11	farm types map
93	Agriculture	Change in extent	Possible expansion into non arable areas due to impacts on other growing areas (international)	T3, P2	Adapt	H	R	H	H	M-L	FF10	farm types map

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Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
94	Agriculture	Change in practice	Sowing and harvesting affected by wetter winters – possible shift from autumn to spring sowing resulting in more winter stubbles or move to cover crops	P1	Adapt	H	N	L	L	S-L	FF10	farm types map
95	Agriculture	Change in practice	Management to reduce fire risk through more fire breaks, and management of grassland.	T2, T4, P2	Adapt	H	N	L	L	S-L	CLIO	
96	Agriculture	Change in practice	Management to minimise soil erosion – ground cover, ploughing, timing of operations	P1, P4	Adapt	H	N	L	L	S-L	CLIO	Farm types map
97	Agriculture	Change in type	Increased use of biomass – oilseed rape, wheat, sugar beet, miscanthus, Short Rotation Coppice resulting in changing character of lowland agricultural areas – focus on existing arable area	-	Mitigation	-	N	M	H	S-L	Sniffer CCO2	Landcover
98	Agriculture	Change in type	New or novel crops and potential conversion from pasture to arable	T2, T5	Direct	H	N	M	M	M-L	FF1	Farm types map
99	Agriculture	Change in type	Expansion of arable and conversion of pasture to arable	T2, T5	Adapt	H	R	H	H	S-L	FF1	ID of pastoral areas suited to arable

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
												cultivation under climate change
100	Agriculture	Change in type	Changing livestock breeds affecting local landscape e.g. loss of belted Galloway	T2, T5	Adapt	H	N	L	L	S-L	FF1	Livestock areas
101	Agriculture	Change in type	Improved field drainage	P1, P4	Adapt	H	N	L	L	S-L	FF3	Farm types map
102	Agriculture	Change in type	Use of vegetation to reduce run-off resulting in less bare earth, more farm woodland, hedges and cover crops.	P1, P4	Adapt	H	N	L	L	S-L	FF3	Farm types map
103	Agriculture	Change in type	Management to reduce soil erosion – plough across slops, avoid gates at bottom of slopes, minimising exposed soil etc	P1, P4	Adapt	H	N	L	L	S-L	FF3	Farm types map
104	Agriculture	Change in type	Nitrogen fixing crops and rotations resulting in change in crops, more rotation - arable and horticultural areas	-	Mitigate (loss of nitrogen)	-	R	L	L	S-L	FF4	farm types map
105	Agriculture	Change in type	Milder winters allowing out-wintering of stock (but erosion and rain)	T2	Adapt	H	R	L	L	S-L	FF4, FF8	farm types map

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
106	Agriculture	Change in type	Pigs – increased opportunities for outdoor finishing, less intensive production	T2	Adapt	H	R	L	L	S-L	FF6	farm types map
107	Agriculture	Change in type	Pigs – change grass or cover crop varieties to reduce soil erosion risk	P1, P4	Adapt	H	L	L	L	S-L	FF6	farm types map
108	Agriculture	Change in type	Changing types of sheep and cattle to reflect higher temps resulting in changes to local landscape	T2, T4	Adapt	H	N	L	L	M-L	FF7	farm types map
109	Agriculture	Change in type	Chickens – more outdoor rearing	T2	Adapt	H	R	L	L	S-L	FF9	farm types map
110	Agriculture	Change in type	New areas suitable for arable production – further north, further west and at higher altitudes, in previously non arable areas Changes in range of crops in existing arable areas	T2, P2, T5	Adapt	H	R	H	H	M-L	FF10	farm types map
111	Agriculture	Change in type	Increase in winter ground cover crops in arable areas, red clover, vetch and rye	P1	Adapt	H	R	L	L	S-L	FF10	farm types map
112	Agriculture	Change in type	Expansion of potato growing into current pastoral areas experiencing decline in rainfall	T2, T5	Adapt	H	R	L	L	M-L	FF11	farm types map

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
113	Agriculture	Change in type	Impact of reduced summer water availability on current potato production areas – move to other catchments, increase in water storage and irrigation	P2, SM1	Adapt	H	R	L	L	M-L	FF11	Farm types map
114	Agriculture	Change in type Built structure	Expansion of horticulture northwards and upslope	T2, T5	Adapt	H	R	H	H	M-L	FF14	farm types map Climate change and Land capability for Agriculture – Macaulay paper
115	Agriculture	Change in type	Increased use of ground cover crops to reduce soil damage	P1, P4	Adapt	H	N	L	L	M-L	FF14	farm types map
116	Agriculture	Change in type	Expansion of orchards northwards	T2, T5	Adapt	H	L	M	L	M-L	FF16	farm types map
117	Agriculture	Change in type	Loss of field boundary trees through stress and wind throw	T1,P2, W1	Direct	H/L	N	M	L	S-L	Topic Paper 9	
118	Agriculture	Change in type	Competitive advantage over other horticultural areas (potentially both overseas and elsewhere in UK)	T2, T5	Adapt	H	L	H	M	M-L	FF14	farm types map

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
			resulting in expansion of horticulture									
119	Agriculture	Event	Risk of fire in areas of moorland and rough grazing	T2, T4, SM1	Adapt	H	R	H	H	S-L	FF7	farm types map
120	Agriculture	Change in type	Sheep and cattle grazing moving uphill into current wild and core mountain areas changing the character of upland areas	T2, T4, SM1	Adapt	H	R	H	H	S-L	SNH Climate Change Action Plan	farm types map, wild land map, altitude
133	Agriculture	Change in type	Growth of biomass crops and short rotation coppice resulting in change in character of agricultural and forestry landscapes through introduction of alternative tree species	-	Mitigation	H	R	M	M	S-L	FCS	
137	Agriculture	Change in extent	Abandonment of smaller upland and marginal farm units resulting in change in character of upland areas, lack of active land management, however landscapes may also be subject to increased woodland cover	T4, P1, P2, P3	Adaptation	H	R	M	M	S-L	Farming futures	
138	Agriculture	Change in extent	Increased farm woodland resulting in change in character of agricultural landscapes	T4, P1, P2, P3	Adaptation Mitigation	H	R	M	M	M-L	Climate change and Scottish Agriculture	

Shaded rows indicate changes taken through to table 5.5

Table 5.4 Climate change matrix

Number	Topic	Type	Change and landscape implications	Caused by	• direct • mitigation • adaptation	climate change confidence	Extent	Magnitude	Significance	Timescale (S,M,L)	Source	Data source
139	Agriculture	Change in extent	Grazing and cropping of marginal land and moorland resulting in change in character of marginal and moorland areas	T4, P1, P2, P3	Adaptation	H	R	M	M	S-L	Farming futures	
121	Historic environment	Built structure	Renewable energy development resulting in loss of integrity of historic buildings and features	T2, T4	Mitigation	H	N	L	M	S-L	Climate change and the historic environment	
122	Historic environment	Change in type	Loss of design integrity of historic buildings and features as new features constructed	T2, T4	Adaptation	H	N	L	M	S-L	Climate change and the historic environment	

Table 5.5 Prioritised climate change matrix

The prioritised matrix provides a summary of the landscape changes identified as being associated with climate changes for which there is a higher degree of confidence and which are identified as being most significant in landscape terms. An explanation of the table headings is provided below:

Table heading	Explanation
Number	Refers to the reference number from Table 5.4
Change and landscape Implications	As in Table 5.4, describes the identified change and landscape implications
Topic	As in Table 5.4, categories of change by primary policy grouping
Approx timescale for visible change	Approximate timescale for visible change indicated by darker shading for the time period when greatest change is anticipated
Landscape data	Indicates the data to be used to map the landscape features
Climate data	Climate variables (see Table 5.1)
Climate change data	Indicates the aspect of the climate data to be used in the mapping
Assumptions/comments	Commentary on how landscape change could be mapped
National level mapping	Indicates if the change is to be mapped

The symbol 09 has been used to indicate which landscape changes were potentially affected by the UKCP09 winter precipitation data (see Appendix 11) which projects different scales, spatial patterns and directions of change to UKCIP02.

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
42	Woodland management / expansion to increase on-farm carbon storage	Forests and woodlands				Farm types map (all areas except LFA)				See change 33 (Habitats-natural and semi-natural)
45	Colonisation by non-native species where compatible with biodiversity	Forests and woodlands				Woodland types	Range of changes			×
46	Pinewoods – drier summers favour drier communities in west and central Highlands	Forests and woodlands				Woodland cover and types	P2	Decrease in summer rainfall		✓
47	Increase in scrub above current tree line and upper edge of pinewoods – juniper, montaine willows – where grazing allows	Forests and woodlands				Woodland cover and types	T1	Increase in average annual temperature		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
48	Wet woodlands – more frequent and extensive with increase in lowland flooding – a part of flood management	Forests and woodlands				Woodland cover and types. SEPA flood risk maps Catchment boundaries	P1	Increase in winter rainfall		✓
50	Woodland expansion to increase carbon sequestration	Forests and woodlands				IFS data (FCS) Macaulay maps of forestry potential	-			×
51	Expansion of LISS, except on windiest sites	Forests and woodlands				Woodland types	-			×
52	Deep fertile soils in southern and eastern Scotland more suitable for high quality broadleaf trees	Forests and woodlands				Woodland types Macaulay maps of forestry potential	T2, T5			×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
53	'Droughty' soils in eastern Scotland will become unsuitable for sitka and other drought sensitive species	Forests and woodlands				Forestry Commission data – Impacts of Climate change on forestry in Scotland spatial modelling research	T2, P2			×
54	Broader species mix and genetic mix to improve resilience to climate and pests	Forests and woodlands				Coniferous forestry (NIWT)	T1, P1, P2	Increase in summer temperatures		×
55	New woodland species – Monterey pine, maritime pine, southern beech, walnut	Forests and woodlands				Woodland potential	T1			×
56	Pinewood colonisation by broadleaves (oak, birch, rowan)	Forests and woodlands				Coniferous woodlands (NIWT) and ancient woodland	T2	Increase in mean temperatures		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
57	Altantic oakwoods on western seaboard – milder winters, severe gales, warmer drier summers – loss of epiphytes, storm damage, colonisation by birch, hazel and rowan and non-natives such as beech.	Forests and woodlands				Broadleaved woodlands (NIWT) and ancient woodland	T2, W1, P2	Winter temp increases, summer temperature increases, reductions in summer rainfall		×
58	Eastern oakwoods – colonisation by sycamore	Forests and woodlands				Broadleaved woodlands (NIWT) and ancient woodland	T2, P2	Winter temp increases and summer temperature increases and reductions in summer rainfall		×
59	Birchwoods – greater use of birch to provide shade and shelter with pasture in central and eastern highlands and eastern Scotland	Forests and woodlands				Land cover and farm type maps (only LFA)	T2, W1, P2	Summer temperature increases and increases in winter rainfall		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
62	Mixed broadleaves – species mix – increase in beech and sycamore – outcompeting oak, ash and elm	Forests and woodlands				Mixed broadleaves (NIWT)	T2			✓
63	Damage to woodlands caused by summer drought	Forests and woodlands				Woodland (all types) - NIWT	P2	Reduction in summer rainfall		✓
64	Damage to woodlands caused by winter flooding esp on poorly draining soils and where linked to summer drought – most evident in eastern Scotland	Forests and woodlands				Woodland all types - NIWT	P1, SM2	Reduction in summer rainfall and increase in winter rainfall		✓
65	Damage to woodland caused by extreme winds, exacerbated by wetter winters	Forests and woodlands				Woodland (NIWT) and exposure	W1, P1, SM2			✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
66	Risk of fire damage to woodlands (greatest in eastern and southern Scotland), linked to increase in recreation activity	Forests and woodlands				Woodland all types Scottish Executive urban-rural classification all areas except very remote rural	T2, P2, T4	Reduction in summer rainfall, and increase in summer temperatures		✓
69	Fire damage to broadleaves	Forests and woodlands				Woodland types	T2, P2, T4	Reduction in summer rainfall, and increase in summer temperatures		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
1	Flood management comprising – upland land management (closing g drains, woodland establishment), temporary flood storage, diversion of flood flows away from urban areas, green roofs, SUDS, one way valves, raising floor levels, increasing drain capacity, flood resilient design and materials, doubling flood defences	Freshwater systems				SEPA flood maps, CMP / RBMPs Urban areas Moorland (landcover)	P1, P4	Increase in winter rainfall	Identify locations of flood risk from map and identify those areas within catchments such as upland areas and flood plains which will be locations for flood management activity.	✓
5	Increase in river flooding severity and frequency, esp. in Western Scotland	Freshwater systems				SEPA floodmap	P1, P4	Increase in winter rainfall		✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
6	Flood damage to river banks and flood plains	Freshwater systems				SEPA floodmaps and river characteristics	P1, P4	Increase in winter rainfall Increase in intensity of rainfall events		✓
7	Physical erosion of river courses with knock on effects for river Habitats (natural and semi-natural)	Freshwater systems				SEPA flood maps	P1, P4	Increase in winter rainfall Increase in intensity of rainfall events		×
75	Flood damage to agricultural crops – from rainfall, sea and flood storage projects	Freshwater systems (category in table 5.4 was Agriculture)				SEPA flood maps, OS maps, SNIFFER coastal data Farm types (all except LFA)	P1, P4, SL5	Increase in winter rainfall		✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
3	Flooding in inner estuaries Impact on mudflats and shingle banks	Coasts, estuaries and sea				Estuaries Intertidal areas (land cover) Mudflats / saltmarsh (land cover)	SL5, SL4, P1, P4, W1	SNIFFER coastal flooding maps (CD)		✓
70	Changes in coastal erosion – affecting cliffs, low - lying coasts and dunes	Coasts, estuaries and sea				Geology /areas vulnerable to coastal erosion SCAPE information SNIFFER coastal data	SL4, SL5, P1, P4	SNIFFER coastal flooding maps		×
71	Changes in coastal deposition – changing species	Coasts, estuaries and sea				Geology /areas vulnerable to coastal erosion SCAPE information	SL4, SL5	SNIFFER coastal flooding maps		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
77	Increased coastal protection	Coasts, estuaries and sea				OS maps – low lying coastal areas	SL4 and response	SNIFFER coastal flooding maps		×
78	Managed realignment along low lying coasts and estuaries	Coasts, estuaries and sea				Managed realignment projects - SNH	SL5, SL4, P1, P4, W1	SNIFFER coastal flooding maps (CD)		×
79	Increased coastal flooding from sea level rise - overtopping, bypassing and breaching of coastal defences due to sea level rise and increased storminess . Sea level rise - expected to be up to 30cm by 2040-2069, although the Northern Isles and Western Isles could see >71.5cm.	Coasts, estuaries and sea				OS maps – low lying coastal areas	SL4	SNIFFER coastal flooding maps (CD)		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
80	Increase in offshore windfarm development	Coasts, estuaries and sea/ Infrastructure				Offshore wind farms locations	-	-		×
8	Increased demand and use of green and blue infrastructure in urban and peri urban areas	Urban and peri-urban				Urban and peri-urban greenspace based on urban areas	T2, T4	Decrease in summer rainfall Increase in summer temperature		✓
9	Stress on green infrastructure caused by summer drought and high temperatures, winter rainfall, pests and disease and increased use	Urban and peri-urban				Urban and peri-urban greenspace based on urban areas	T2, P2, P4	Decrease in summer rainfall Increase in winter rainfall Increase in summer temperature		✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
10	Building design to maximise shading, passive ventilation, use of cool materials, reflective and insulating materials	Urban and peri-urban				Urban and peri-urban areas – new communities, regeneration areas	T2, T4	Increase in summer temperature		×
11	Increased provision of network of open water and water features, and green infrastructure	Urban and peri-urban				Urban and peri-urban greenspace based on urban areas	T2, T4	Decrease in summer rainfall Increase in winter rainfall Increase in summer temperature	Local level only	×
13	Impact on skiing industry. Since the late 1970s, there has been a reduction of 12 days with snow lying in the altitude range 100-400m per decade.	Tourism and recreation				OS map Ski areas : Cairngorm, Lecht, Glenshee, Glen Coe, Nevis Range	T1, T2, SN1	Increase in winter temperature		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
14	Changing tourism and recreation products, destinations	Tourism and recreation				Scottish Executive 8 fold urban rural classification all areas except very remote rural	T1, T2, T3, P2, C1, SN1, T4, ST1	Decrease in summer rainfall Increase in summer temperature	Areas within the 'accessible rural' area will be under greatest pressure for recreational provision	✓
16	Upgrade of road drainage infrastructure where existing flooding occurs – capacity, storage	Infrastructure				Trunk roads and A roads T:\45\4503 SNH Climate & downloads\transport landslides.pdf figure 7.1 page 86	P1, P4	Increase in winter rainfall		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
18	Increase in water infrastructure associated with export	Infrastructure				Areas above 200 metres in Dumfries and Galloway, and Scottish Borders	P1, P2	Increase in winter rainfall, reduction in summer rainfall	Assume areas south of central belt and in close proximity to the border will be most appropriate	✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
19	Further development of wind energy at domestic and commercial scales	Infrastructure				Grid network and transmission reinforcements (Scottish Government/ national grid) http://www.scotland.gov.uk/Publications/2008/01/07093039/5 map 20– 400kv, Beauly Denny and planned re-inforcements Buffer the 400 kv grid - 20km Wind resource (DTI) http://www.esru.strath.ac.uk/EandE/Web_sites/03-04/wind/content/ukwindspeedmap.html	-	-		✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
19b	Further development of off shore wind energy	Infrastructure				Marine energy potential (Scottish Government) http://www.snh.org.uk/pdfs/publications/commissioned_reports/F03AA06.pdf Figure 32 http://openscotland.gov.uk/Resource/Doc/208174/0055210.pdf	-	-		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
21	Biomass plants	Infrastructure				Coniferous forestry (NIWT) Arable farmland (Farm types map)	-	-	Areas of commercial forestry Areas of farmland are also suitable for biomass cropping, however insufficient data exists to identify specific locations where this would be concentrated. Willow is the most suitable species for Short Rotation Coppice (SRC) in Scotland and the best yields are achieved on sheltered, fertile sites which can be readily cultivated, although it will grow on a wide range of soils.	✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
22	Tidal power schemes	Infrastructure				Areas with tidal potential Estuaries: Firth of Forth Firth of Tay Moray Firth Cromarty Firth Dornoch Firth Montrose basin Inner Firth of Clyde Solway Firth http://www.carbontrust.co.uk/NR/rdonlyres/CF053293-72CB-4204-B4DA-418AFD1244E2/0/PhaseIITidalStreamResourceReport.pdf	-	-	Scottish Marine Renewables SEA - Scoping Report Scottish Executive February 2006. The report identified that there has been little attention given to barrages or lagoons within the study area (focused around the north west of Scotland). No data identified on tidal range of estuaries outwith the Scottish Marine Renewables SEA study area.	×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
24	Nuclear power stations	Infrastructure				Existing nuclear power stations (Dounreay, Hunterston, Torness) SNIFFER Coastal map	-	-		×
72	Damage to peatland – quicker erosion, gullying and bogbursts	Habitats (natural and semi-natural)				Peatbog. Blanket bog, peatland (landcover)	P1, P4	Increase in winter rainfall		✓
76	Loss of coastal wetlands - as intertidal habitats are lost to the sea as they are trapped between rising seawaters and hard coastal defences	Habitats (natural and semi-natural) (Category 5.4 was Coasts, Estuaries, Sea)				Land cover estuaries coastal areas Intertidal areas (land cover) Mudflats / saltmarsh (land cover)	SL4 and response	SNIFFER coastal flooding maps	See change 3 (Coasts, estuaries and sea)	×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
27	Impact on heather moorlands	Habitats (natural and semi-natural)				Heather moorland (land cover)	T1, T2, T3,	Increase in summer temperatures Decrease in summer rainfall		✓
28	Abandonment of muirburn	Habitats (natural and semi-natural)				Heather moorland (land cover)	T1, T2, P2	Increase in summer temperatures Decrease in summer rainfall		×
29	Loss of biodiversity, reduction in ecosystem productivity	Habitats (natural and semi-natural)				Land cover	T1-3, P1-3, SN1, SM1, SM2, T4, T5, SL4, ST1	Changes in snowfall, soil moisture		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
30	Reduction in snow lie	Habitats (natural and semi-natural)				Data from Scottish Executive (2001) Climate Change and Changing Patterns of Snowfall in Scotland	SN1			×
31	Loss of arctic-alpine species / change in upland plant communities	Habitats (natural and semi-natural)				Elevation Map areas over 600m Map areas over 875m	T2, T5			×
32	Restoring peatbog	Habitats (natural and semi-natural)				Peatland (land cover)	-			×
33	Habitat networks – woodland, coastal, urban and peri urban	Habitats (natural and semi-natural)				Farm types – all areas except Locally Favoured Areas (LFA)	Range of changes		Increase in woodland in lowland farmland	×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
34	Rewilding – blanket bogs, moorland, upland woodlands, managed realignment, flood plains	Habitats (natural and semi-natural)				Blanket bog (land cover) Moorland, (land cover) Woodlands (land cover) Coastal areas at risk of flooding (SNIFFER) Floodplains in catchment with high incidence of flooding SEPA Floodmaps	P1, P3			✓
35	Biodiversity – change in species range and composition – move north and uphill.	Habitats (natural and semi-natural)				landcover	T2	Increase in temperatures (annual) Increase in summer temperatures		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
36	Biodiversity – more rapid decomposition and nutrient recycling – affecting nutrient status of some Habitats (natural and semi-natural) – montane and moorland – invasion of grasses	Habitats (natural and semi-natural)				Areas above 600m Heather moorland (landcover)	T2	Increase in temperatures (annual) Increase in summer temperatures		✓
39	Changes in peat accumulations – growth where temp and rainfall increase, decay where rainfall decreases	Habitats (natural and semi-natural)				Blanket bog (landcover) Peat (landcover)	T1, P1, P2 	Areas with net increase in rainfall Areas with net decrease in rainfall		✓
41	Shelter belts to shade and shelter livestock and crops	Agriculture				Farm types map (all areas except Locally Favoured Areas)	T2, P1, W1 	Increase in summer temperatures Or Increase in winter rainfall		✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
43	Loss of field boundary and other farmland trees due to storm damage and stress	Agriculture				Farm types map (all areas except Locally Favoured Areas)	T1, P1, P2, W1	Increase in summer temperatures and Reduction in summer rainfall		✓
81	Increase in irrigation and on-farm water storage	Agriculture				Farm types map	P2, T2, SM1	Reductions in summer rainfall Increases in summer temperature		×
83	Increased development of anaerobic digestion to reduce methane from farm waste	Agriculture				Farm types map Dairy Cattle and sheep lowland	-	-		×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
86	New farm buildings poultry on-farms storage Dairy	Agriculture				Farm types map Specialist poultry Cereals General cropping Dairy	T2, T4	Increased summer temperature		×
87	Arable – potential increase in productivity if nitrogen and soil moisture – requirement for greater on-farm storage of crops	Agriculture				Farm types map Cereals	T2	Increase summer temperature		✓
88	Increased requirement for irrigation of arable	Agriculture				Farm types map Cereals	T3, P2, SM1	Increase summer temperature And Reduction in summer rainfall		✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
93	Possible expansion of dairy due to impacts on other growing areas (international) arable	Agriculture				Farm types map Dairy	T3, P2	Increase in summer temperature Reduction in summer rainfall		×
94	Sowing and harvesting affected by wetter winters – poss shift from autumn to spring sowing	Agriculture				Farm types map Cereals General Cropping	P1	Increase in winter rainfall		✓
97	Increased use of biomass – oilseed rape, wheat, sugar beet, miscanthus, SRC	Agriculture				Landcover Farm types map (cereals, general cropping)	-	-		×
98	New or novel crops	Agriculture				Farm types map Cereals General Cropping	T2, T5			✓

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
99	Conversion from pasture to arable	Agriculture				Farm types map Cereals	T2, T5			×
110	New areas suitable for arable production – further north, further west and at higher altitudes Changes in range of crops in existing arable areas	Agriculture				SEERAD Farm types map Land capability for agriculture	T2, P2, T5			×
114	Expansion of horticulture northwards and upslope	Agriculture				farm types map Climate change and Land capability for Agriculture – Macaulay study	T2, T5			×

Table 5.5										
			Approx timescale for visible change (years)							
Number	Change and landscape implications	Topic	<10	10-100	100 +	Landscape data	Climate data	Climate change data 2050, High emissions	Assumptions/ comments	National level mapping
120	Sheep and cattle grazing moving uphill into current wild and core mountain areas	Agriculture				Farm types map, wild land map, altitude	T2, T4, SM1		Cattle grazing is infrequent above enclosure. Sheep graze all areas except core wild areas which may not be grazed due to accessibility issues (distances involved when gathering stock, lack of hefted stock)	×

6. LANDSCAPE CHARACTER DESCRIPTIONS FOR TAYSIDE DETAILED STUDY AREA, EXISTING AND WITH CLIMATE CHANGE

6.1. This Appendix provides detailed landscape character descriptions drawing on the information in the Tayside Landscape Character Assessment (1999) and Fife Landscape Character Assessment (1999). The information in these tables informed the text in Section 5 of the main report.

Landscape Character Type: **Lower Highland Glens** Landscape Character Unit: **Strath Tay**	
Regional Character Area: The West Highlands	
Existing key landscape characteristics	**Possible 2050 key landscape characteristics**
Topography and Geology	
Glens with wide floodplains (around 0.5-1km across). Valley floor is around 50-200m AOD and valley sides are elevated to around 500m AOD. Harder rock has created a number of gorges and falls. A number of glacial deposition features.	Glens with wide floodplains (around 0.5-1km across). Valley floor is around 50-200m AOD and valley sides are elevated to around 500m AOD. Harder rock has created a number of gorges and falls. A number of glacial deposition features.
Forests and woodlands	
Extensive broad-leaf woodland (semi-natural on steeper slopes and managed estate woodland). Some ancient broad-leaf woodland. Extensive coniferous woodland on valley sides associated with estates (larch)	Extensive broad-leaf woodland (semi-natural on steeper slopes and managed estate woodland) sees further expansion to provide carbon sequestration and enhanced habitats. Some ancient broad-leaf woodland. Extensive coniferous woodland on valley sides associated with estates, mostly larch with some conversion to biomass cropping. Evident tree damage from summer drought, storm damage and fire in areas. Recent expansion of genetic species mix including pines, southern beech, walnut. Areas of wet woodland on glen floor.
Freshwater Systems	
Large river meanders across floodplain and flows down incised narrow channels	Large river meanders across floodplain and flows down incised narrow channels. Flood management includes the rewilding of some floodplains to provide storage for flood water.

Coasts, estuaries and sea	
n/a	n/a
Urban and Peri-Urban	
Well settled villages, large estates and some planned villages. Some uniform style and layout settlements e.g. Blair Atholl. Small estates of distinctive landscape and architecture e.g. Findynate, Derulich. Victorian settlement, with more recent expansion e.g. Pitlochry. General transitional use of building materials including granite, schist, slate and some sandstone.	Well settled villages, large estates and some planned villages. Some uniform style and layout settlements e.g. Blair Atholl. Small estates of distinctive landscape and architecture e.g. Findynate, Derulich. Expanded settlements with Victorian core include Pitlochry. Evident historical transitional use of building materials including granite, schist, slate and some sandstone. Shift in recent architectural materials and layout to maximise shading and use of cool reflective and insulating materials. Some development of urban green and blue infrastructure links. Solar collectors visible on building roofs.
Tourism and Recreation	
Historically area has attracted tourists from 19th Century onwards. Estates, castles and settlements of Pitlochry, Bruar and Dunkeld are popular tourist destinations.	Historically area has attracted tourists from 19th Century onwards. Estates, castles and settlements of Pitlochry, Bruar and Dunkeld are popular tourist destinations.
Infrastructure	
Provides important communication routes through the Highlands (A9(T) and railway). Several telecommunication masts. Transmission lines pass along the glen.	Provides important communication routes through the Highlands (A9(T) and railway). Several telecommunication masts. Visible wind farms in neighbouring landscape. Transmission lines pass along the glen.
Natural and semi-natural habitats	
Native ancient and semi-natural woodland. Some gorge vegetation and cultivated fertile farmland.	Native ancient and semi-natural woodland (including recent expansion of semi-natural habitat areas). Some gorge vegetation and cultivated fertile farmland.

Agriculture	
Some arable farming on lower/mid valley sides and drained valley floor. Pasture on valley floor and upper slopes. Large and rectilinear fields occupy valley floor. Medium and rectilinear fields occupy gentler valley slopes. Shelterbelts and post-and-wire fences act as field boundaries on the floodplain. Hedges, trees and walls are used as field boundaries on valley slopes. General structure of field boundary trees in decline.	Some arable farming on lower/mid valley sides and drained valley floor. Pasture on valley floor and upper slopes. Large and rectilinear fields occupy valley floor. Medium and rectilinear fields occupy gentler valley slopes. Shelterbelts and post-and-wire fences act as field boundaries on the floodplain. Hedges, trees and walls are used as field boundaries on valley slopes, although there is a pattern of removal. Structure and integrity of field boundary trees in decline. Evident on-farm water storage and irrigation systems in some areas.
Historic Environment	
Numerous historic features including castles, fortified manor lodges and estate features e.g. Blair Castle. Traces of General Wade's Military Road.	Numerous historic features including castles, fortified manor lodges and estate features e.g. Blair Castle. Traces of General Wade's Military Road. Evident damage to trees associated with features. Relatively recent perceptible changes to setting of features include increased woodland, field boundary removal and wind turbines.

Landscape Character Type: **Highland Summits and Plateau** Landscape Character Unit: **Forest of Atholl**	
Regional Character Area: The Mounth Highlands	
Existing key landscape characteristics	**Possible 2050 key landscape characteristics**
Topography and Geology	
Extensive upland area with spurs orientated south, separating main glens. Hills are generally more rounded than to the west and rocky outcrops are fewer. Hill summits range from 400 to 1000m AOD.	Extensive upland area with spurs orientated south, separating main glens. Hills are generally more rounded than to the west and rocky outcrops are fewer. Hill summits range from 400 to 1000m AOD. Localised patterns of erosion and deposition may change and there is an increased likelihood of slope instability associated with more intense rainfall events which could result in landslips and visible scars.
Forests and woodlands	
A few areas of semi-natural broadleaf woodland up to 600m AOD. Tree growth is prevented by burning, cutting and grazing. The little areas of coniferous plantation are limited to below 450m AOD.	A few areas of semi-natural broadleaf woodland up to 600m AOD and scrub occurring above. Recent increase in genetic mix of species within broad-leaf areas and possible expansion of semi-natural woodlands on lower slopes. Tree growth is affected by grazing. Areas of coniferous plantation are increasingly restructured to comprise a mixture of species and managed on a continuous cover basis. There is some evidence of tree damage from summer drought, fire, storms and pests and diseases.
Freshwater Systems	
Various rivers, burns and tributaries connect to lochs in the neighbouring landscape.	Various rivers, burns and tributaries connect to lochs in the neighbouring landscape. Some upland flood management including closed drains and establishment of woodland on lower slopes around water systems.
Coasts, estuaries and sea	
n/a	n/a

Urban and Peri-Urban	
Remote nature means there is minimal evidence of settlement, limited to the remains of old sheilings.	Remote nature means there is minimal evidence of settlement, limited to the remains of old sheilings.
Tourism and Recreation	
Paths provide opportunities for informal recreation, walking and climbing. Appreciated for its panoramic scenic and wild views. Landscape used for gaming. Some cross-country skiing opportunities.	Area increasingly used for informal recreation. Paths provide opportunities for informal recreation, walking and climbing. Appreciated for its panoramic scenic and wild views. Landscape used for gaming.
Infrastructure	
Limited infrastructure. Historically old route ways and paths pass through this upland landscape. There is evidence of recent stalkers paths and footpaths.	Limited infrastructure. Historically old route ways and paths pass through this upland landscape. There is evidence of recent stalkers paths and footpaths. Perceptible wind turbines in neighbouring landscapes.
Natural and semi-natural habitats	
Below 600m AOD, habitat is dominated by heather (mixed with sedge, rush, bog asphodel, cotton grass and purple moor grass). Between 600-900m AOD habitats comprise rich artic-alpine flora and fauna (blueberry, crowberry and occasional mat of prostrate heather). Shallower plateau slopes comprise blanket bog with peat 1m plus deep. Lichens are found in high exposed areas. Vegetation patterns closely reflect altitude, exposure and underlying geology. The area is managed as open moorland. An abundance of bird species, plus squirrel, mountain hare and wildcat can be found on higher ground occupy this landscape.	Below 600m AOD, heather habitat (mixed with sedge, rush, bog asphodel, cotton grass and purple moor grass) is in decline as muirburn is abandoned. Between 600-900m AOD artic-alpine flora and fauna habitat (blueberry, crowberry and occasional mat of prostrate heather) is in decline, with expansion of grasses. Shallower plateau slopes comprise blanket bog with peat 1m plus deep. Lichens are found in high exposed areas. Vegetation patterns closely reflect altitude, exposure and underlying geology. The area is managed as open moorland. An abundance of bird species, plus squirrel, mountain hare and wildcat can be found on higher ground occupy this landscape. A noticeable movement of flora and fauna to elevations and latitudes not previously tolerated.
Agriculture	
Arable farming is absent. Agriculture is limited to rough and unimproved pasture of open fields with no field boundaries. Grouse, deer and sheep management.	Arable farming is absent. Agriculture is limited to rough and unimproved pasture of open fields with no field boundaries at increasing elevations. Grouse, deer and sheep management.

Historic Environment	
Evidence of ancient route ways and former sheilings. Some large managed hunting and shooting estates.	Evidence of ancient route ways and former sheilings. Some large managed hunting and shooting estates.

Landscape Character Type: **Broad Valley Lowlands** Landscape Character Unit: **Strathmore**	
Regional Character Area: **The Tayside Lowlands**	
Existing key landscape characteristics	**Possible 2050 key landscape characteristics**
Topography and Geology	
Glacial erosion has formed broad straths and a complex landscape of glacial deposition including outwash terraces, eskers and dry valleys. Strathmore is up to 10km wide.	Glacial erosion has formed broad straths and a complex landscape of glacial deposition including outwash terraces, eskers and dry valleys. Strathmore is up to 10km wide.
Forests and woodlands	
Overall there is a limited extent of woodland. Broad-leaf woodland is limited to inner policy woodland and a few areas of unimproved land. Coniferous plantations can be found on areas of poorer land, especially valley sides. Native birch woodland is located on pockets of unimproved land. Existing policy and estate woodland. There is a pattern of tree loss.	Variety of broad-leaf woodland can be found as inner policy woodland and some areas of unimproved land. Coniferous plantations can be found on areas of poorer land, especially valley sides. Native birch woodland is located on pockets of unimproved land. Some recent expansion of woodland shelter belts has occurred. Evidence of tree damage resulting from summer droughts, winter flooding and fire. Occasional wet woodlands are located around river systems.
Freshwater Systems	
Undersized mis-fit rivers occupy the valley floor. Existing flood defences are located along rivers	Undersized mis-fit rivers occupy the valley floor. Numerous flood defences and management techniques are located along rivers and within the floodplain. Visible flood damage to floodplains and river banks. Low flow in summer.
Coasts, estuaries and sea	
n/a	n/a

Urban and Peri-Urban	
Settlements are small, often planned villages, small market/processing towns and larger market towns can be found. The 19th century saw a growth in market towns, e.g. Coupar Angus, Forfar. Some recent modern house building expansions are found on settlement edges. Outside settlements, development is limited to scattered farmsteads and agricultural buildings. Building materials are predominantly red sandstone.	Settlements are small, often planned villages, small market/processing towns and larger market towns can be found. The 19th century saw a growth in market towns, e.g. Coupar Angus, Forfar. Modern house building expansions are found on settlement edges. Increased stress and demand has resulted in the improvement and creation of blue and green infrastructure within urban areas. Outside settlements, development is limited to scattered farmsteads, agricultural buildings and biomass plants. Building materials are a mix of historically predominant red sandstone and modern cool, reflective and insulating materials. Solar collectors visible on building roofs.
Tourism and Recreation	
Generally limited opportunities for tourism and recreation. Occasional historic features provide tourist destinations.	Generally limited opportunities for tourism and recreation, although occasional historic features provide a draw for tourists.
Infrastructure	
Some important road connections, e.g. A94 travel through this landscape. A network of relatively long straight minor roads travel between fields. Roads are relatively visible within this flat open agricultural landscape. Electricity transmission lines are present.	Some important road connections, e.g. A94 travel through this landscape. A network of relatively long straight minor roads travel between fields. Roads are relatively visible within this flat open agricultural landscape. Several electricity transmission lines pass through the landscape connecting several small to medium scale wind farms and biomass plants to the national grid.
Natural and semi-natural habitats	
Ecological interest is limited to a few unimproved areas. Most habitats are cultivated arable land.	Ecological interest is limited to a few unimproved areas and some rewilded areas of the floodplain. Most habitats are cultivated arable land. Some broad-leaf woodland contributing to habitat networks.

Agriculture	
Arable agriculture dominates this landscape – cereals, potatoes and oil seed rape. Some arable cultivation has occurred on floodplains. There is limited pasture (mostly of pig farming). Fields are medium sized and regular, some enlarged, most dating back to parliamentary enclosure. Field boundaries are characteristically hedges with a high density of mature hedgerows, however intensification of farming has led to some removal. Agriculture has led to large modern agricultural buildings (especially potato stores) which are often white.	Agriculture dominates the landscape with arable farming of cereals, potatoes and oil seed rape, and biomass cropping. Cultivated floodplains have been subject to flooding, resulting in some areas being rewilded and planted as wet woodlands. There is limited pasture (mostly of pig farming). Fields are medium sized and regular, some enlarged, most dating back to parliamentary enclosure. Intensification of agriculture has removed many field boundaries, although some characteristic hedges and mature hedgerows remain. Agriculture, including biomass plants has led to a large number of large modern agricultural buildings, stores and biomass plants.
Historic Environment	
Limited features due to intensity of agriculture. Some historic houses, estates and surviving medieval standing stones and other monuments.	Limited historic features including some historic houses, estates and surviving medieval standing stones and other monuments. Evident damage to trees associated with features. Relatively recent perceptible changes to setting of features include increased woodland, field boundary removal and wind turbines.

Landscape Character Type: **Firth Lowlands** Landscape Character Unit: **Firth Lowlands**	
Regional Character Area: **The Tayside Lowlands**	
Existing key landscape characteristics	**Possible 2050 key landscape characteristics**
Topography and Geology	
Area is predominantly flat with a bank marking the south edge before the Firth of Tay. Landform is around 10-50m AOD.	Area is predominantly flat with a bank marking the south edge before the Firth of Tay. Landform is around 10-50 meters AOD.
Forests and woodlands	
General limited tree cover. Broad-leaf trees are limited to field boundaries, shelterbelts and policy woodlands. Very limited areas of coniferous policy woodland. History of orchards means some apple trees still remain.	Broad-leaf trees are limited to expanding shelterbelts and policy woodlands. Very limited areas of coniferous policy woodland. History of orchards means some apple trees remain, recent planting has seen orchards expand. Limited remaining apple trees from history of orchards. Evidence of tree damage resulting from summer droughts, winter flooding and fire.
Freshwater Systems	
Network of small burns flowing into estuary.	Network of small burns flowing into estuary. Flood defences and management techniques are located along burns. Visible flood damage to floodplains and burn banks.
Coasts, estuaries and sea	
Estuary edge is marked by a distinct bank before reed beds. Reed beds at Errol provide commercial source of thatching reeds.	Encroachment of sea and development of hard flood defences has destroyed inter-tidal habitat. Limited areas of reed beds remain. Coastal management has resulted in realignment of estuary. Potential development of tidal barrage could result in significant landscape and ecological change.

Urban and Peri-Urban	
Nucleated settlement is located on higher ground. A scatter of large farmsteads and hamlets are located on tracks leading from principal roads. Recent housing demand has led to settlement expansion and some ribbon and dispersed development. Building materials include red sandstone and harder igneous rocks from the Sidlaws.	Nucleated settlement is located on higher ground. A scatter of large farmsteads and hamlets are located on tracks leading from principal roads. Settlement expansion has occurred as ribbon and dispersed development. Building materials include a mixture of red sandstone, harder igneous rocks from the Sidlaws and modern materials such as cool, reflective and insulating materials. Solar collectors visible on building roofs.
Tourism and Recreation	
Limited opportunities for tourism and recreation, however historic features provide tourist destination and some camping sites.	Limited opportunities for tourism and recreation, however historic features provide tourist destination and some camping sites.
Infrastructure	
Acts as a communication corridor (A90 (T)) connecting Perth and Dundee. There is a geometric pattern of road and railways. Several transmission lines cross this landscape. A disused airfield is located at Errol.	Acts as a communication corridor (A90 (T)) connecting Perth and Dundee. There is a geometric pattern of road and railways, with adjacent flood control measures. Several larger transmission lines cross this landscape. Tidal power schemes are visible within the adjacent Firth Estuary. Distant turbines are visible in neighbouring landscapes. Distribution of biomass plants where arable land has been converted.
Natural and semi-natural habitats	
Estuarine habitats comprise reed beds and mud-flats. Elevated fertile land is occupied by extensive arable agriculture.	Elevated fertile land is occupied by extensive arable agriculture. Changing coastal deposition and flood management is resulting in a loss of estuarine inter-tidal habitat and reed beds.

Agriculture	
Extensive arable land and limited pasture occupy large rectilinear fields. Field boundaries comprise gappy hedges, post-and-wire fences and wet ditches. There is a decaying structure of hedgerow trees. Recent years have seen a significant expansion in the use of polytunnels to provide controlled conditions for fruit cultivation.	Extensive arable land, some biomass production and limited pasture occupy large rectilinear fields. Field boundaries comprise post-and-wire fences and wet ditches, most hedgerows and field trees have been removed. Coastal flooding has damaged crops along estuarine edge. Scattered buildings associated with agriculture, such as crop stores and biomass plants.
Historic Environment	
Castles, historic house and designed landscapes	Castles, historic house and designed landscapes. Loss and damage of associated trees, such as policy planting, has affected the setting of these historic features.

Landscape Character Type: **Igneous Hills** Landscape Character Unit: **Sidlaw Hills**	
Regional Character Area: **The Tayside Lowlands**	
Existing key landscape characteristics	**Possible 2050 key landscape characteristics**
Topography and Geology	
Hard volcanic rocks have formed a range of low smooth rounded hills (up to 300m AOD). The hills are most distinctive to the south, where the vertical scarp of Braes of the Carse) face south-east. To the north the hills subside to farmland plateau.	Hard volcanic rocks have formed a range of low smooth rounded hills (up to 300m AOD). The hills are most distinctive to the south, where the vertical scarp of Braes of the Carse) face south-east. To the north the hills subside to farmland plateau.
Forests and woodlands	
Areas of extensive coniferous forestry plantation e.g. eastern Sidlaws are uniform in character. Very limited broad-leaf woodland can be found on steep slopes and in river valleys. There are a few isolated pines.	Areas of extensive mixed species coniferous forestry plantation e.g. eastern Sidlaws. Limited broad-leaf woodland can be found on steep slopes and in river valleys (some recent broad-leaf expansion in areas and species mix). There are a few isolated pines. Evidence of tree damage resulting from summer droughts, winter flooding and fire. Occasional wet woodlands are located around river systems.
Freshwater Systems	
Short burns and rivers flowing through short steep glens.	Short burns and rivers flowing through short steep glens. Evidence of flood damage to river banks and floodplains. Some upland flood management.
Coasts, estuaries and sea	
n/a	n/a

Urban and Peri-Urban	
The area is largely unsettled. Some settlement can be found on the lower gentler slopes of the Sidlaws extending hamlets and farmsteads near Dundee. Farms and hamlets are concentrated in main glens. Building materials include local hard rock and some sandstone. Pattern of defensive historical settlements (hill-forts, castles, motes burial mounds).	The area is largely unsettled. Some settlement can be found on the lower gentler slopes of the Sidlaws extending hamlets and farmsteads near Dundee. Farms and hamlets are concentrated in main glens. Building materials are a mix of local hard rock, sandstone and modern cool, reflective and insulating materials. Solar collectors visible on building roofs. Pattern of defensive historical settlements (hill-forts, castles, motes burial mounds).
Tourism and Recreation	
Public access to commercial woodlands provides opportunities for countryside and informal recreation. Formal recreation is comparatively limited.	Public access to commercial woodlands provides opportunities for countryside and informal recreation. Notable increasing pressure on recreational and tourist resources.
Infrastructure	
Telecommunication masts and aerials prominent are features. Landscape provides opportunities for wind farm development.	Telecommunication masts, aerials and small-medium scale wind farms are prominent features. Expansion of biomass cropping has resulted in occasional biomass plant on lower previously arable slopes. Small to medium scale wind farms on hills and perceptible in surrounding landscape.
Natural and semi-natural habitats	
Grass and heather moorland dominate upper parts of hills.	Grass and heather moorland dominate upper parts of hills. Management of heather moorland is in decline as muirburn has been abandoned and encroaching cultivated land is viable at higher elevations. Some rewilded habitat is located around river systems.

Agriculture	
A few areas of arable cultivation and improved grassland fields on gentle lower slopes, especially south and west Sidlaws. Unimproved rough pastures are common on steeper slopes and rougher more exposed hilltops. Fields are mostly large and regular shaped. Field boundaries comprise stone dykes and post-and wire fences. Occasional isolated Scots pine field boundaries in upper areas and deciduous species in sheltered parts.	A few areas of arable cultivation, biomass cropping and improved grassland fields on gentle lower slopes, especially south and west Sidlaws. Unimproved rough pastures are common on steeper slopes and rougher more exposed hilltops. Fields are mostly large and regular shaped. Field boundaries comprise stone dykes and post-and wire fences. Occasional isolated Scots pine field boundaries in upper areas and deciduous species in sheltered parts have experienced some damage and removal. However expansion of shelterbelts in their proximity has provided some protection.
Historic Environment	
Some old field systems, burial sites, hill-forts and later castle sites	Some old field systems, burial sites, hill-forts and later castle sites. Evident damage to trees associated with features. Relatively recent perceptible changes to setting of features include increased woodland, field boundary removal and wind turbines.

7. CULTURAL ECOSYSTEM SERVICES TABLES – CURRENT, WITH CLIMATE CHANGE, WITH CLIMATE CHANGE AND SOCIO-ECONOMIC SCENARIOS

7.1. This Appendix sets out the impacts of climate change on the cultural ecosystem services for each detailed study area example. This illustrates how the impacts would alter under the four socio economic scenarios of World Markets (WM), National Enterprise (NE), Global Sustainability (GS) and Local Stewardship (LS).

7.2. The symbols used in the tables to illustrate how the change would alter under each scenario are explained below:

++ strongly positive change

+ positive change

= no change to that described

- negative change

-- strongly negative change

KILLIECRANKIE

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Inspiration and enrichment	This is an inspirational landscape, reflecting the combination of Highland summits, extensive heather moorland, rich broadleaf and mixed woodlands and forests, pastures on the slopes of the glen and of course the distinctive gorge and settlement at Killiecrankie. It inspires and enriches local communities, visitors and travellers along road, rail, cycle and walking routes	This would remain an inspirational landscape though the changing balance of farmland and woodland would have a less significant effect on the middle slopes.	--	=/+	++	++
Health and wellbeing	The landscape accommodates a range of low level walking routes, together with hill walking, horseriding and cycling opportunities, all contributing to physical health. The landscape also provides broader mental and wellbeing benefits – comprising a high quality, accessible but largely intact landscape that is with reach of urban populations to the south	Some of the infrastructure changes for drainage could have a negative impact on recreation activity and indirectly on physical activity and health.	+	+	+	++

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Aesthetic values	The combination of landscape elements, features and qualities means this landscape makes a significant contribution to aesthetic values	Drainage infrastructure would alter this landscape's contribution to aesthetic values	+/-	+/-	+	++
Sense of place	While many of the individual landscape elements are found in other parts of the south east Highlands, the particular combination, and specific features such as pass of Killicrankie, make this a highly distinctive landscape	This would remain a highly distinctive landscape.	=	+	++	++
Cultural heritage values	Many will view this landscape as timeless even though the last century saw considerable change in terms of power generating infrastructure, forestry and transport infrastructure. The historic pattern of settlement and land management is, however, evident throughout this landscape	It is possible that expansions in woodland could affect the historic structure and appearance of field systems on the middle slopes of the glen.	-	+	+	+

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Recreation and tourism	The landscape accommodates a range of low level walking routes, together with hill walking, horseriding and cycling opportunities. In addition, many people travelling north and south along main road and rail links will experience this landscape.	It is likely that infrastructure development such as drainage could have a negative impact on recreation activity and on perceptions of visitors.	=/+	+	+	++

STRATHMORE

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Inspiration and enrichment	Strathmore is a distinctive working rural landscape which is broadly typical of central and eastern parts of Scotland. While the scale and productivity of agriculture, and the structure of fields, boundary trees, settlement and historic landscapes can be impressive, this is not one of Scotland's most inspirational landscapes.	When the landscape implications of climate change are taken into account, it is likely that the inspirational and enrichment value of this landscape will be reduced. This reflects the introduction of new structures such as biomass plants, new large farm buildings, an upgraded pylon line and a modern windfarm (though the latter element could be seen as inspirational by some)	--/+	-/+	+	+/-
Health and wellbeing	The countryside of Strathmore provides a range of recreation opportunities, benefiting local communities, residents of Dundee and the wider population.	It is likely that these changes would reduce the area's attraction for informal recreational so health benefits for the wider population could be reduced, or people attracted to other areas.	+	=	+	++

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Aesthetic values	This landscape has a distinctive structure of rectilinear arable fields, repeating lines of field boundary trees, shelter belts, farm woodland and policies associated with designed landscapes, and small agricultural villages. The aesthetic value of this landscape has been weakened by trends such as field enlargement, the progressive loss of field boundary trees, the development of large farm buildings, and the influence of infrastructure such as A90 trunk road.	The aesthetic values of this landscape would also be adversely affected. The continued loss of field boundary trees, amalgamation of fields and introduction of quite different crops (including biomass) would make this a larger scale and more open landscape. The introduction of large modern structures including pylons, turbines, farm buildings and even a smaller scale biomass plant, would also undermine its distinctive rural and almost timeless character.	--/+	-/+	+	+/-
Sense of place	This is a distinctively Scottish, east coast landscape. Key identifiers include the arable fields, boundary trees, building styles and materials. Scale of the landscape and its relationship with the Mounth mountains to the north, define this landscape as Strathmore.	Some of these changes would weaken the sense of place, though it is likely that the landscape would still be easily identified as Strathmore, in part because of the field patterns and arable crops, in part because of the relationship with adjoining hill masses.	-	-/+	+	

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Cultural heritage values	This landscape has a number of distinctive historic and cultural elements, including, the eighteenth and nineteenth century pattern field patterns, the policy and wider woodland influence of landed estates, and villages of single storey, sandstone and pantile farm workers cottages.	The cultural heritage values of the landscape would be adversely affected by the further weakening of the field structure, and by the introduction of large scale, modern structures and buildings. Even historic cottages would be upgraded and retrofitted with renewable energy equipment	--	-	-	+
Recreation and tourism	Strathmore supports local access and recreation networks, country parks together with a number of visitor attractions including Glamis Castle. East coast rail and main road corridors run across the eastern side of the strath, so many visitors to the north east and eastern Cairngorms, together with the Angus Glens experience this landscape.	It is likely that the informal recreational value of this landscape would be reduced, though particular attractions, together with managed areas such as Country Parks would be largely unaffected. For travellers, the contrast with protected and wild land areas would be more distinct.	+	=	+	++

FIRTH OF TAY

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Inspiration and enrichment	The juxtaposition of steeply enclosing hills to the north and south, the flat carselands and the meandering course of the tidal Tay, together with a series of historic settlements and influences, create a rich and varied landscape, though its inspirational value is perhaps reduced by modern road infrastructure, pylon lines and the spread of polytunnels associated with intensive fruit cultivation.	It is likely that the inspirational and enrichment roles would be further reduced by the introduction of pylons, turbines, new farm buildings and estuarine flood defences and the loss of field boundaries and trees	-	-	++/-	++
Health and wellbeing	The hills enclosing the estuary are reasonably popular with walkers and cyclists, though the estuary itself is largely inaccessible.	It is likely that the area would see an increase in recreation activity during the summer months, but perhaps less during the winter	+	-	+	++

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Aesthetic values	The upper Firth of Tay is a high quality landscape, where the influence of the landform, woodland, river, settlements and wetlands overcome the effects of transport infrastructure, electricity pylons and intensive horticulture. Downstream, the human influences are greater, and the enclosure and influence of land form reduced	The balance between human and naturalistic influences would change with the introduction of turbines and new pylons and the loss of intertidal habitats. This would weaken its aesthetic value	-	-	+	++
Sense of place	This is a distinctive landscape, even when compared to other East Coast firths	The Firth of Tay would remain a distinctive landscape, reflecting its distinctive landform, the river and the interaction with land use and land cover	-	-	+	++
Cultural heritage values	While the influence of landform, woodland cover and of course the tidal river dominate, the pattern of settlement (‘coastal’ villages such as Newburgh, defensive sites such as at Rhynd, estates and follies such as on Kinnoull Hill), together with the pattern of agricultural fields, contribute to the character of this landscape	There could be impacts on the character of historic settlements immediately adjacent to the river where improved flood defences would be required to deal with sea level rise and the risk of tidal surges. The loss of field boundary trees and the potential amalgamation of fields would have an impact on the historic structure of the wider landscape.	--	-	+	+

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Recreation and tourism	The hills enclosing the estuary are reasonably popular with walkers and cyclists, though the estuary itself is largely inaccessible.	It is likely that the area would see an increase in recreation activity during the summer months, but perhaps less during the winter	+	-	+	++

PERTH

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Inspiration and enrichment	The contribution of Perth's urban environment to inspiration and enrichment is based on a combination of its historic character, stock of historic buildings, relationship with the River Tay, the range of open spaces including civic spaces, formal parks (including the North and South Inches), historic gardens (notably Scone Palace) and semi-natural greenspaces and the landscape setting provided by enclosing hills, narrow valley of the River Tay and more open landscapes to the north.	Key aspects that could be affected by climate change include, a possible weakening of the relationship with the River Tay, due to further hard flood defences, changes in the use of existing open spaces (e.g. to accommodate SUDs), stress on urban vegetation caused by summer drought, winter rainfall, increase summer use, the development of habitat networks based upon, and linking open spaces, the effects of retrofitting micro-renewables onto existing building stock (e.g. south facing solar panels) and the use of energy efficient (e.g. passive solar) and environmental friendly (e.g. green roofs) design and materials. It is likely that these changes would alter, though not significantly reduce the overall contribution to inspiration and enrichment.	-	-	+	+

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Health and wellbeing	Open spaces in particular have an existing and potential role to play in facilitating active recreation, walking and cycling. They include informal recreation areas, semi-natural areas (particularly on steeper ground on the edges of the city) and formal provision such as golf course. It is likely that the natural setting of the city, the role of the river corridor, and the network of open spaces also contribute to mental health and well being.	It is likely that the development of measures to increase the role of open spaces in contributing to flood management and habitat networks, together with mitigation measures designed to encourage sustainable travel could increase the overall contribution to health and well being. An increase in flood risk from fluvial, pluvial or estuarine events could have a significant influence on people living or working in areas affected.	--	--	++	++/-

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Aesthetic values	Perth's contribution to aesthetic values is based on the city's historic core, its relationship with the River Tay, key city centre open spaces and the influence of surrounding hills. These qualities are less prominent in extensive areas of twentieth century development to the north, west and south of the centre.	Some of these values could be adversely affected, for example as a result of the need for increased flood defences along the river corridor, though the recent works in this area demonstrates how this can be undertaken in a manner sensitive to the wider townscape. The need for measures in the city centre could be reduced by catchment scale measures, and by more radical options such as a tidal barrage. It is likely that new types of development would be concentrated away from the historic core of the city, though an extensive uptake of solar power equipment could have an impact on the appearance of the historic core and adjoining Victorian neighbourhoods. Habitat enhancement and other greenspace enhancements could increase the contribution of open spaces to aesthetic values.	--	=	+	+/-

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Sense of place	The historic structure of the city centre, its relationship with the River Tay (including bridging points), city centre open spaces, and relationship with the surrounding landscape (including landmarks such as Kinnoull Hill) mean that much of the city has a distinctive sense of place, though this is significantly weakened in suburban areas to the west and north.	It is possible that Perth's sense of place could be marginally affected by new building styles, the take up of micro-renewables, and any additional flood protection measures along the River Tay.	--	+	=	=
Cultural heritage values	The city has a rich historic character reflecting its location at the lowest bridging point on the River Tay, its medieval street layout, the relationship with Scone Palace, the Victorian heritage of villas, shopping streets, railway and industrial infrastructure.	The principal impacts on city's contribution to cultural heritage values could result from new building styles, the take up of micro-renewables, any additional flood protection measures along the River Tay and changes in the management or use of historic open spaces such as the North and South Inches	--	-	--	=

			With socio economic scenarios + cc			
Ecosystem services	Current	With climate change	WM	NE	GS	LS
Recreation and tourism	The network of open spaces within and around Perth provides a local resource for recreation. Specific sites, including Scone Palace, Kinnoull Hill, Cherrybank Gardens and the River Tay play a wider role. Many visitors to the Highlands pass through or close to Perth, though road travellers in particular largely by-pass the city.	It is likely that the local recreation resource would be enhanced as the network of open spaces and greenspaces is improved to provide walking and cycling routes, habitation	-/=	-	+	=

8. SOCIO-ECONOMIC SCENARIOS – DETAILED DESCRIPTIONS

8.1. This Appendix describes how each of the four socio economic scenarios would affect the likely landscape changes identified in the detailed study areas.

Killiecrankie Socio-Economic Scenarios

World Markets

8.2. Under the **World Markets** scenario, the countryside comes under considerable pressure from a combination of increases in recreation development, weakly controlled demand for housing development and more intensive farming. The low importance attached to biodiversity is reflected in a loss of natural and semi-natural habitats such as woodlands. The area given over to agriculture declines, with the abandonment of some marginal areas, and an increase in the area given over to leisure uses such as caravan parks. This scenario sees little or no renewable energy development of any kind. It also sees an increase in dependence on road transport with an increase in investment in road infrastructure. Environmental protection is focused on those areas catering for the recreation interests of wealthier people. There is an increase in housing development, though less retention of traditional buildings.

8.3. The World Markets scenario could result in the following outcomes:

- The decline of upland farming could result in the expansion of native and semi-natural woodland on the slopes of the glen;
- Recreation pressure could be reflected in the development of caravan sites or timber lodge developments on gentler slopes, though overall the area receives some landscape protection reflecting its status as a National Scenic Area, and its accessibility to wealthy consumers;
- The village of Killiecrankie could become a holiday home and commuting settlement, with new houses built on the edges of the village. There could also be development of prestigious houses on the middle slopes of the valley, on new sites and replacing existing farm buildings;
- It is likely that stalking and shooting remain at current levels or expand in popularity, with resulting pressures to maintain heather moorlands in their current condition
- The A9 would be upgraded to dual-carriageway with little concerns for its environmental impact and significant visual and aural impacts on the landscape as a result
- No renewable energy schemes, including windfarms, are developed.

8.4. Under the **World Markets** scenario, it is likely that the key influences on landscape character would be the decline of agriculture and development associated with the expansion of Killiecrankie and associated recreation and tourism facilities. Changes affecting the upland landscape would be limited to the direct impacts of climate change, since traditional fieldsports would remain popular and there would be little further development of wind power. The upgrade of the A9 would increase its influence on the character of Glen Garry at this point.

National Enterprise

8.5. The implications of the **National Markets** scenario differ from those for the World Markets scenario described above. Under this scenario there would be an emphasis on maintaining UK food production, so it is likely that agricultural activity would intensify, with some amalgamation of farms, further improvement of pastures and perhaps the loss of woodland and rough areas on the middle slopes of Highland glens. However, there would be relatively little adaptation of agriculture to climate change, so the emphasis would be on business as usual.

8.6. Rural areas also come under pressure for housing development, with weak planning controls resulting in development within the wider countryside, though areas such as the Loch Tummel National Scenic Area may receive a higher level of protection. There is also some pressure for recreation related development, though less significantly than in the World Markets scenario. With a failure to curb emissions of greenhouse gases, and little or no renewable energy development, the effect of the changing climate is relatively high.

8.7. The **National Markets** scenario could result in the following outcomes:

- An intensification of agricultural activity on the middle slopes of the glen, with a loss of trees and woodland, improvement of pastures and some field amalgamation. It is possible that agricultural activity could push uphill, particularly if heather moorlands are increasingly replaced by grass moorland. There could be new farm buildings.
- The intensification of farming would result in further loss and fragmentation of natural and semi-natural habitats, with woodland being confined to steeper terraces along the main river valley and along the course of the tributary.
- Farm amalgamation could be reflected in the conversion of older buildings where they have become redundant.
- It is likely that there would be some additional housing development on the edge of Killiecrankie.

- Renewable energy, including windfarms, biomass and solar would not be developed.

8.8. Under the **National Markets** scenario, it is likely that the range of 'human related' landscape changes would compound some of the effects of climate change. One of the most significant changes would be the intensification and possible expansion of agricultural activity, with a loss of moorland, woodland and the improvement and enlargement of existing fields. However, climate change mitigation would be limited, so the landscape effects of wind energy development, biomass cultivation and use, and the expansion of woodland for carbon sequestration purposes would be limited or absent altogether.

Global Sustainability

8.9. Under the **Global Sustainability** scenario national policy places an emphasis on achieving sustainable development and the protection of 'global commons' including wilderness areas. Agricultural policy links the achievement of high yields with low environmental impacts, using support payments to encourage the sustainable management of rural landscapes. The area of agricultural production falls, with some land being used to create natural and semi-natural habitats, reversing the fragmentation of existing habitats and helping species adapt to climate change. There is a decline in meat consumption and reductions in stock rearing as a result.

8.10. An emphasis on achieving energy efficiency means that many older buildings and elements of infrastructure are replaced. New housing development is concentrated within urban centres and on brownfield sites. Renewable energy is widely developed and sees an emphasis on solar power and, beyond 2020, the emphasis shifts to hydrogen fuel. There is a growing emphasis on quality of life and Scotland is increasingly recognised as a good place to live. Accessible areas of countryside come under more pressure for informal recreation.

8.11. The **Global Sustainability** scenario could result in the following outcomes:

- The emphasis on environmental protection and habitat enhancement, together with contraction of animal husbandry in more marginal areas could result in a the conversion of large areas of farmland to semi-natural habitats including low input pastures and woodlands, particularly on the valley slopes.
- There would be increased demand for informal recreation, reflecting the accessibility of the area and its status as a National Scenic Area.
- It is likely that older, inefficient buildings would be replaced, but otherwise new development would be strictly restrained.

- The A9 would be upgraded to dual carriageway, but it is likely that there would be an emphasis on limiting environmental impacts and maximising the landscape 'fit'.
- The policy emphasis of conserving wilderness areas would discourage the development of upland windfarms within or close to the National Scenic Area, though the wider emphasis on developing renewable energy could see the development of biomass sources, particularly those associated with woodland and forestry. It is likely that woodland expansion would also be used as a means of increasing carbon sequestration and catchment scale flood management.

8.12. Under the **Global Sustainability** scenario, it is likely that the landscape would experience a significant reduction in agricultural activity and a corresponding increase in semi-natural woodland cover linked to habitat enhancement, carbon sequestration, production of timber based fuel and catchment scale flood management. It is likely that management would aim to enhance the wild land qualities of the uplands with no development of windfarms.

Local Stewardship

8.13. Under the **Local Stewardship** scenario there in an emphasis on small scale food production, increasing self sufficiency and achieving food security. Trends such as an increase in vegetarianism, and increasing demand for locally produced organic foods result in a decline in farm size, a decrease in livestock production and a slow increase in the area of arable farmland. Local landscapes are protected and there is an emphasis on protecting biodiversity and helping species to adapt to climate change. A conservationist ethic, added to low levels of investment, means that traditional buildings are retained. There is an emphasis on walking and cycling as means of everyday transport, while renewable energy development focuses on local energy sources, including locally based heat and power schemes.

8.14. Within the landscape illustrated in Figure 5.2b, the **Local Stewardship** scenario could result in the following outcomes:

- A reduction in agricultural activity reflecting the decreased demand for meat products. Possible conversion of some farmland to cultivation, with fruit and vegetable growing, particularly on the more fertile lower slopes and valley floor.
- An increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks, particularly on the middle slopes of the glen, and an expansion of native woodland and scrub on some of the upper hills slopes.

- The positive management of landscape features including field boundary trees and hedges.
- An increase in the network of footpaths and cycleways and no upgrading of the A9;
- Little or no housing development.
- Expansion of locally based renewables including biomass and small scale wind turbines.

8.15. Under the **Local Stewardship** scenario, it is likely that the landscape would see the loss of the existing ‘pastoral’ landscape on the middle slopes of the glen and some expansion of fruit and vegetable growing on lower slopes and valley floor. It is likely that the middle slopes would revert to woodland and scrub, with semi-natural woodland expansion along the tributary valley and up the hillslopes. The result would be a much more wooded landscape.

Strathmore Socio-Economic Scenarios

World Markets

8.16. Under the **World Markets** scenario, the countryside comes under considerable pressure from a combination of more intensive farming, increases in recreation development and land use, and weakly controlled demand for housing development. The low importance attached to biodiversity is reflected in a loss of natural and semi-natural habitats such as woodlands. The area given over to agriculture, and total agricultural production both decline as land is given over to leisure uses such as golf. Remaining areas of farmland are managed more intensively, with an increase in farm size and extensive use of genetically modified crops. This scenario sees little or no renewable energy development of any kind. It also sees an increase in dependence on road transport with an increase in investment in road infrastructure.

8.17. The World Markets scenario could result in the following outcomes:

- An accelerated loss of natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges. It is likely that some fields would be enlarged.
- The emphasis on arable production would remain, though it is likely that there would be an increase in the use of GM based crops. It is likely that irrigation will be increasingly common.
- Farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant. There could be additional pressure for new, large farmbuildings for crop storage.
- Some of the land that is currently being farmed would be taken out of agricultural production, with a conversion to leisure uses, including golf courses which would be particularly visible in this otherwise open and arable landscape.
- It is likely that there would be additional housing development, with some new houses replacing the traditional cottages in the foreground, some expanding the overall size of the settlement, and some occupying isolated locations in the wider countryside.
- This would result in a much more open, arable landscape.
- It is likely that the road in the right hand part of the picture would be widened, adding to the loss of trees and hedges.
- Renewable energy, including windfarms, biomass and solar would not be developed.

8.18. Under the **World Markets** scenario, it is likely that the range of 'human related' landscape changes would have a more profound effect on landscape character than those resulting directly or indirectly from climate change. The resulting landscape would be much more open in character, with additional housing development and the introduction of countryside based leisure uses such as golf courses or caravan parks, weakening its current rural and agricultural character. However, climate change mitigation would be limited, so the landscape effects of wind energy development, biomass cultivation and use, and the expansion of woodland for carbon sequestration purposes would be limited or absent altogether.

National Enterprise

8.19. The implications of the **National Enterprise** scenario are similar to, though less extreme than, the World Markets scenario described above. Although the area of agriculture contracts overall, the use of high inputs of pesticides and fertilisers, together with some take up of genetically modified crops, result in an increase in productivity. There is some amalgamation of farm units. Within farmed areas, there is a continued loss and fragmentation of natural and semi-natural habitats and a resultant decline in biodiversity. Rural areas also come under pressure for housing development, with weak planning controls resulting in development in greenbelts and the wider countryside. There is also some pressure for recreation related development, though less significantly than in the World Markets scenario. With a failure to curb emissions of greenhouse gases, and little or no renewable energy development, the effect of the changing climate is relatively high.

8.20. The **National Enterprise** scenario could result in the following outcomes:

- A further loss and fragmentation of natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges. It is likely that some fields would be enlarged.
- The emphasis on arable production would remain, with greater us of chemical pesticides and fertilisers and some use of GM based crops. It is likely that irrigation will be increasingly common.
- Farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant.
- It is likely that there would be additional housing development, with some new houses replacing the traditional cottages in the foreground, some expanding the overall size of the settlement, and some occupying isolated locations in the wider countryside.
- This would result in a much more open, arable landscape.

- Renewable energy, including windfarms, biomass and solar would not be developed.

8.21. Under the **National Enterprise** scenario, it is likely that the range of 'human related' landscape changes would compound some of the effects of climate change. The resulting landscape would be much more open in character, with additional housing development and the loss of woodland and trees altering its current agricultural character. However, climate change mitigation would be limited, so the landscape effects of wind energy development, biomass cultivation and use, and the expansion of woodland for carbon sequestration purposes would be limited or absent altogether.

Global Sustainability

8.22. Under the **Global Sustainability** scenario national policy places an emphasis on achieving sustainable development. Agricultural policy links the achievement of high yields with low environmental impacts, using support payments to encourage the sustainable management of rural landscapes. The area of agricultural production falls, with some land being used to create natural and semi-natural habitats, reversing the fragmentation of existing habitats and helping species adapt to climate change. There is a decline in meat consumption and reductions in stock rearing as a result.

8.23. An emphasis on achieving energy efficiency means that many older buildings and elements of infrastructure are replaced. New housing development is, however, concentrated within urban centres and on brownfield sites. Renewable energy sees an emphasis on solar power and, beyond 2020, the emphasis shifts to hydrogen fuel, with the development of production, storage and distribution infrastructure which could result in short term impacts associated with new pipelines.

8.24. There is a growing emphasis on quality of life and Scotland is increasingly recognised as a good place to live. Accessible areas of countryside come under more pressure for informal recreation.

8.25. The **Global Sustainability** scenario could result in the following outcomes:

- An increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks.
- The positive management of landscape features including field boundary trees and hedges.
- A reduction overall in the extent of farmland, and a further emphasis on arable as opposed to pastoral production.

- The replacement of a number of the traditional cottages with modern, energy efficient dwellings, with integrated micro-renewables such as solar power, solar hot water, biomass and small scale wind power.
- The possible development of some form of commercial scale solar collector, reflecting the trend towards sunnier summers and, in the longer term, a hydrogen fuel network (temporary landscape effect).
- No further expansion of the settlement.
- An increase in the network of footpaths used for informal recreation.

8.26. Under the **Global Sustainability** scenario, it is likely that the landscape would experience a number of apparently contrasting trends. On the one hand, an expanded network of woodlands, restored hedges and field boundaries would reinforce the existing character of the landscape or perhaps create a more enclosed, less open and arable landscape than at present. On the other hand, the replacement of energy inefficient buildings and the introduction of novel forms of renewable energy (including solar energy collectors) could introduce distinctly modern elements into an apparently traditional landscape. Changing crops, and the shift from pastoral to arable cultivation would have a relatively limited impact here. It is likely that more people would experience and enjoy landscapes such as this.

Local Stewardship

8.27. Under the **Local Stewardship** scenario there in an emphasis on small scale food production, increasing self sufficiency and achieving food security. Trends such as an increase in vegetarianism, and increasing demand for locally produced organic foods result in a decline in farm size, a decrease in livestock production and a slow increase in the area of arable farmland. Local landscapes are protected and there is an emphasis on protecting biodiversity and helping species to adapt to climate change. A conservationist ethic, added to low levels of investment, means that traditional buildings are retained. There is an emphasis on walking and cycling as means of everyday transport, while renewable energy development focuses on local energy sources, including locally based heat and power schemes.

8.28. Within the landscape illustrated in Figure 5.3b, the **Local Stewardship** scenario could result in the following outcomes:

- An increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks.
- The positive management of landscape features including field boundary trees and hedges.

- A reduction overall in the extent of farmland, and a further emphasis on arable as opposed to pastoral production, with a possible reduction in the size of some fields;
- The development of horticulture and market gardens around the village, with allotments, polytunnels and small fields.
- The development of a local biomass plant serving the settlement, together with other forms of small scale renewable energy development.
- No further expansion of the settlement.
- An increase in the network of footpaths and cycleways.

8.29. Under the **Local Stewardship** scenario, it is likely that the landscape would experience an intensification of agricultural and horticultural production, allied to the conservation and enhancement of key landscape features and habitats. It is likely that change would be gradual, organic and relatively small scale, perhaps resulting in a slow change in character from the current dominance of extensive, arable production. The existing structure of the landscape, together with the settlement pattern would be retained and reinforced. New structures would be limited in size, for example taking the form of small scale biomass plants, polytunnels and fairly modest farm buildings.

Firth of Tay Socio-Economic Scenarios

World Markets

8.30. Under the **World Markets** scenario, the countryside comes under considerable pressure from a combination of more intensive farming, increases in recreation development and land use, and weakly controlled demand for housing development. The low importance attached to biodiversity is reflected in a loss of natural and semi-natural habitats such as woodlands and wetland. The area given over to agriculture, and total agricultural production both decline as land is given over to leisure uses such as golf and caravan parks. Remaining areas of farmland are managed more intensively, with an increase in farm size and extensive use of genetically modified crops. Coastal areas come under particular pressure for housing development, with weak planning controls and higher income groups building houses even where insurance is refused. Some housing developments use novel construction techniques to improve their resilience to flooding. Flood defences are largely privatised. This scenario sees little or no renewable energy development of any kind. It also sees an increase in dependence on road transport with an increase in investment in road infrastructure.

8.31. The World Markets scenario could result in the following outcomes:

- The loss of coastal reedbeds and mudflats as sea levels rise and flood defences are improved around private properties and also more productive farmland.
- An accelerated loss of natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges.
- The emphasis on arable and fruit production would remain, though it is likely that there would be an increase in the use of GM based crops. It is likely that irrigation will be increasingly common.
- Farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant. There could be additional pressure for new, large farmbuildings for crop storage.
- Some of the land that is currently being farmed would be taken out of agricultural production, with a conversion to leisure uses, including golf courses and caravan parks which would be visible on the open carselands, and on the southern slopes of the Sidlaw hills.
- It is likely that there would be additional housing development, with some new houses built on the carse itself, and in positions on rising ground to the south.
- Renewable energy, including windfarms, biomass and solar would not be developed.

8.32. Under the **World Markets** scenario, it is likely that the range of 'human related' landscape changes combine with climate changes such as sea level rise, to alter the character of the landscape. The resulting landscape would be much more open in character, with additional housing development and the introduction of countryside based leisure uses such as golf courses or caravan parks, accentuating existing urban influences and weakening its current rural and agricultural character. However, climate change mitigation would be limited, so the landscape effects of wind energy development, biomass cultivation and use, and the expansion of woodland for carbon sequestration purposes would be limited or absent altogether.

National Enterprise

8.33. The implications of the **National Enterprise** scenario are similar to, though less extreme than, the World Markets scenario described above. Although the area of agriculture contracts overall, the use of high inputs of pesticides and fertilisers, together with some take up of genetically modified crops, result in an increase in productivity. There is some amalgamation of farm units. Within farmed areas, there is a continued loss and fragmentation of natural and semi-natural habitats and a resultant decline in biodiversity. Rural areas also come under pressure for housing development, with weak planning controls resulting in development in greenbelts and the wider countryside, including in coastal locations. Coastal defence aims to protect all coastal areas, including farmland. There is also some pressure for recreation related development, though less significantly than in the World Markets scenario. With a failure to curb emissions of greenhouse gases, and little or no renewable energy development, the effect of the changing climate is relatively high.

8.34. The **National Enterprise** scenario could result in the following outcomes:

- A significant upgrading of flood defences along the northern side of the River Tay in order to protect farmland, property and transport infrastructure on the Carse of Gowrie. These defences, allied to rising sea levels are likely to result in the loss of distinctive riverside landscapes and habitats including mudflats and the distinctive areas of reedbed.
- A further loss and fragmentation of other natural and semi-natural habitats, including existing areas of woodland, hedgerow trees and hedges. It is likely that some fields would be enlarged.
- The emphasis on arable and fruit production would remain, with greater us of chemical pesticides and fertilisers and some use of GM based crops. It is likely that irrigation will be increasingly common.

- Farm amalgamation could be reflected in the loss of some more recent farm buildings and the conversion of older steadings where they have become redundant.
- It is likely that there would be some additional housing development, including on the Carse where they would be protected by the upgraded flood defences.
- Renewable energy, including windfarms, biomass and solar would not be developed.

8.35. Under the **National Enterprise** scenario, it is likely that the range of 'human related' landscape changes would compound some of the effects of climate change. One of the most significant changes would be the further loss of 'natural' estuarine landscapes of mudflats and reedbeds, and the 'screening' effect of the flood defence bunds. On the Carse and on the Sidlaw slopes beyond the landscape would be more open in character, with additional housing development and the loss of woodland and trees altering its current agricultural character. However, climate change mitigation would be limited, so the landscape effects of wind energy development, biomass cultivation and use, and the expansion of woodland for carbon sequestration purposes would be limited or absent altogether.

Global Sustainability

8.36. Under the **Global Sustainability** scenario national policy places an emphasis on achieving sustainable development. Agricultural policy links the achievement of high yields with low environmental impacts, using support payments to encourage the sustainable management of rural landscapes. The area of agricultural production falls, with some land being used to create natural and semi-natural habitats, reversing the fragmentation of existing habitats and helping species adapt to climate change. There is a decline in meat consumption and reductions in stock rearing as a result.

8.37. An emphasis on achieving energy efficiency means that many older buildings and elements of infrastructure are replaced. New housing development is, however, concentrated within urban centres and on brownfield sites, with development in vulnerable coastal locations also restricted. Coastal flood defences are confined to areas with high value assets, with managed realignment being used elsewhere. Renewable energy sees an emphasis on solar power and, beyond 2020, the emphasis shifts to hydrogen fuel, with the development of production, storage and distribution infrastructure which could result in short term impacts associated with new pipelines. There could also be growing interest in marine energy, including the development of tidal barrages in locations such as the Firth of Tay (subject of course to its international importance for biodiversity).

8.38. There is a growing emphasis on quality of life and Scotland is increasingly recognised as a good place to live. Accessible areas of countryside come under more pressure for informal recreation.

8.39. Within the landscape illustrated in Figure 5.4b, the **Global Sustainability** scenario could result in the following outcomes:

- The use of managed realignment to create soft flood defences. This could result in creation of new wetlands and reedbeds in areas of the Carse that are currently farmed.
- An increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks.
- The positive management of landscape features including field boundary trees and hedges.
- A reduction overall in the extent of farmland, and a further emphasis on arable as opposed to pastoral production.
- The replacement of traditional buildings with modern, energy efficient dwellings, with integrated micro-renewables such as solar power, solar hot water, biomass and small scale wind power.
- The possible development of a tidal barrage renewable energy project, altering or removing the pattern of tides along the Firth, with further implications for habitats and species.
- The possible development of some form of commercial scale solar collector, reflecting the trend towards sunnier summers and, in the longer term, a hydrogen fuel network (temporary landscape effect).
- An increase in the network of footpaths used for informal recreation.

8.40. Under the **Global Sustainability** scenario, it is likely that the landscape would experience a number of apparently contrasting trends. It is likely that the increased risk of tidal flooding (sea level rise and coastal surge tide) would result in managed retreat responses, with the creation of new wetlands in areas of the Carse that are currently farmed. An expanded network of woodlands, restored hedges and field boundaries would reinforce the existing character of the landscape or perhaps create a more enclosed, less open and arable landscape than at present. On the other hand, the replacement of energy inefficient buildings and the introduction of novel forms of renewable energy (including tidal barrage and solar energy collectors) could introduce distinctly modern elements into an apparently traditional landscape. Changing crops, and the shift from pastoral to arable and horticultural cultivation would have a relatively limited impact here. It is likely that more people would experience and enjoy landscapes such as this.

Local Stewardship

8.41. Under the **Local Stewardship** scenario there in an emphasis on small scale food production, increasing self sufficiency and achieving food security. Trends such as an increase in vegetarianism, and increasing demand for locally produced organic foods result in a decline in farm size, a decrease in livestock production and a slow increase in the area of arable farmland. Local landscapes are protected and there is an emphasis on protecting biodiversity and helping species to adapt to climate change. A conservationist ethic, added to low levels of investment, means that traditional buildings are retained. There is an emphasis on walking and cycling as means of everyday transport, while renewable energy development focuses on local energy sources, including locally based heat and power schemes. Development in coastal locations is restricted and coastal flood defence based on managed realignment, with hard flood defences only where there are major areas of productive farmland.

8.42. The **Local Stewardship** scenario could result in the following outcomes:

- An increase in the extent of semi-natural habitats including an expansion of woodland based habitat networks.
- The positive management of landscape features including field boundary trees and hedges.
- A carefully balanced approach to coastal flood defence which aims to protect some areas of productive farmland, but which uses managed realignment elsewhere as a means of conserving or enhancing estuarine habitats including reedbeds and mudflats.
- A reduction overall in the extent of farmland, and a further emphasis on arable as opposed to pastoral production, with a possible reduction in the size of some fields.
- An increase in the network of footpaths and cycleways.

8.43. Under the **Local Stewardship** scenario, it is likely that the landscape would experience an intensification of agricultural and horticultural production, allied to the conservation and enhancement of key landscape features and habitats. It is likely that change would be gradual, organic and relatively small scale, perhaps resulting in a slow change in character from the current dominance of extensive, arable and fruit production. The existing structure of the landscape, together with the settlement pattern would be retained and reinforced. New structures would be limited in size, for example taking the form of small scale biomass plants, polytunnels and fairly modest farm buildings. Flood defences would probably include a combination of hard measures to protect some areas of the best farmland, and managed realignment to conserve and enhance intertidal habitats such as mudflats and reedbeds.

Perth Socio-Economic Scenarios

World Markets

8.44. Under the **World Markets** scenario, urban areas experience significant growth based on further reductions in household size and growth of the service sector (financial sector, health and IT), though there is a decline in traditional manufacturing and food processing. This growth places greater pressure on undeveloped areas within the town, and results in its expansion onto surrounding agricultural land. The existing stock of houses and commercial properties is renewed or upgraded, though there is little development of micro-renewables such as solar based heating or small wind turbines. Growth is dependent on high levels of mobility, and the existing road network is expanded and upgraded within and around the town, with little or no investment in walking and cycling provision. Those natural and semi-natural habitats that survive within, and around the town are managed with recreation in mind. Flooding becomes an increasing issue with the state playing a decreasing role in providing flood defences, with more affluent people accepting the risk, or providing their own defences, and other areas becoming uninsurable and blighted. Water quality in the Tay deteriorates as runoff from upstream agricultural intensification becomes more polluted.

8.45. The key changes associated with this socio-economic scenario therefore include:

- Development pressure on urban greenspaces and surrounding countryside with impacts on amenity, health, recreation, biodiversity and sustainable flood management.
- Deterioration of conditions for pedestrians and cyclists.
- Increased risk of flooding associated with higher winter rainfall, loss of greenspaces within the settlement and an increase risk in estuarine flooding.
- Modernisation of the building stock.
- Management of retained greenspaces and habitats in and around the town for recreation.

National Enterprise

8.46. The National Enterprise scenario sees much lower rates of urban expansion and renewal than under the World Markets model. While this means that the demand for additional land is reduced, the overall quality of the urban environment declines, with continued habitat fragmentation, weak planning, road congestion and deteriorating water quality. More affluent residents succeed in securing protection for their local environments. While flood protection is maintained and where necessary improved, there is little or no investment in renewable energy. Economic growth is lower than

the UK average, with an emphasis on traditional industries, including the processing of agricultural produce.

8.47. The key changes associated with this socio-economic scenario therefore include:

- Deterioration of environmental quality within the urban area, and a further loss and fragmentation of urban greenspaces.
- A disparate pattern of environmental protection, responding to affluence and political influence.
- No significant expansion of the urban area, upgrading the existing building stock or regeneration of former industrial areas.
- Declining water quality but an ongoing commitment to flood protection.

Global Sustainability

8.48. The **Global** Sustainability scenario places an emphasis on conserving and enhancing environmental quality. In the urban context, this means that the quality of urban greenspaces and the public realm is improved. However, it also means that new housing development is concentrated within high density, low rise developments on brownfield and other urban sites. This could result in the loss of some existing greenspaces and increase pressure on those that are retained. Old and inefficient buildings and infrastructure are replaced. While this could result in significant disruption (e.g. upgrading the Victorian rail infrastructure through Perth), it could provide significant opportunities to integrate renewable energy into new buildings, with an increase in the take up of solar technologies and more environmentally friendly building designs incorporating green roofs and natural materials. Development in the countryside, and in areas at risk of flooding, is not generally allowed. Water quality is good and improving as agriculture becomes less intensive and heavy industry is replaced by cleaner manufacturing and research and development activities.

8.49. The key changes associated with this socio-economic scenario therefore include:

- An emphasis on environmental quality which would be reflected in high quality greenspaces, public realm, walking and cycling networks.
- An increase in the density of urban development, with new housing on brownfield, former industrial and other urban sites.
- Conservation and enhancement of biodiversity within and around the urban area, but also an increasing demand for recreation in accessible countryside around Perth.
- Replacement of the existing stock of older buildings, with an increase in the use of sustainable design, construction and materials, and the take up of solar energy;
- Investment in transport infrastructure.

Local Stewardship

8.50. The **Local Stewardship** scenario sees a more localised and sustainable pattern of development. This includes the recognition and protection of community assets such as greenspaces and the enhancement of habitat networks, community gardens and allotments. While growth overall is stable, there is a decentralisation from larger cities to small and medium sized towns such as Perth. With tight restrictions on development in the countryside, this growth is achieved through an increase in the density of development. With more mixed patterns of land uses, denser urban forms and increasing energy and transport costs, there is considerable emphasis on walking and cycling as means of getting around urban areas. While the existing building stock is largely retained, there is an emphasis on energy efficiency, the development of local energy sources including district biomass plants generating combined heat and power, and solar energy for water heating. Wind energy is developed close to the town. Water quality improves, reflecting more environmentally sustainable patterns of farming, but investment in flood defences do not keep pace with the increased risk, raising the prospect of significant flood events. There are restrictions on development in areas at risk of flooding.

8.51. The key changes associated with this socio-economic scenario therefore include:

- A reinforcement of the existing urban form, but redevelopment to create a denser and less homogeneous structure.
- An increased emphasis on the role of greenspaces within the city, particularly in terms of providing habitat networks, accommodating walking and cycling routes and providing land for allotments and community gardens.
- An increase in the take up of urban renewables including district combined heat and power and the retrofitting of solar energy equipment.
- An increase risk of flooding, and a withdrawal from areas at risk of inundation.

9. UKCIP02 CLIMATE CHANGE MAPS

9.1. This section of the Appendices includes climate change maps which illustrate the maximum and minimum change for the UKCIP02 climate change scenarios for the following weather variables:

- Humidity;
- Annual temperature;
- Autumn temperature;
- Number of hot days;
- Maximum temperature;
- Minimum temperature;
- Winter cloud cover;
- Summer cloud cover;
- Winter precipitation;
- Summer precipitation;
- Winter and summer precipitation;
- Snowfall;
- Seasonal difference in precipitation;
- Summer daily mean windspeed;
- Winter daily mean windspeed.

9.2. The maps show the relative degree of change across Scotland and formed the basis for the national level mapping in Chapter 4.

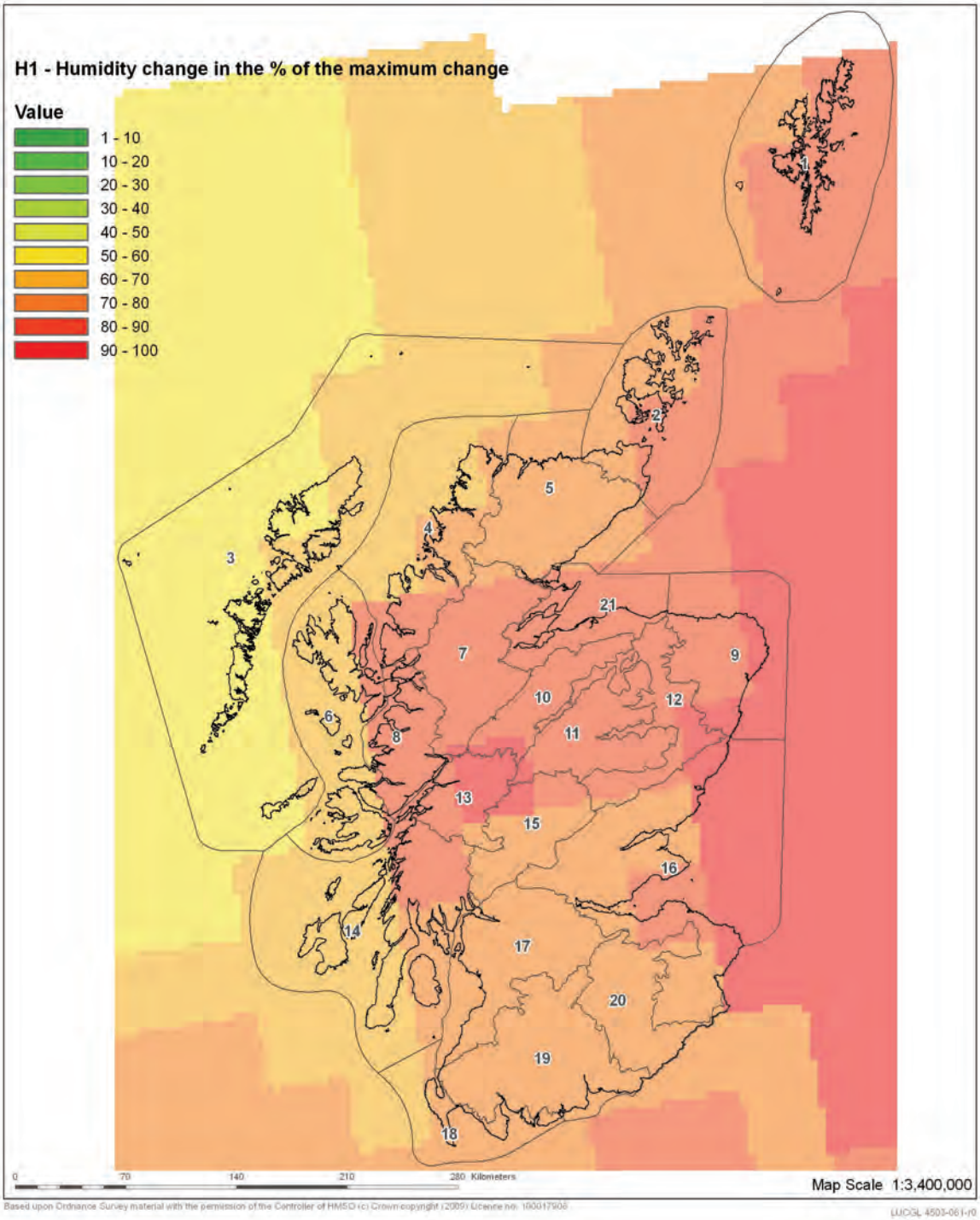


Figure 9.1

▸Mapping based on UKCIP02 Climate Change Scenario data

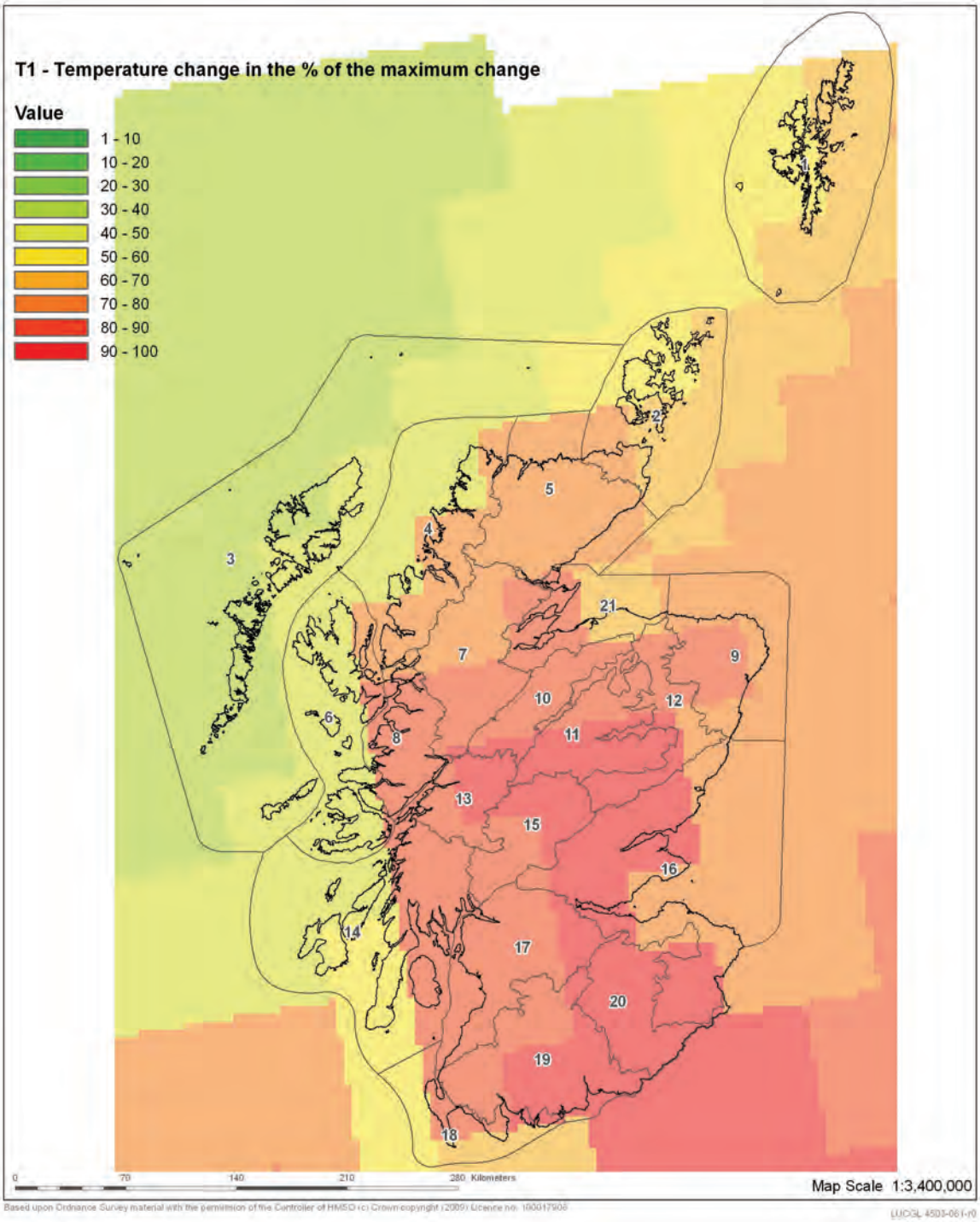


Figure 9.2

▸Mapping based on UKCIP02 Climate Change Scenario data

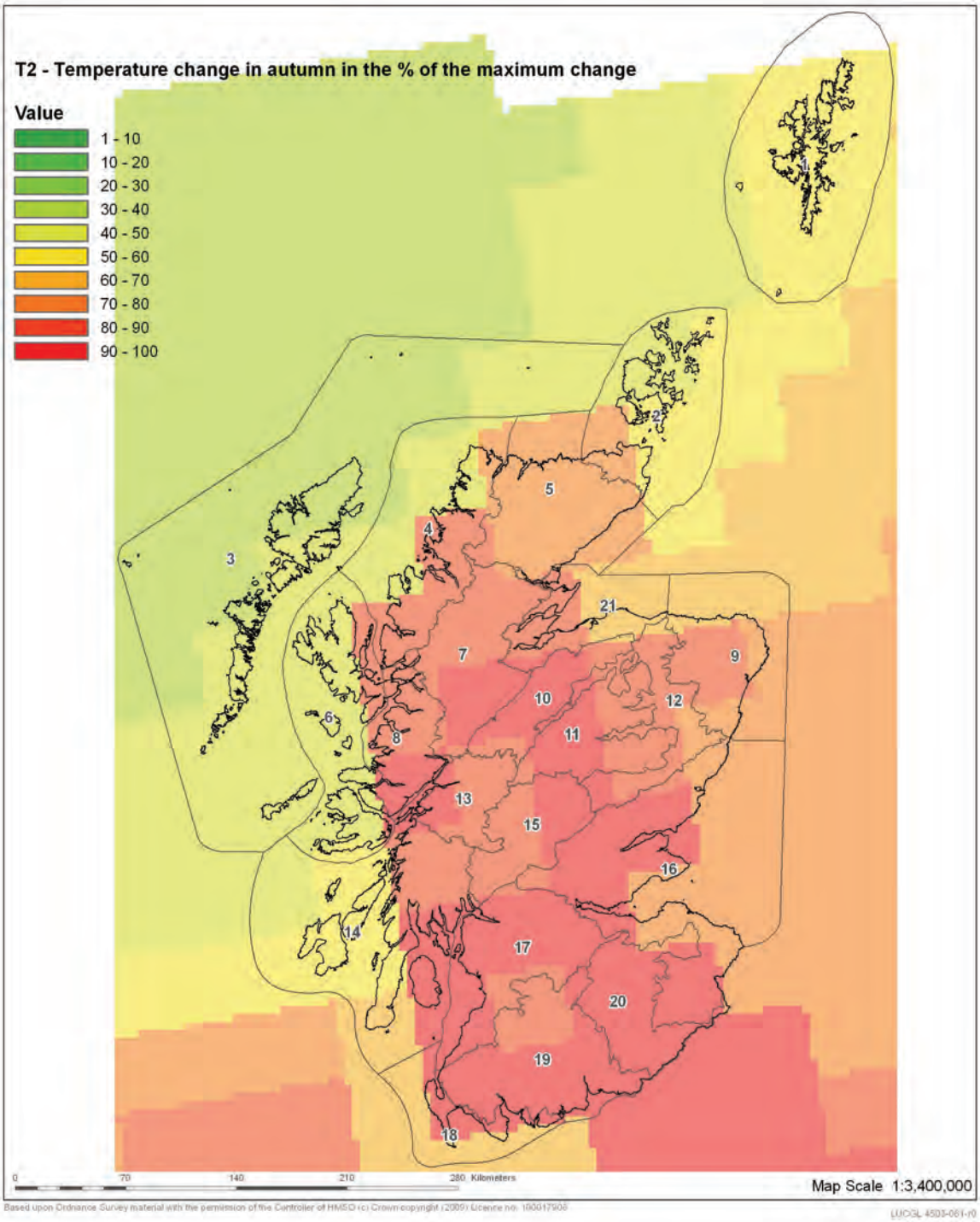


Figure 9.3

▸Mapping based on UKCIP02 Climate Change Scenario data

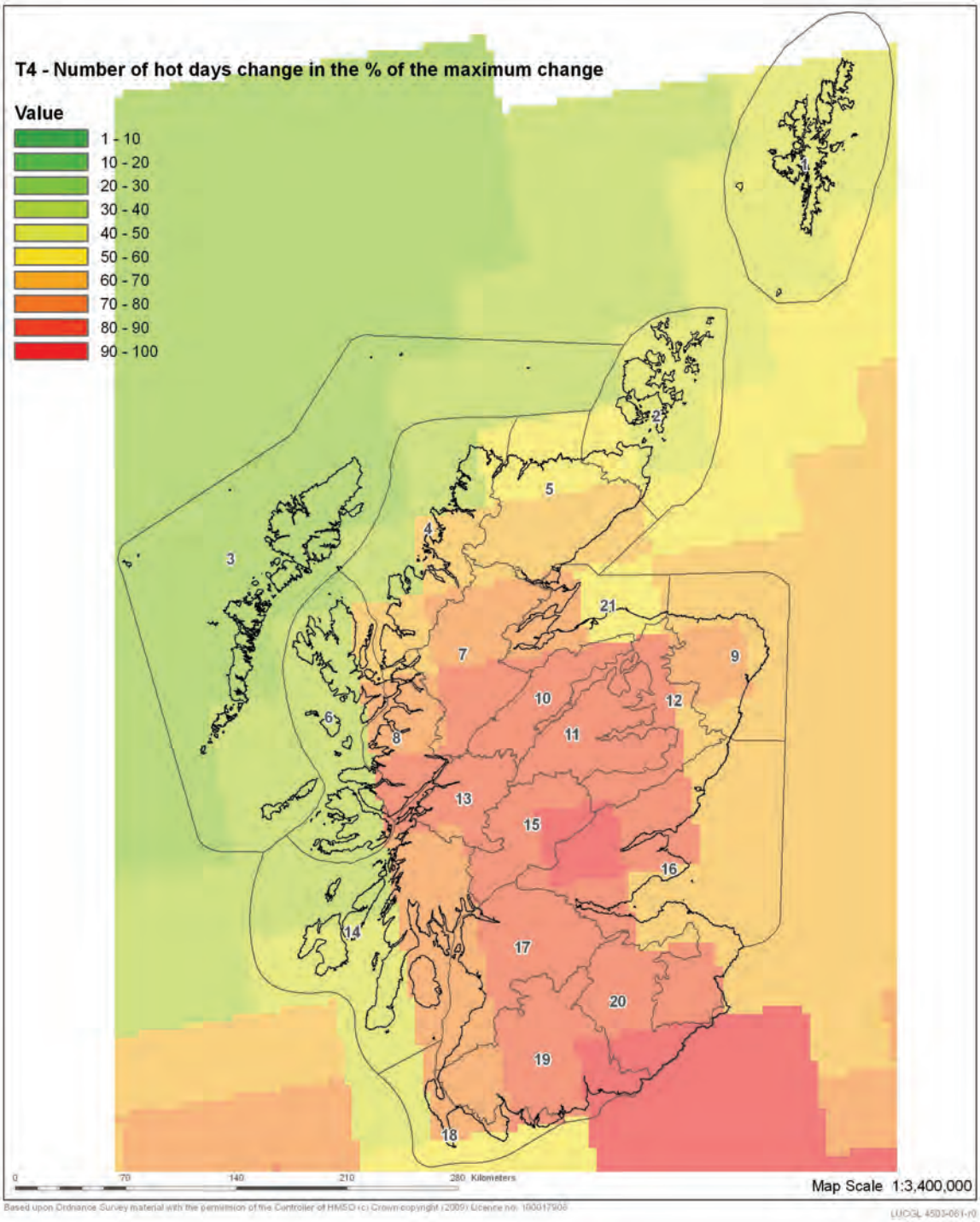


Figure 9.4

▸Mapping based on UKCIP02 Climate Change Scenario data

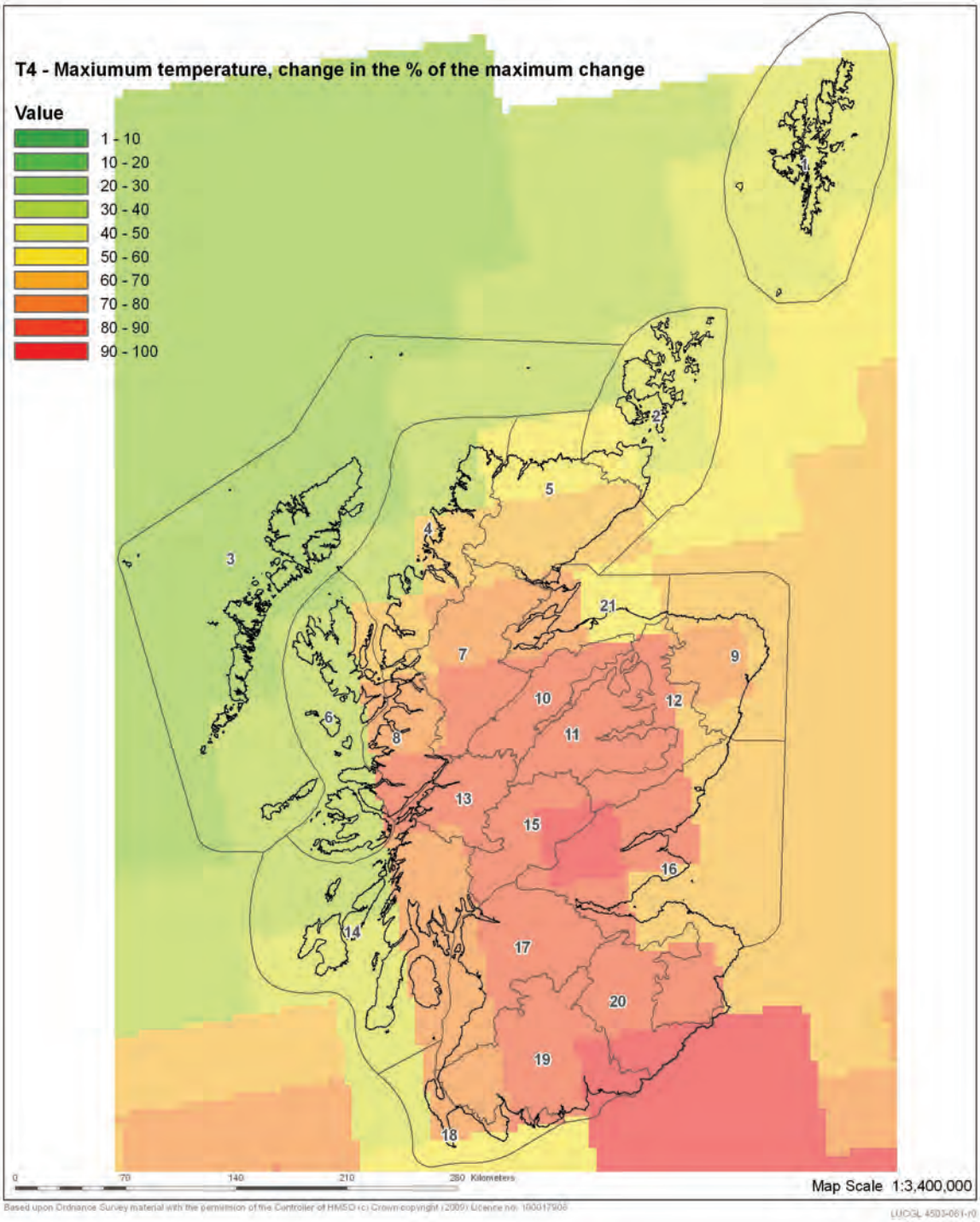


Figure 9.5

▸Mapping based on UKCIP02 Climate Change Scenario data

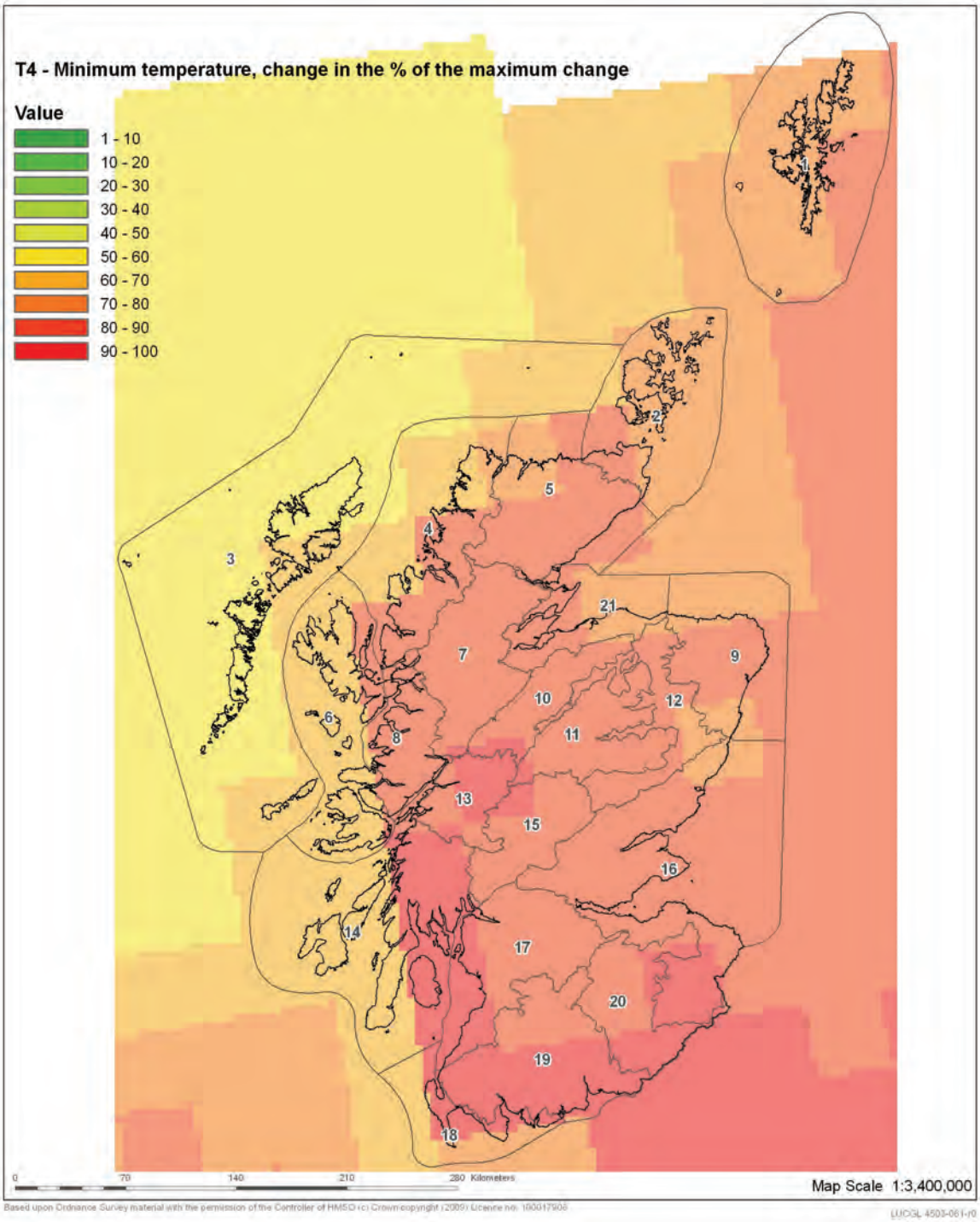


Figure 9.6

▸Mapping based on UKCIP02 Climate Change Scenario data

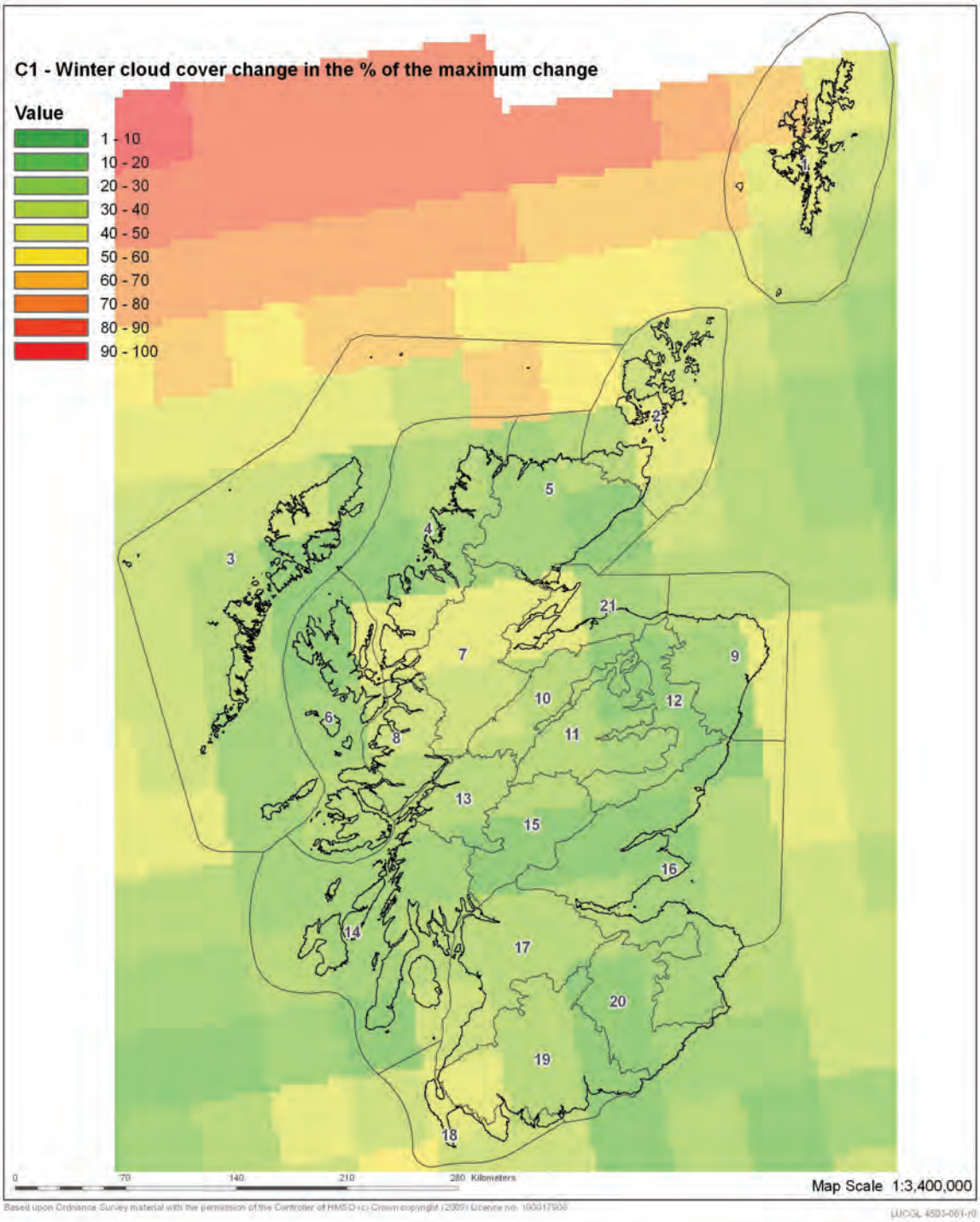


Figure 9.7

▸Mapping based on UKCIP02 Climate Change Scenario data

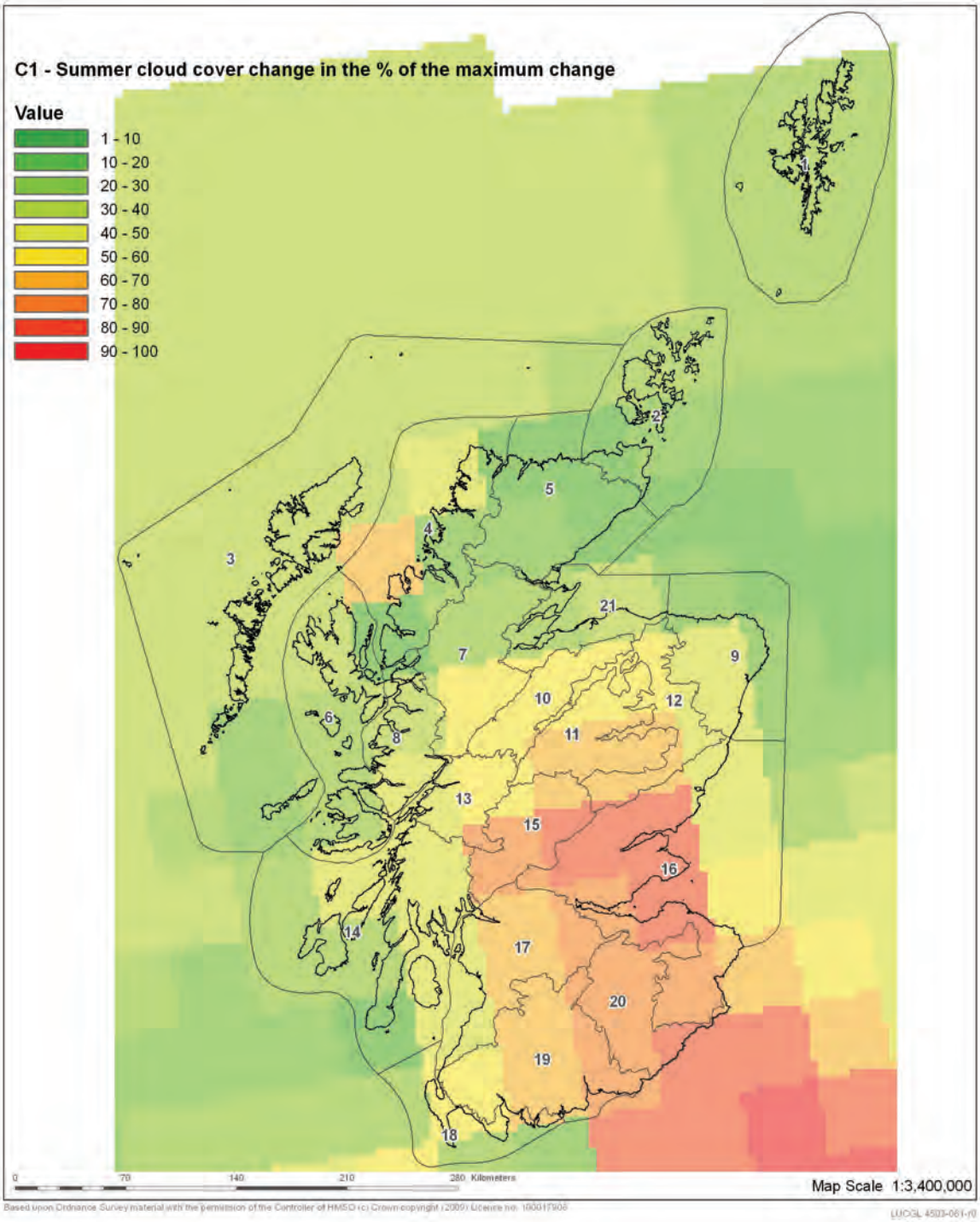


Figure 9.8

▸Mapping based on UKCIP02 Climate Change Scenario data

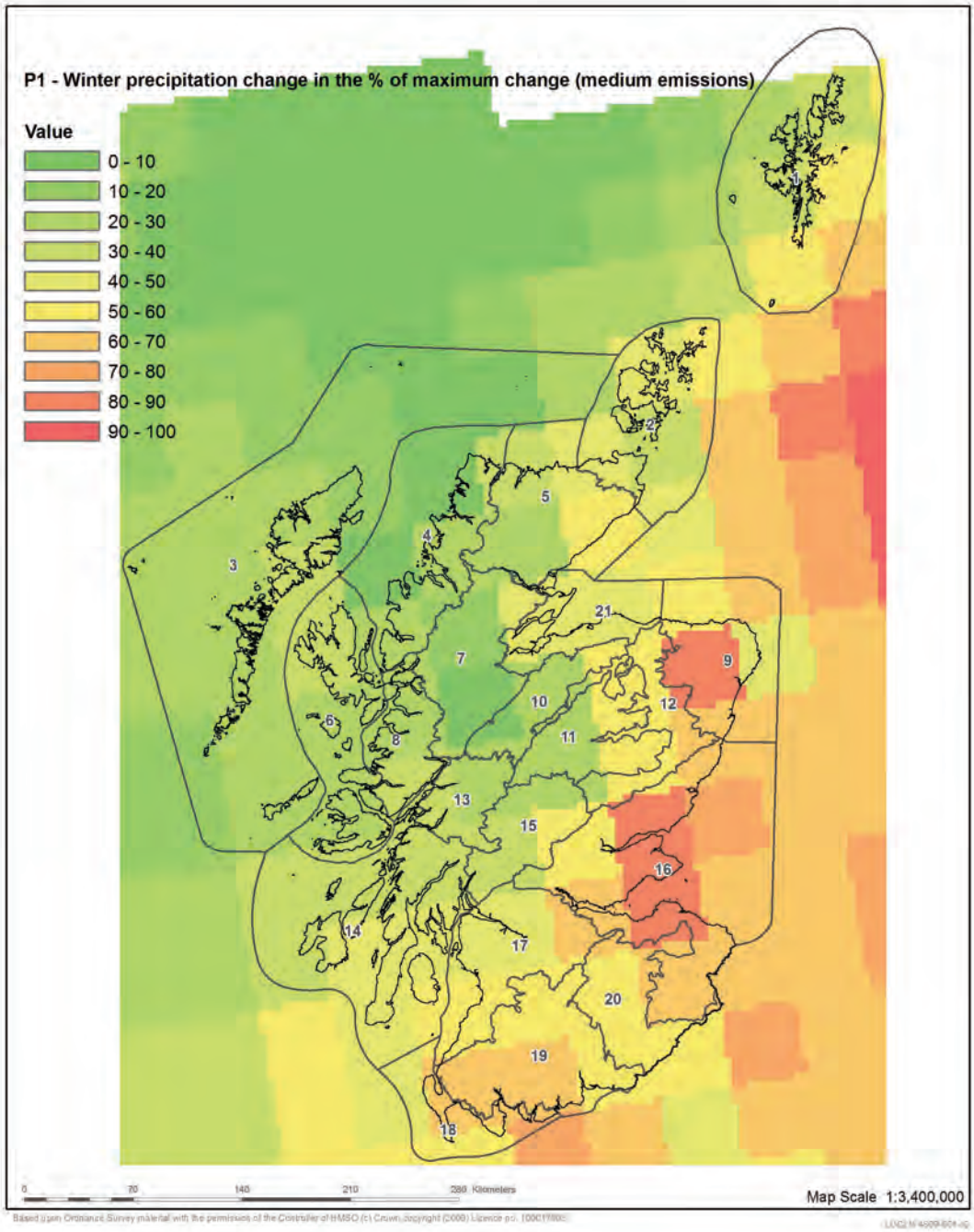


Figure 9.9a

▸Mapping based on UKCIP02 Climate Change Scenario data

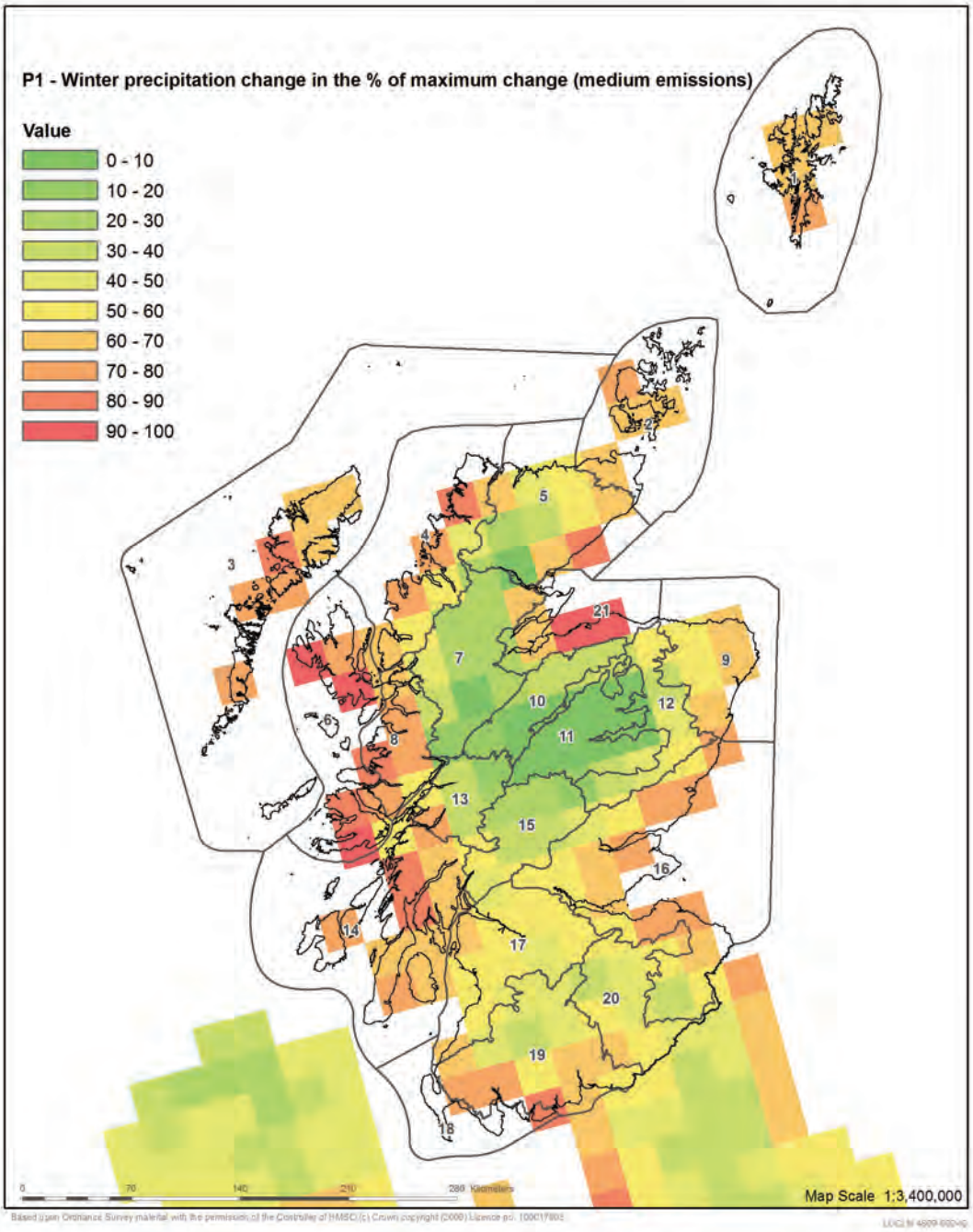


Figure 9.9b

▸Mapping based on UKCP09 Climate Change Scenario data

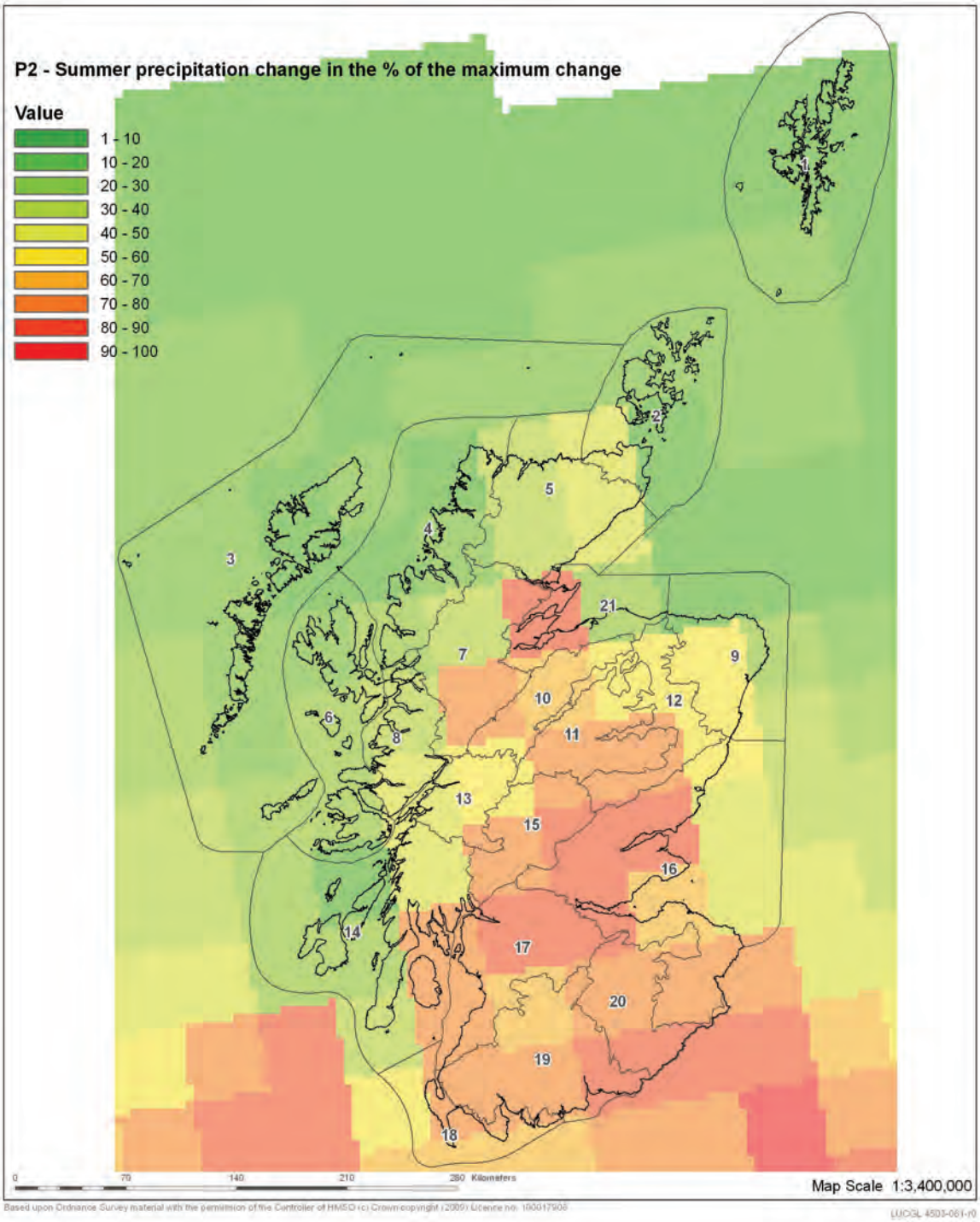


Figure 9.10

▸Mapping based on UKCIP02 Climate Change Scenario data

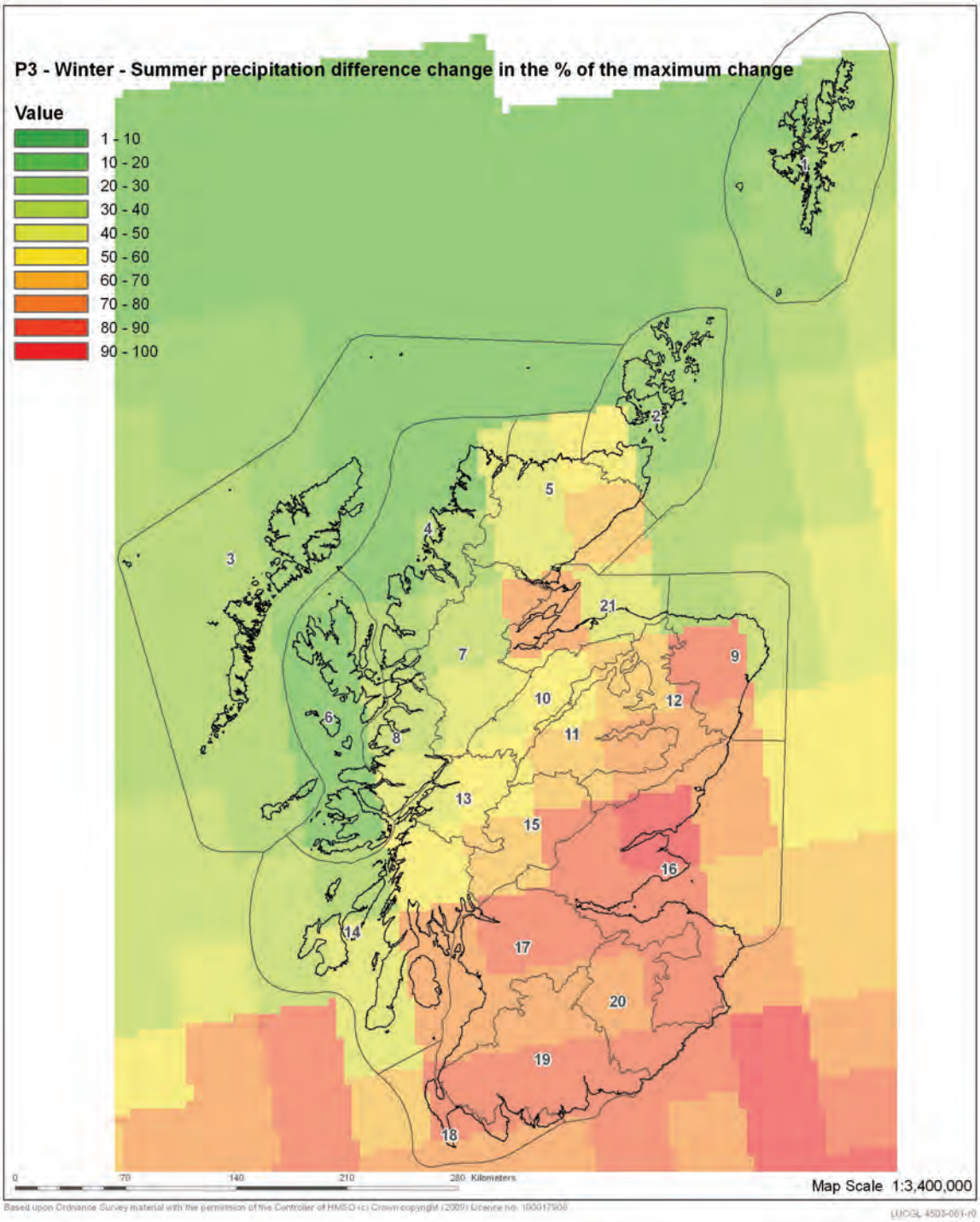


Figure 9.11

▸Mapping based on UKCIP02 Climate Change Scenario data

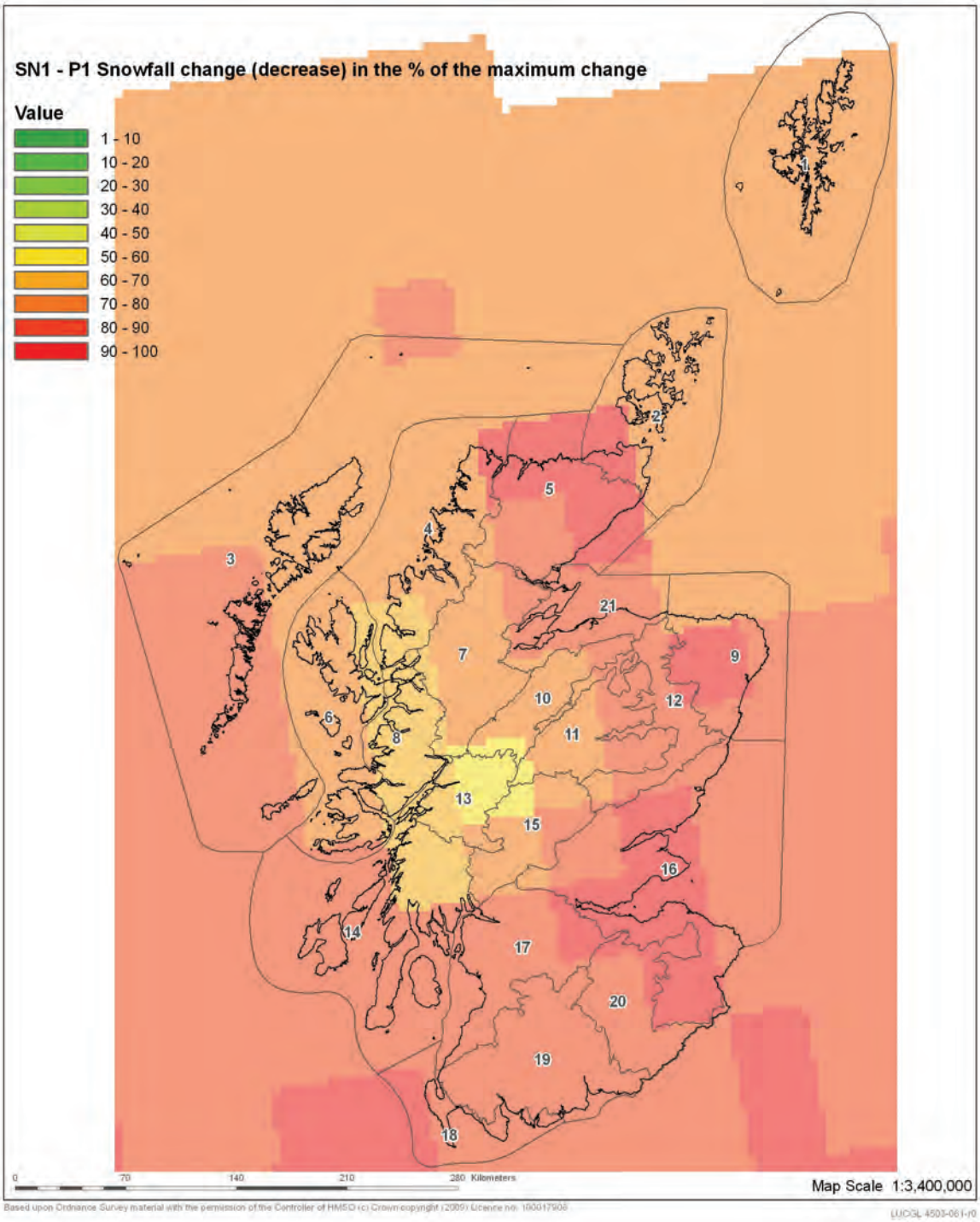


Figure 9.12

▸Mapping based on UKCIP02 Climate Change Scenario data

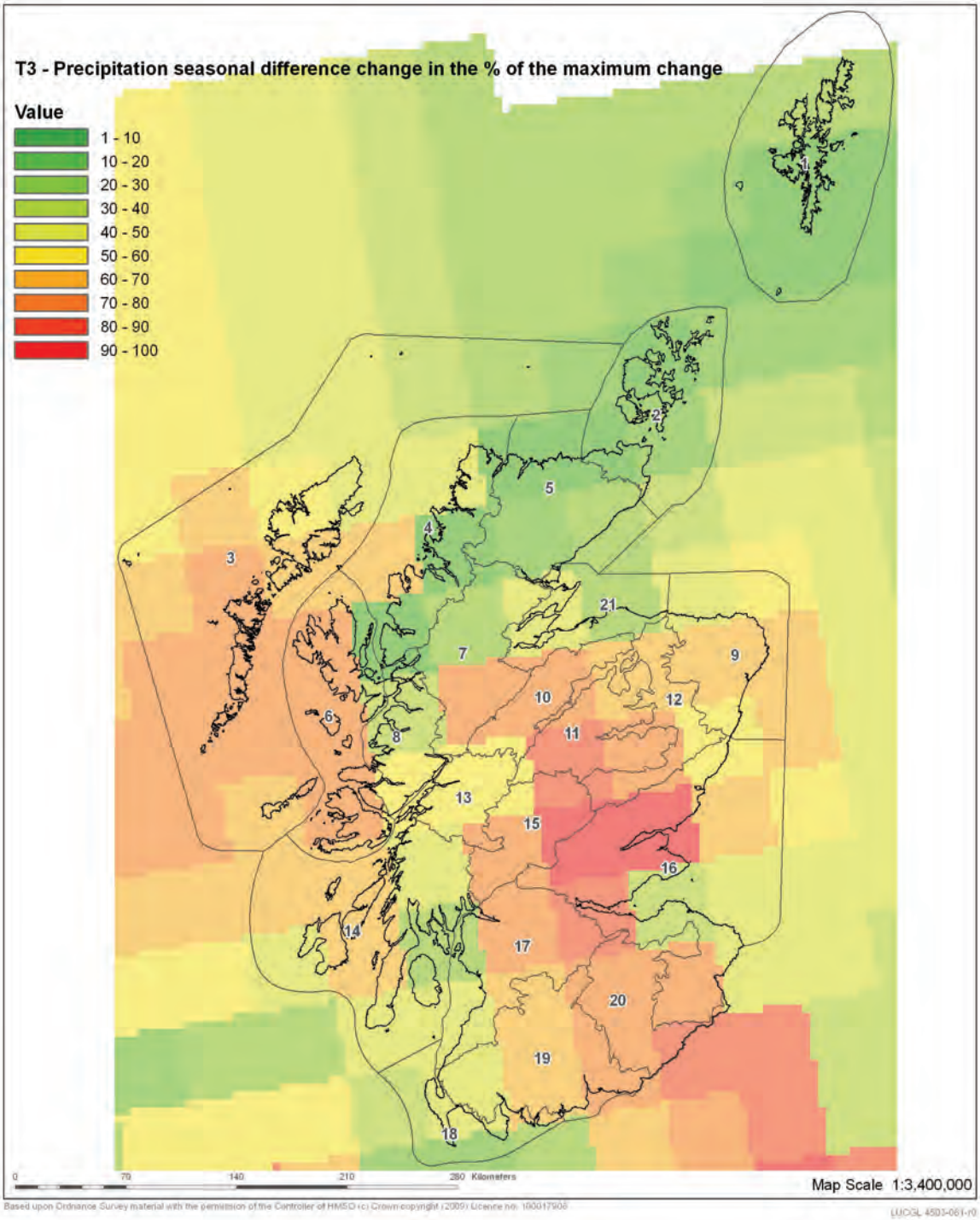


Figure 9.13

▸Mapping based on UKCIP02 Climate Change Scenario data

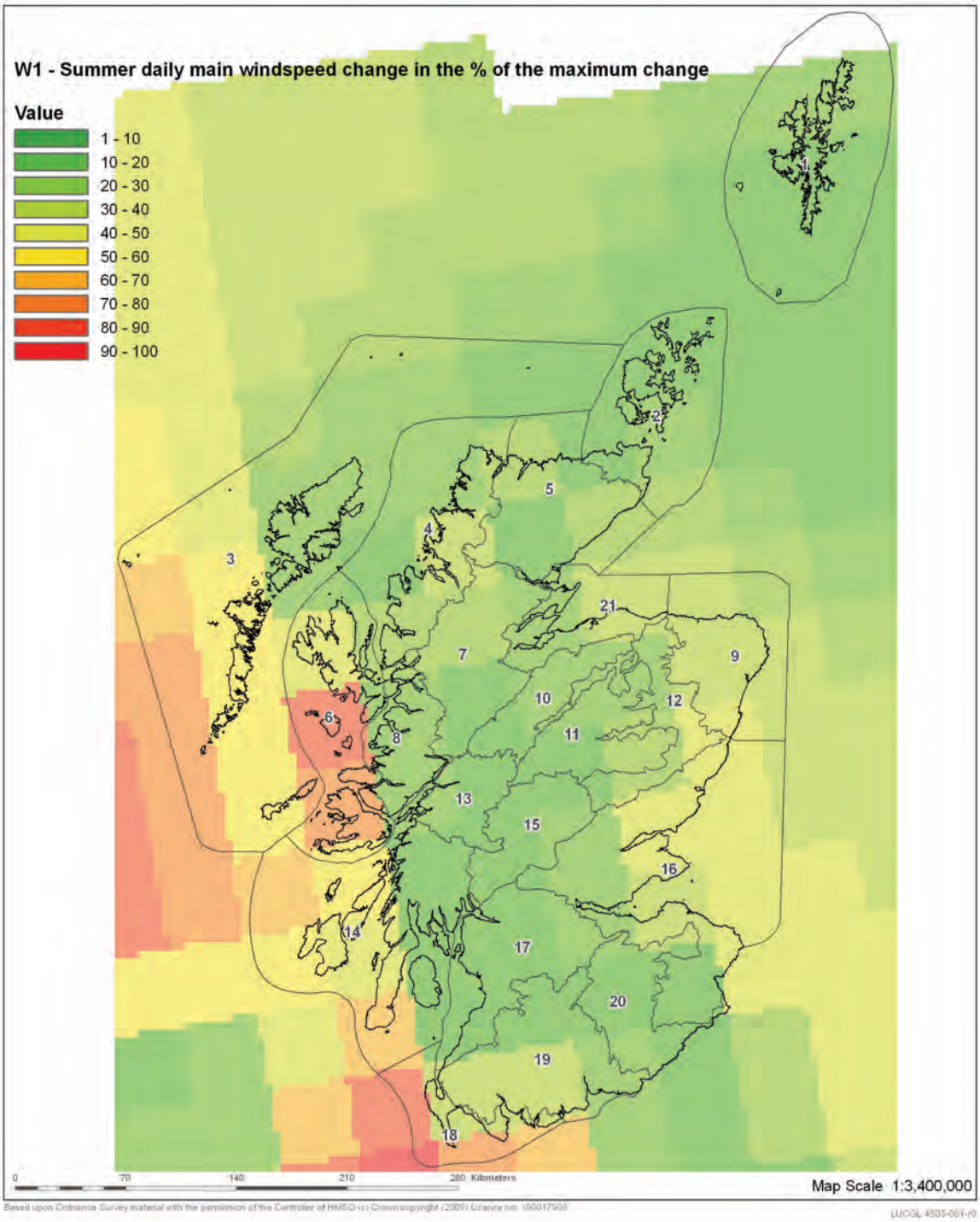


Figure 9.14

▸Mapping based on UKCIP02 Climate Change Scenario data

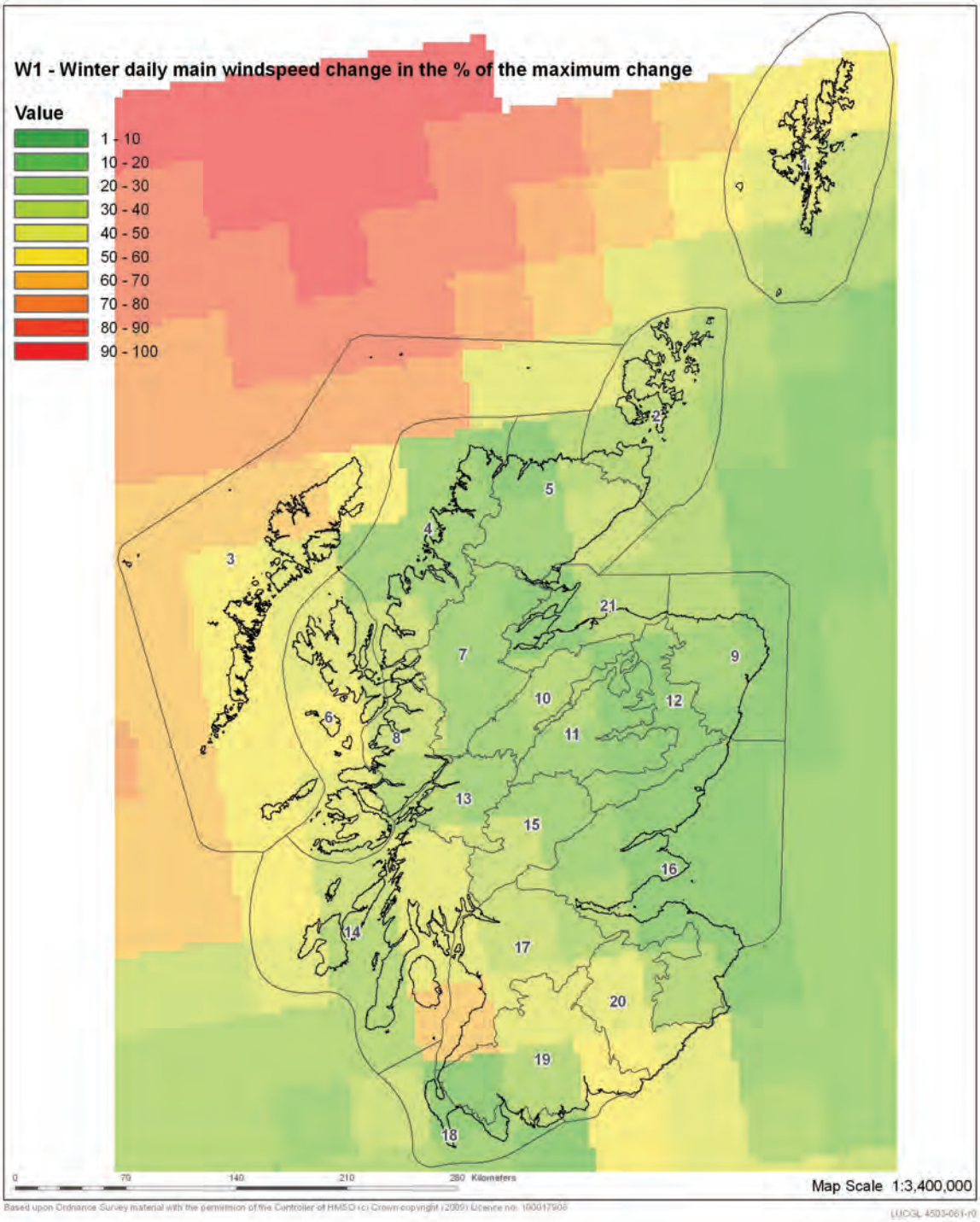


Figure 9.15

▸Mapping based on UKCIP02 Climate Change Scenario data

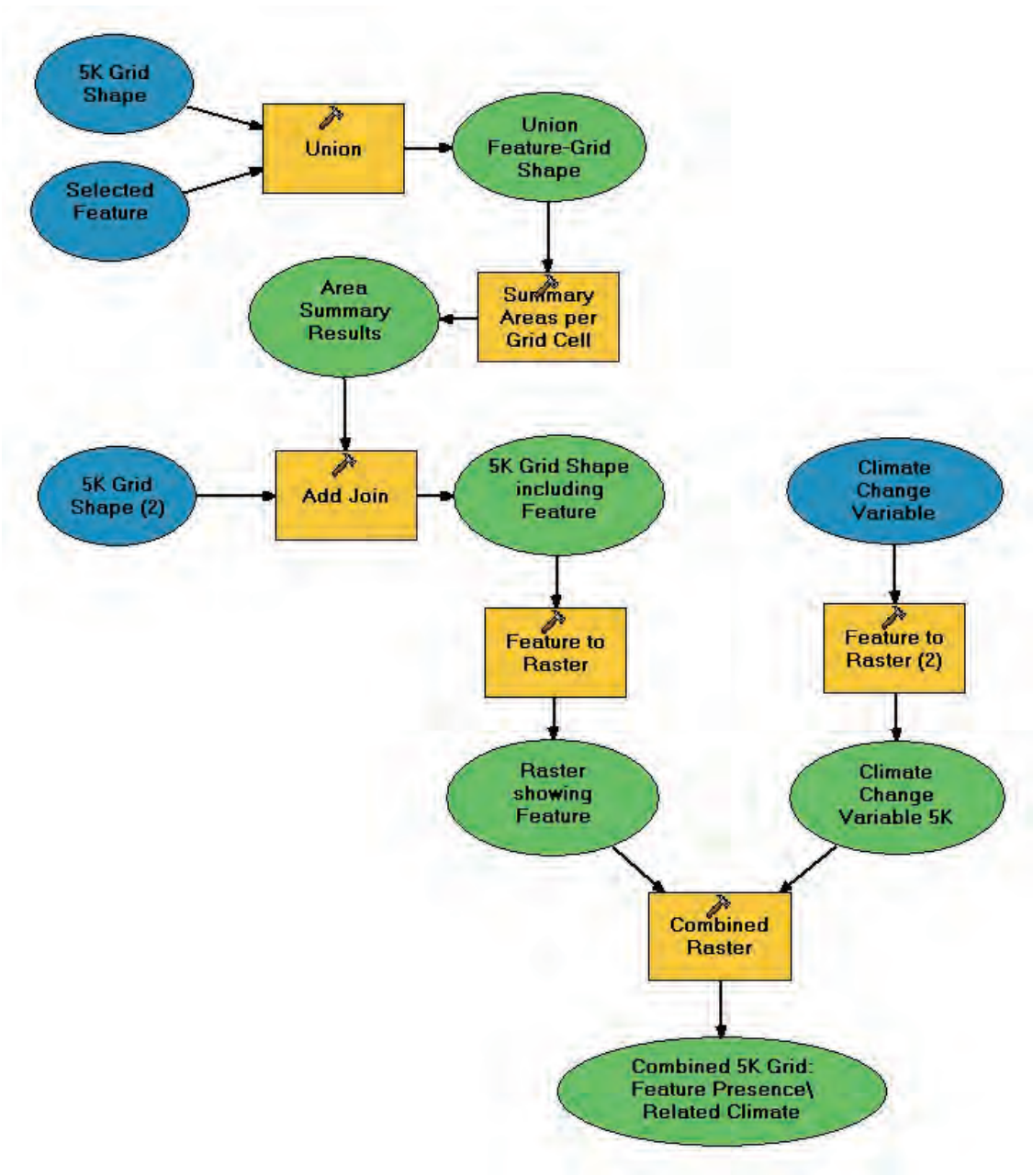
10. MAPPING METHODOLOGY

10.1. The task was to identify the geographic distribution of potential landscape change under the influence of climate change. For each potential climate related landscape change identified from the desk based review, one or more Scotland wide geographical data layers were identified locating the particular landscape features. By combining the feature data sets with the relevant climate change variables, a relative degree of change could be mapped.

10.2. All feature data was converted into a 5km grid attributed with a percentage of cover for each feature. This allowed the combination of different feature data sets with varying scales and accuracy, and mapping these at a Scotland wide scale.

10.3. To obtain this, a Union operation has been performed between each feature data set and the 5km grid layer. In the resulting union dataset, the areas were calculated for all polygons of the feature data set and subsequently for each 5km grid cell, the total area covered by the particular feature has been summarized. Percentages were calculated and the results were exported into a table. This table was then joined with the base 5km grid layer. The resulting grids show the spread and concentration of each feature in a uniform format.

10.4. In order to be able to combine the climate change variables, the original 50km grid climate data was converted to a grid, matching the 5km base grid used for the feature data. UKCIP02 climate change variables were interpolated from their 50km grid to the 5km grid used for the study. UKCP09 climate change variables were converted from their 25km grid to the 5km grid used for the study by taking the cetre oint value for each 5km cell. The difference in approach reflects the use of probabilistic projections in the UKCP09 variables which means that averaging across cell boundaries is not a valid operation. This revised approach for UKCP09 also overcame the fact that the UKCIP02 and UKCP09 projections are presented on differently orientated grids. The diagram overleaf illustrates the stages in the process.


5K Grid Shape
Selected Feature
Union
Union Feature-Grid Shape
Summary Areas per Grid Cell
Area Summary Results
5K Grid Shape (2)
Add Join
5K Grid Shape including Feature
Climate Change Variable
Feature to Raster
Feature to Raster (2)
Raster showing Feature
Climate Change Variable 5K
Combined Raster
Combined 5K Grid: Feature Presence\ Related Climate

An assessment of the impacts of climate change on Scottish landscapes and their contribution to quality of life: Final report
***Scottish Natural Heritage Commissioned Report (enter no)*.**

Appendix 11: UKCP09 report: Comparison of UKCP09 and UKCIP02 and implications for Interim Report

Appendix 11: UKCP09 Report: Comparison of UKCP09 & UKCIP02 and implications for Interim Report

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Tables and Figures

Tables

Figures

SUMMARY

Introduction

This appendix sets out the results of an assessment of the implications of the recently published UKCP09 climate change projections for Phase 1 of the research into the effects of climate change on landscape and quality of life undertaken for Scottish Natural Heritage by Land Use Consultants[1]. This earlier research was based on UKCIP02 projections.

Method

The exercise comprised a series of discrete steps, as follows:

- comparison of the UKCIP02[2] and UKCP09 projections[3], including comparative mapping for key climate change variables (Section 2). This review was informed by discussions with a specialist adviser[4] from the Scottish Climate Change Impacts Partnership;
- identification of those elements of the Phase 1 analysis that require updating in the form of revised GIS mapping (Section 3) to reflect major differences between the UKCIP02 and UKCP09 projections;
- re-running GIS mapping and analysis of the results for national, regional and local descriptions of climate related landscape change (Section 4);
- analysis of UKCP09 probabilistic projections to provide a commentary on the uncertainty associated with different climate change variables (Section 5);
- auditing of the Phase 1 Interim Report to identify those sections which require to be updated to reflect the differences between the UKCIP02 and UKCP09 projections, including the updated mapping (Section 6);
- consideration of how updated information should be presented within an updated (Final) Phase 1 Report (Section 7).

Differences between UKCIP02 and UKCP09 projections

UKCP09 projections differ from their predecessors in a number of respects, including:

- UKCIP02 projections were provided on a 50km grid whereas the UKCP09 projections use a 25km grid. The two grids are not directly comparable and are on different orientations;
- UKCIP02 scenarios were derived from a single UK climate model whilst the UKCP09 projections are based on an ensemble of different models;
- UKCIP02 used four emissions scenarios (low, medium-low, medium-high and high) whereas the UKCP09 projections are based on 3 emissions scenarios (low, medium, high). However, the differences between emissions scenarios are greatest after 2050,

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[1] Land Use Consultants (2010). An assessment of the impacts of climate change on Scottish Landscapes and their contribution to quality of life: Phase 1 – Interim report. *Scottish Natural Heritage* Commissioned Report No. 343

[2] http://www.ukcip.org.uk/index.php?id=161&option=com_content&task=view

[3] http://ukclimateprojections.defra.gov.uk/

[4] See advice received from J. Hagg, SCCIP adviser in Annex 2

so qualified comparison of the UKCIP02 medium/high or medium/low emissions scenarios with the UKCP09 medium emissions scenario may be acceptable[5];

- UKCIP02 projections provided a single value for each emissions scenario / timeframe, whereas the UKCP09 projections provide a range of probabilistic values indicating, for example, the levels of change which have a probability of less than 10%, 50% or 90% chance of occurring. The differing nature of these data mean that direct comparison of the UKCIP02 and UKCP09 projections is not recommended, though it is considered that the UKCP09 50% probability projection is most similar to the 02 projections. The use of probabilistic projections means that averaging of 09 data across cell boundaries is not possible.

Analysis of the differences between UKCIP02 and UKCP09 projections

The comparison of UKCIP02 and UKCP09 projections explored differences in the direction, scale and spatial pattern of climate change for a series of variables including winter precipitation, summer precipitation, winter temperatures, summer temperatures, autumn temperatures, annual temperatures and sea level rise.

For most of these variables, the analysis concluded that while the rate of change indicated by UKCP09 differed from that indicated by UKCIP02, the direction and broad spatial pattern of change remained largely unchanged. Given that the mapping analysis carried out during the first phase of the research placed each variable onto a common scale (from least change to greatest change), it was concluded that, although the change should be reflected in the updated text where appropriate, there was no requirement to re-run the GIS mapping analysis since the overall patterns of change would be unchanged.

The one exception was the winter precipitation variable, where the UKCP09 projections suggest different rates, directions and spatial patterns of change than projected under UKCIP02. It was therefore concluded that a total of 13 national maps from the Phase 1 Interim report should be re-run using the UKCP09 winter precipitation variable. It was confirmed that such analysis could combine information from the two sets of projections, though this should be noted in the accompanying text.

Revised national mapping analysis

Section 4 of this report presents the analysis for these 13 maps. In each case it includes:

- a map showing the landscape feature(s) in question (unchanged from Phase 1 Interim report);
- a map showing the analysis of spatial change based on the relevant UKCIP02 climate variable(s) (unchanged from Phase 1 Interim report);
- a map showing the analysis of spatial change based on the corresponding UKCP09 climate variable (new maps);
- a table summarising the key differences and implications for the descriptions of national, regional and local patterns of climate related landscape change.

A table at the end of Section 4 updates Table 4.1 from the Phase 1 Interim report, based on the analysis of changes for each of these maps.

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[5] See advice received from J. Hagg, SCCIP adviser in Annex 2

Probabilistic projections and uncertainty

Section 5 of this report reviews the implications of the UKCP09 probabilistic projections for the level of uncertainty associated with different climate change variables. The UKCP09 projections provide a range of probabilistic values[6]:

- The 10% probability projections indicate that the probability that the change in question will be less than that shown is 10%. UKCP uses the term 'very unlikely to be less than' (and therefore very likely to be more than) to describe such changes indicating a higher level of confidence of the effect occurring.

- The 90% probability projections indicate that the probability that the change in question will be less than that shown is 90% - it is very unlikely to be greater than that shown and therefore very likely to be less.

- The 50% probability projections indicate that the projected change is just as likely to be greater as it is to be less than the value shown. This is the central estimate and, importantly, does not indicate the projection that is most likely to occur.

Analysis of the more extreme probabilistic projections (e.g. 90% and 10%) allows the variation in potential changes to be explored, helping to inform the way in which the projections should be applied. For example, if there is relatively little difference between the scales of change which have a 90%, 50% and 10% probability of being exceeded, any conclusions based on the projections are likely to be reasonably reliable, providing a firm foundation for policy or other responses. On the other hand, if there is a significant difference between either the 90% or 10% projections and the 50% projection, the conclusions will be more tentative and, importantly, a judgment will need to be made about the level of risk that any subsequent response should adopt.

Comparison of the probabilistic projections for a number of climate change variables found that there is greater difference between the 10% and 90% projections for precipitation during both winter and summer than for temperature changes. This suggests that there is greater certainty about climate related landscape changes associated with temperature changes and lower certainty about those associated with changes in rainfall. These conclusions will be used in the updated Phase 1 report to provide an additional commentary on uncertainty.

Audit of implications for Phase 1 Interim report

Section 6 of this Appendix sets out the results of a detailed audit of the implications of the UKCP09 analysis for the Phase 1 Interim report. This includes a commentary on each section of the report, the key findings emerging from the research and analysis of the implications for the Tayside case studies (including photomontages).

Implications for key conclusions from Phase 1 of the research

Phase 1 of the research concluded that 'overall, human mitigation and adaptation measures may have a more significant influence on landscape character than the direct effects of climate change'. It also concluded that : 'the combined influence of these direct, mitigation and adaptation changes may be greatest in lowland and coastal landscapes reflecting the dominance of land management, settlement and land use in shaping landscape character and the likely impact of changing sea levels'. The analysis of UKCP09 data suggests that these conclusions remain valid, though some of the detail underpinning them has changed.

Conclusions about the effects on wildland qualities also remain valid, though again some of the detail of the changes is now slightly different.

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[6] http://ukclimateprojections.defra.gov.uk/content/view/1338/543/

Conclusions about the effects on ecosystem services remain largely unchanged, as does the conclusion that ‘climate related landscape change will have some of the greatest impacts in those areas where people live and work’.

1. INTRODUCTION AND BACKGROUND

1.1. This appendix sets out the results of an assessment of the implications of the recently published UKCP09 climate change projections for Phase 1 of the research into the effects of climate change on landscape and quality of life undertaken for Scottish Natural Heritage by Land Use Consultants. This earlier research was based on UKCIP02 projections.

1.2. This exercise comprised a series of discrete steps, as follows:

- comparison of the UKCIP02[7] and UKCP09 projections[8], including comparative mapping for key climate change variables (Section 2). This review was informed by discussions with a specialist adviser[9] from SCCIP;
- identification of those elements of the Phase 1 analysis that require updating in the form of revised GIS mapping (Section 3) to reflect major differences between the UKCIP02 and UKCP09 projections;
- rerunning of GIS mapping and analysis of the results for national, regional and local descriptions of climate related landscape change (Section 4);
- analysis of UKCP09 probabilistic projections to provide a commentary on the uncertainty associated with different climate change variables (Section 5);
- auditing of the Phase 1 Interim Report to identify those sections which require to be updated to reflect the differences between the UKCIP02 and UKCP09 projections, including the updated mapping (Section 6);
- consideration of how updated information should be presented within the Phase 1 Final Report.

Phase 1 analysis

1.3. Phase 1 of the research into the effects of climate change on landscape and quality of life included a comparatively simple spatial analysis based on:

- the identification of potential landscape effects of climate change (e.g. summer drought affecting some tree species) based on literature review and input from our steering group;
- GIS mapping of the landscape feature in question (e.g. deciduous woodland);
- GIS mapping of relevant climate change variables (e.g. summer rainfall and summer temperatures) drawing information from UKCIP02 projections (based on the 2050 figures for the medium-high emissions scenario);
- the combination of these layers to identify areas where there are concentrations of the landscape feature and the most pronounced climate change.

1.4. The GIS mapping converted all data to a 5km grid and placed climate change variables on a percentage scale, thereby allowing unweighted combination of different climate change variables. It was recognised that this was a simplistic approach and it was used to illustrate rather than predict where and how much

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[7] http://www.ukcip.org.uk/index.php?id=161&option=com_content&task=view
[8] http://ukclimateprojections.defra.gov.uk/
[9] See advice received from J. Hagg, SCCIP adviser in Annex 2 of this Appendix

change could occur. The report referenced the degree of certainty associated with each of these climate change variables.

UKCP09

1.5. The UKCP09 projections were published shortly after the completion of the Phase 1 research. While a comprehensive reworking of the research was not envisaged, SNH required an initial review to identify the implications of the new data, followed by a limited updating of the GIS analysis and the research and conclusions based upon it, where this is necessary. This represented a pragmatic approach which reflects the importance of responding to the new projections and the need to focus effort where the new data have significant potential to affect the research findings.

1.6. UKCP09 projections differ from their predecessors in a number of respects, including:

- UKCIP02 projections were provided on a 50km grid whereas the UKCP09 projections use a 25km grid. The two grids are differently oriented and not directly comparable as a result;

- UKCIP02 scenarios were derived from a single UK climate model whilst the UKCP09 projections are based on an ensemble of different models. This limits the comparability of the two datasets;

- UKCIP02 used four emissions scenarios whereas the UKCP09 projections are based on 3 emissions scenarios. While the high and low emission scenarios are comparable, the medium scenarios are different (UKCIP02 included 'medium/low' and 'medium/high' emissions scenarios, whereas UKCP09 includes a single 'medium' emissions scenario). It is however worth noting that the differences between emissions scenarios are greatest after 2050, so qualified comparison of the UKCIP02 medium/high or medium/low emissions scenarios with the UKCP09 medium emissions scenario may be acceptable[10];

- UKCIP02 projections provided a single value for each emissions scenario / timeframe, whereas the UKCP09 projections provide a range of probabilistic values:

  - the 10% probability projections indicate that the probability that the change in question will be less than that shown is 10%. UKCP uses the term 'very unlikely to be less than' (and therefore very likely to be more than) to describe such changes indicating a higher level of confidence of the effect occurring;

  - the 90% probability projections indicate that the probability of that the change in question will be less than that shown is 90% - it is very unlikely to be greater than that shown and therefore very likely to be less;

  - the 50% probability projections indicate that the strength of evidence for the projected change is just as likely to be greater as it is to be less than the value shown. This is the central estimate and, importantly, does not indicate the projection that is most likely to occur.

  This is illustrated in Figure 1.1 which shows the spectrum from 0% probability (i.e. the change has a 0% probability of being less than the value shown) to 100% probability (i.e. the change has a 100% probability of being less than the value shown, together with the 10%, 50% and 90% probabilities. UKCP09 advises

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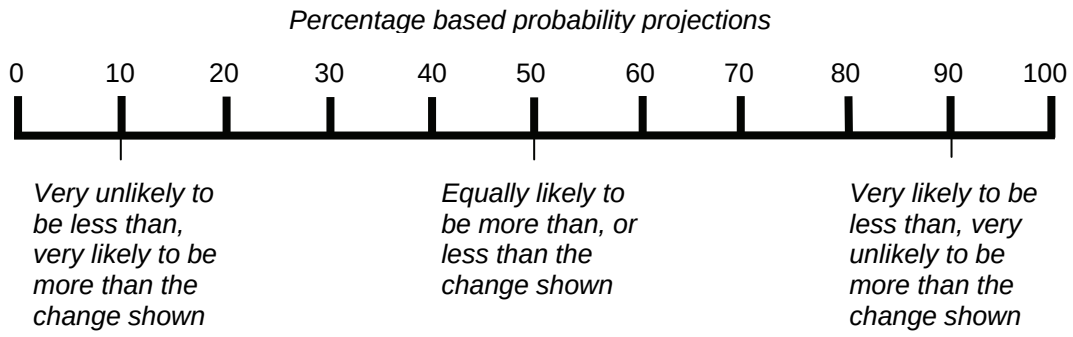
[10] See advice received from J. Hagg, SCCIP adviser in Annex 2 of this Appendix

against using probability levels outside of 10% and 90%[11]. UKCP09 notes that probabilistic projections should not be averaged across cell boundaries.

UKCP09 suggests that the 50% probability projection is likely to be most similar to the 02 projections, though direct comparison is discouraged.

Figure 1.1: Percentage based probability projections



Judging the implications of UKCP09 projections

1.7. While the above differences between the two datasets make a like-for-like comparison of the UKCIP09 and UKCP02 climate change variables impossible, it is possible to set out some parameters which should guide analysis of the implications for Phase 1 of the research into the effects of climate change on landscape and quality of life.

1.8. Where the 2009 projections indicate a similar spatial pattern of climate change, but where the rate of change is altered, the GIS analysis will not be reworked using the new data. This reflects the use of a GIS methodology[12] which placed each variable onto a common percentage based axis from low to high. However, where there is a notable difference between the rates of change set out in the two projections (either faster or slower than previously indicated), this is recorded in the form of a commentary and in revised text within the Phase 1 report where appropriate.

1.9. Where the 2009 projections indicate a notably different spatial pattern of climate change, consideration was given to rerunning those elements of the GIS analysis using the variable in question. This is particularly relevant where different spatial patterns are associated with greater, lesser or even reversed patterns of change.

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[11] See advice received from J. Hagg, SCCIP adviser in Annex 2 of this Appendix

[12] The methodology developed in Phase 1 of the work was designed to analyse a combination of climate change and landscape feature variables. Recognising the difficulty of reconciling variables that were on different scales (e.g. millimetres of rainfall or degrees Celsius) the approach placed each on a relative percentage scale ranging from the greatest change to the lowest change. This allowed different variables to be considered within the same analysis, showing areas where the change was judged likely to be greatest or least, but not indicating the absolute level of change. This was considered to be acceptable since the research aimed to illustrate the types of change that could occur, rather than providing a deterministic prediction of the scale and nature of the effects of climate change.

1.10. As noted above, the 2009 projections are presented on a probabilistic basis. Whilst the main focus is placed on the 50% probability projections (representing the central projection which is most comparable to the UKCIP02 projections), use is also made of the outlying projections as a means of indicating the level of risk or certainty associated with the changes covered by the research. This helps reduce some of the uncertainty built into the Phase 1 Interim report, and should also inform the production of sectoral summaries in Phase 2 of the work.

2 COMPARISON OF CLIMATE CHANGE VARIABLES

2.1 This section sets out a comparison of the UKCIP02 and UKCP09 projections, focusing on climate change variables most relevant to Phase 1 of this research into the effects of climate change on landscape and quality of life. This analysis compares the high emissions scenarios for both sets of projections, focusing on the 30 year time slice, centred on 2050. This reflects the lack of an equivalent to the UKCIP02 medium-high emission scenario (used in the Phase 1 research) in the suite of UKCP09 projections.

Precipitation

Winter precipitation

2.2 The UKCIP02 2050 high emissions scenario projections (Figure 2.1a[13]) suggested that virtually all of Scotland could experience an increase in winter precipitation in 2050, with the smallest changes affecting the north west (up to 5% increase), large increases experienced along the east coast and central and southern Scotland (up to 16% increase) and largest increases in localised areas in the east (up to 24%).

2.3 While the largest increases suggested by the UKCP09 2050 high emissions scenario projections (Figure 2.1b) are similar to those in the 02 projections (23%), there are some important differences in the spatial pattern of change. Firstly, some areas may now be more likely to experience a slight decrease in winter rainfall of up to 1.5%. These areas include the wider Cairngorms massif. Secondly, it now appears that parts of the west coast, Hebrides and Northern Isles, along with the east coast may experience the largest increases in winter rainfall (up to 24%), with most of the remaining coastal fringes and southern Scotland experiencing increases of up to 16%.

2.4 Figure 2.1c shows a comparison of the two projections confirming that UKCP09 projections show some areas as having up to 14% less winter precipitation than the 02 projections and large areas of the eastern Highlands and Southern uplands experiencing reductions of up to 8% than previously projected. Parts of the west coast, the Hebrides and Northern Isles are shown as having between 8 and 24% more rainfall than previously predicted.

2.5 These are significant differences in the direction, scale and spatial pattern of change and it was therefore recommended that all the GIS analyses using the winter precipitation climate change variable are re-run.

Summer precipitation

2.6 The UKCIP02 2050 high emissions scenario projections (Figure 2.2a) suggested that all of Scotland with the exception of parts of the inner and outer Hebrides and the Northern Isles could experience a decrease in summer precipitation. These decreases might be greatest in parts of central Scotland, southern Scotland and in the central Highlands (up to 24% reduction).

2.7 The UKCP09 2050 high emissions scenario projections (Figure 2.2b) show a similar pattern, though the maximum decrease is now lower than previously suggested (19% compared with 24%). The principal spatial differences are that all of Scotland is now projected to experience a decrease in summer precipitation, and the areas

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[13] UKCIP02 and UKCP09 data are shown on the 5km^2 grid that was used to combine information during Phase 1 of the work. The UKCIP02 data have been interpolated across cell boundaries, whereas the UKCP09 data are based on the value at the centre-point of each 5km cell, reflecting advice from SCCIP that probabilistic projections should not be averaged.

experienced the largest reductions have contracted, covering parts of central Scotland and small areas of Dumfries and Galloway.

2.8 These differences are noted in the revised Phase 1 report but GIS analysis using the summer precipitation climate change variable was not re-run since the spatial pattern of change remained broadly unchanged.

Temperature

Winter temperature

2.9 The UKCIP02 2050 high emissions scenario projections (Figure 2.3a) suggested that all of Scotland could experience an increase in average winter temperatures. The increases could be greatest in southern and central Scotland, together with the Grampians (up to a 2° Celsius increase) and lowest around the western coastal fringes and outer Hebrides (up to 1° Celsius increase).

2.10 The UKCP09 2050 high emissions scenario projections (Figure 2.3b) show a broadly similar pattern, though the maximum projected increase is now greater than previously suggested (up to 2.5° Celsius in parts of central and southern Scotland). Areas with the least increase, covering northern and eastern Scotland, the Hebrides and Northern Isles, could still experience an increase of up to 2° Celsius – towards the upper range suggested by UKCIP02.

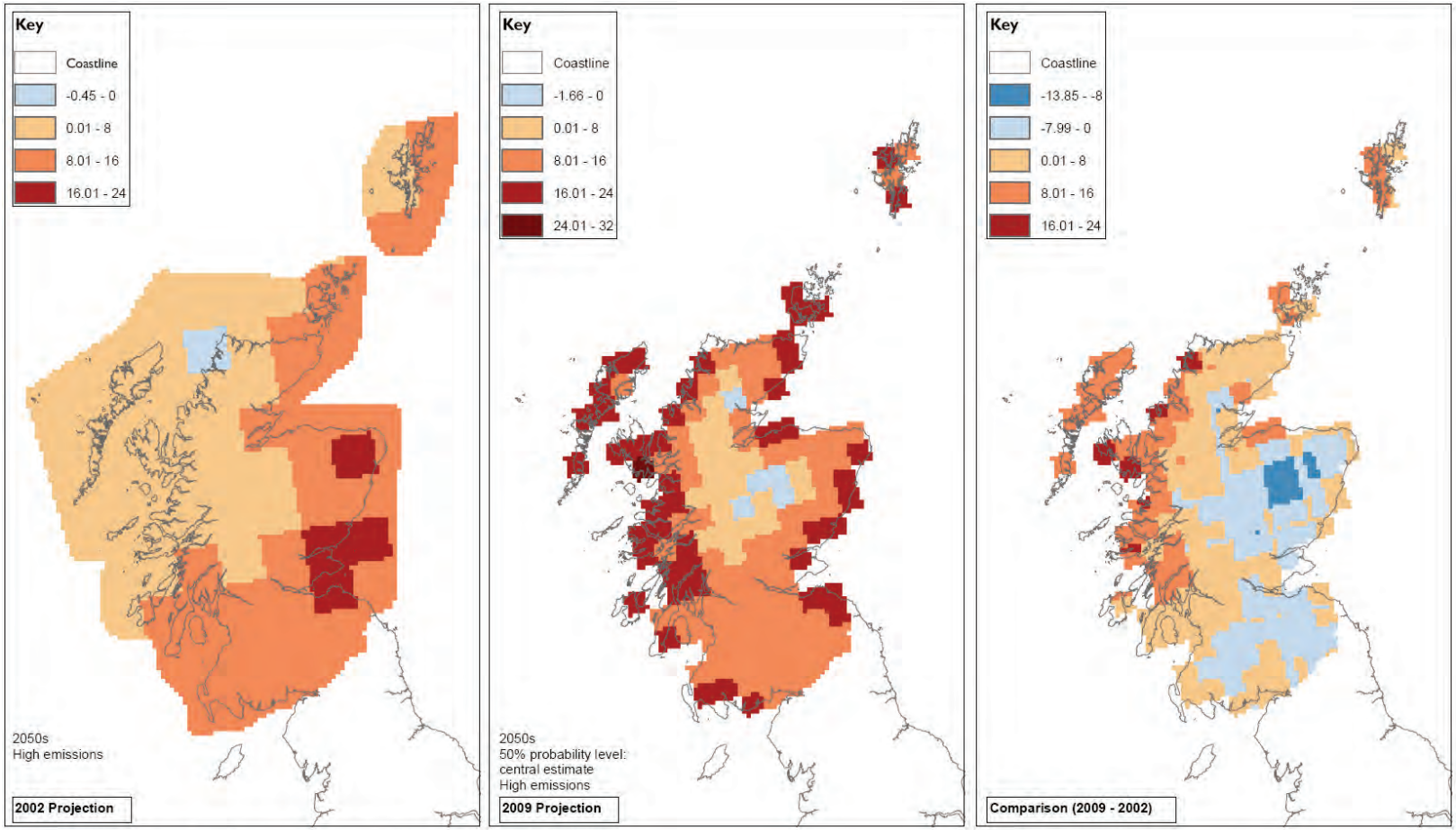
2.11 Figure 2.3c maps the difference between the two scenarios, again demonstrating that the 09 projections suggest that all of Scotland may see higher winter temperatures than indicated in the 02 projections. The greatest difference in the projections appears to be Southern Scotland, parts of Argyll and the Hebrides.

2.12 These differences are noted in the revised Phase 1 report but GIS analysis using the winter temperature climate change variable was not re-run since the spatial pattern of change remained broadly unchanged.

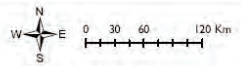
Figure 2.1a
Winter precipitation (UKCIP02)

Figure 2.1b
Winter precipitation (UKCP09)

Figure 2.1c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Winter Precipitation (% change from current precipitation)

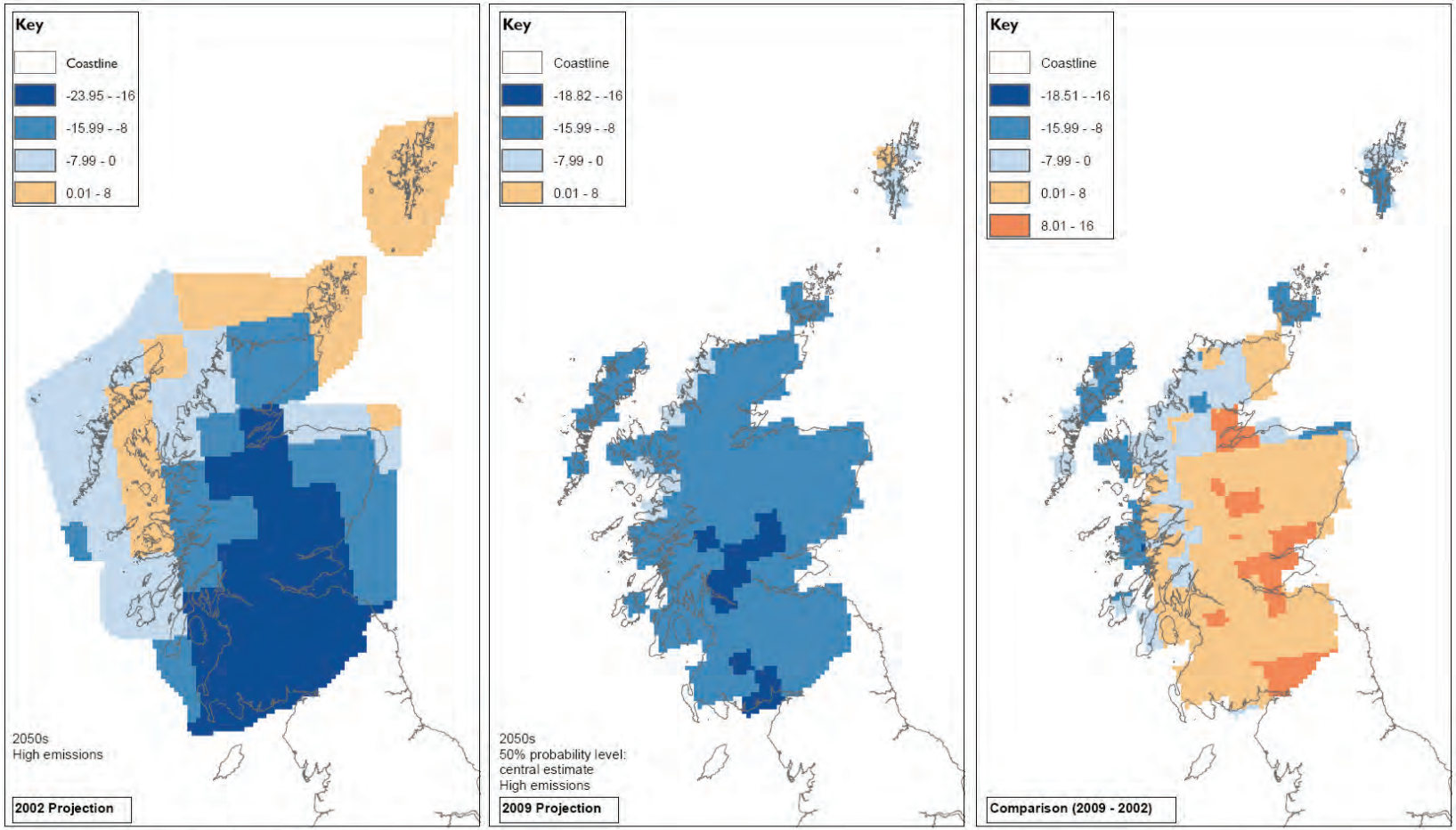


Source: UKCIP02, UKCP09

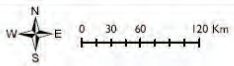
Figure 2.2a
Summer precipitation (UKCIP02)

Figure 2.2b
Summer precipitation (UKCP09)

Figure 2.2c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Summer Precipitation
(% change from current precipitation)



Source: UKCIP02, UKCP09

Summer temperature

2.13 The UKCIP02 2050 high emissions scenario projections (Figure 2.4a) suggested that all of Scotland could experience an increase in average summer temperatures. The increases could be greatest in southern and central Scotland, together with the Grampians (up to a 2.5° Celsius increase) and lowest around the western coastal fringes and outer Hebrides (up to 1° Celsius increase).

2.14 The UKCP09 2050 high emissions scenario projections (Figure 2.4b) show a broadly similar pattern, though the maximum increase could now be greater than previously suggested (up to 3° Celsius in much of mainland Scotland away from the north and north east). Areas with the least increase (e.g. Hebrides and Northern Isles) could still experience an increase of up to 2° Celsius – towards the upper range suggested by the 02 projections.

2.15 Figure 2.4c maps the difference between the two scenarios, again demonstrating that most of Scotland may see higher summer temperatures under the 09 projections than under the 02 projections. The greatest differences in the projections may be found along the west coast, including parts of Kintyre and the inner and outer Hebrides. Changes appear to be least pronounced in parts of Moray, Angus and Fife.

2.16 These are significant differences in the scale of change, though the spatial pattern is broadly similar. These differences are noted in the revised Phase 1 Report, but GIS analysis using the summer temperature climate change variable was not re-run.

Autumn temperature

2.17 The UKCIP02 2050 high emissions scenario projections (Figure 2.5a) suggested that all of Scotland could experience an increase in average autumn temperatures. The increases might be greatest in southern, central and much of Highland Scotland away from the far north and parts of the east coast (up to a 2.5° Celsius increase) and lowest around the outer Hebrides (up to 1° Celsius increase).

2.18 The UKCP09 2050 high emissions scenario projections (Figure 2.5b) show a similar pattern, with southern and central Scotland potentially experiencing increases of up to 3° Celsius and the rest of Scotland potentially experiencing increases of up to 2.5° Celsius.

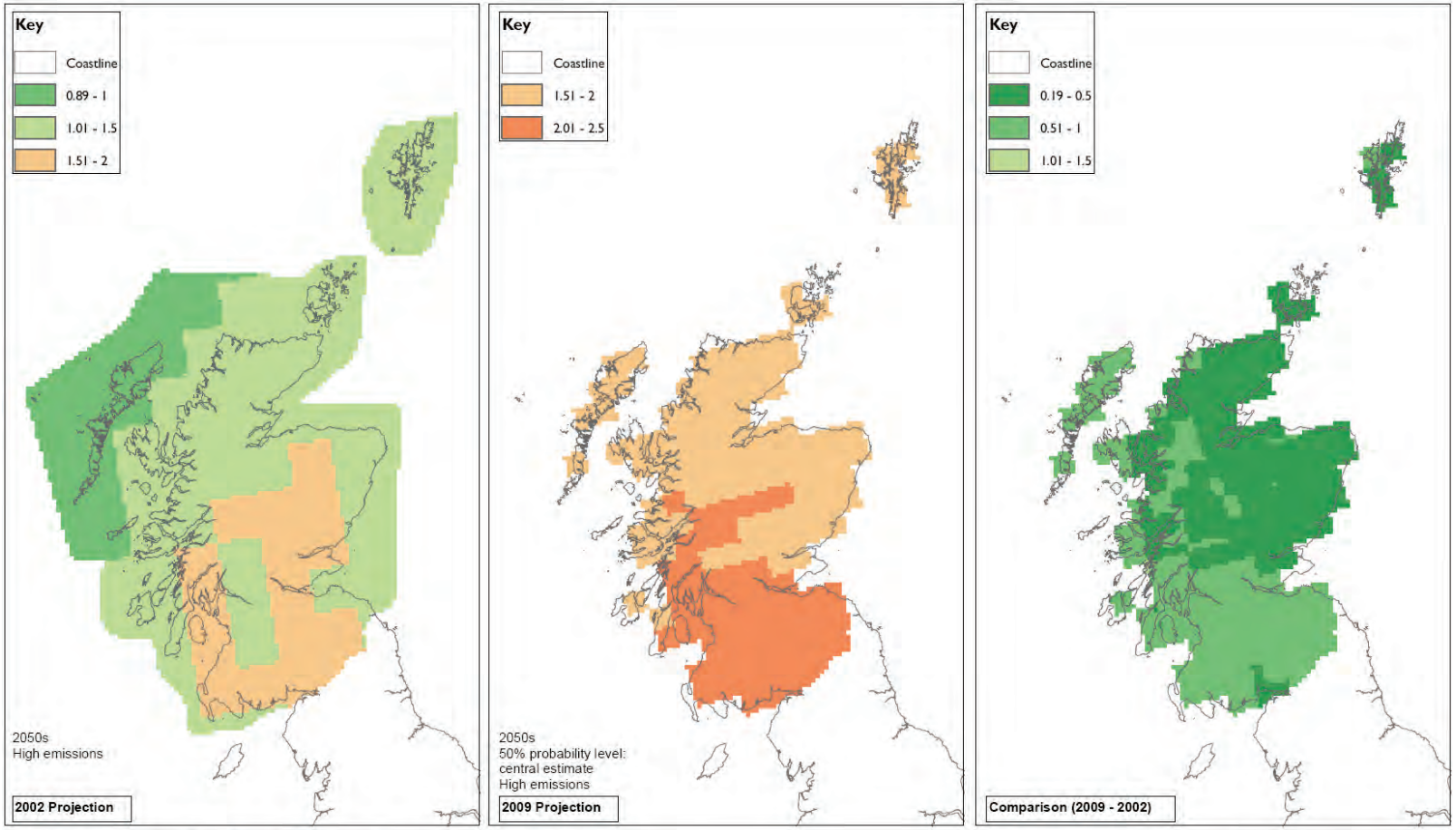
2.19 Figure 2.5c maps the difference between the two scenarios suggesting that across the majority of Scotland there is relatively little difference in the scale of change (maximum of 0.5° Celsius) with relatively small areas along the west and east coasts showing differences between 0.5 and 1.5 ° Celsius.

2.20 These differences were noted in the revised Phase 1 report, but GIS analysis using the autumn temperature climate change variable was not re-run.

Figure 2.3a
Winter temperature (UKCIP02)

Figure 2.3b
Winter temperature (UKCP09)

Figure 2.3c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Winter Temperature (°C)

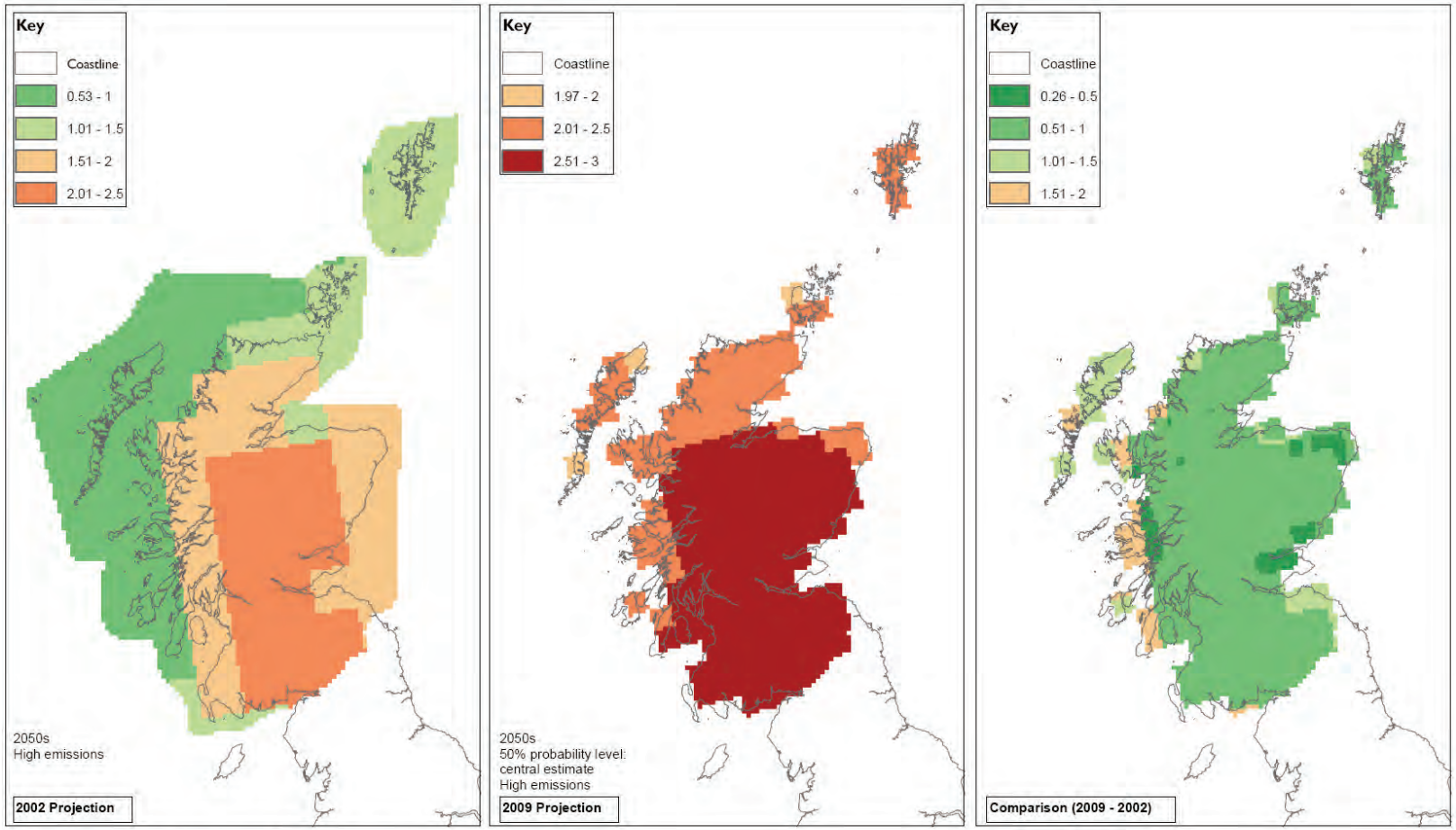
N W E S 0 30 60 120 Km

Source: UKCIP02, UKCP09

Figure 2.4a
Summer temperature (UKCIP02)

Figure 2.4b
Summer temperature (UKCP09)

Figure 2.4c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Summer Temperature (°C)

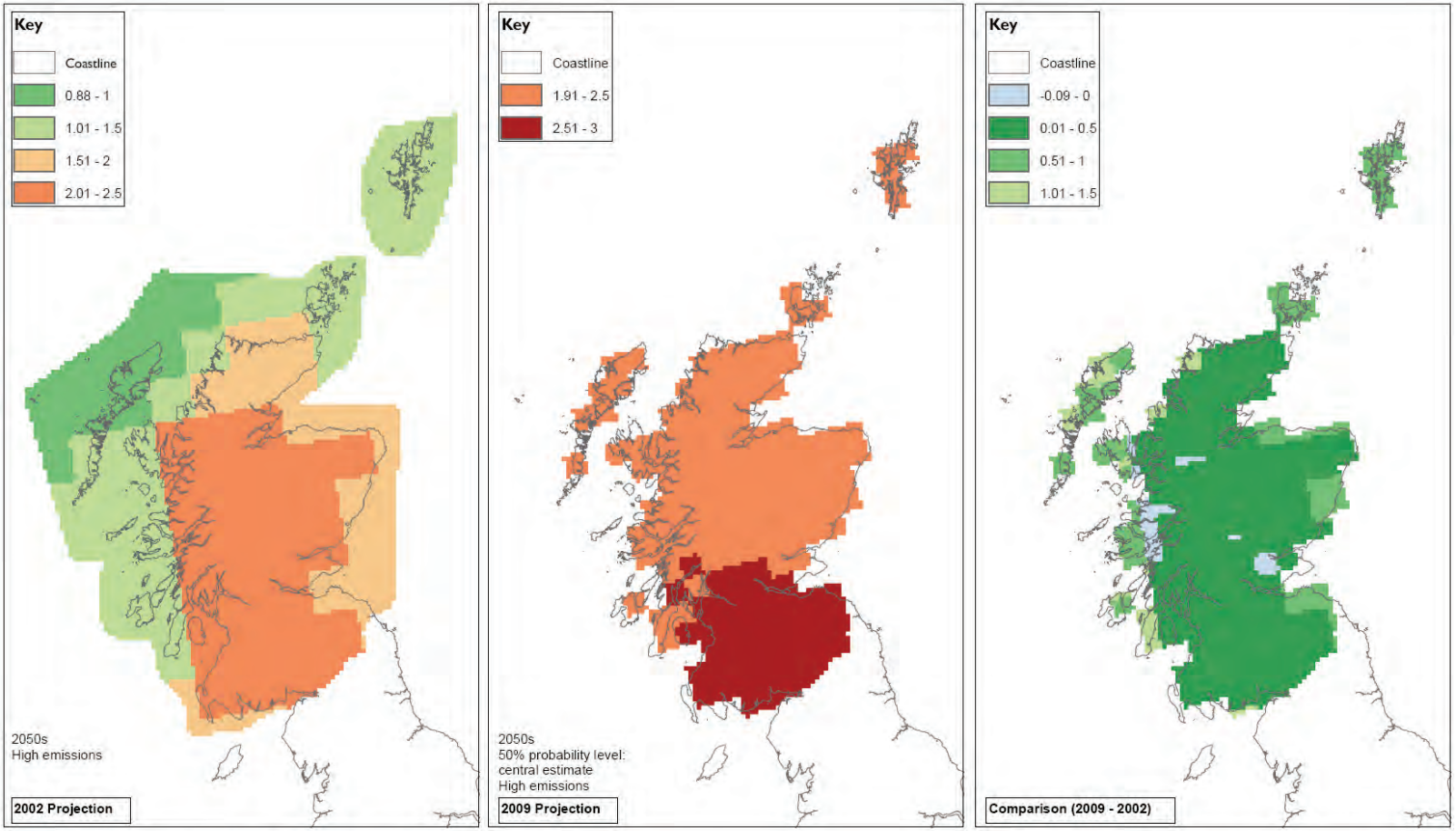
N W E S 0 30 60 120 Km

Source: UKCIP02, UKCP09

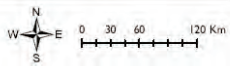
Figure 2.5a
Autumn temperature (UKCIP02)

Figure 2.5b
Autumn temperature (UKCP09)

Figure 2.5c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Autumn Temperature (°C)

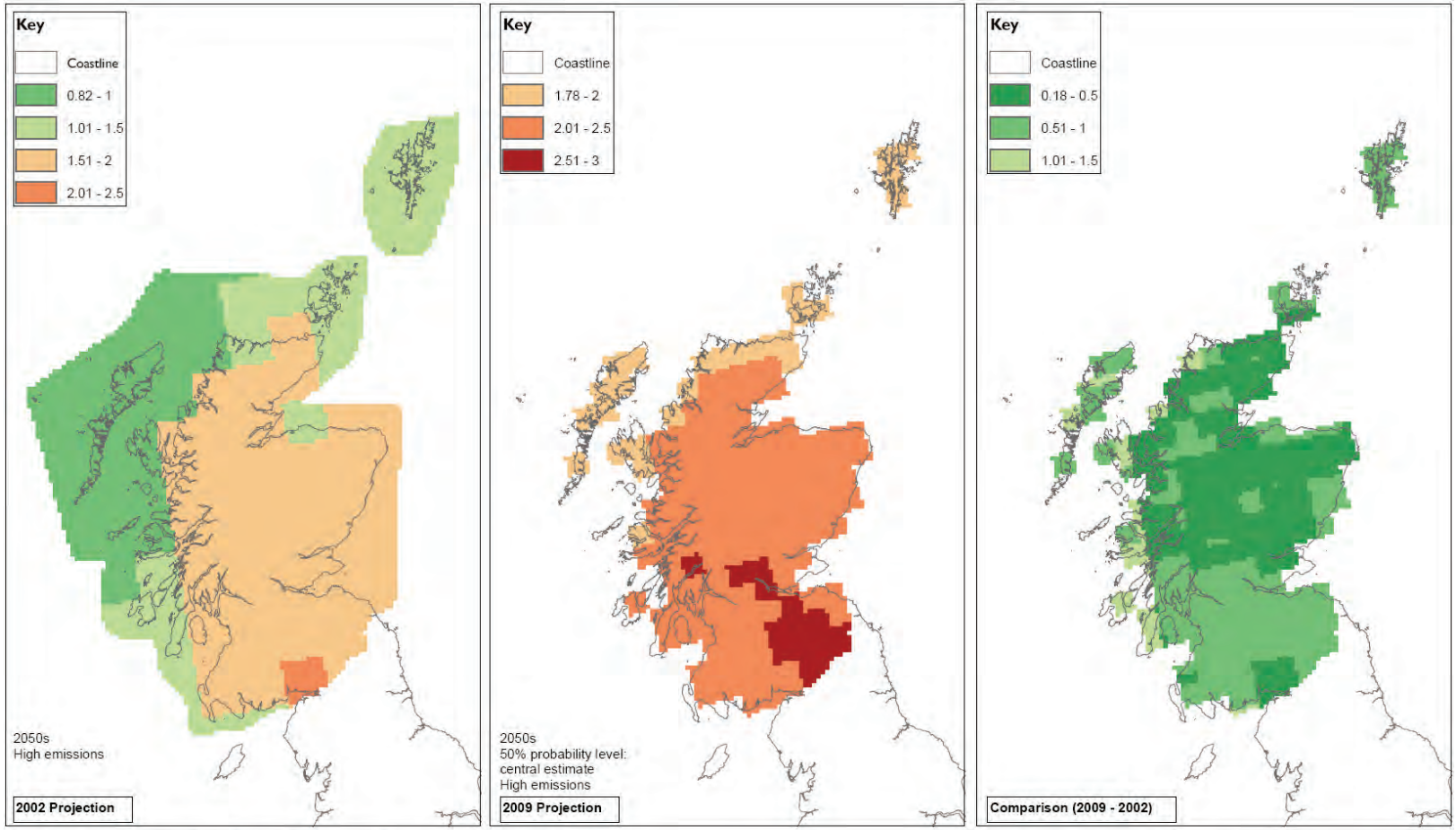


Source: UKCIP02, UKCP09

Figure 2.6a
Annual temperature (UKCIP02)

Figure 2.6b
Annual temperature (UKCP09)

Figure 2.6c
Difference between UKCIP02 and UKCP09



Change in future climate change projections – Annual Temperature (°C)

N W E S 0 30 60 120 Km

Source: UKCIP02, UKCP09

File: S:\4800\4809 Climate Change and Landscape Phase 2\GIS\Themes\ArcGIS9\4503-02_007_Annual_Temp_Comparison_high.mxd

Annual temperature

2.21 The UKCIP02 2050 high emissions scenario projections (Figure 2.6a) suggested that all of Scotland could experience an increase in average annual temperatures. The increases could be greatest across most of mainland Scotland (up to a 2° Celsius increase, with a small area on the inner Solway Firth experiencing up to 2.5° Celsius increase) and lowest around the west coast and Hebrides (up to 1° Celsius increase).

2.22 The UKCP09 2050 high emissions scenario projections (Figure 2.6b) show a similar pattern, though the scale of change has increased, with most of mainland Scotland showing possible increases of up to 2.5° Celsius, and areas of southern and central Scotland showing possible increases of up to 3° Celsius. The Hebrides, north coast and Northern Isles could experience the lowest increases (up to 2° Celsius).

2.23 Figure 2.6c maps the difference between the two scenarios suggesting that for most of Scotland the pattern of difference is fairly even, with the greatest variation (of between 1 and 1.5° Celsius) limited to small areas along the west coast and Hebrides.

2.24 These differences are noted in the revised Phase 1 report, but GIS analysis using the annual temperature climate change variable was not re-run.

Sea level rise

2.25 Phase 1 of the research into the effects of climate change on landscape and quality of life drew on research into sea level rise carried out for the Scotland and Northern Ireland Forum for Environmental Research (published as FRM10 in 2008[14]). This research presented estimates for sea level change around the Scottish coast between 2000 and 2080. These were based on the IPCC global mean sea level projections adjusted to reflect geological and isostatic rebound modelling, similar to those used in the UKCIP02 projections. This research has been updated in the light of the UKCP09 projections[15].

2.26 The UKCP09 projections include new figures for sea level rise using the modelling approach described above (emission scenarios, timescales, probabilistic projections) combined with the latest assessment of land movement around the UK coast which differ from those used in the earlier research into sea level rise. The latter have been revised downwards slightly, resulting in an upward adjustment in sea level projections.

Table 2.1: 2080 sea level projections for Edinburgh, cm

	High emissions	Medium emissions	Low emissions
FRM10 (in line with UKCIP02)	+6 to +35	+1.6 to +24	
UKCP09 50% percentile	+31.4	+24.4	+18.6
UKCP09 5% / 95% percentiles	+7 to +54	+5 to +45	+4 to +32

2.27 These figures suggest that the 09 projections lie towards the upper end of the FRM10 UKCIP02 projections.

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[14] SNIFFER (2008) Coastal Flooding in Scotland: A Scoping Study, Project FRM10

[15] Update to Project FRM10: Coastal Flooding in Scotland: A Scoping Study, in the light of the UK Climate Projections (2009) report http://www.sniffer.org.uk/Webcontrol/Secure/ClientSpecific/ResourceManagement/UploadedFiles/updated%20summary%20Nov%2009.pdf

2.28 The update to the research concludes that the spatial pattern of change is broadly the same as reported in FRM10, though no new maps are available. A relative sea level rise of around +30-35 cm over the period 1990 to 2095 at Edinburgh compares with 25-30 cm in the Clyde Estuary, around 40-45 cm in the Western Isles and Orkney Islands and around 50-55 cm in the Shetland Islands.

2.29 The UKCP09 projections include an additional scenario based on high plus plus emissions (H++). This scenario is intended to represent the effects of the melting of large ice sheets on sea level rise, an area where there is a current lack of scientific understanding. While this is considered to be a very unlikely scenario, the projections suggest that beyond the end of the century sea levels could rise by between 93cm and 1.9m.

2.30 The updated research also considers the issue of storm surges. It concludes that storm surges show considerable less change in overall height (and consequently less influence on coastal flood risk) compared to sea level rise around the Scottish coast. However, taking the H++ emissions scenario for sea level and combining this with surge predictions from the higher emissions estimate give much more significant increases in the effect of surge tides on coastal flooding.

2.31 While the scale of projected sea level rise is somewhat greater than suggested by the UKCIP02 scenarios, the spatial implications (when viewed at a national level) are broadly similar. This is reflected in a commentary and in terms of the weight attached to coastal impacts in the text of the Phase 1 report, but GIS analysis for this variable was not rerun.

Compatibility of 02 and 09 emissions scenarios

2.32 The foregoing analysis was based on a comparison of the UKCIP02 and UKCP09 high emissions scenarios. However, the Phase 1 analysis was based on UKCIP02 medium-high emissions scenario, whereas the UKCP09 projections include only ‘low’, ‘medium’ and ‘high’ emissions scenarios. Further analysis was therefore carried out to assess the implications of comparing the 02 medium-high scenario with the 09 medium scenario.

2.33 Figure 2.7 focuses on the winter precipitation variable, and shows that the differences between the 09 medium emissions projection and the 09 high emissions projection are very limited. It appears that the divergence between emissions scenarios become most significant after 2050 (the time horizon for the Phase 1 report analysis). The high emissions scenarios projection suggests that a small number of areas might experience smaller increases in winter precipitation than under the medium projection, and a slightly larger number of areas could experience larger increases. However, these differences are very localised and the overall pattern across Scotland is very similar. It was therefore agreed that the re-running of analysis using 09 data would be based on the medium emissions scenario alone.

Figure 2.7a
Winter precipitation (UKCIP02)
Medium/high emissions

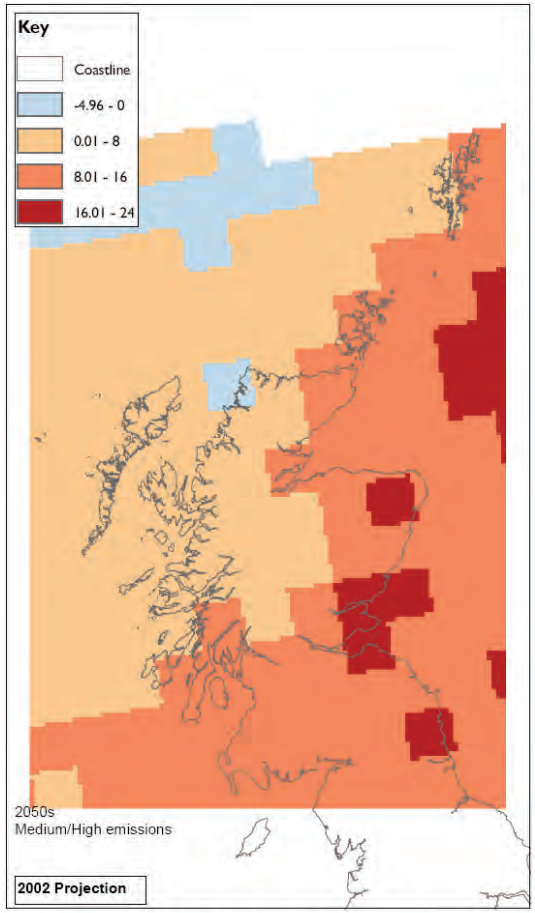


Figure 2.7b
Winter precipitation (UKCP09)
Medium emissions

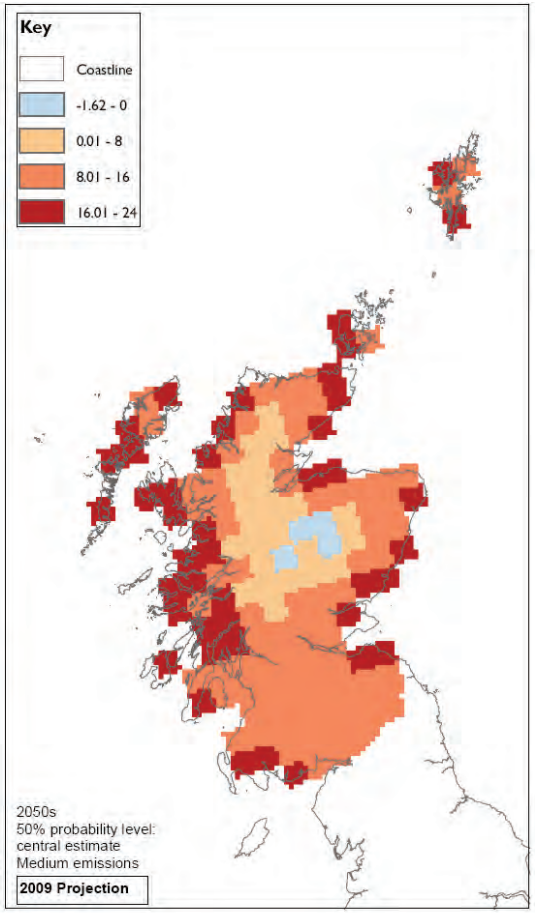
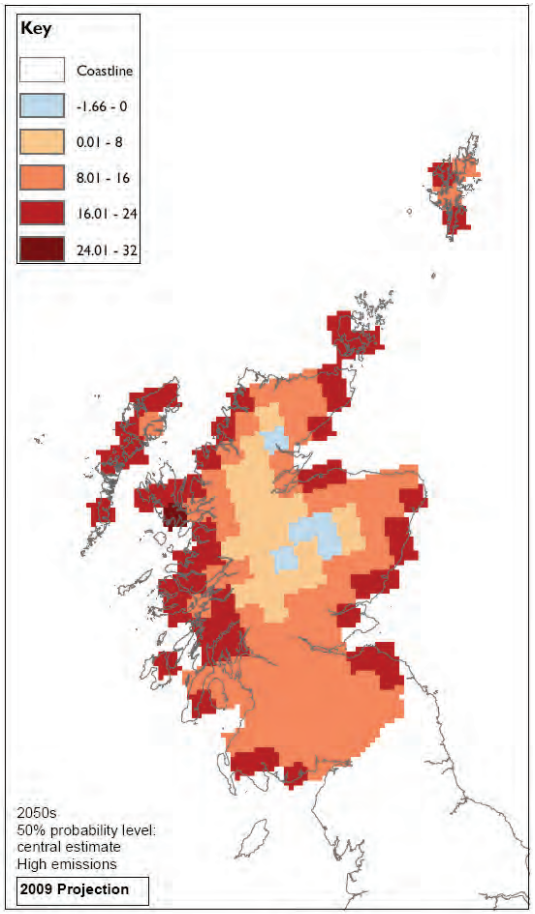
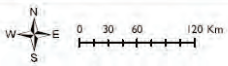


Figure 2.7c
Winter precipitation (UKCP09)
High emissions



Comparison of change in winter precipitation for the 2050s between UKCIP02 (medium/high emissions scenario) and the UKCP09 (medium and high emission scenarios) projections, expressed as % change from current precipitation



Source: UKCIP02, UKCP09

3 RECOMMENDATIONS

3.1 This section draws together the findings from the review of UKCIP02 and UKCP09 climate change projections to identify which elements of the national map analysis required updating to reflect the new data.

3.2 The review suggested that there are some important differences in the direction, scale and spatial pattern of change for **winter precipitation** requiring relevant GIS analysis to be re-run.

3.3 The review found more minor differences in the spatial pattern of change for the following climate change variables, suggesting that relevant GIS analysis will not require to be re-run, but that the changes should be noted in a commentary:

- *summer temperatures (greater projected increases in average summer temperatures under UKCP09);*
- *summer precipitation (smaller projected decreases in average summer precipitation under UKCP09)*;
- *winter temperatures (greater projected increases in average winter temperatures under UKCP09);*
- *autumn temperatures (little difference between the20 02 and 2009 projections);*
- *annual mean temperatures (greater projected increases in average annual temperatures under UKCP09);*
- *sea level rise (greater projected sea level rise under UKCP09).*

3.4 The implications of these recommendations for the Phase 1 national map analysis are set out in Table 3.1. This shows that a total of 13 maps required revision using UKCP09 winter precipitation data. The rights and wrongs of combining elements of the 02 and 09 projections within a single map analysis (for example where we have combined a number of different climate change variables) were discussed with an adviser from SCCIP[16] and were agreed as a pragmatic response provided the different data sources are acknowledged.

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[16] See advice received from J. Hagg, SCCIP adviser in Annex 2 of this Appendix

Table 3.1: National Map Analysis – implications of recommendations (*italicised, bold text* indicating those maps which include the winter precipitation variable).

Map figure number	Topographic\ Landscape data	Climate\Flooding data	Change type (direct, mitigation or adaptation) and certainty	09 update?
Figure 4.2a and 4.2b	Broadleaves, National Inventory of Woodlands & Trees (NIWT)	T2: Autumn temperature change (TEMP)	Direct, high	NO
Figure 4.3a and 4.3b	National Inventory of Woodlands & Trees (NIWT)	P2: Average decrease in summer precipitation (PREC)	Direct, high	NO
Figure 4.4a and 4.4b	National Inventory of Woodlands & Trees (NIWT)	***P1: Average change in winter precipitation (PREC)***	Direct, high	YES
Figure 4.5a and 4.5b	National Inventory of Woodlands & Trees (NIWT)	***P1: Average change in winter precipitation*** (PREC) W1: average wind speed change in the winter (WIND)	Direct, high	YES
Figure 4.6a and 4.6b	National Inventory of Woodlands & Trees (NIWT) All areas except remote, SE Urban-Rural classification	T2: Autumn temperature change (TEMP) P2: Average decrease in summer precipitation (PREC) T4: change in daily max. temperature in Summer-Autumn (TMAX)	Direct, high	NO
Figure 4.7a and 4.7b	National Inventory of Woodlands & Trees (NIWT)	SEPA Fluvial Flooding risk SEPA Coastal Flooding risk	Direct and adaptation, high	NO
Figure 4.8a and 4.8b	Urban, SE Urban-Rural classification Moorland, Landcover	***P1: Average change in winter precipitation*** (PREC) SEPA Fluvial Flooding risk	Adaptation, medium	YES
Figure 4.9a and 4.9b	SEPA Fluvial Flooding risk	***P1: Average change in winter precipitation*** (PREC)	Direct, high	YES
Figure 4.10a and 4.10b	SEPA Coastal Flooding risk SEPA Fluvial Flooding risk	***P1: Average change in winter precipitation*** (PREC)	Direct, high	YES

Map figure number	Topographic\ Landscape data	Climate\Flooding data	Change type (direct, mitigation or adaptation) and certainty	09 update?
Figure 4.11	Sea level rise	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Sea level rise data	Direct	NO
Figure 4.12	Surge risk	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Surge risk data	Direct	NO
Figure 4.13	Wave fetch	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Wave fetch data	Direct	NO
Figure 4.14	Combined risk (wave action, storm surge and sea level change)	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Combined risk data	Direct	NO
Figure 4.15a and 4.15b	Estuaries, digitised Intertidal Area, Landcover Mudflats-saltmarsh, landcover	SEPA Coastal Flooding risk ***P1: Average change in winter precipitation*** (PREC) W1: average wind speed change in the winter (WIND)	Direct, high	YES
Figure 4.16a and 4.16b	Urban-Peri Urban, SE Urban-Rural classification	P2: Average change in summer precipitation (PREC) T2: Autumn temperature change (TEMP)	Direct, high	NO
Figure 4.18a and 4.18b	Urban-Peri Urban, SE Urban-Rural classification	T2: Autumn temperature change (TEMP) T4: change in daily max. temperature in Summer-Autumn (TMAX)	Adaptation. medium	NO

Map figure number	Topographic\ Landscape data	Climate\Flooding data	Change type (direct, mitigation or adaptation) and certainty	09 update?
Figure 4.17a and 4.17b	All areas except remote, SE Urban-Rural classification	T1: Average annual temperature increase (TEMP) T2: Autumn temperature change (TEMP) T3: Increased difference between summer-winter (TEMP) P2: Average decrease in summer precipitation (PREC) C1: Increased cloud cover (TCLW) SN1: Change in snowfall (SNOW) T4: change in daily max. temperature in Summer-Autumn (TMAX)	Adaptation, medium	NO
Figure 4.19	Scottish Natural Heritage Windfarm Footprint and Turbine datasets		Mitigation, high	NO
Figure 4.20a and 4.20b	Upland areas (200m+) in the Borders, OS Panorama height data	***P1: Average change in winter precipitation*** (PREC) P2: Average decrease in summer precipitation (PREC)	Adaptation, High	YES
Figure 4.21	Coniferous forests, NIWT Arable Farmland, digitised farm types		Mitigation, medium	NO
Figure 4.22a and 4.22b	Peat, Landcover	***P1: Average change in winter precipitation*** (PREC)	Direct, high	YES

Map figure number	Topographic\ Landscape data	Climate\Flooding data	Change type (direct, mitigation or adaptation) and certainty	09 update?
Figure 4.23a and 4.23b	Blanket Bog, Landcover Peat, Landcover	T1: Average annual temperature increase (TEMP) ***P1: Average change in winter precipitation*** (PREC) P2: Average decrease in summer precipitation (PREC)	Direct, high	YES
Figure 4.24a and 4.24b	Upland areas (600m+), OS Panorama height data Heather Moorland, Landcover	T2: Autumn temperature change (TEMP)	Direct, high	NO
Figure 4.25a and 4.25b	Upland areas (600m+), OS Panorama height data	T2: Autumn temperature change (TEMP)	Direct, high	NO
Figure 4.26a and 4.26b	Heather Moorland, Landcover	T1: Average annual temperature increase (TEMP) T2: Autumn temperature change (TEMP) T3: Increased difference between summer-winter (TEMP)	Direct, high	NO
Figure 4.27a and 4.27b	Intensive farming (all areas except LFA), digitised farm types	T2: Autumn temperature change (TEMP) ***P1: Average change in winter precipitation*** (PREC) W1: average wind speed change in the winter (WIND)	Adaptation, medium	YES

Map figure number	Topographic\ Landscape data	Climate\Flooding data	Change type (direct, mitigation or adaptation) and certainty	09 update?
Figure 4.28a and 4.28b	Intensive farming (all areas except LFA), digitised farm types	T1: Average annual temperature increase (TEMP) ***P1: Average change in winter precipitation*** (PREC) P2: Average decrease in summer precipitation (PREC) W1: average wind speed change in the winter (WIND)	Direct, high	YES
Figure 4.29a and 4.29b	Intensive farming (all areas except LFA), digitised farm types	***P1: Average change in winter precipitation*** (PREC) SEPA Fluvial Flooding risk SEPA Coastal Flooding risk	Direct and adaptation, high	YES
Figure 4.30a and 4.30b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	T2: Autumn temperature change (TEMP)	Direct and adaptation, high	NO
Figure 4.31a and 4.31b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	T3: Increased difference between summer-winter (TEMP) P2: Average decrease in summer precipitation (PREC) SM1: Change in soil moisture during summer-autumn (SMOI)	Adaptation, medium	NO
Figure 4.32a and 4.32b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	***P1: Average change in winter precipitation*** (PREC)	Adaptation, medium	YES
Figure 4.33a and 4.33b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	T2: Autumn temperature change (TEMP)	Adaptation, medium	NO

4 UPDATE OF NATIONAL MAP ANALYSIS

4.1 Having compared the UKCIP02 and UKCP09 climate change projections, identified where there are major differences in projections for specific climate change variables, and identified those parts of the Phase 1 analysis that required updating, the next task was to re-run national maps where this was required.

4.2 Subsequent pages present the following for each of the maps identified as requiring an update:

- a map showing the landscape feature(s) in question (unchanged from Phase 1 Interim report);
- a map showing the analysis of spatial change based on the relevant UKCIP02 climate variable(s) (unchanged from Phase 1 Interim report);
- a map showing the analysis of spatial change based on the corresponding UKCP09 climate variable (new maps);
- a table summarising the key differences and implications for the descriptions of national, regional and local patterns of climate related landscape change.

4.3 To aid comparison, the maps have the same figure numbers as the Phase 1 Interim & Final reports.

4.4 Table 4.14 at the end of the chapter provides an update of Table 4.1 from the Phase 1 report, with information added to describe the implications of the updated climate change information. The table also provides a summary of the detailed assessment of changes in covered in this section of the report.

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Change 64: Damage to woodlands caused by winter flooding resulting in early leaf fall and dying trees especially on poorly draining soils and where linked to summer drought – most evident in eastern Scotland

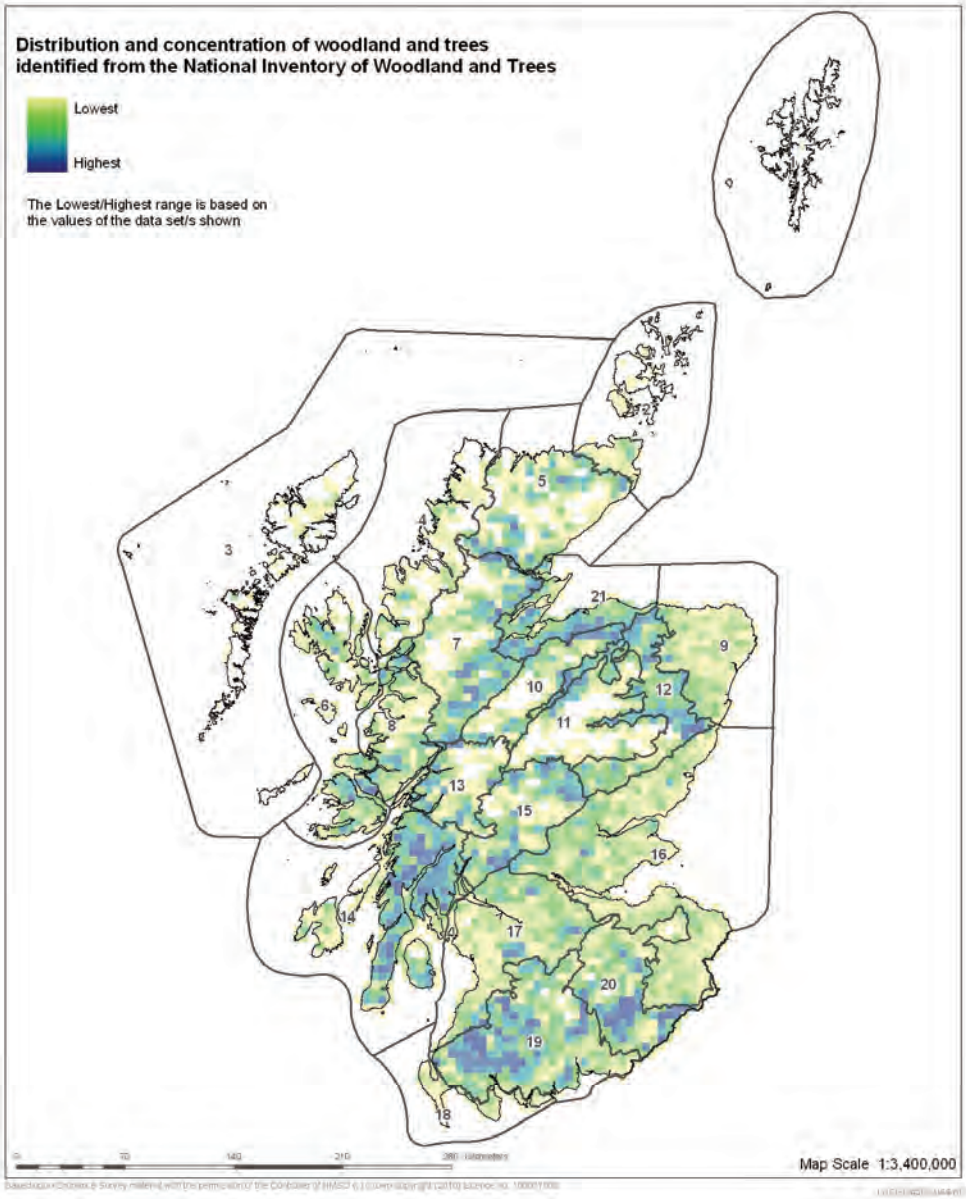

Figure 4.4a, Change 64

UKCIP02 data

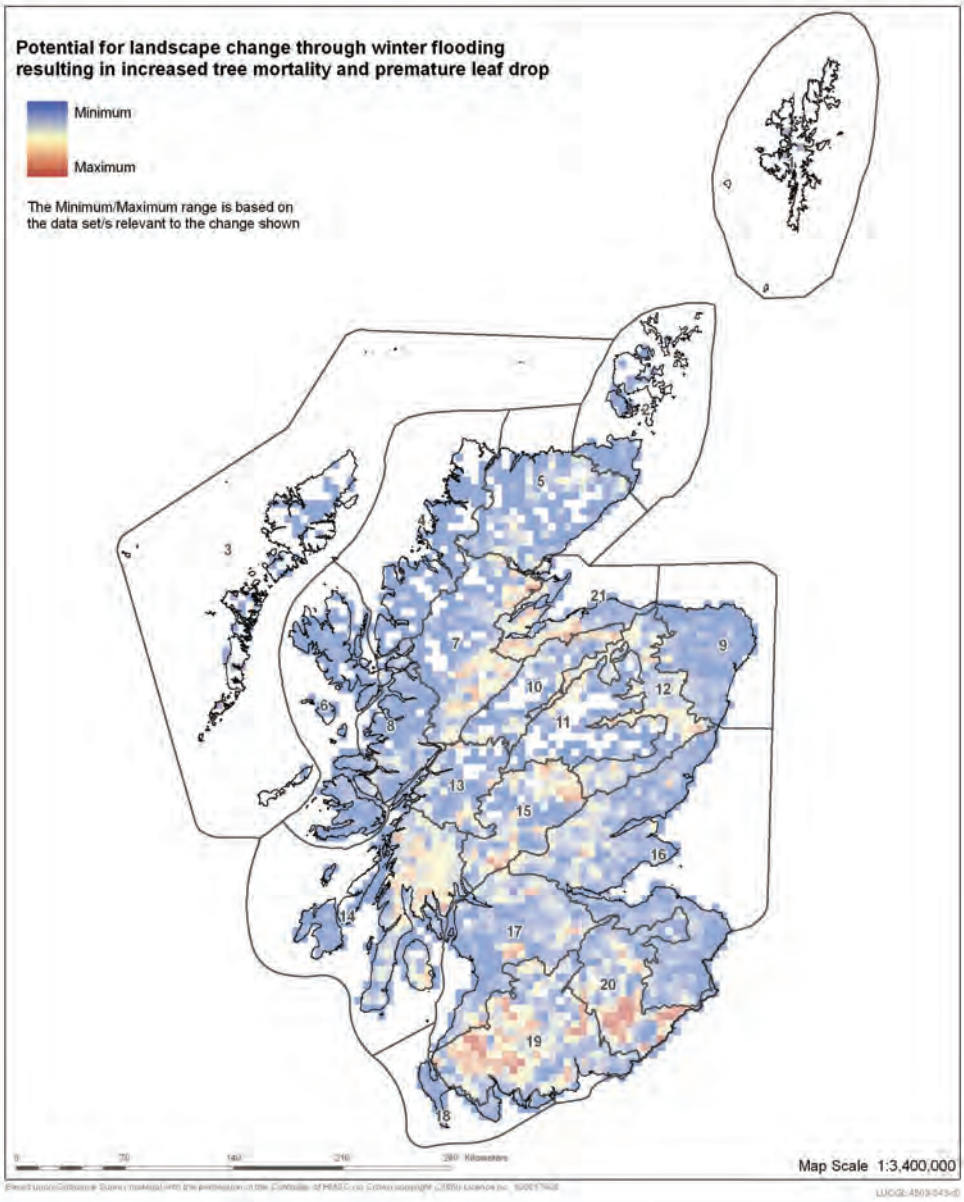

Figure 4.4b, Change 64

▸Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

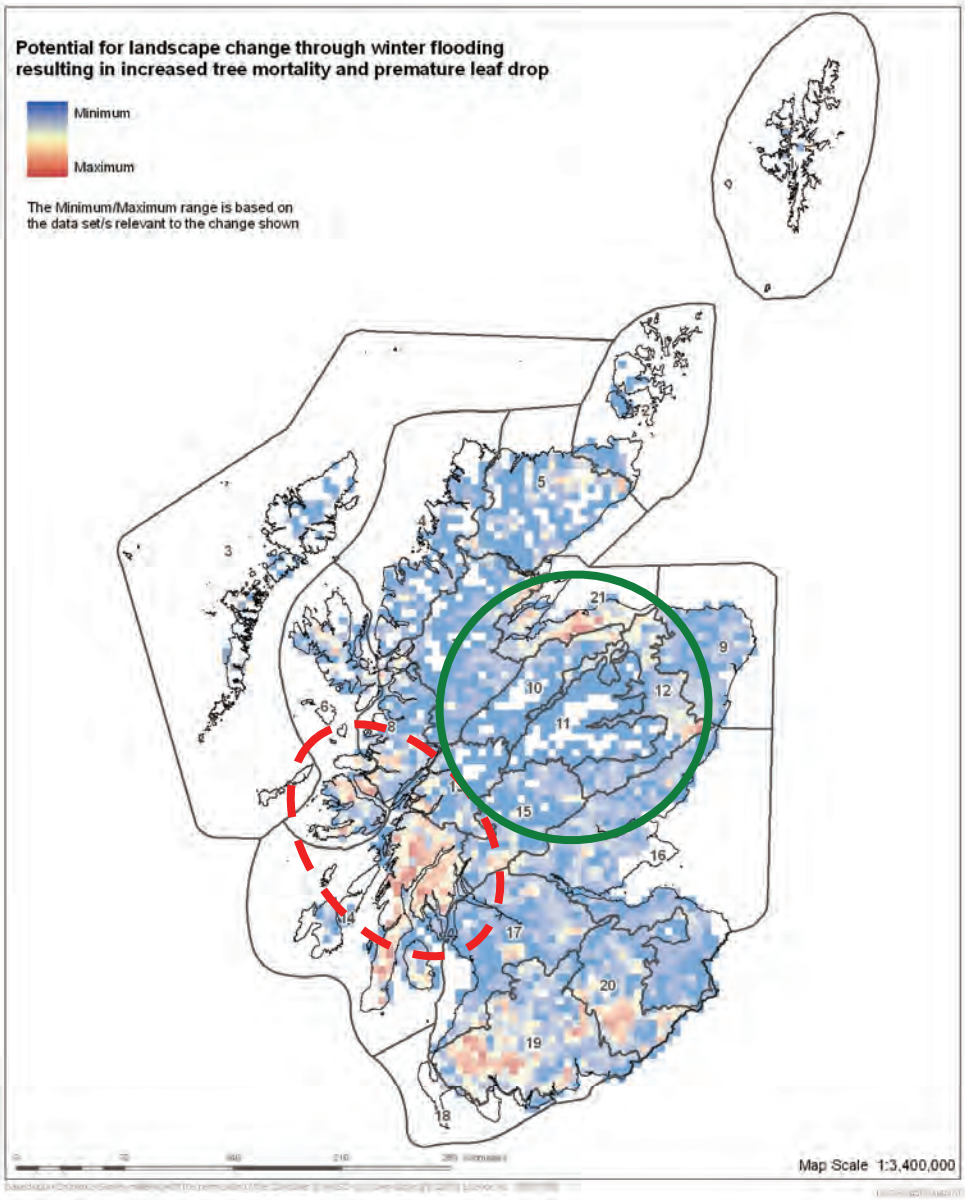

Figure 4.4b, Change 64

▸Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with climate change variable P1: Average change in winter precipitation (UKCP09)

UKCP09 Climate Change Probability Level: **50%**

Emission Scenario: **Medium**

Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.1: Analysis of changes to Figure 4.4b

Landscape change				
Change 64 Figure 4.4b Damage to woodlands caused by winter flooding resulting in early leaf fall and dying trees especially on poorly draining soils and where linked to summer drought – most evident in eastern Scotland.				
Key differences between the 02 and 09 national maps				
The overall extent of change is broadly similar under UKCIP02 and UKCP09 however there is a reduction in the degree of change in the central and eastern Highland areas, particularly on the fringes of the Cairngorms massif. Areas which could experience the greatest degree of change under both projections include the Moray Coast (area 21) Argyll and Mull (areas 8 and 14), Dumfries and Galloway (area 19) and the western Borders (area 20).				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
Fringes of the Cairngorms massif Woodland south of Inverness along the Great Glen		Lochaber, Ardnamurchan, much of Argyll and Bute, including islands such as Mull		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Most areas could experience lower to medium level of change as a result of damage to woodland resulting from winter flooding or water-logging and summer drought.	Most areas could experience lower to medium level of change as a result of damage to woodland resulting from winter flooding or water-logging and summer drought.	None	No change
Highland Perthshire	Some areas could experience higher damage to woodland resulting from winter flooding or water-logging and summer drought.	Some areas could experience moderate damage to woodland resulting from winter flooding or water-logging and summer drought.	None	Minor reduction

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	No significant change as a result of damage to woodland resulting from winter flooding or water-logging and summer drought.	None	None	No change
Strathmore	Some loss of field boundary trees due to stress from high winter rainfall.	Possible reduced extent of loss, although winter rainfall is not the only factor which may cause tree loss.	None	No change
Firth of Tay	Some loss of hedgerow trees due to stress caused by higher winter rainfall.	Possible reduced extent of loss, although winter rainfall is not the only factor which may cause tree loss.	None	No change
Perth	No significant change as a result of damage to woodland resulting from winter flooding or water-logging and summer drought.	None	None	No change

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Change 65: Wind throw damage to woodland caused by extreme winds, exacerbated by wetter winters

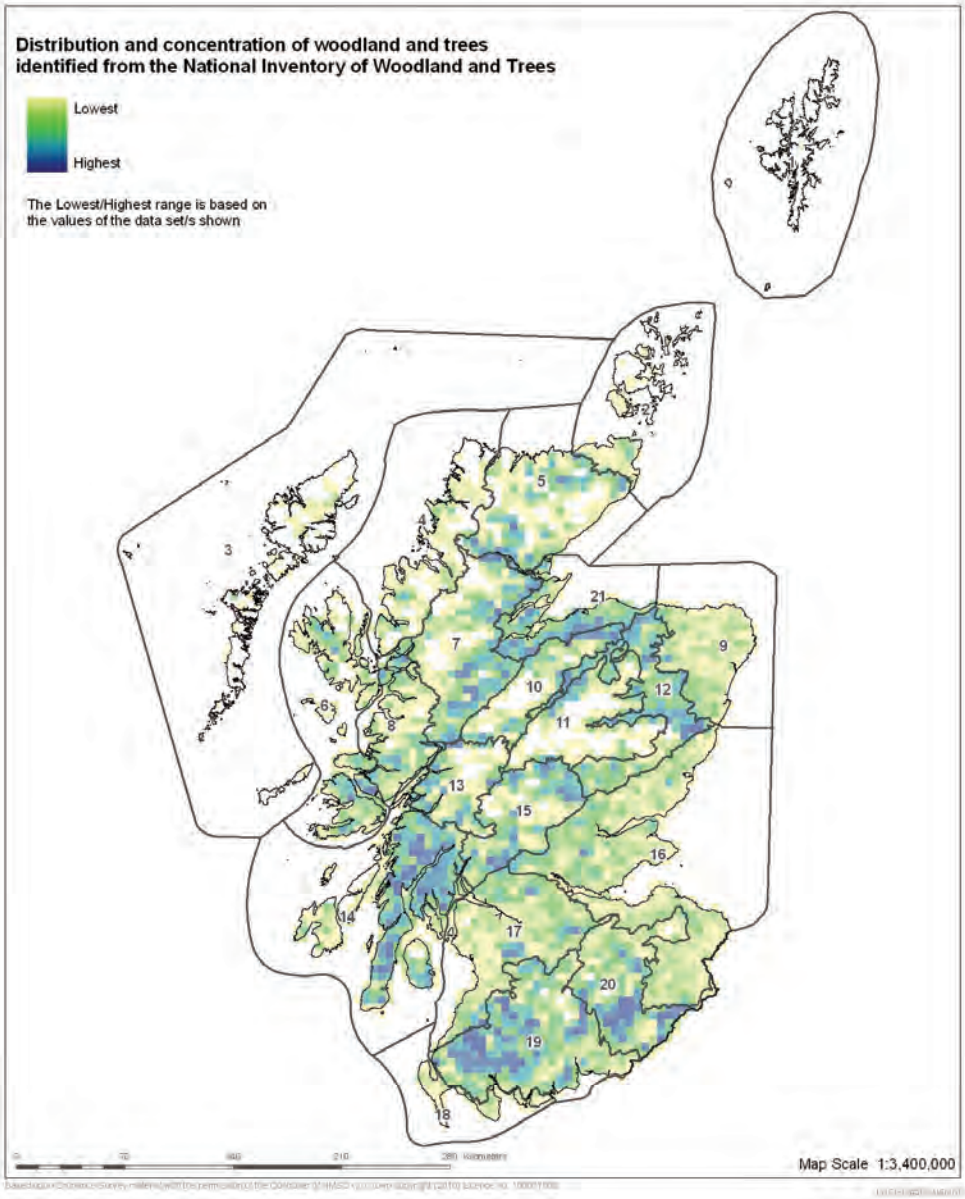

Figure 4.5a, Change 65

UKCIP02 data

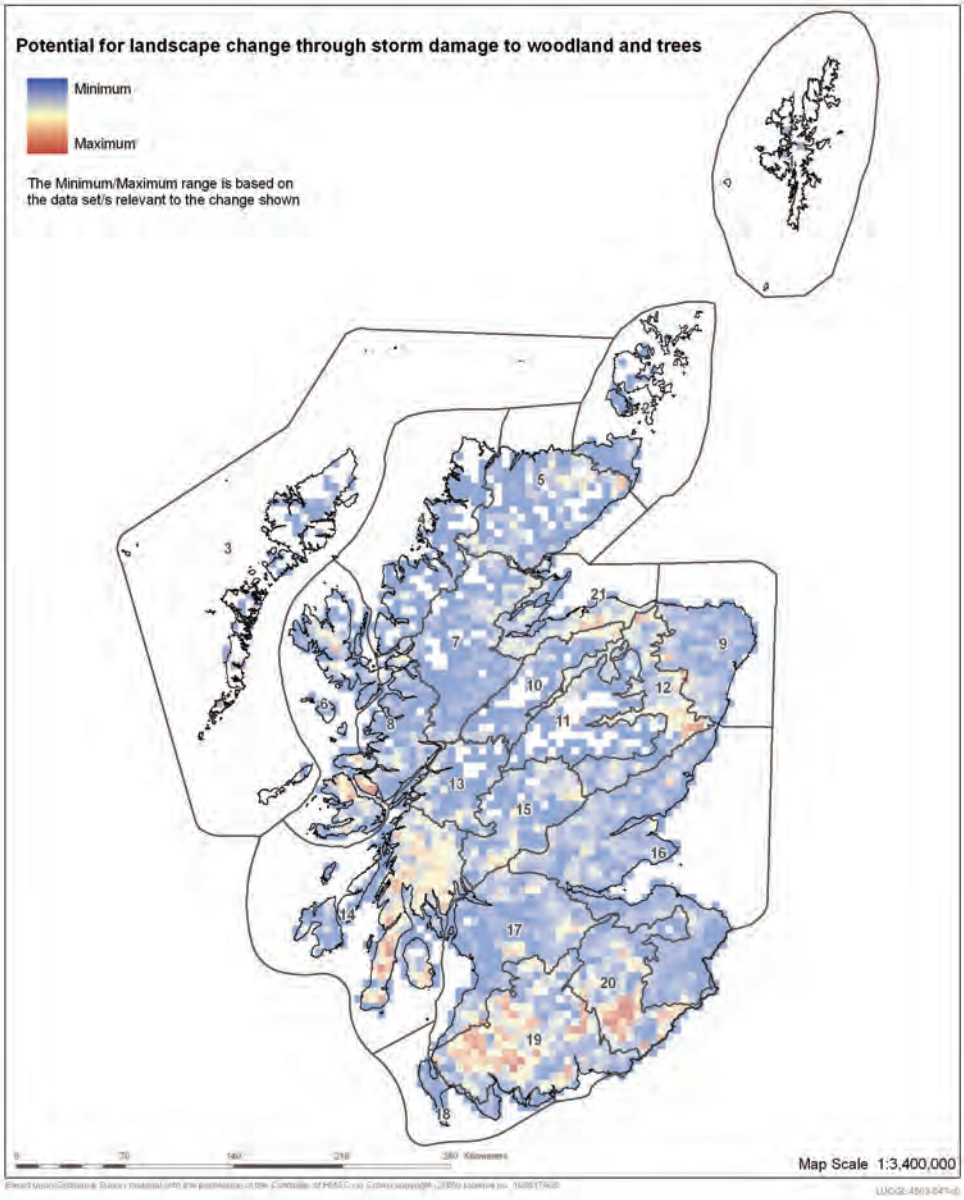

Figure 4.5b, Change 65

- Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with climate change variable P1: Average change in winter precipitation and W1:average wind speed change in winter

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

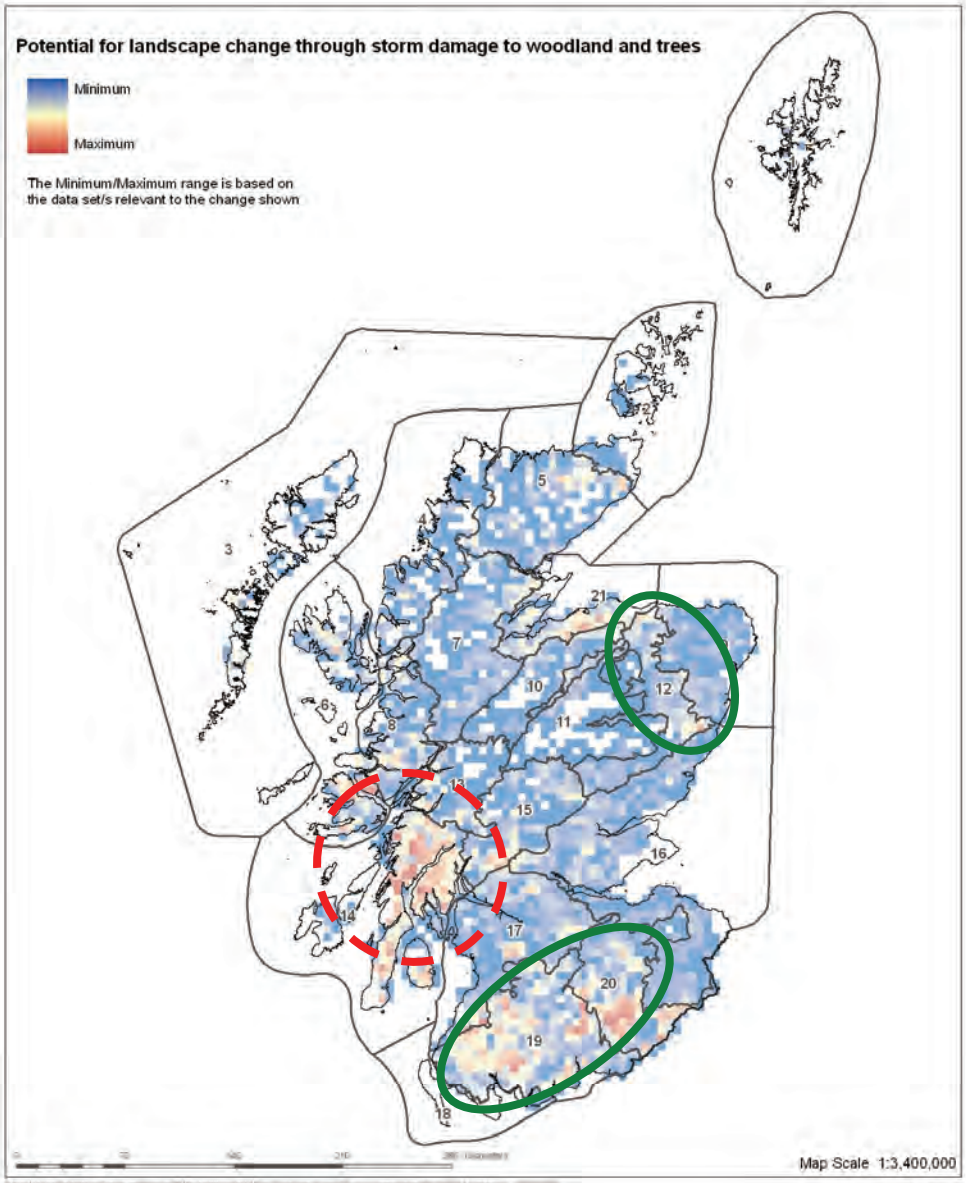

Figure 4.5b, Change 65

▸Change distribution based on comparison of areas of woodland and trees from the National Inventory of Woodland and Trees with climate change variable P1: Average change in winter precipitation (UKCP09) and W1:average wind speed change in winter (UKCIP02)

Certainty level: UKCIP02 climate change	Low	Med	High	UKCP09 Climate Change Probability Level: **50%**
Certainty level: mapped data	Low	Med	High	Emission Scenario: **Medium**
Timescale of change (years)	<10	10-100	100+	Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.2: Analysis of changes to Figure 4.5b

Landscape change				
Change 65 Figure 4.5b Wind throw damage to woodland caused by extreme winds, exacerbated by wetter winters.				
Key differences between the 02 and 09 national maps				
The extent and degree of change is very similar under UKCIP02 and UKCP09. The main difference is a reduction in the degree of change in the north eastern fringes of the Cairngorms (area 12), a slight decrease in the degree of change in the Southern Uplands (area 19), and a slight increase in the degree of change in Argyll (area 14).				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
North east fringes of the Cairngorms massif Solway Firth, Southern Uplands, and Borders Hills		Much of Argyll and Bute		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Most areas could experience lower to medium level of change as a result of wind throw damage to woodland caused by extreme winds, exacerbated by wetter winters.	None	None	No change
Highland Perthshire	Some areas such as glen slopes could experience higher damage to woodland resulting from Wind throw damage to woodland caused by extreme winds, exacerbated by wetter winters.	None	None	No change

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	No significant change as a result of damage to woodland resulting from wind throw.	None	None	No change
Strathmore	No significant change as a result of damage to woodland resulting from wind throw.	None	None	No change
Firth of Tay	Some change as a result of increased damage to woodland resulting from wind throw.	None	None	No change
Perth	No significant change as a result of damage to woodland resulting from wind throw.	None	None	No change

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Change 1: Flood management comprising – upland land management (closing drains, woodland establishment), temporary flood storage, diversion of flood flows away from urban areas, green roofs, SUDS, one way valves, raising floor levels, increasing drain capacity, flood resilient design and materials, doubling flood defences

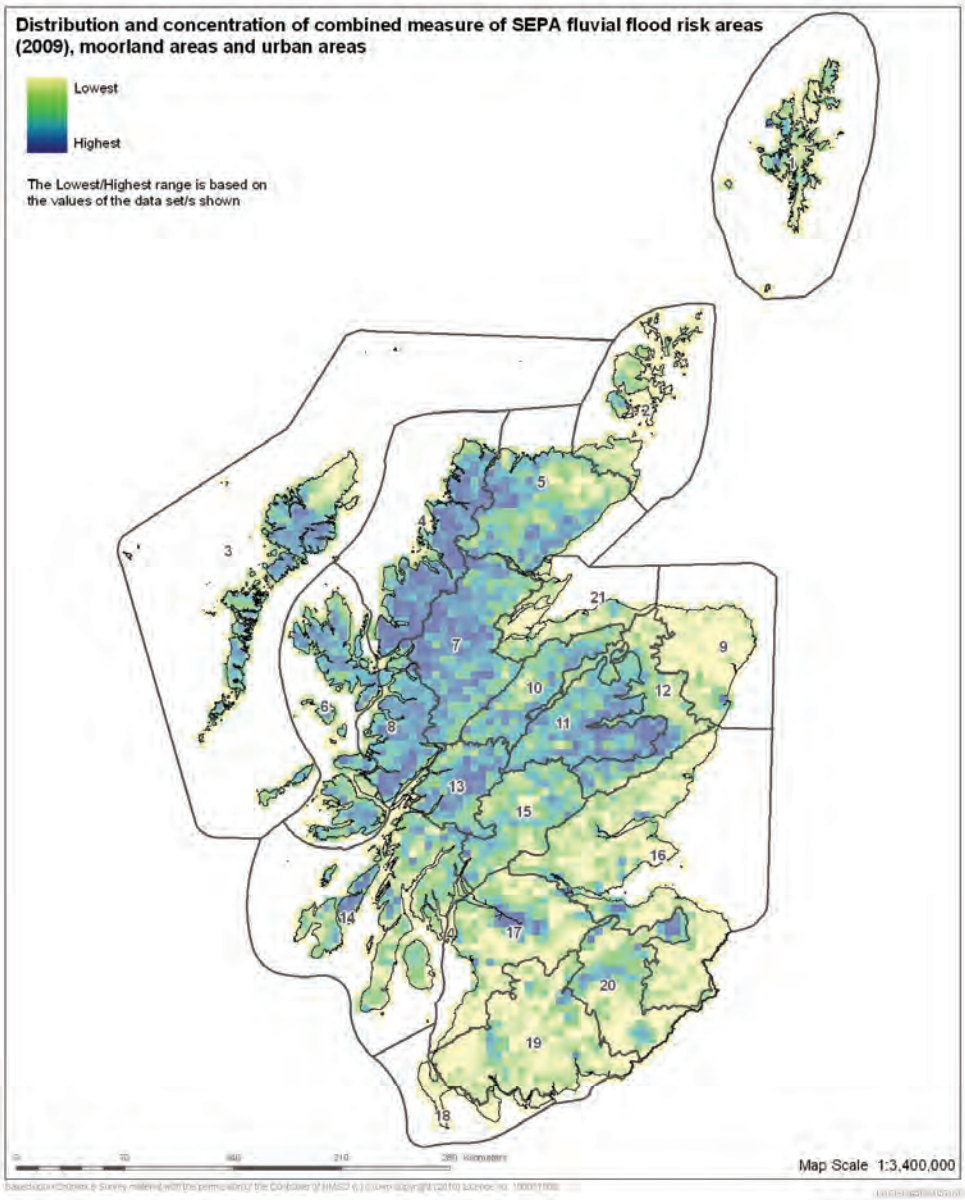

Figure 4.8a, Change 1

UKCIP02 data

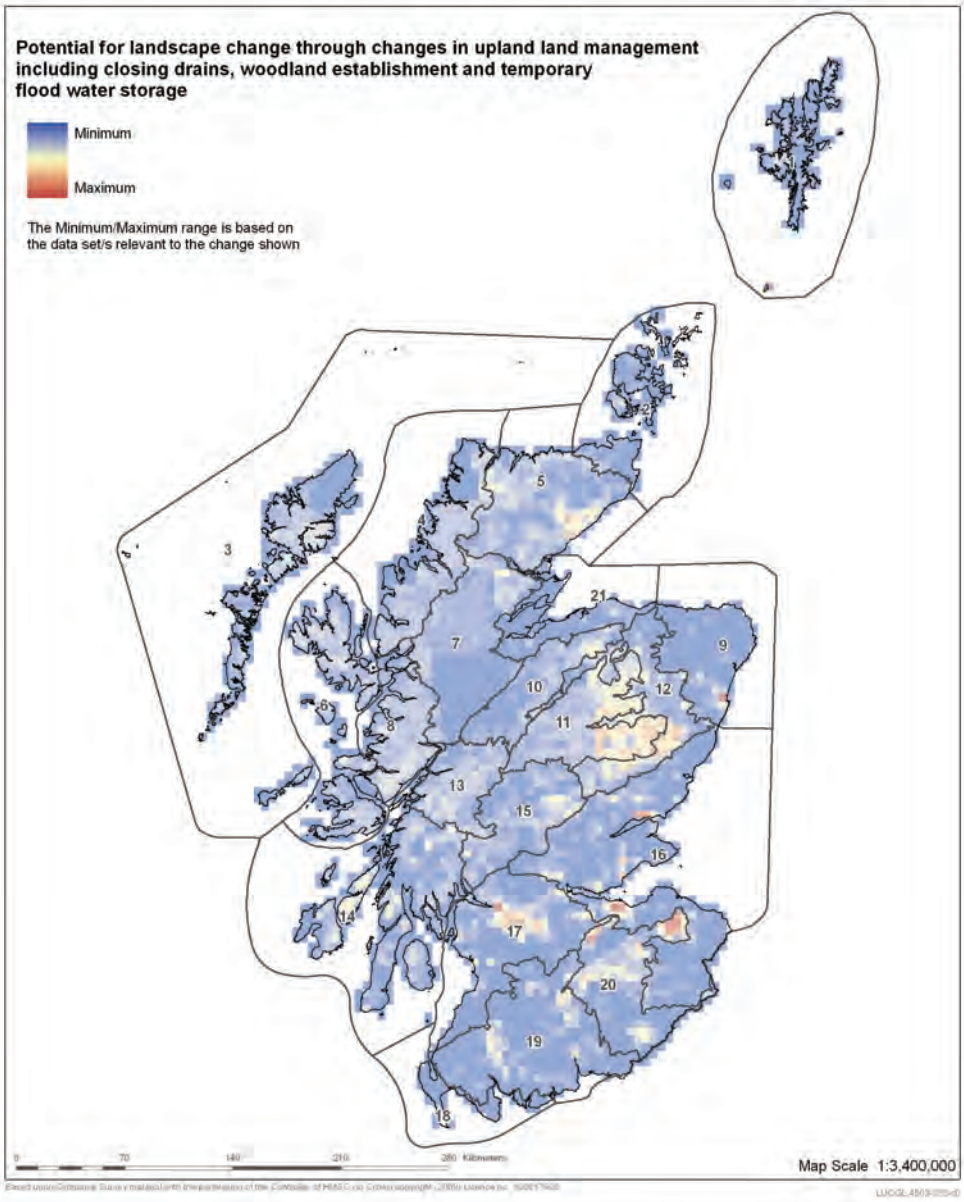

Figure 4.8b, Change 1

Change distribution based on comparison of the location of urban areas as defined in the Scottish Executive Urban-Rural classification and areas of moorland, with climate change variable P1: Average change in winter precipitation and combined measure of SEPA fluvial flooding risk for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009)

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

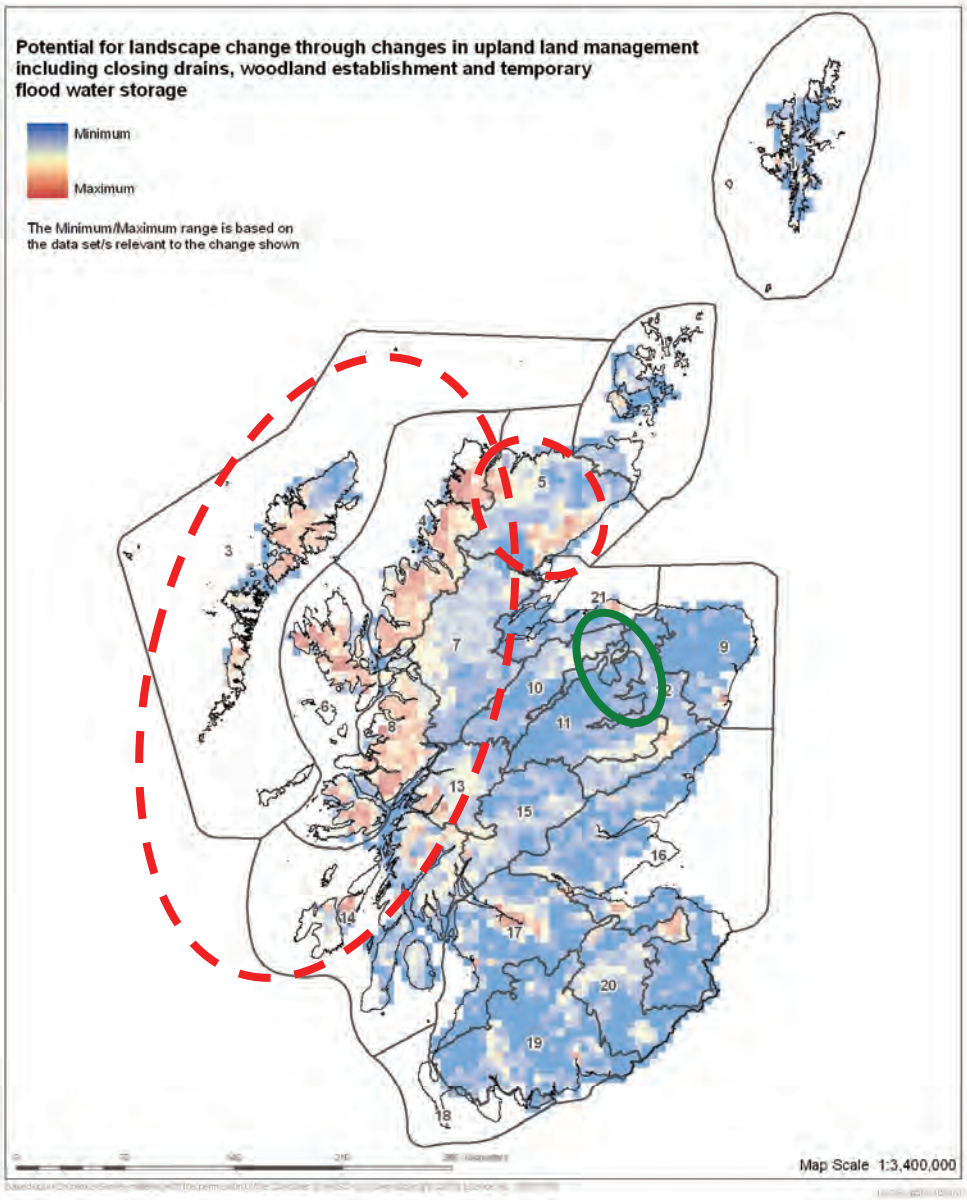

Figure 4.8b, Change 1

Change distribution based on comparison of the location of urban areas as defined in the Scottish Executive Urban-Rural classification and areas of moorland, with climate change variable P1: Average change in winter precipitation (UKCP09) and combined measure of SEPA fluvial flooding risk for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009)

UKCP09 Climate Change Probability Level: **50%**

Emission Scenario: **Medium**

Time Period: **2050s (2040 - 2069)**

	Areas projected to experience less change under UKCP09 than UKCIP02
	Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.3: Analysis of changes to Figure 4.8b

Landscape change				
Change 1 Figure 4.8b Flood management comprising – upland land management (closing drains, woodland establishment), temporary flood storage, diversion of flood flows away from urban areas, green roofs, SUDS, one way valves, raising floor levels, increasing drain capacity, flood resilient design and materials, doubling flood defences.				
Key differences between the 02 and 09 national maps				
There is a notable difference between the maps for UKCIP02 and UKCP09 - an area along the western coastal edge from Argyll to Kinlochbervie, including the Outer Hebrides, could experience a high degree of potential landscape change under UKCP09. This reflects the increase in projected winter rainfall in this area under UKCP09. However, it should be noted that most changes in upland land management to mitigate flooding will be focused in areas closest to urban areas, so the change in these more remote parts of the west coast may be less than indicated by this national analysis. The broad pattern of change across the rest of Scotland is similar for UKCIP02 and UKCP09, although there is a slight increase in the extent and degree of change for the areas surrounding the main urban centres.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
North east fringes of the Cairngorms massif		The west coast, extending south from Cape Wrath as far south as Argyll and Bute, including Skye, Mull, Jura and Islay, together with the Western Isles.		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Most areas could experience lower level of change resulting from changes in upland flood management measures.	None	None	No change
Highland Perthshire	Most areas could experience lower to medium level of change resulting from changes in upland flood management measures.	None	None	No change

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Medium level of change resulting from upland flood management measures – including woodland expansion and closing of moorland drains.	None	None	No change
Strathmore	No significant change as a result of upland flood management measures.	None	None	No change
Firth of Tay	Low to medium level of change resulting from upland flood management measures – including woodland expansion and closing of moorland drains.	None	None	No change
Perth	No significant change as a result of upland flood management measures.	None	None	No change

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Change 5: Increase in river flooding severity and frequency, especially in Western Scotland. Events resulting in damage to property, crops, habitats. Human response of flood protection, catchment management

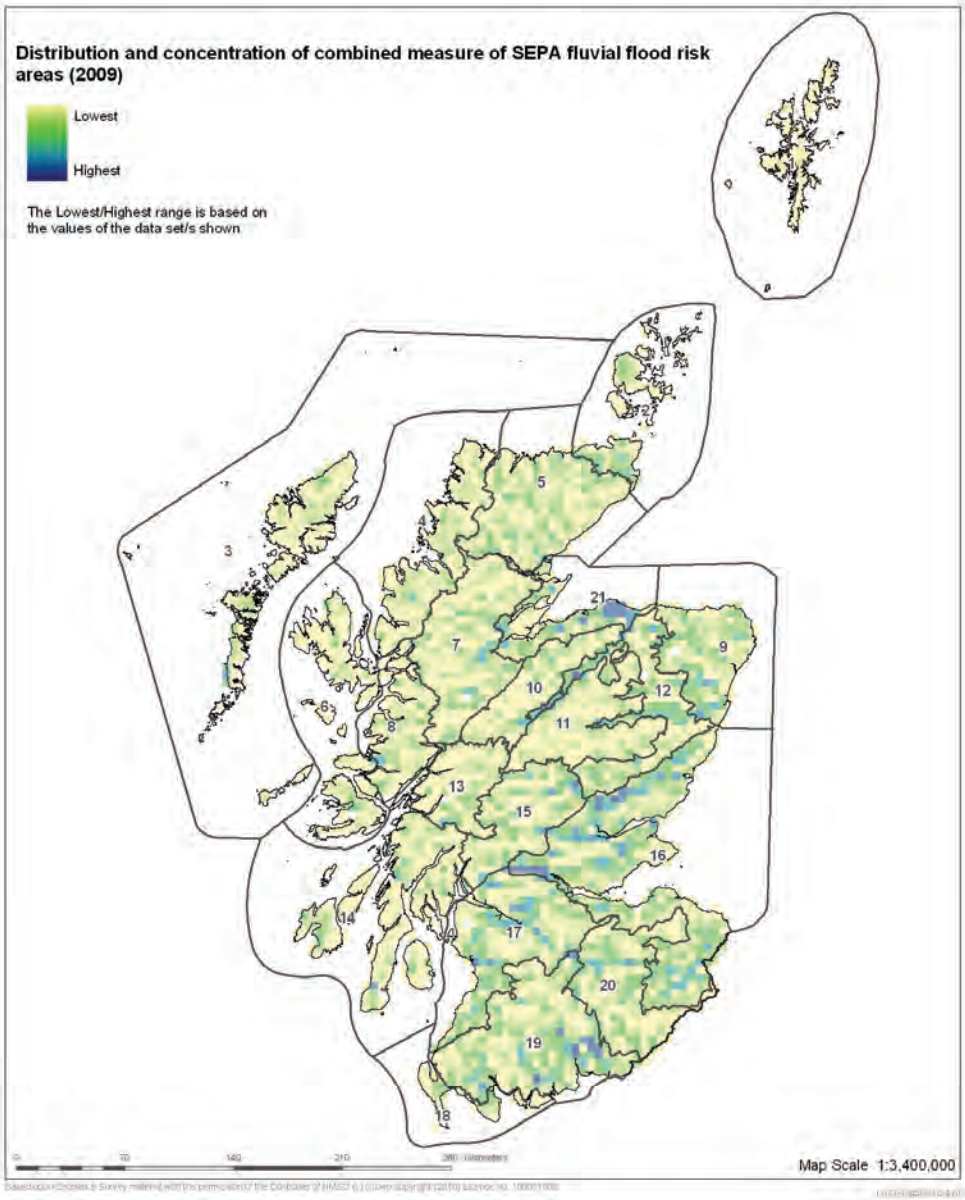

Figure 4.9a, Change 5

UKCIP02 data

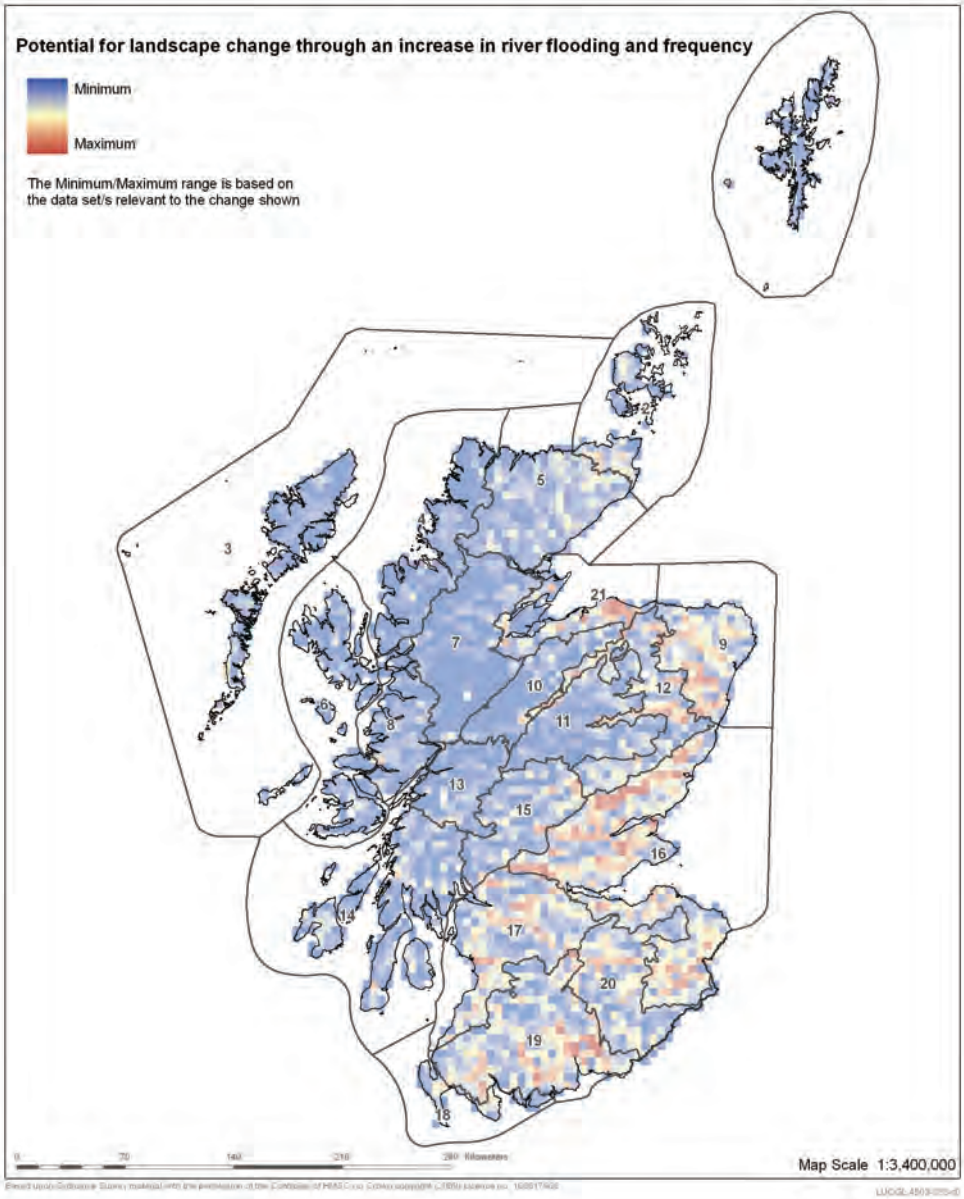

Figure 4.9b, Change 5

- Change distribution based on comparison of combined measure of SEPA fluvial flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

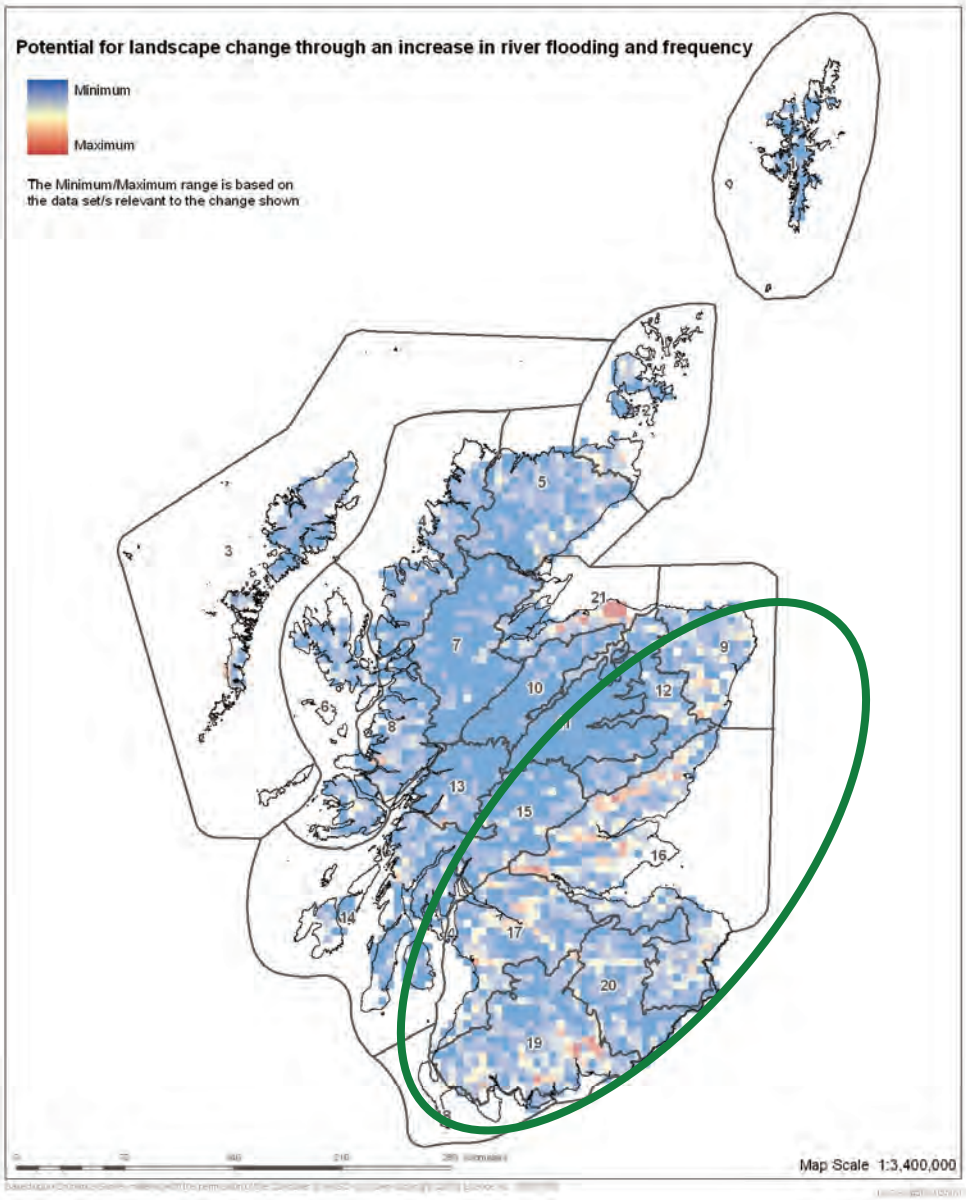

Figure 4.9b, Change 5

- Change distribution based on comparison of combined measure of SEPA fluvial flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) with climate change variable P1: Average change in winter precipitation (UKCP09)

UKCP09 Climate Change Probability Level: **50%**

Emission Scenario: **Medium**

Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.4: Analysis of changes to Figure 4.9b

Landscape change				
Change 5 Figure 4.9b Increase in river flooding severity and frequency, especially in Western Scotland. Events resulting in damage to property, crops, habitats. Human response of flood protection, catchment management.				
Differences between 02 and 09 national analysis				
There is an overall reduction in the extent of areas that could experience a greater degree of change.				
National differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
Large areas of southern Scotland (Dumfries and Galloway and the Borders), central Scotland (Ayrshire, Glasgow and the Clyde Valley, and the Lothians) and Eastern Scotland (Fife, lowland Perthshire, Angus, Aberdeenshire).		None		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Most of Lowland Perthshire could experience medium to higher increase in risk of flooding and the implementation of flood defence responses.	Most of lowland Perthshire could experience low to medium increase in the risk of flooding and the implementation of flood defence responses. Key exceptions include areas to the immediate south of the Angus Glens and to the south of Perth where higher rates of change may occur.	None	Some reduction in the risk of flooding, and the response in terms of flood defences, though some areas remaining at higher risk.

Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Highland Perthshire	Most of Highland Perthshire could experience low to medium increase in risk of flooding and the implementation of flood defence responses.	Most of Highland Perthshire could experience low increase in risk of flooding and the implementation of flood defence responses	None	Some reduction in the risk of flooding, and the response in terms of flood defences.

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Rewilding of valley and upland areas to slow run-off and reduce flood risk downstream. Possible increase in erosion along streams and rivers, and impact on upland peat.	The extent of rewilding may be less than anticipated within the valley and upland areas, and erosion and loss of peat may be less pronounced than previously anticipated in the UKCIP02 conclusions.	None	Minor reduction in the extent of woodland expansion and rewilding of peat moorlands.
Strathmore	Increased risk of flooding and changed patterns of erosion and deposition. Adaptation responses in terms of flood protection for settlements, and some sustainable flood management within the wider catchment.	The creation of flood defences, extent of rewilding and impacts on patterns of river erosion and deposition may be less pronounced than previously anticipated in the UKCIP02 conclusions.	None	Minor reduction in the risk of flooding, erosion and the development of engineered and sustainable flood management.
Firth of Tay	Increased risk of flooding and changed patterns of erosion and deposition. Adaptation responses in terms of flood protection along burns draining the Sidlaws.	The extent of flood protection required along streams and burns from areas such as the Sidlaws, and erosion may be less than previously anticipated in the UKCIP02 conclusions.	None	Minor reduction in the risk of flooding, erosion and the development of engineered and sustainable flood management.
Perth	Increase in the requirement for	Some increase in the	None	Minor reduction in landscape

Local analysis - differences between the effects of 02 and 09 projections on landscape				
	engineered flood management measures.	requirement for engineered flood defence measures, though less than in UKCIP02.		and townscape effects.

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Change 6: Flood damage to river banks and flood plains resulting in scouring and erosion of river valleys and floodplains and deposition downstream

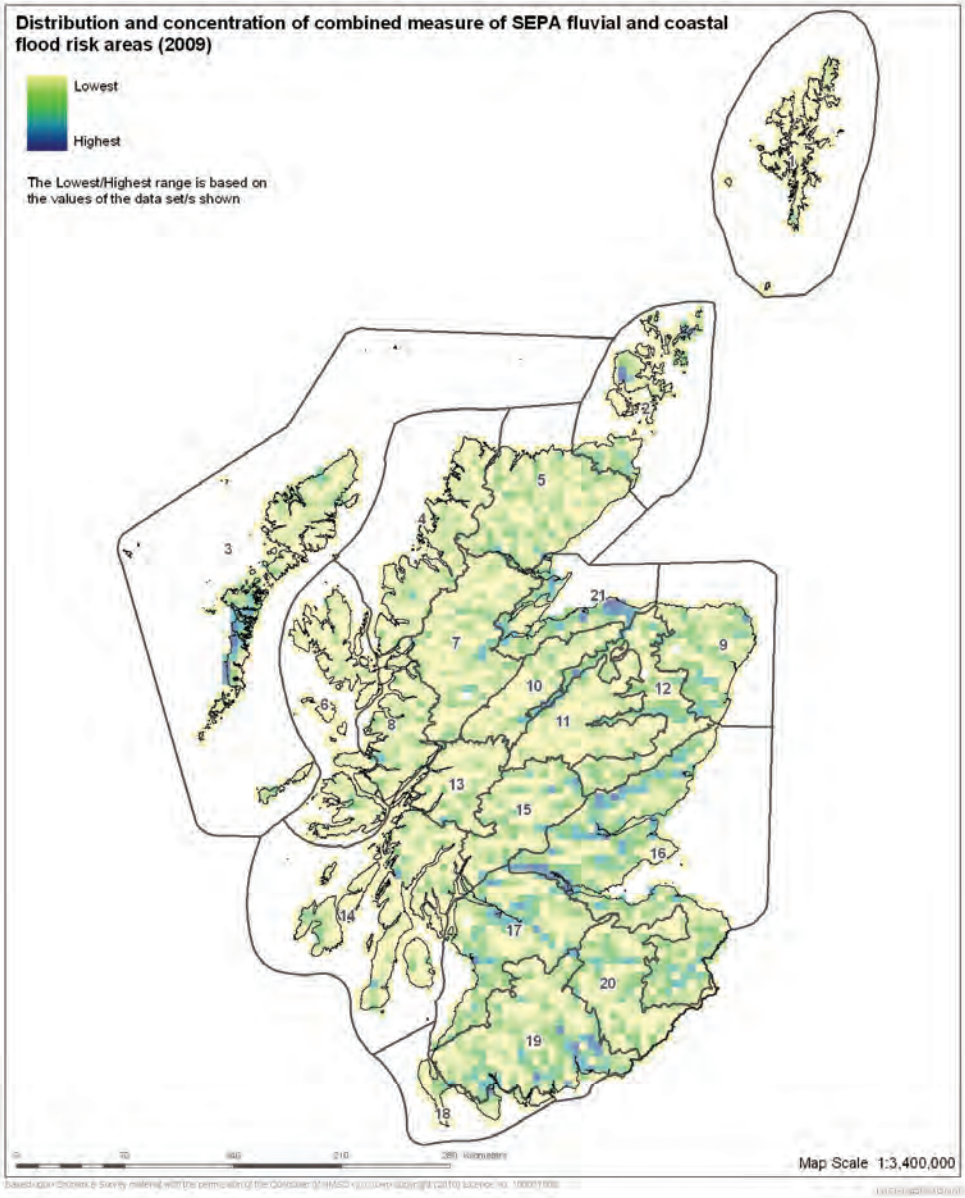

Figure 4.10a, Change 6

UKCIP02 data

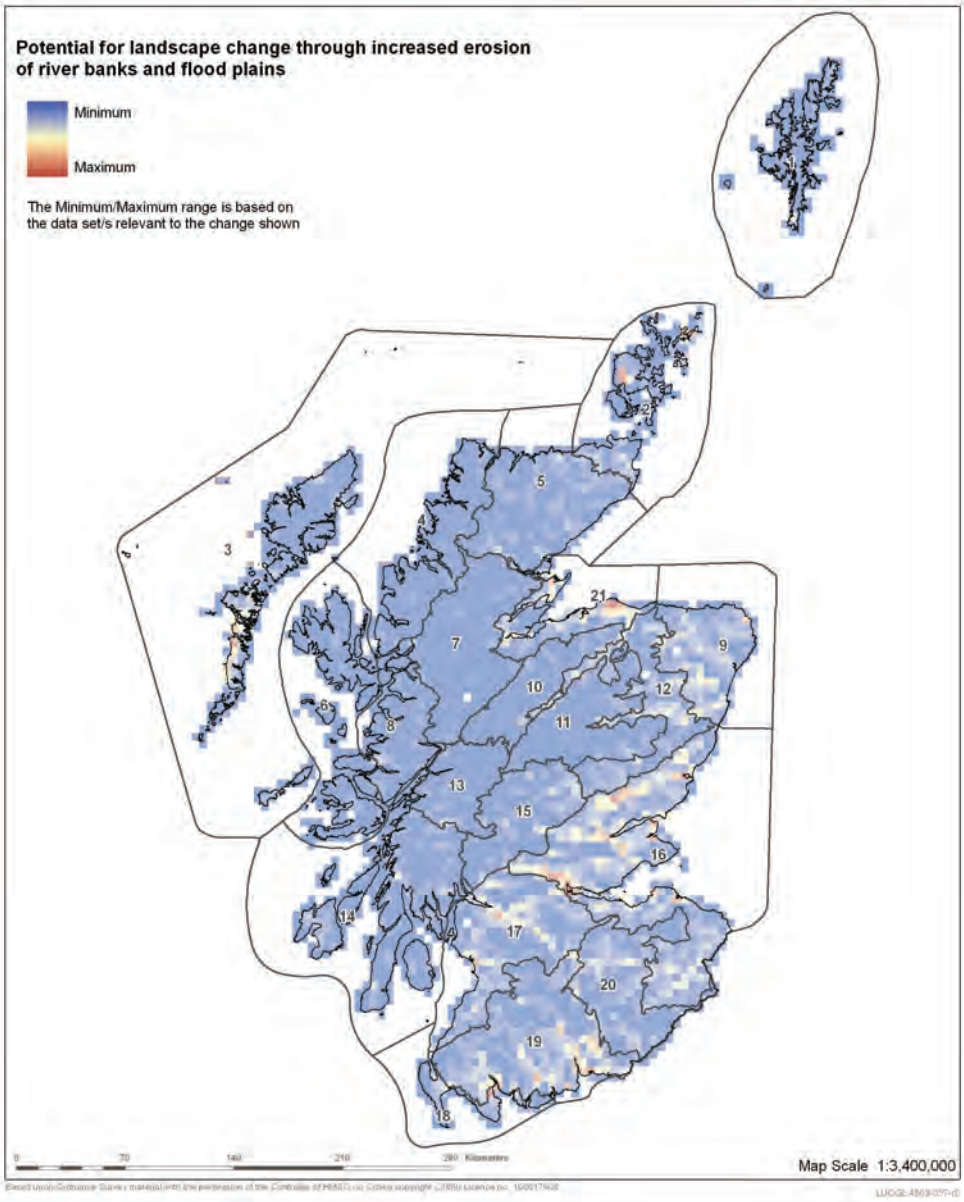

Figure 4.10b, Change 6

- Change distribution based on comparison of combined measure of SEPA fluvial flood risk and coastal flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

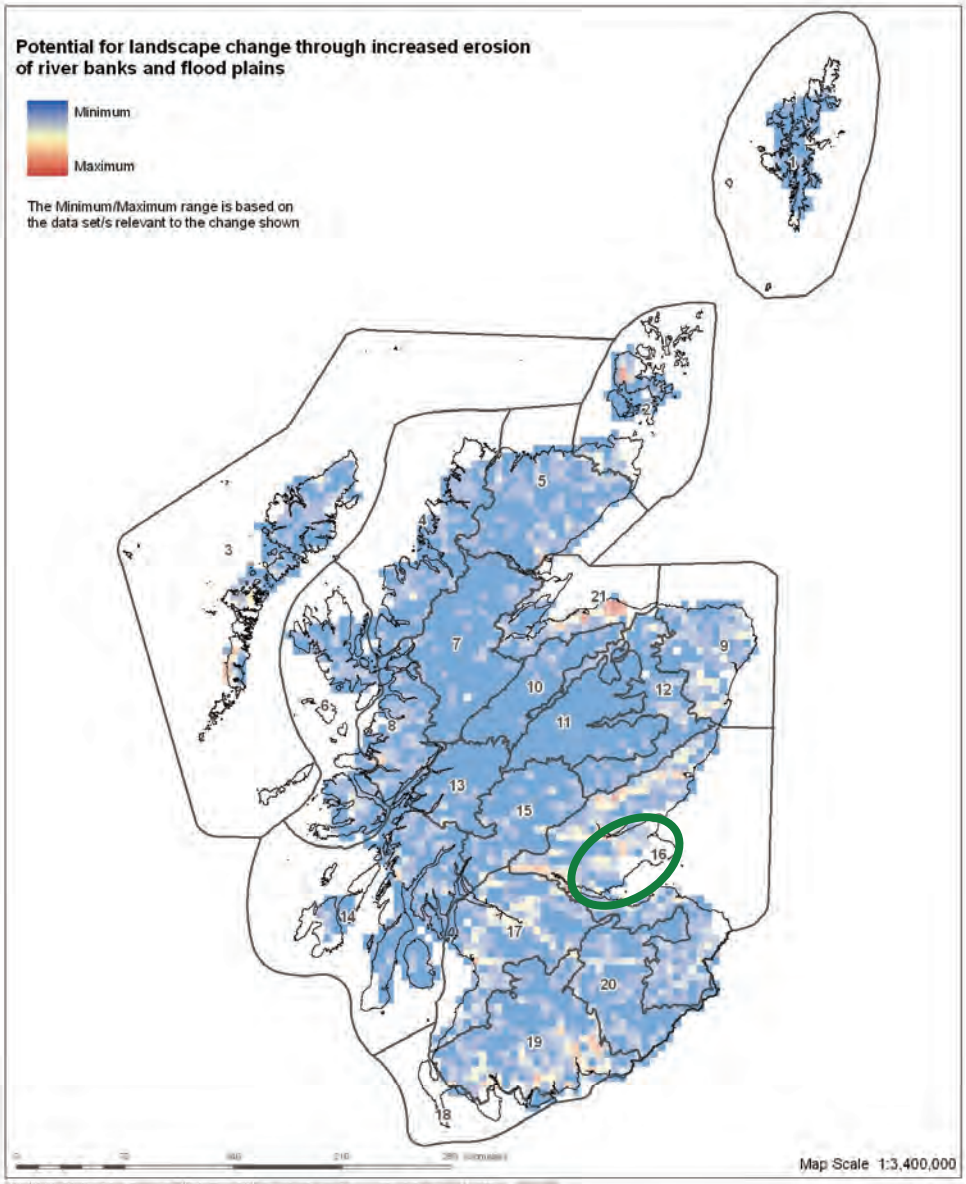

Figure 4.10b, Change 6

▸Change distribution based on comparison of combined measure of SEPA fluvial flood risk and coastal flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) with climate change variable P1: Average change in winter precipitation (UKCP09)

UKCP09 Climate Change Probability Level: **50%**

Emission Scenario: **Medium**

Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.5: Analysis of changes to Figure 4.10b

Landscape change				
Change 6 Figure 4.10b Flood damage to river banks and flood plains resulting in scouring and erosion of river valleys and floodplains and deposition downstream				
Key differences between the 02 and 09 national maps				
The location, extent and degree of change are very similar				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
Reduced change in some of the peripheral coastal areas including eastern Fife, and the Western and Northern Isles		None		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Low to medium increase in the risk of flood damage to river banks and floodplains.	None	None	No change
Highland Perthshire	Low increase in the risk of flood damage to river banks and floodplains.	None	None	No change

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Low increase in the risk of flood damage to river banks and floodplains.	None	None	No change
Strathmore	Low to medium increase in the risk of flood damage to river banks and floodplains.	None	None	No change
Firth of Tay	Low to medium increase in the risk of flood damage to river banks and floodplains.	None	None	No change
Perth	Low to medium increase in the risk of flood damage to river banks and floodplains.	None	None	No change

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Change 3: Flooding in inner estuaries and erosion of mudflats and shingle banks

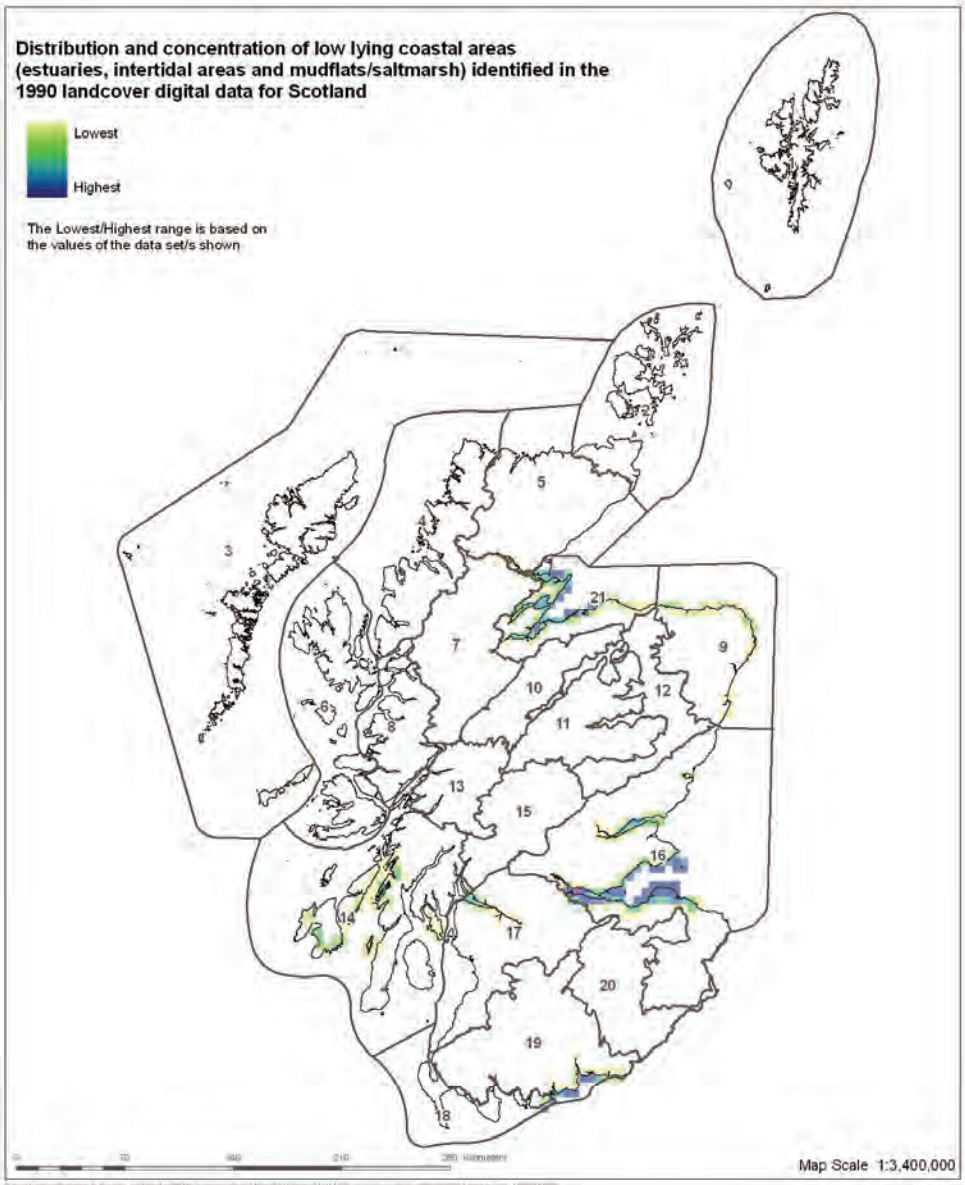

Figure 4.15a, Change 3

UKCIP02 data

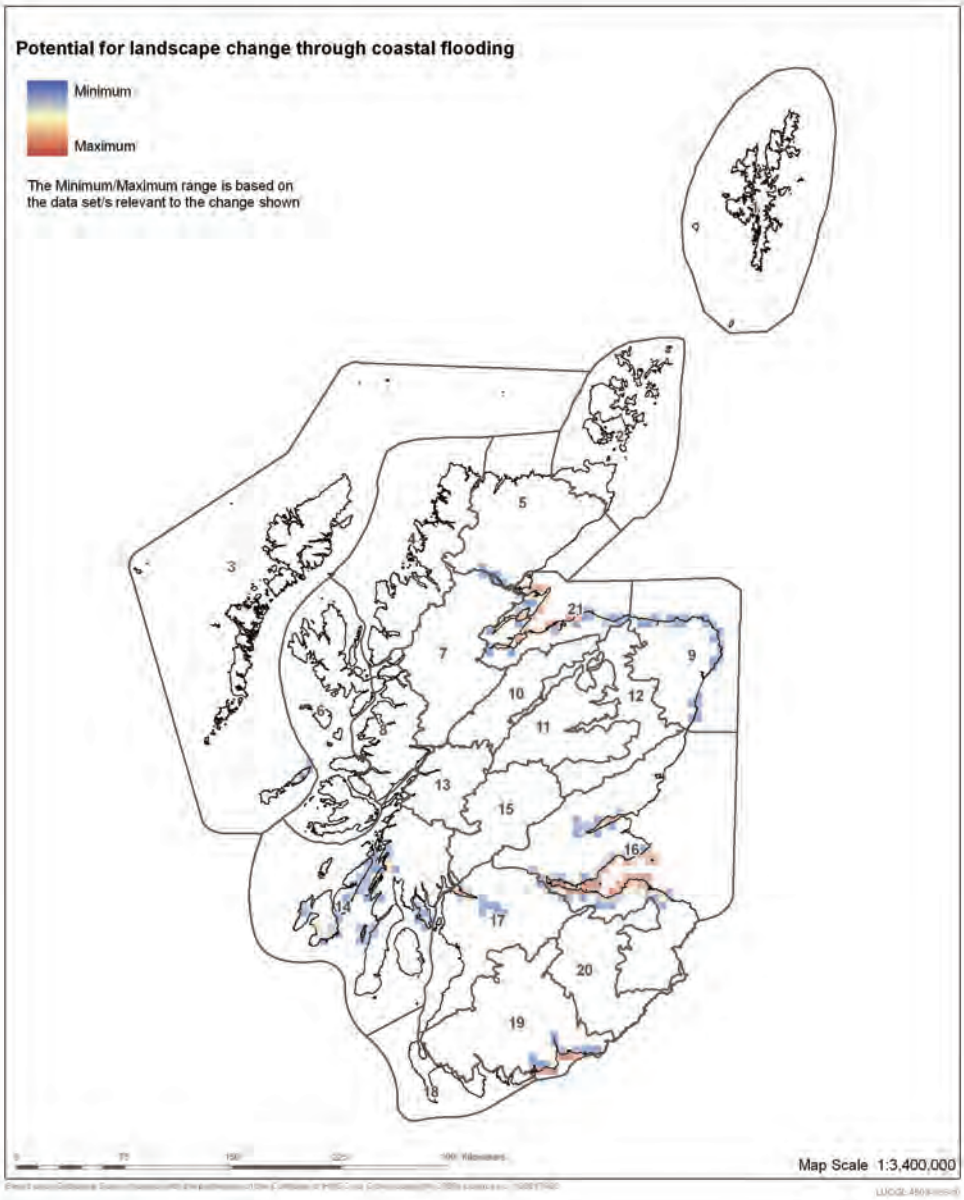

Figure 4.15b, Change 3

▸Change distribution estuaries, intertidal areas and mudflats-saltmarsh identified in the 1990 landcover digital data for Scotland, with combined measure of SEPA coastal flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) , and climate change variables P1: Average change in winter precipitation, W1: Average wind speed change in the winter

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

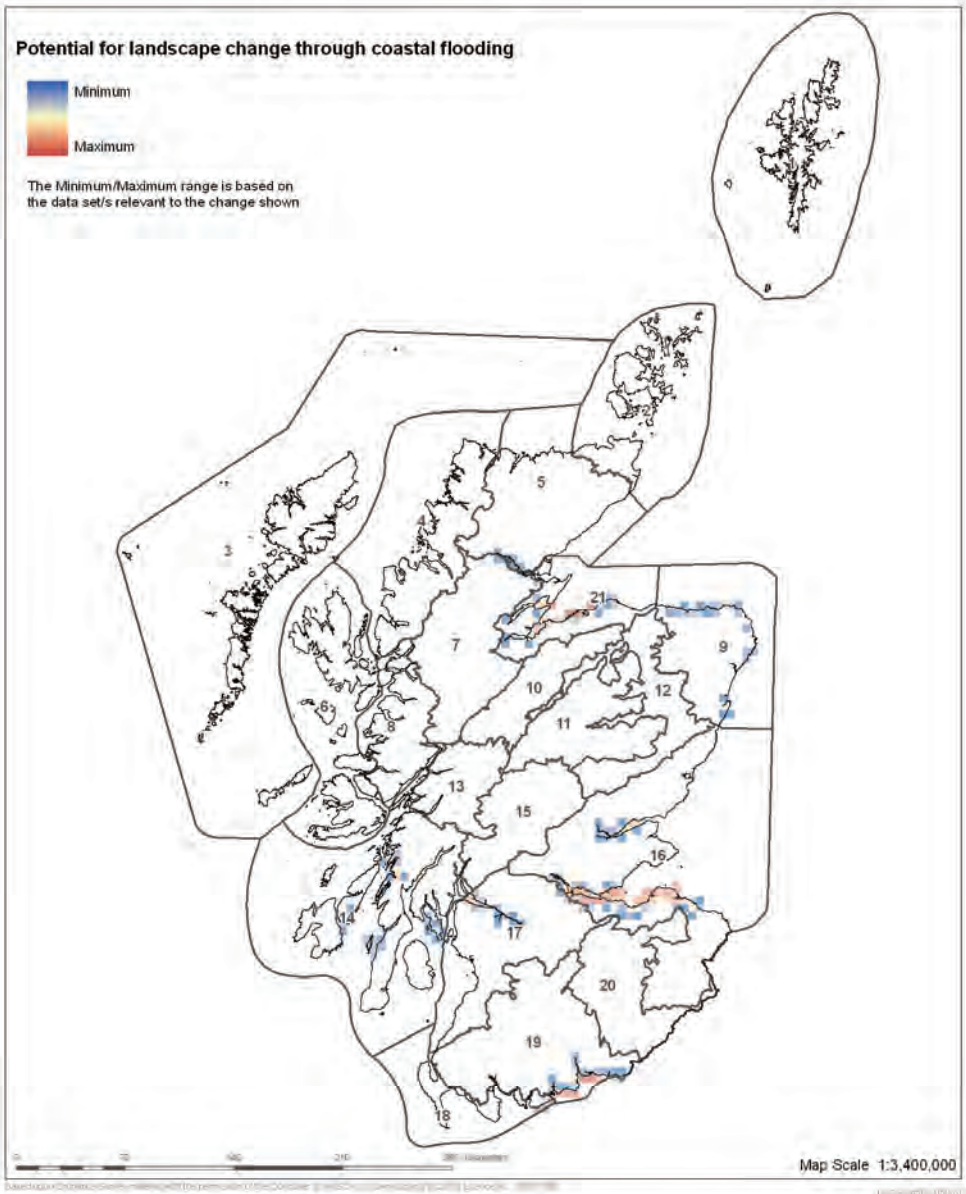

Figure 4.15b, Change 3

▸Change distribution estuaries, intertidal areas and mudflats-saltmarsh identified in the 1990 landcover digital data for Scotland, with combined measure of SEPA coastal flood risk areas for 1 in 100 year, 1 in 200 year and 1 in 1000 year events (2009) , and climate change variables P1: Average change in winter precipitation (UKCP09), W1: Average wind speed change in the winter (UKCIP02)

Certainty level: UKCIP02 climate change	Low	Med	High	UKCP09 Climate Change Probability Level: **50%**
Certainty level: mapped data	Low	Med	High	Emission Scenario: **Medium**
Timescale of change (years)	<10	10-100	100+	Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.6: Analysis of changes to Figure 4.15b

Landscape change				
Change 3 Figure 4.15b Flooding in inner estuaries and erosion of mudflats and shingle banks.				
Key differences between the 02 and 09 national maps				
The location, extent and degree of change are very similar.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
None		None		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Increase in risk of flooding along the Firth of Tay.	None	None	No change
Highland Perthshire	N/a	N/a	N/a	No change
Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	N/a	N/a		No change
Strathmore	N/a	N/a		No change
Firth of Tay	Increase in risk of flooding along the Firth of Tay.	None	None	No change
Perth	Increase in risk of flooding along the Firth of Tay.	None	None	No change

Change 18: Increase in water infrastructure associated with export resulting in new large reservoirs, aqueducts etc

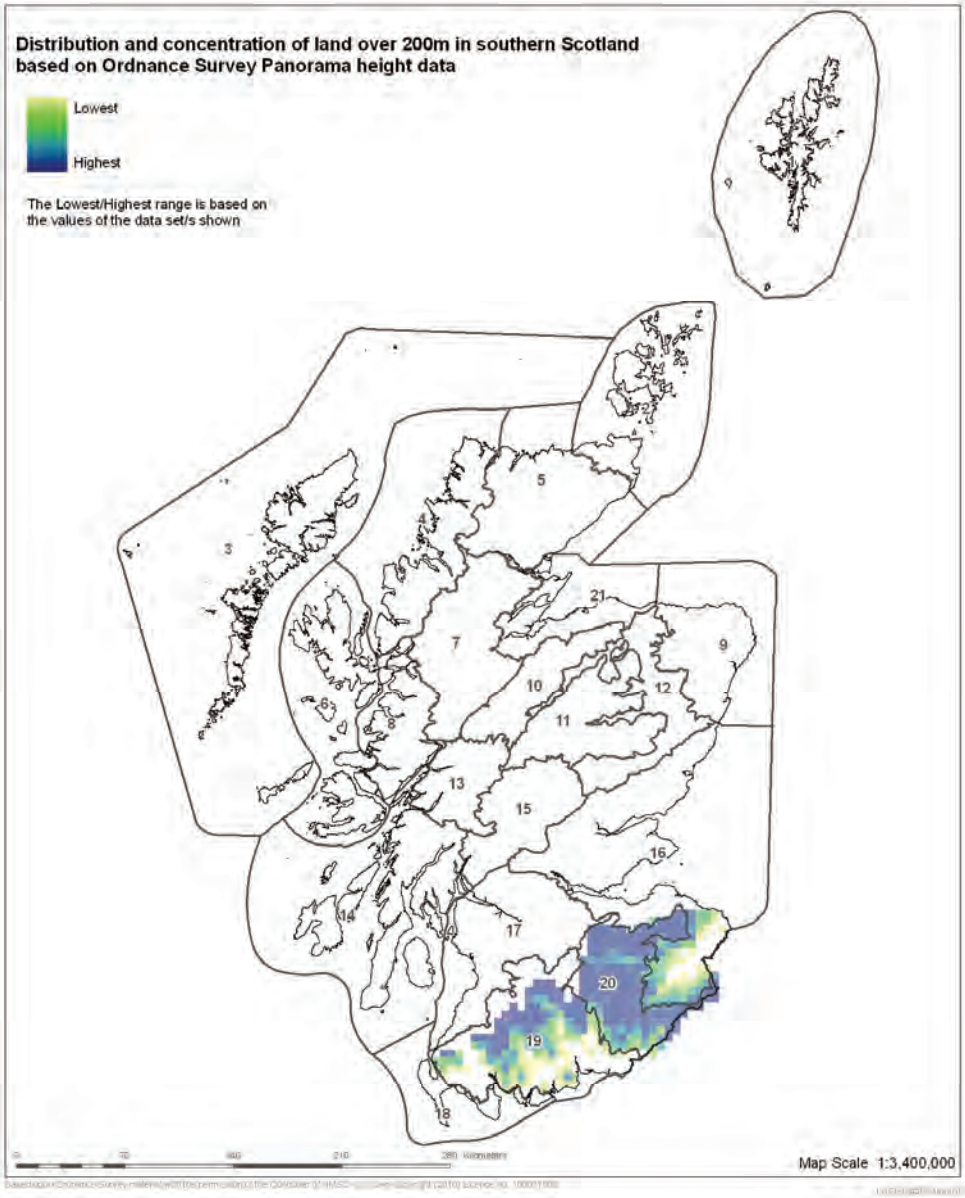

Figure 4.20a, Change 18

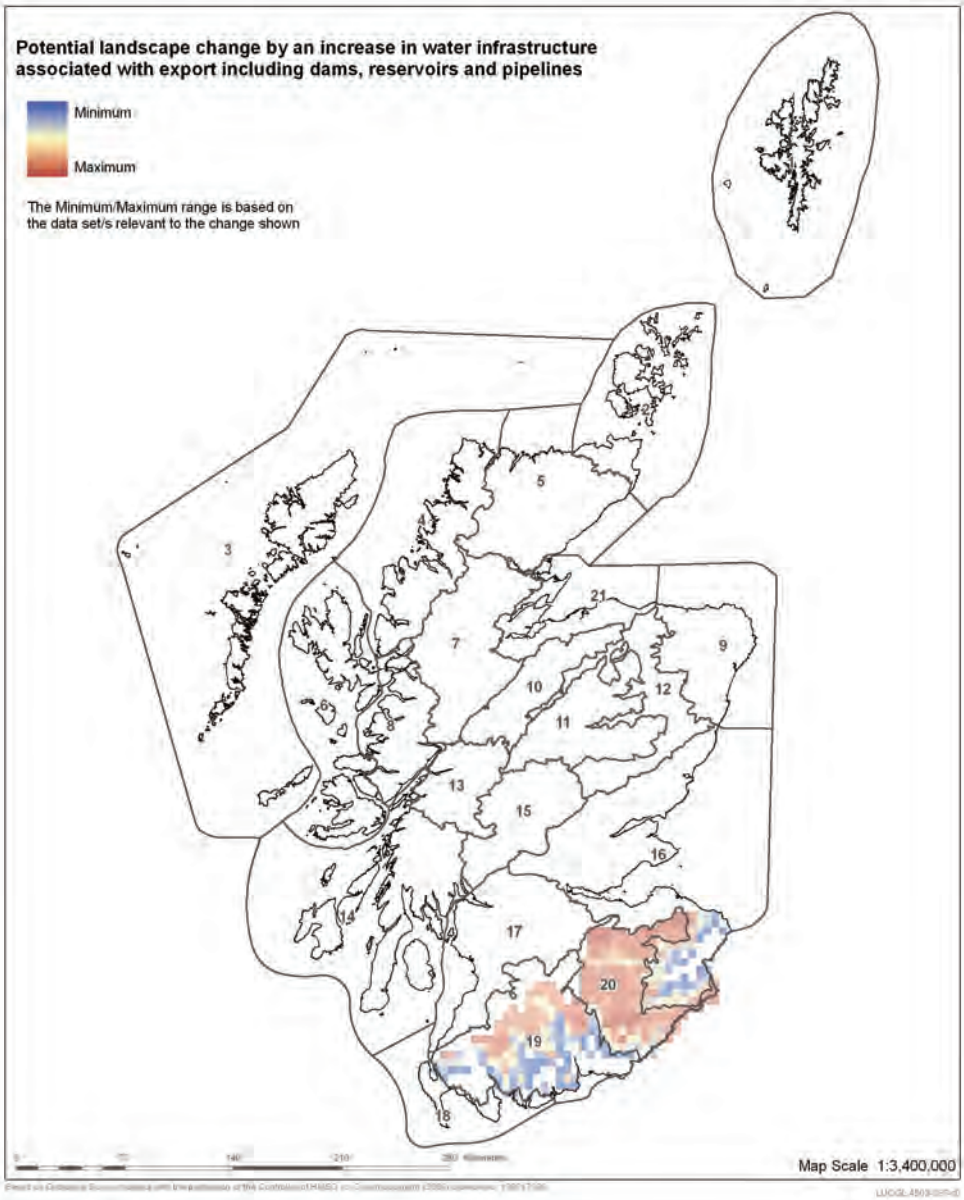

Figure 4.20b, Change 18

▸Change distribution based on comparison of land over 200m in southern Scotland based on Ordnance Survey Panorama height data with climate change variables P1:Average change in winter precipitation and P2: Average decrease in summer precipitation climate change variables

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

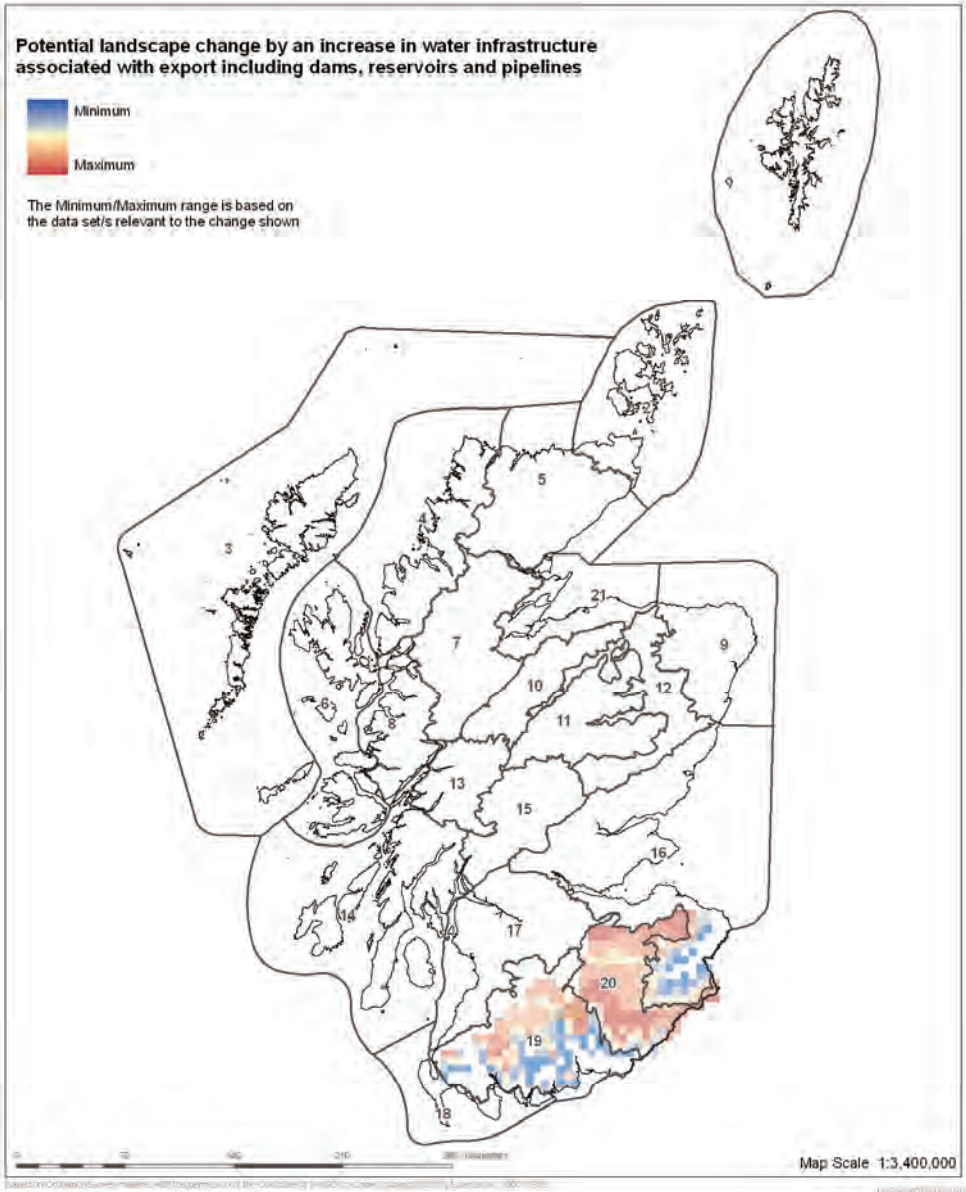

Figure 4.20b, Change 18

▸Change distribution based on comparison of land over 200m in southern Scotland based on Ordnance Survey Panorama height data with climate change variables P1:Average change in winter precipitation (UKCP09) and P2: Average decrease in summer precipitation climate change (UKCIP02) variables

Certainty level: UKCIP02 climate change	Low	Med	High	UKCP09 Climate Change Probability Level: **50%**
Certainty level: mapped data	Low	Med	High	Emission Scenario: **Medium**
Timescale of change (years)	<10	10-100	100+	Time Period: **2050s (2040 - 2069)**

No significant differences between UKCP09 and UKCIP02

Table 4.7: Analysis of changes to Figure 4.20b

Landscape change				
Change 18 Figure 4.20b Increase in water infrastructure associated with export resulting in new large reservoirs, aqueducts etc.				
Key differences between the 02 and 09 national maps				
The location, extent and degree of change are very similar.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
None		None		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	n/a	n/a	n/a	No change
Highland Perthshire	n/a	n/a	n/a	No change
Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location		Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	n/a	n/a	n/a	No change
Strathmore	n/a	n/a	n/a	No change
Firth of Tay	n/a	n/a	n/a	No change
Perth	n/a	n/a	n/a	No change

Change 72: Damage to peatland – quicker erosion, gullying and bogbursts

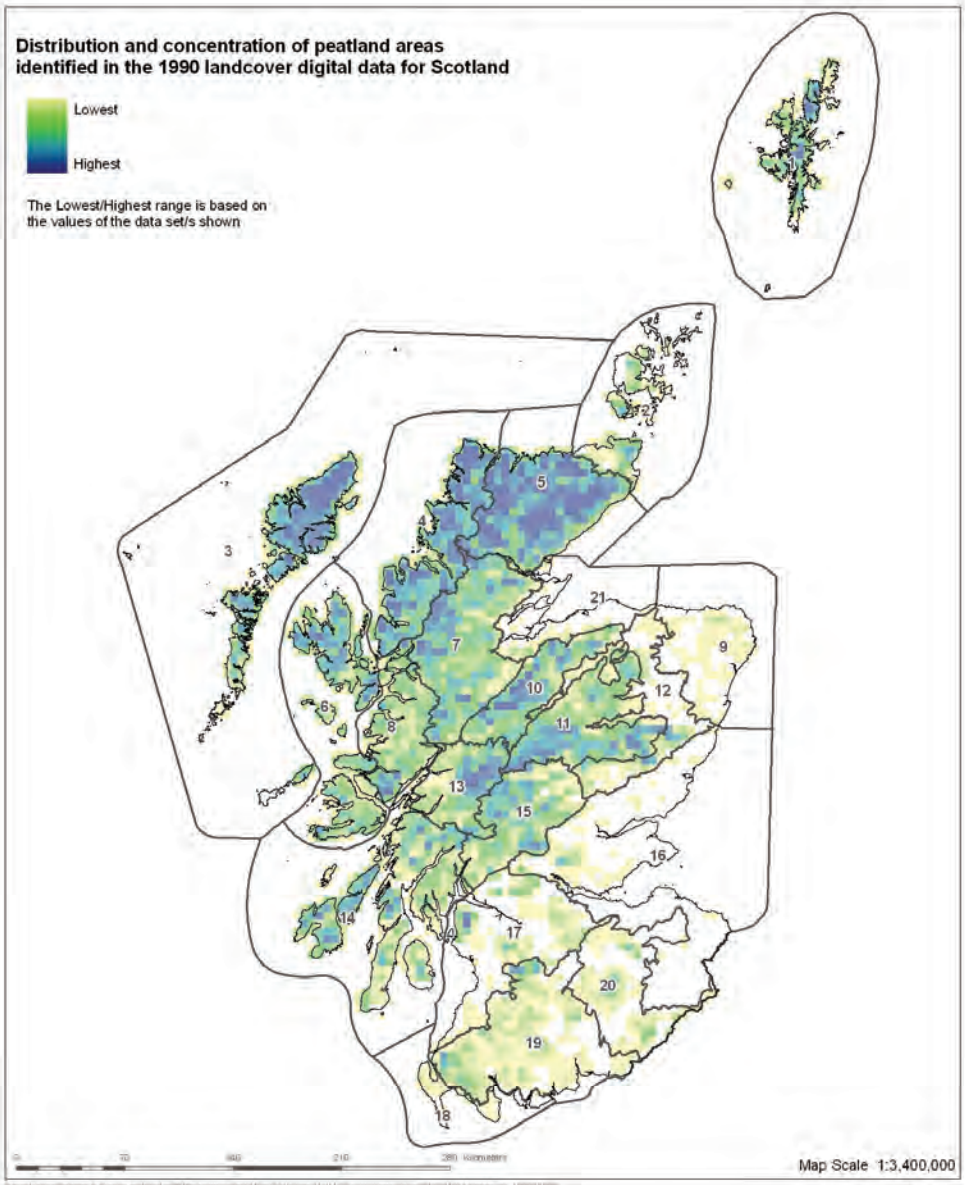

Figure 4.22a, Change 72

UKCIP02 data

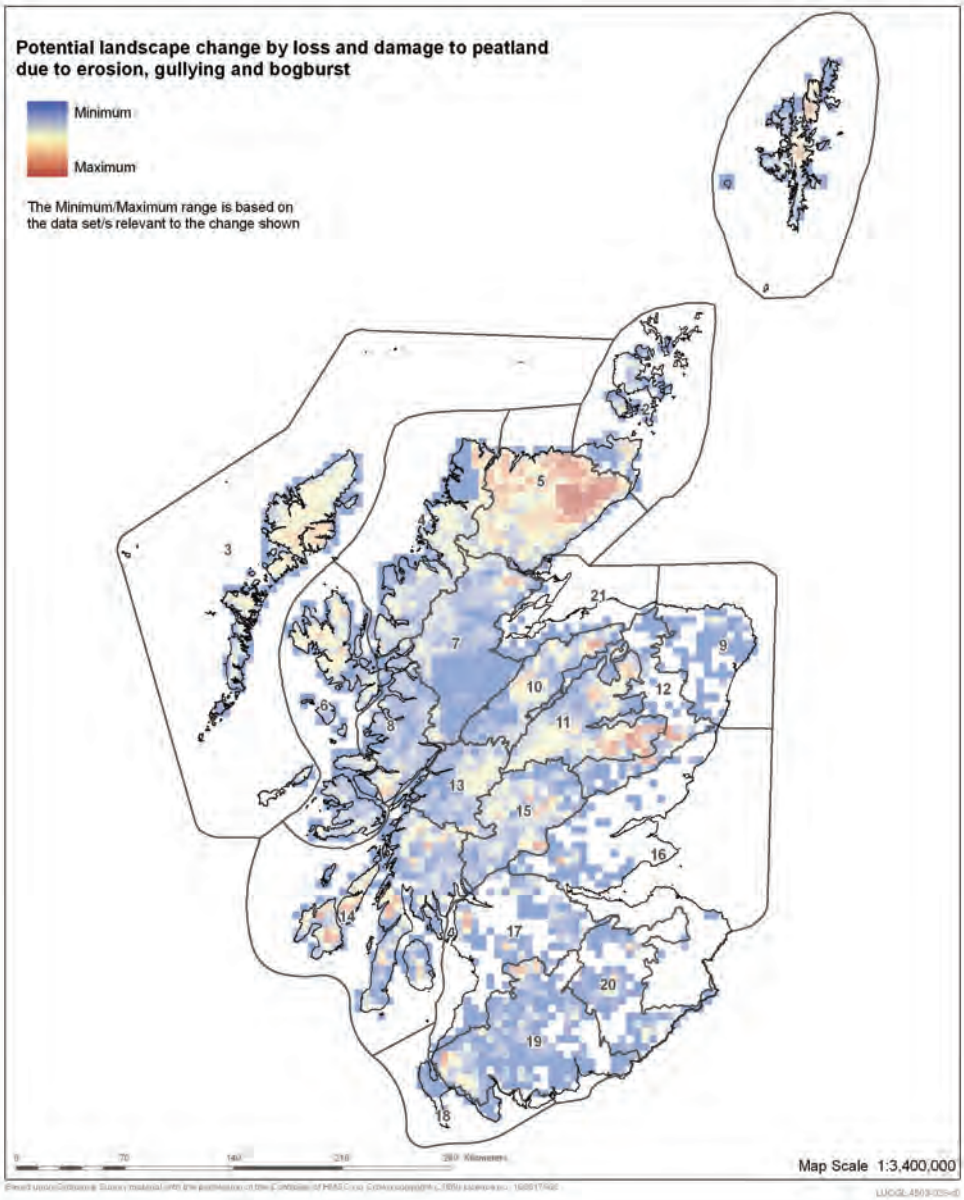

Figure 4.22b, Change 72

▸ Change distribution based on comparison of peatland areas identified in the 1990 landcover digital data for Scotland with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

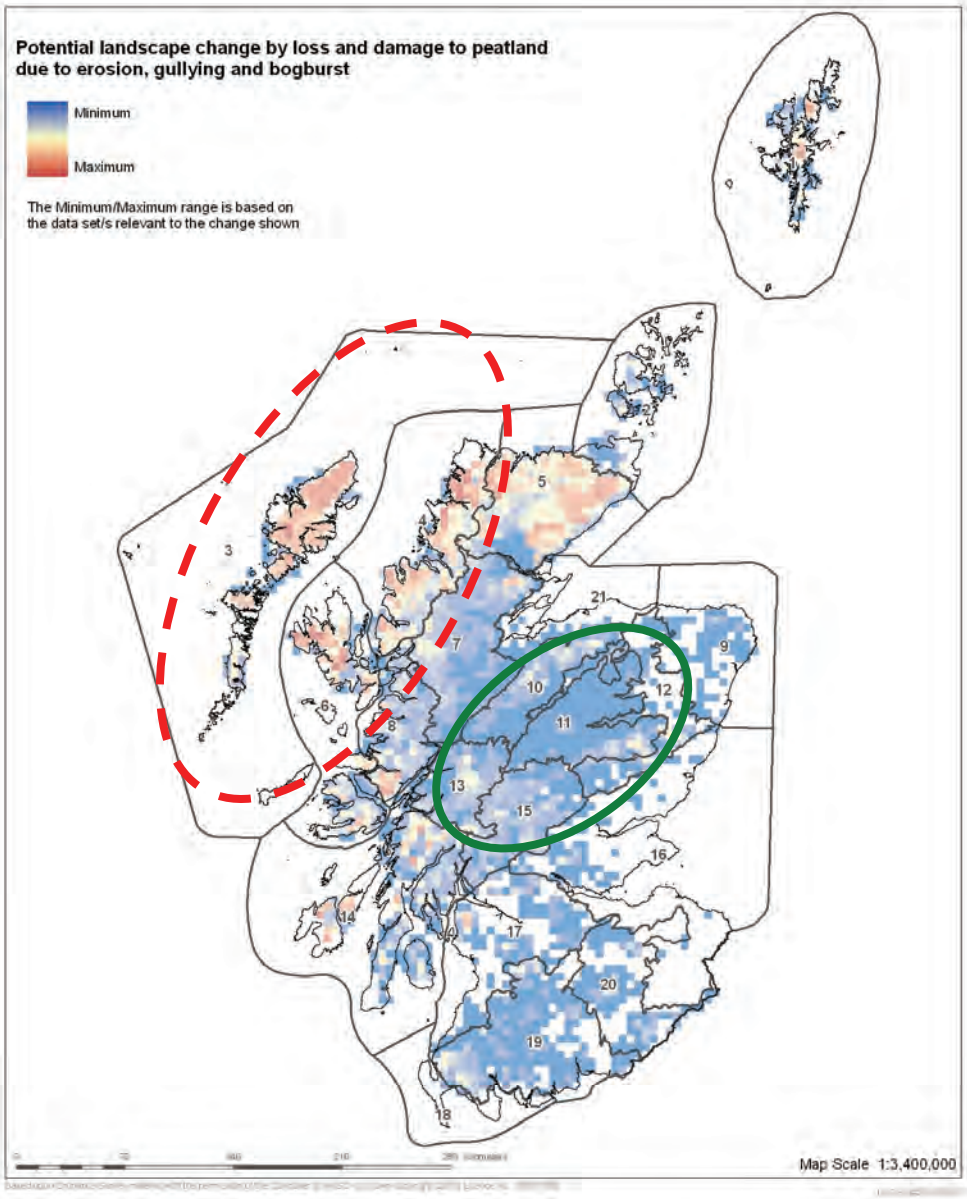

Figure 4.22b, Change 72

▸Change distribution based on comparison of peatland areas identified in the 1990 landcover digital data for Scotland with climate change variable P1: Average change in winter precipitation (UKCP09)

UKCP09 Climate Change Probability Level: **50%**

Emission Scenario: **Medium**

Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.8: Analysis of changes to Figure 4.22b

Landscape change				
Change 72 Figure 4.22b Damage to peatland – quicker erosion, gullying and bogbursts.				
Key differences between the 02 and 09 national maps				
There is a notable shift in the location and degree of change between UKCIP02 and UKCP09. Areas identified as likely to experience the greatest degree of change are now located in north western and northern Scotland, while a lesser degree of change is indicated for the Highlands to the south and east of the Great Glen.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
All the Highland areas between the Highland Boundary Fault and the Great Glen, taking in the Argyll hills, much of Lochaber, Breadalbane, the Lagan Hills, Highland Perthshire and the Cairngorms Massif.		The western seaboard, including the coast and coastal mountains between Cape Wrath and Applecross together with Applecross and the Western Isles.		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	n/a	n/a	n/a	No change
Highland Perthshire	Potential for damage to peatland where increases in total rainfall, or in the intensity of rainfall events, results in peat erosion.	Some potential for damage to peatland remains across much of Highland Perthshire.	None	No change

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Changes in peatland were not highlighted in the Killiecrankie conclusions, though it is anticipated that UKCIP02 would see an increase in the risk of damage.	A reduced risk of damage to peatlands, relative to UKCIP02 projections.	None	No change
Strathmore	n/a	n/a	None	No change
Firth of Tay	n/a	n/a	None	No change
Perth	n/a	n/a	None	No change

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Change 39: Changes in peat accumulation – growth where temp and rainfall increase, decay where rainfall decreases

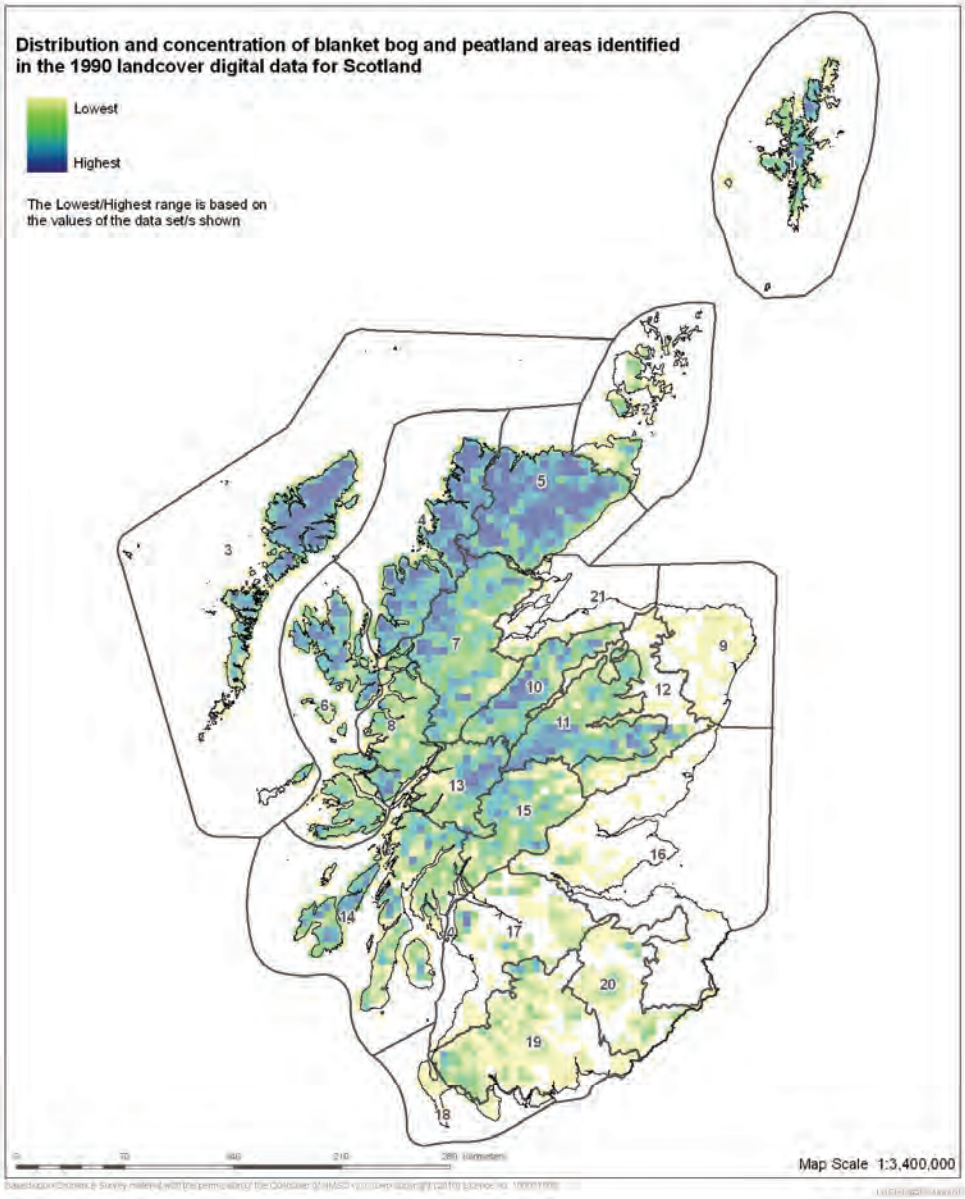

Figure 4.23a, Change 39

UKCIP02 data

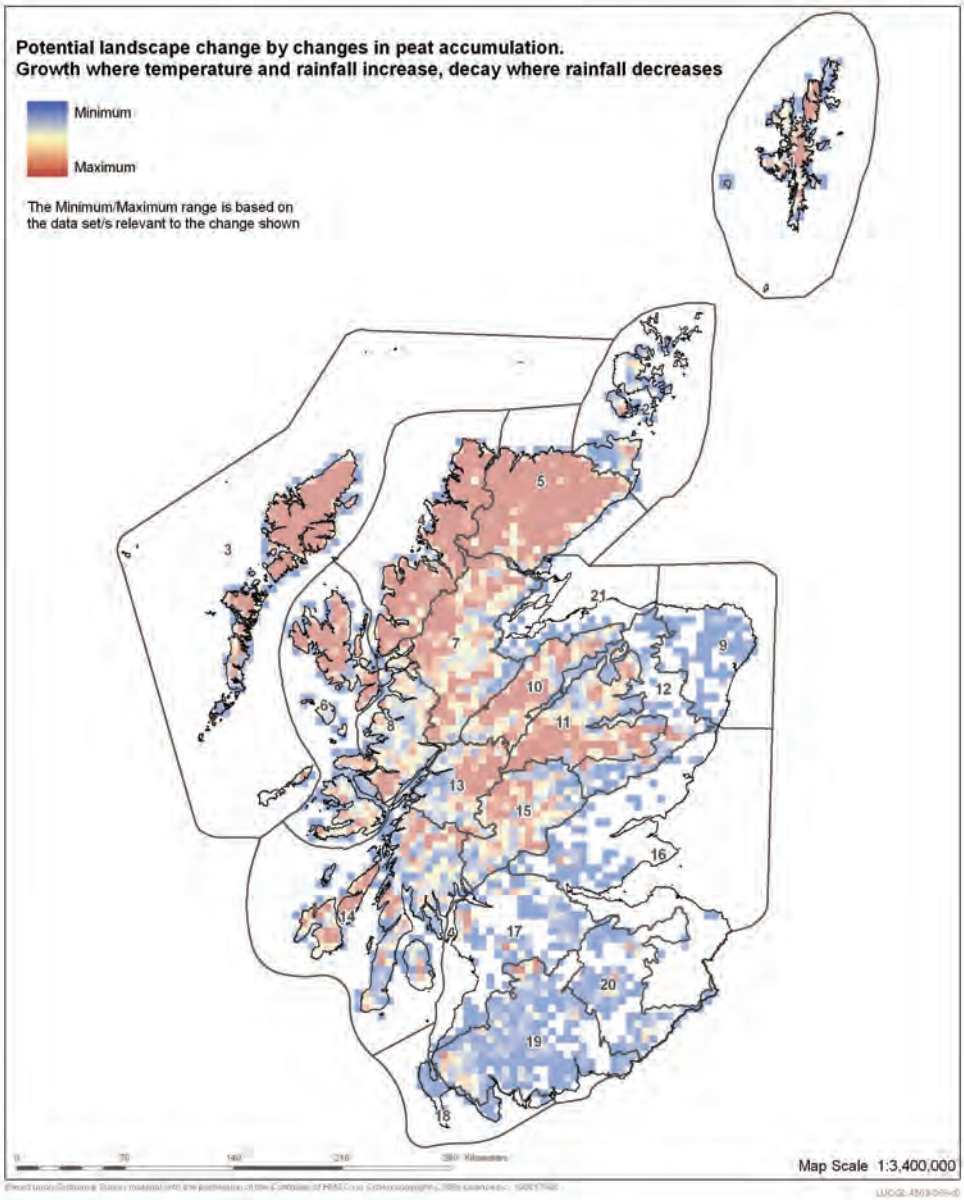

Figure 4.23b, Change 39

- Change distribution based on comparison of blanket bog and peatland areas identified in the 1990 landcover digital data for Scotland with climate change variables T1: Average annual temperature increase, P1: Average change in winter precipitation, and P2: average decrease in summer precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

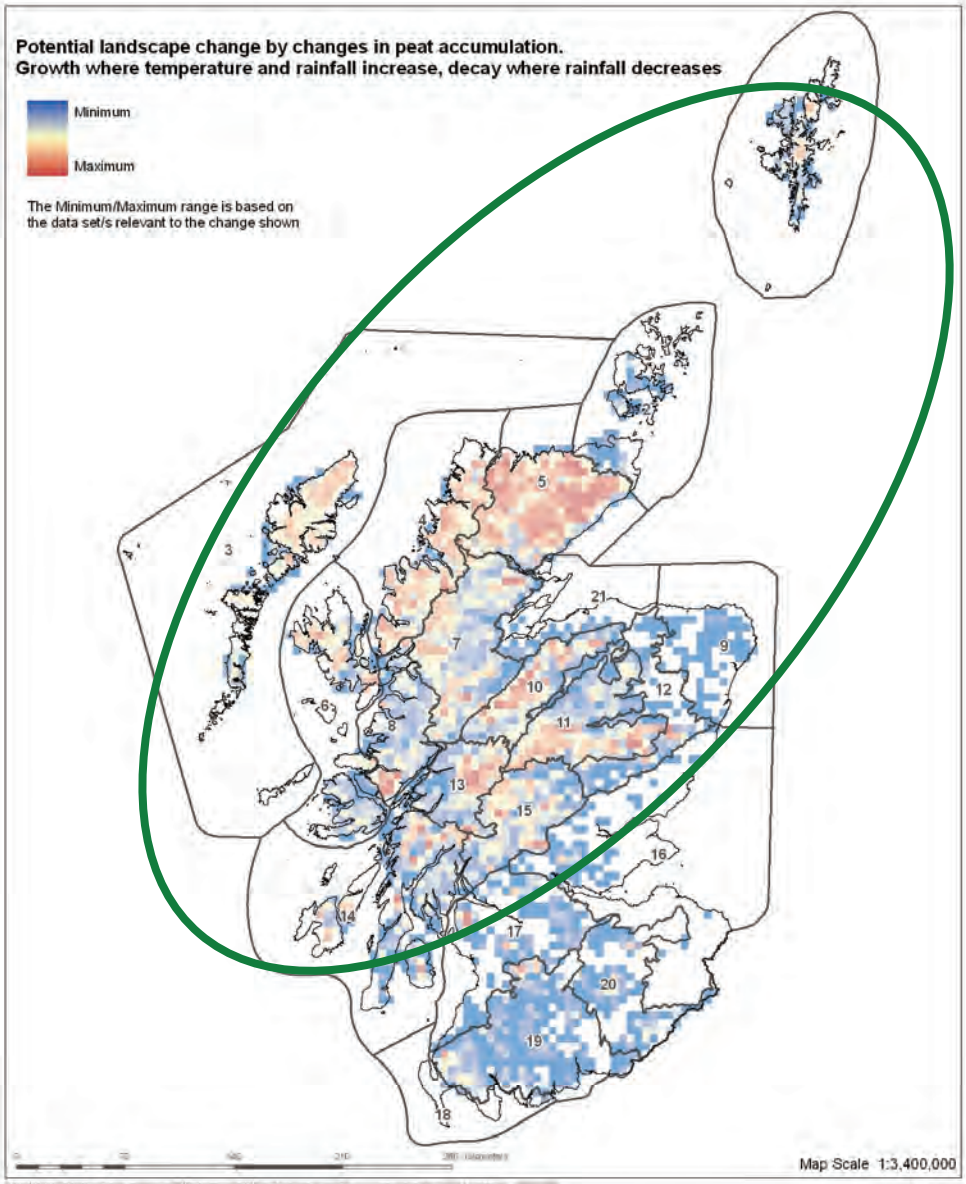

Figure 4.23b, Change 39

▸Change distribution based on comparison of blanket bog and peatland areas identified in the 1990 landcover digital data for Scotland with climate change variables T1: Average annual temperature increase (UKCIP02), P1: Average change in winter precipitation (UKCP09), and P2: average decrease in summer precipitation (UKCIP02)

Certainty level: UKCIP02 climate change	Low	Med	High	UKCP09 Climate Change Probability Level: **50%**
Certainty level: mapped data	Low	Med	High	Emission Scenario: **Medium**
Timescale of change (years)	<10	10-100	100+	Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.9: Analysis of changes to Figure 4.23b

Landscape change				
Change 39 Figure 4.23b Changes in peat accumulation – growth where temp and rainfall increase, decay where rainfall decreases.				
Key differences between the 02 and 09 national maps				
The extent of change under both UKCIP02 and UKCP09 is broadly similar, however the degree of change is significantly reduced under UKCP09.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
Much of Highland Scotland, the inner and outer Hebrides and Northern Isles. The principal exception to this pattern is Caithness, where the reduction in impact is less pronounced.		None		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	n/a	n/a	n/a	No change
Highland Perthshire	Pattern of peat accumulation could change as a result of climate change, areas of growth may occur where rainfall increases and areas of decay may occur where rainfall decreases.	Slightly reduced pattern of change.	None	No significant change.

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Changes in peatland were not highlighted in the Killiecrankie conclusions, though it is anticipated that UKCIP02 would see some change in the rate of accumulation.	A reduced pattern of change affecting peatlands, relative to UKCIP02 projections.	None	No change
Strathmore	n/a	n/a	None	No change
Firth of Tay	n/a	n/a	None	No change
Perth	n/a	n/a	None	No change

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Change 41: Shelter belts to shade and shelter livestock and crops in farmed areas – especially those with livestock and with sensitive crops

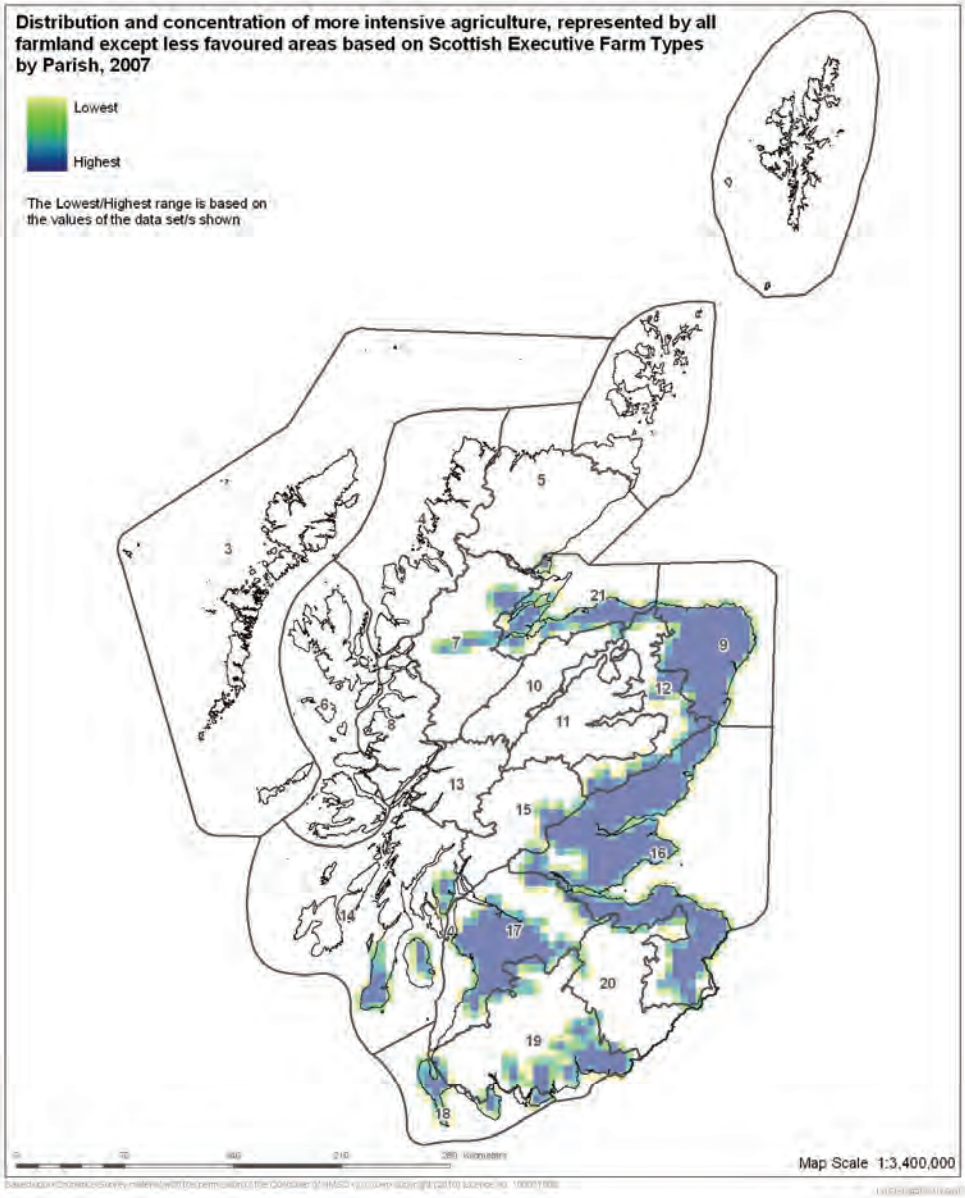

Figure 4.27a Change 41

UKCIP02 data

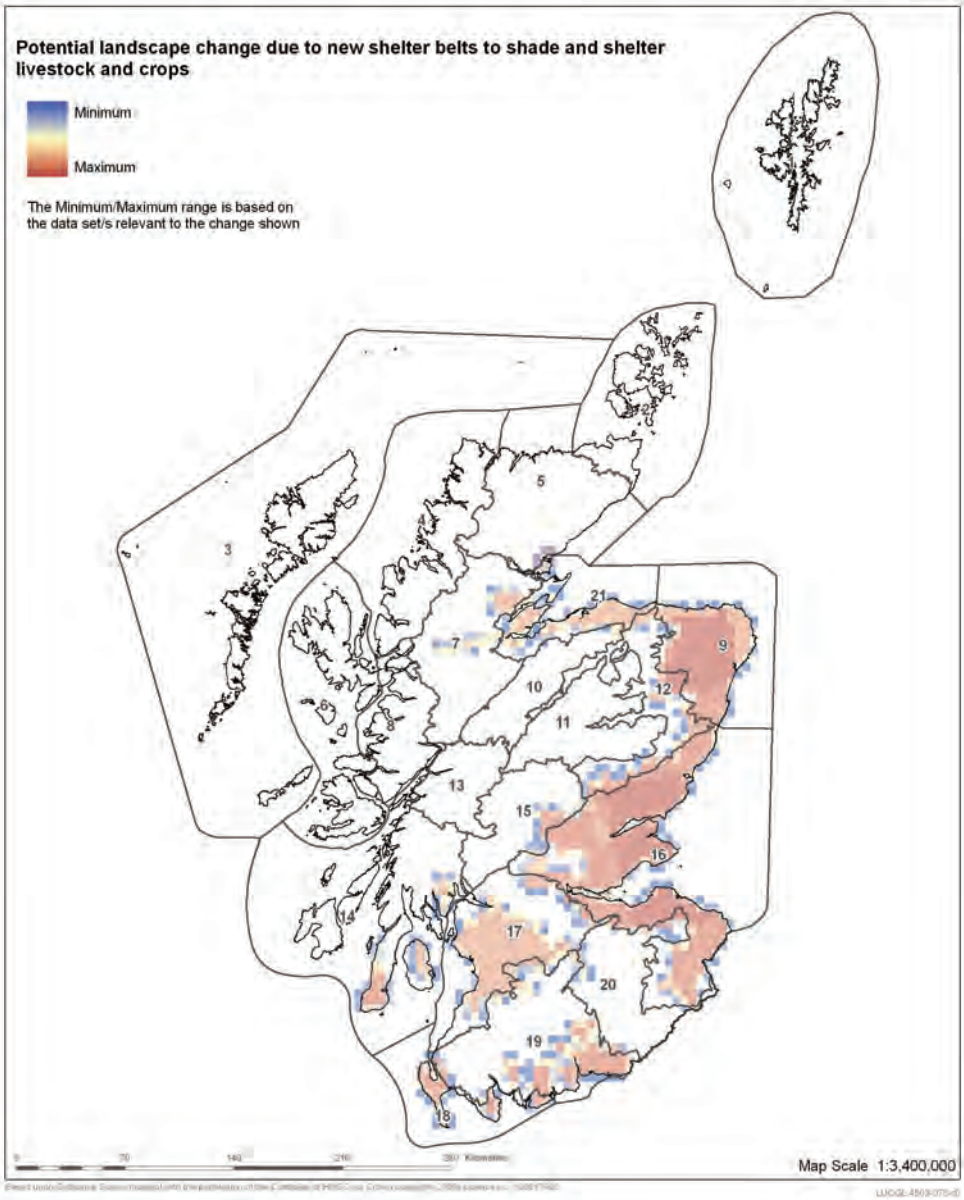

Figure 4.27b, Change 41

▸Change distribution based on comparison of more intensive agriculture represented by all farmland except less favoured areas with climate change variables T2: Autumn temperature change, P1: Average change in winter precipitation, and W1: Average wind speed change in the winter climate change variables

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

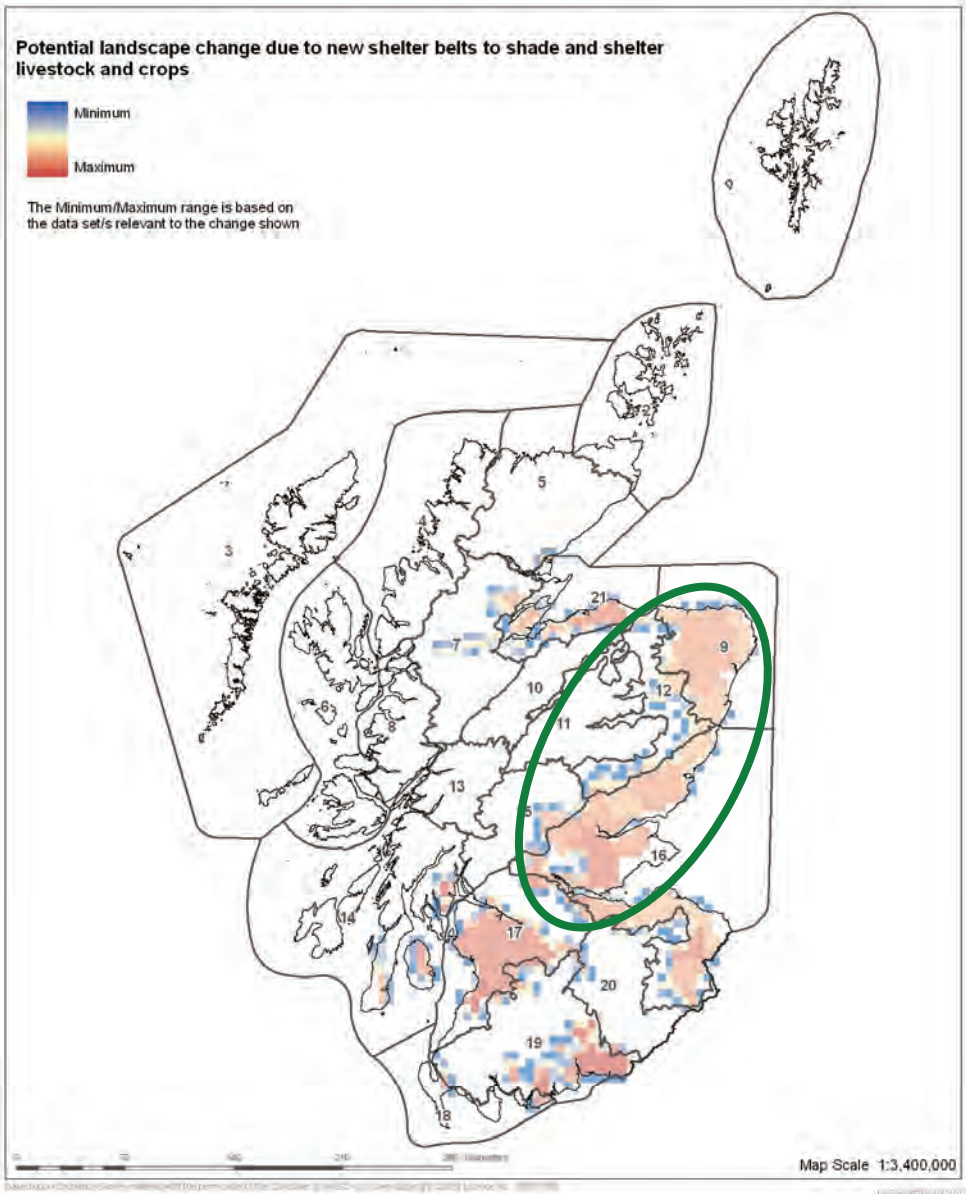

Figure 4.27b, Change 41

▸Change distribution based on comparison of more intensive agriculture represented by all farmland except less favoured areas with climate change variables T2: Autumn temperature change (UKCIP02), P1: Average change in winter precipitation (UKCP09), and W1: Average wind speed change in the winter climate change (UKCIP02) variables

Certainty level: UKCIP02 climate change	Low	Med	High	UKCP09 Climate Change Probability Level: **50%**
Certainty level: mapped data	Low	Med	High	Emission Scenario: **Medium**
Timescale of change (years)	<10	10-100	100+	Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.10: Analysis of changes to Figure 4.27b

Landscape change				
Change 41 Figure 4.27b Shelter belts to shade and shelter livestock and crops in farmed areas – especially those with livestock and with sensitive crops				
Key differences between the 02 and 09 national maps				
The extent of change for both UKCIP02 and UKCP09 is very similar, however there is some difference in the degree of change with parts of the east coast experiencing less change, and a slight increase affecting some areas in the west. There is some reduction in the areas experiencing the greatest degree of change particularly in (area 16). There is a slight increase in the degree of change within Ayrshire (area 17).				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
North east Scotland, the east coast, Fife, Lothians and Borders.		Ayrshire might experience a slight increase in the degree of change.		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	The Tayside Lowlands lie within the area likely to see an increase in the requirement for new shelter belts to shade and shelter livestock and crops.	There is likely to be some reduction in the anticipated landscape change due to new shelter belts to shade and shelter livestock and crops.	None	No significant change
Highland Perthshire	Increase in the requirement for new shelter belts to shade and shelter livestock and crops is unlikely.	None	None	No change

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Increase in the requirement for new shelter belts to shade and shelter livestock and crops is unlikely.	None	None	No change
Strathmore	Likely to see an increase in the requirement for new shelter belts to shade and shelter livestock and crops.	There is likely to be some reduction in the anticipated landscape change due to new shelter belts to shade and shelter livestock and crops.	None	No significant change
Firth of Tay	Likely to see an increase in the requirement for new shelter belts to shade and shelter livestock and crops.	There is likely to be some reduction in the anticipated landscape change due to new shelter belts to shade and shelter livestock and crops.	None	No significant change
Perth	n/a	n/a	None	No change

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Change 43: Loss of field boundary and other farmland trees due to storm damage and stress resulting in more open farmland landscapes

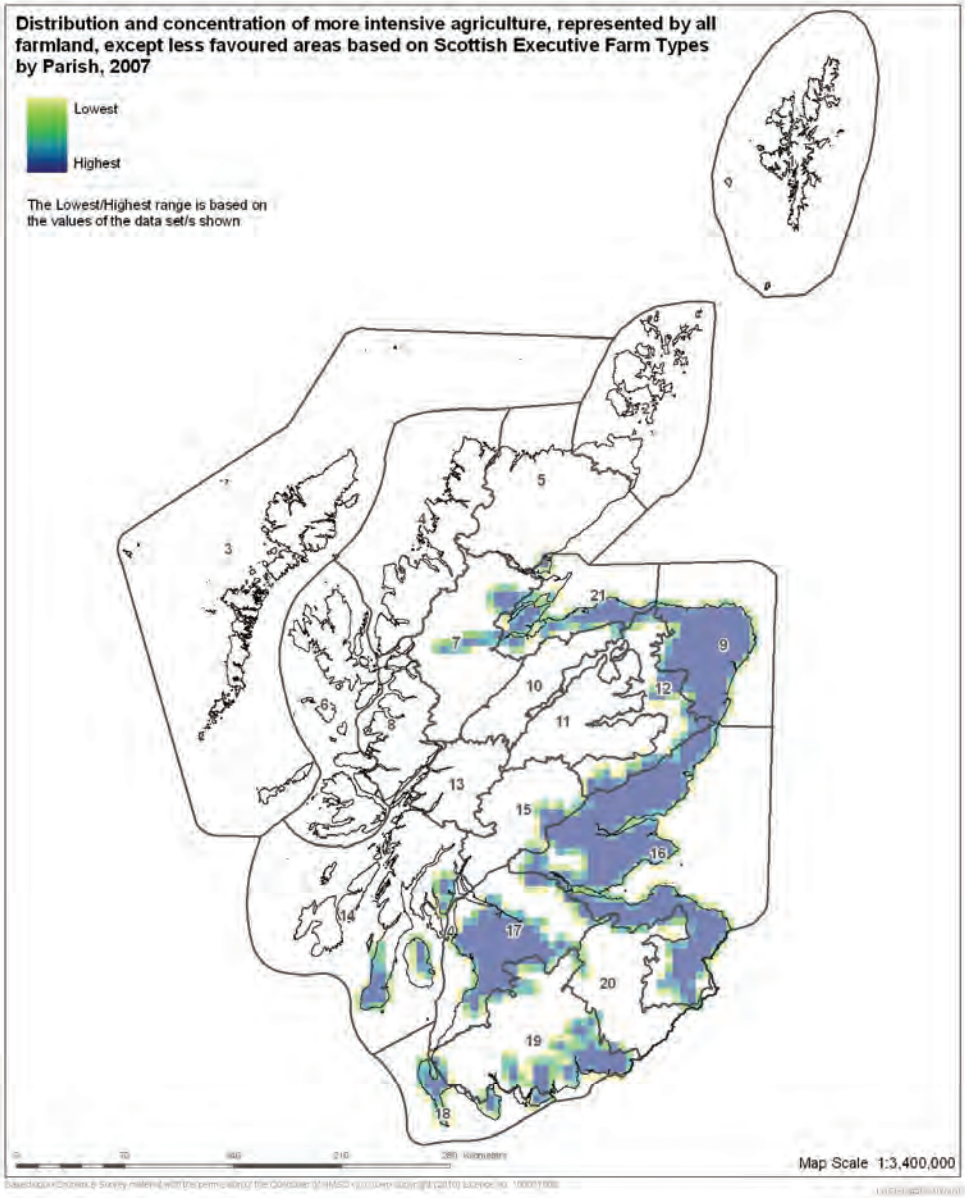

Figure 4.28a, Change 43

UKCIP02 data

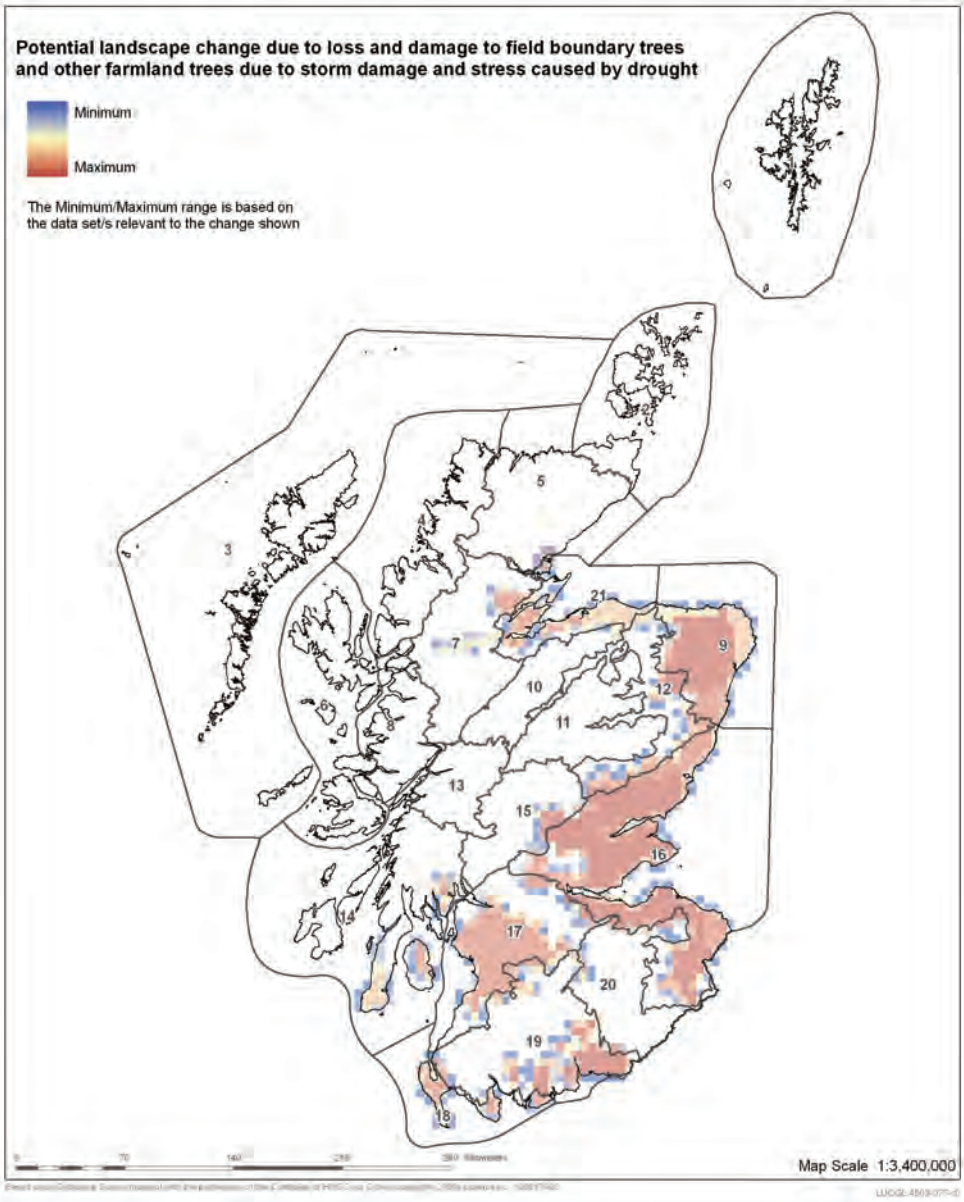

Figure 4.28b, Change 43

▸Change distribution based on comparison of more intensive agriculture, represented by all farmland excluding less favoured areas with climate change variables T1: Average annual temperature increase, P1: Average change in winter precipitation, P2: Average decrease in summer precipitation and W1: average wind speed change in the winter

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

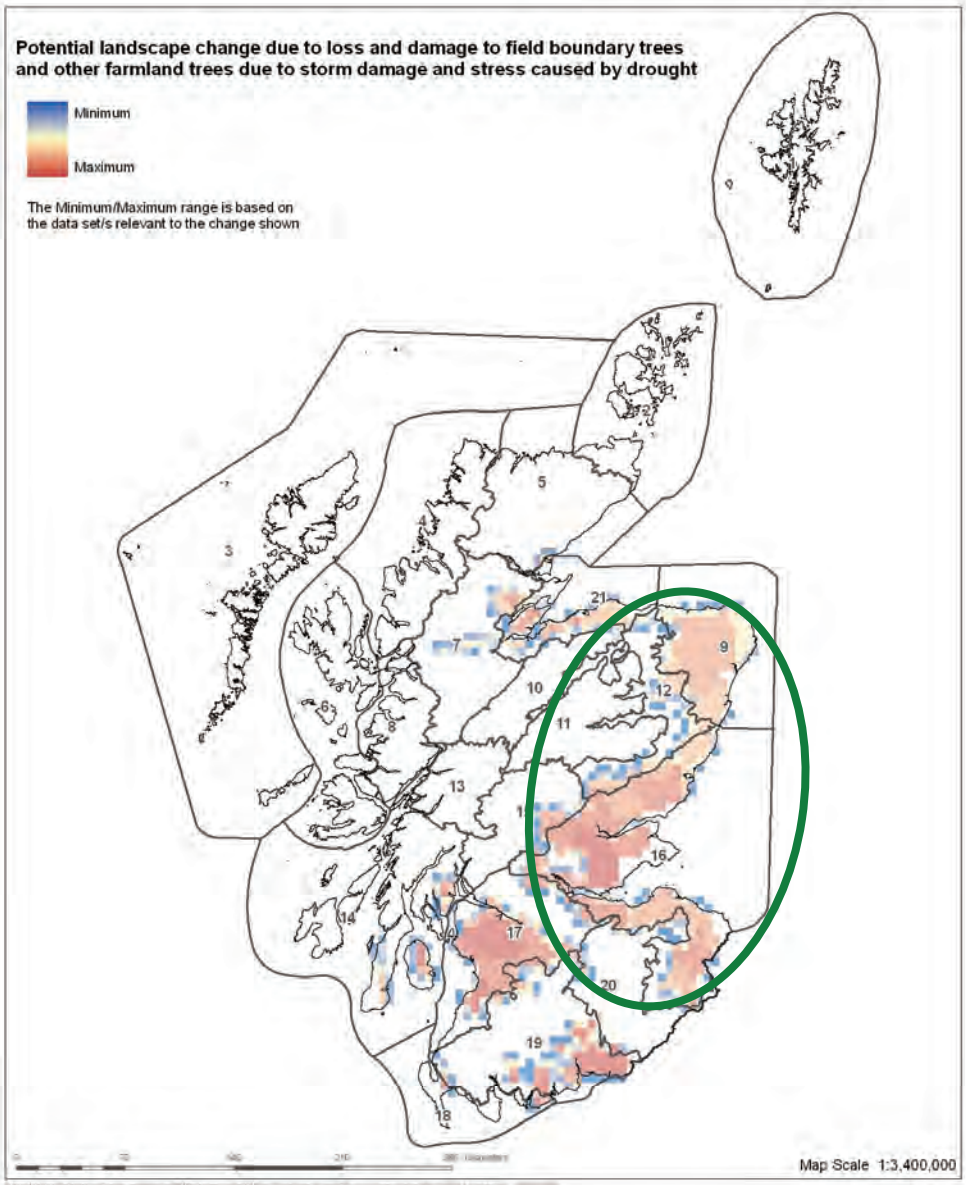

Figure 4.28b, Change 43

▸Change distribution based on comparison of more intensive agriculture, represented by all farmland excluding less favoured areas with climate change variables T1: Average annual temperature increase (UKCIP02), P1: Average change in winter precipitation (UKCP09), P2: Average decrease in summer precipitation and W1 (UKCIP02): average wind speed change in the winter (UKCIP02)

Certainty level: UKCIP02 climate change	Low	Med	High	UKCP09 Climate Change Probability Level: **50%**
Certainty level: mapped data	Low	Med	High	Emission Scenario: **Medium**
Timescale of change (years)	<10	10-100	100+	Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.11: Analysis of changes to Figure 4.28b

Landscape change				
Change 43 Figure 4.28b Loss of field boundary and other farmland trees due to storm damage and stress resulting in more open farmland landscapes.				
Key differences between the 02 and 09 national maps				
The location and extent of areas affected by change is broadly similar, however under UKCP09 the extent of areas experiencing the highest degree of change is reduced from UKCPI02.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
North east Scotland, Aberdeenshire, Angus, lowland Perthshire, east Fife, Lothian and eastern parts of the Borders		None		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Potential loss of field boundary trees as a result of stresses from increases in winter rainfall and storm damage.	Slight reduction in the potential loss of field boundary trees as a result of stresses from increases in winter rainfall and storm damage.	None	No significant change
Highland Perthshire	n/a	n/a	n/a	No change

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Loss of field boundary and other farmland trees is not highlighted in the Killiecrankie conclusions.	None	None	No change
Strathmore	The loss of characteristic field boundary trees as a result of stress caused by wetter winters and drier summers.	This is still an issue under UKCP09 although the degree of change is less pronounced than that identified under UKCIP02.	None	No significant change
Firth of Tay	The loss of characteristic field boundary trees as a result of stress caused by wetter winters and drier summers.	This is still an issue under UKCP09 although the degree of change is less pronounced than that identified under UKCIP02.	None	No significant change
Perth	n/a	n/a	None	No change

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Change 75: Flood damage to agricultural crops – from rainfall, sea and flood storage projects

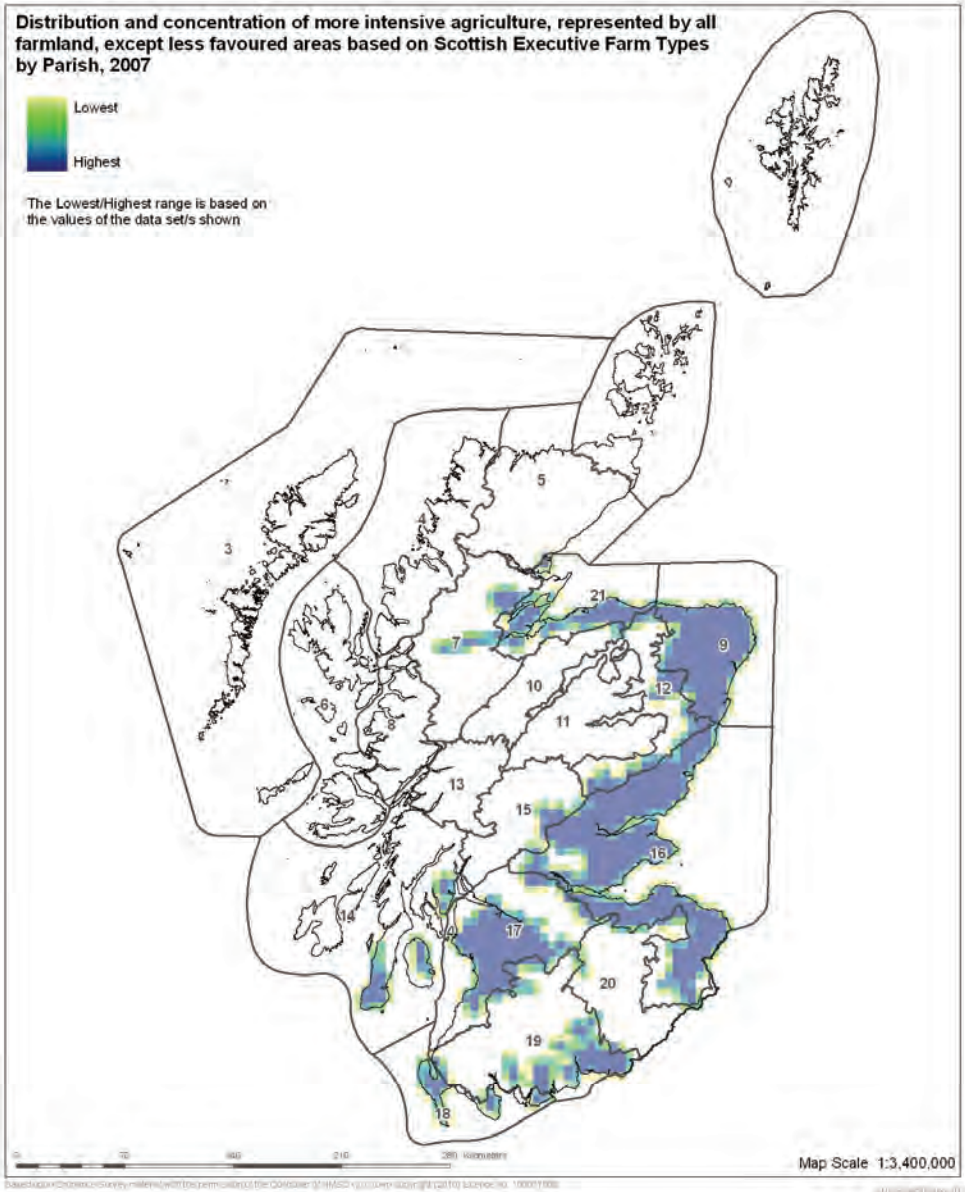

Figure 4.29a, Change 75

UKCIP02 data

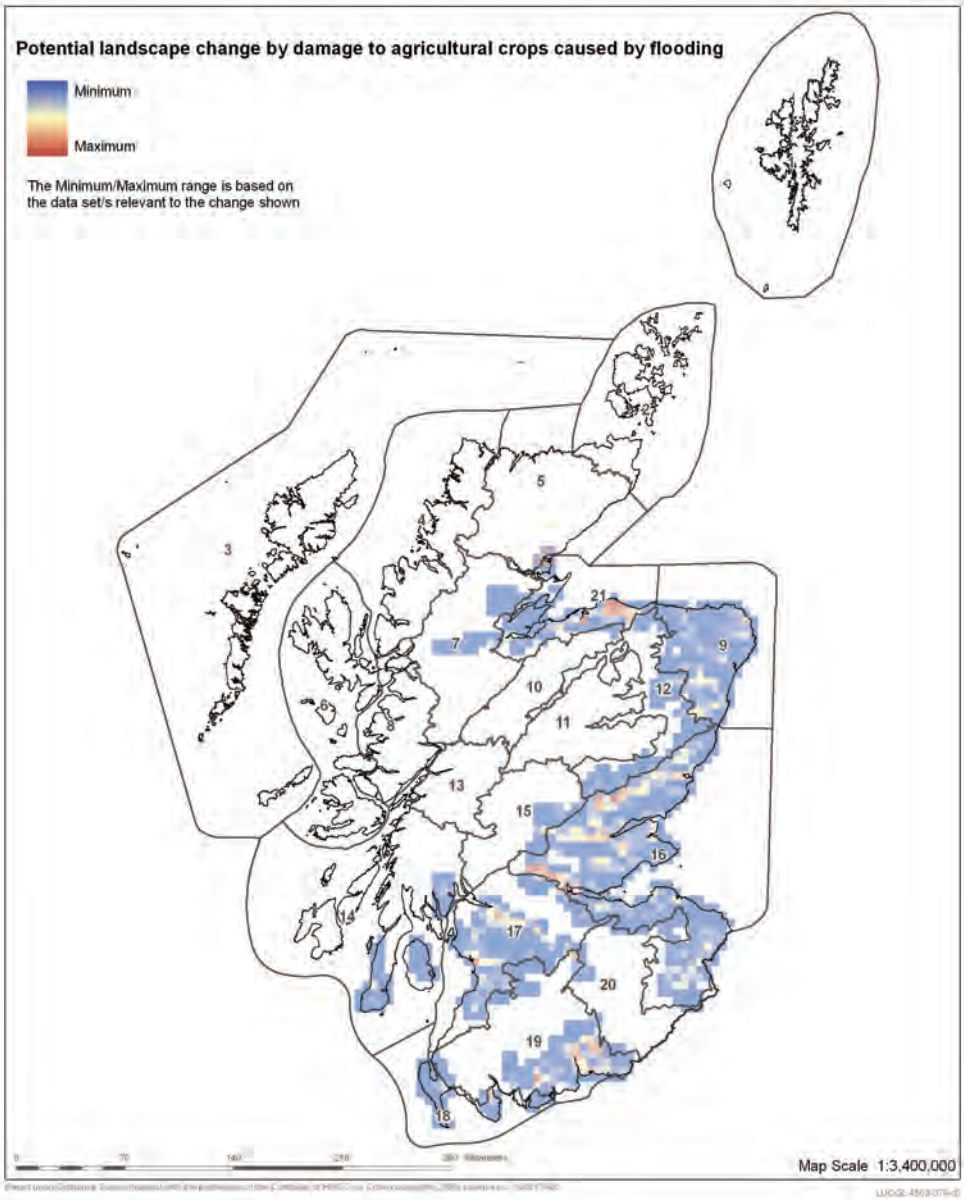

Figure 4.29b, Change 75

- Change distribution based on comparison of more intensive agriculture represented by all farmland excluding less favoured areas with SEPA coastal and fluvial flooding risk and climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

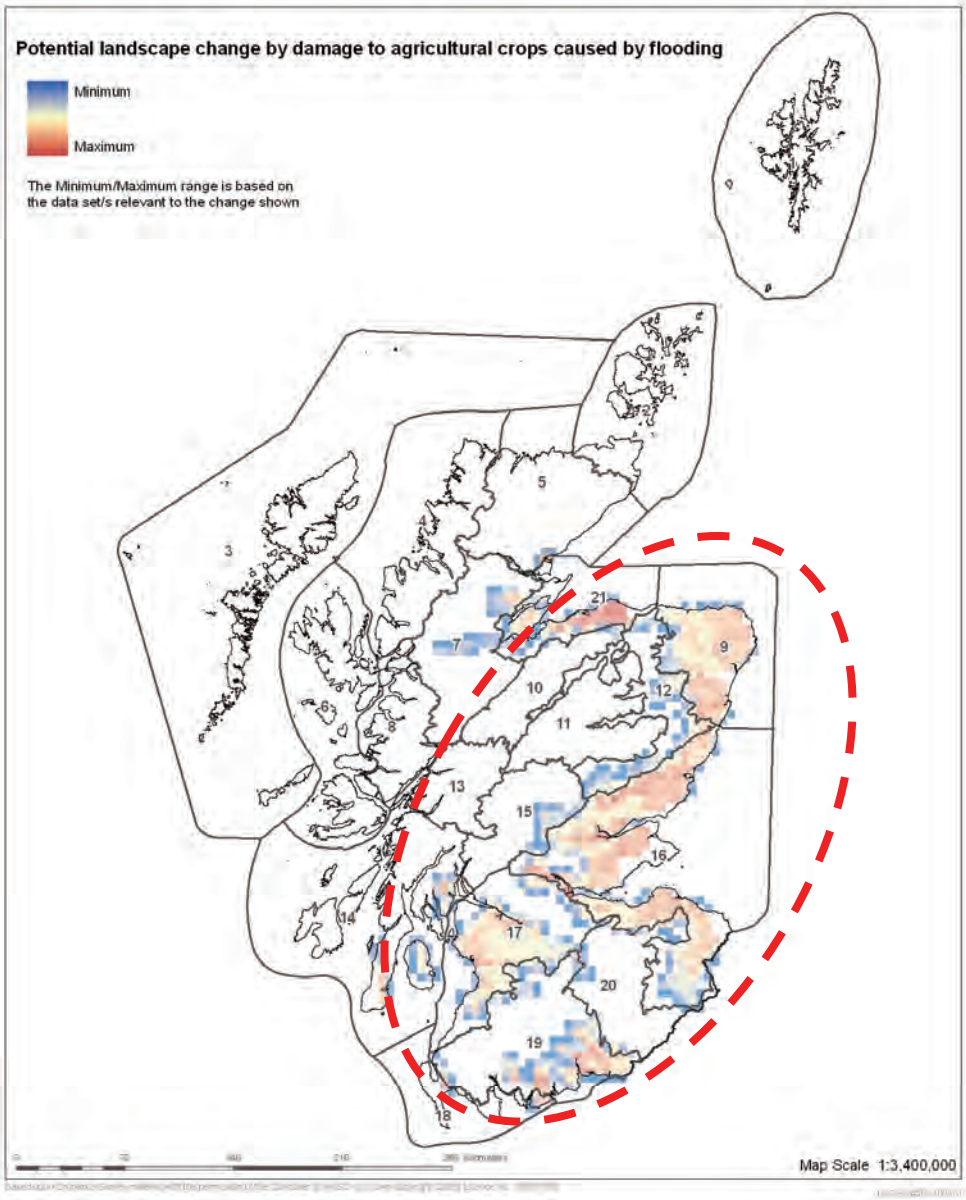

Figure 4.29b, Change 75

- Change distribution based on comparison of more intensive agriculture represented by all farmland excluding less favoured areas with SEPA coastal and fluvial flooding risk and climate change variable P1: Average change in winter precipitation (UKCP09)

UKCP09 Climate Change Probability Level: **50%**

Emission Scenario: **Medium**

Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.12: Analysis of changes to Figure 4.29b

Landscape change				
Change 75 Figure 4.29b Flood damage to agricultural crops – from rainfall, sea and flood storage projects.				
Key differences between the 02 and 09 national maps				
Under UKCIP02 the areas experiencing the greatest degree of change are focused within the river catchments in more lowland agricultural areas. There is a notable difference under UKCP09 as the extent of areas experiencing a higher degree of change is more widespread across all intensive agricultural areas.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
None		North east Scotland, Aberdeenshire, Angus, lowland Perthshire, east Fife, Lothian and eastern parts of the Borders, Ayrshire and southern Dumfries and Galloway		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Winter flooding and summer drought events are likely to result in direct impacts on crops and vegetation.	None	Increase in the damage to crops caused by flooding and drought.	Note increase in likely scale of change.
Highland Perthshire	Winter flooding and summer drought events are likely to result in some impacts on crops and vegetation.	None	Minor increase in the damage to crops caused by flooding and drought.	No significant change.

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Impacts on agricultural crops are not an issue for this area.	None	None	No change
Strathmore	Conclusions do not highlight flood damage to crops.	None	Increased risk of damage to crops.	Reflect this change in updated conclusions.
Firth of Tay	Conclusions do not highlight flood damage to crops.	None	Increased risk of damage to crops.	Reflect this change in updated conclusions.
Perth	n/a	n/a	None	No change

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Change 94: Sowing and harvesting affected by wetter winters – possible shift from autumn to spring sowing resulting in more winter stubbles or move to ground cover crops

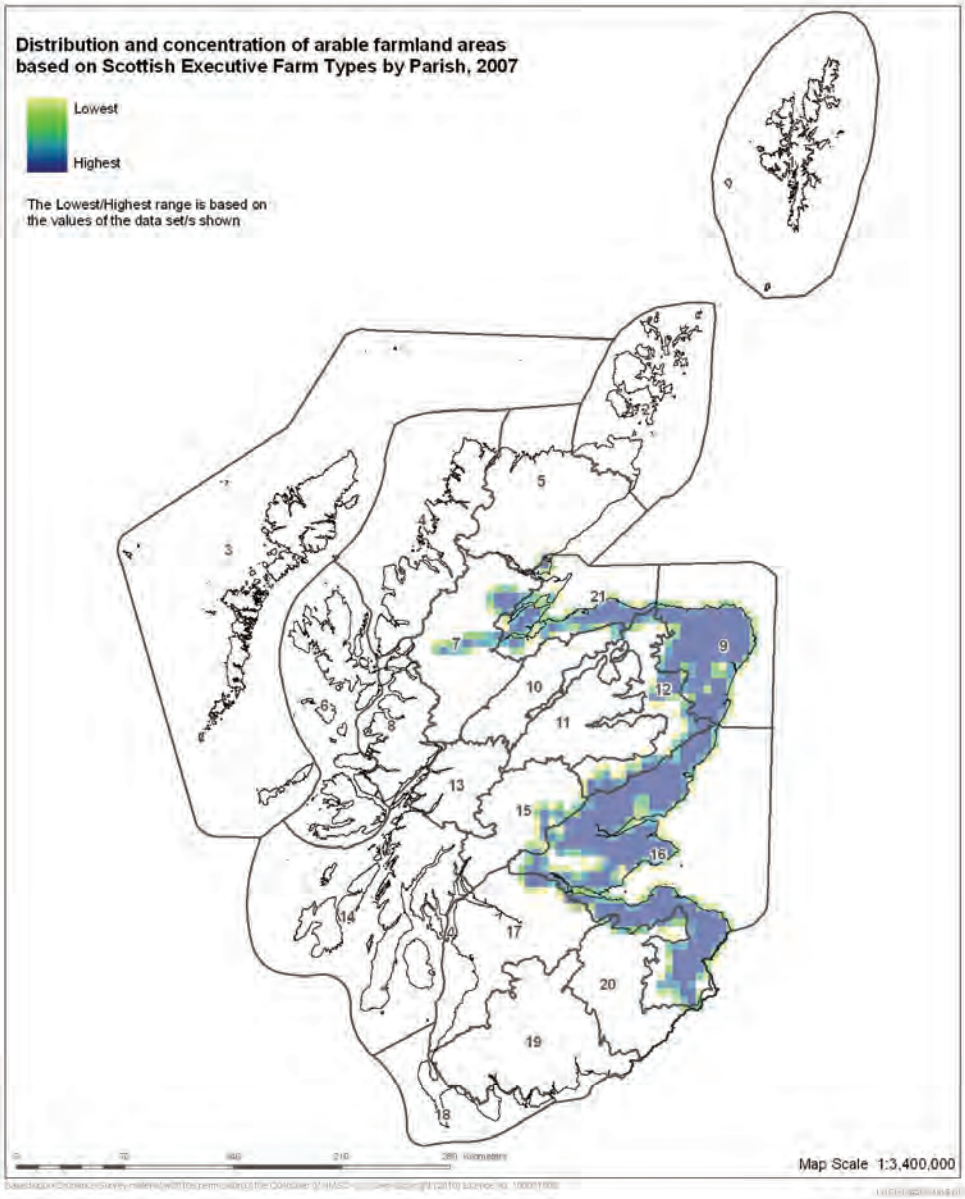

Figure 4.32a, Change 94

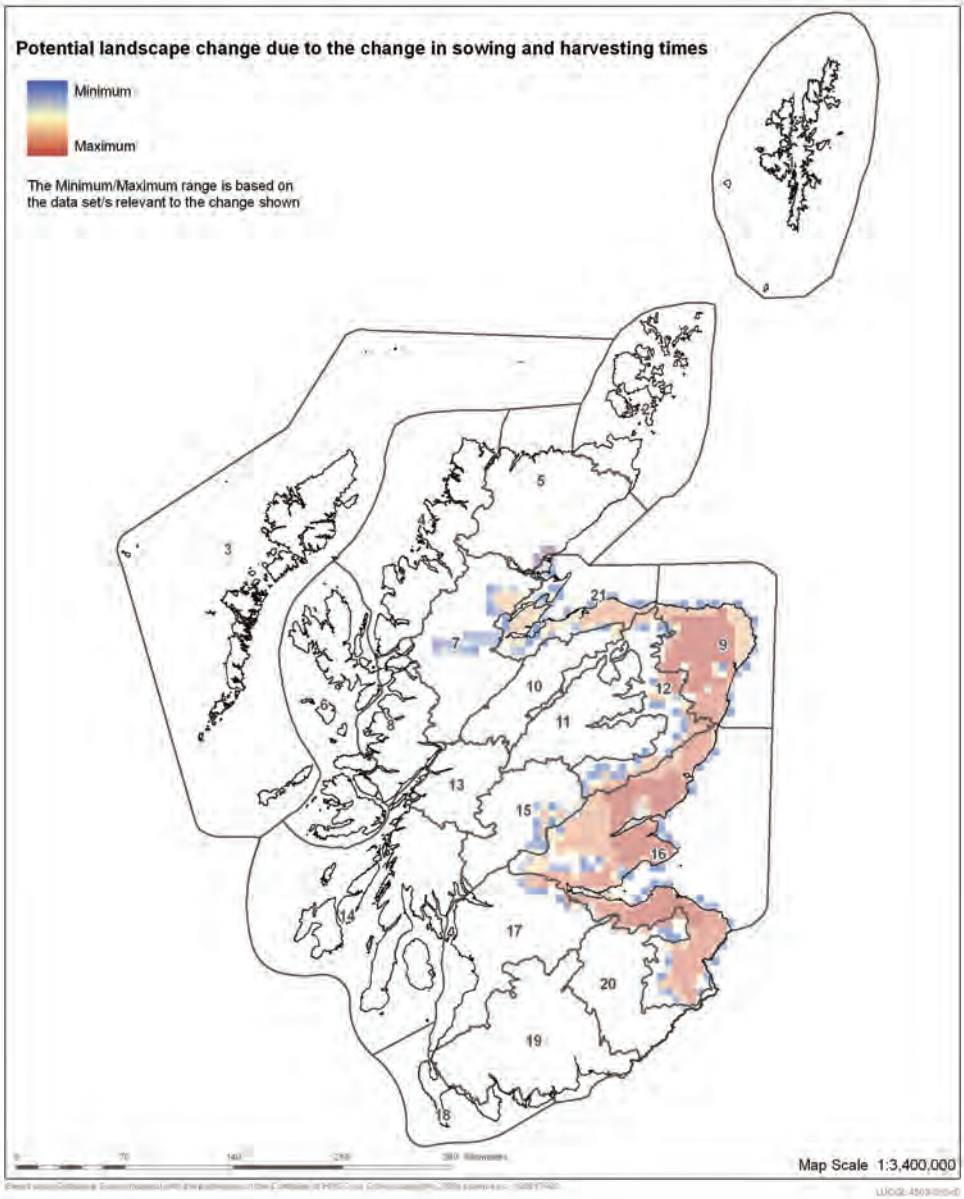

Figure 4.32b, Change 94

▸Change distribution based on comparison of arable farmland areas (including cereals, general cropping, horticulture and mixed farming farm types) with climate change variable P1: Average change in winter precipitation

Certainty level: UKCIP02 climate change	Low	Med	High
Certainty level: mapped data	Low	Med	High
Timescale of change (years)	<10	10-100	100+

UKCP09 data

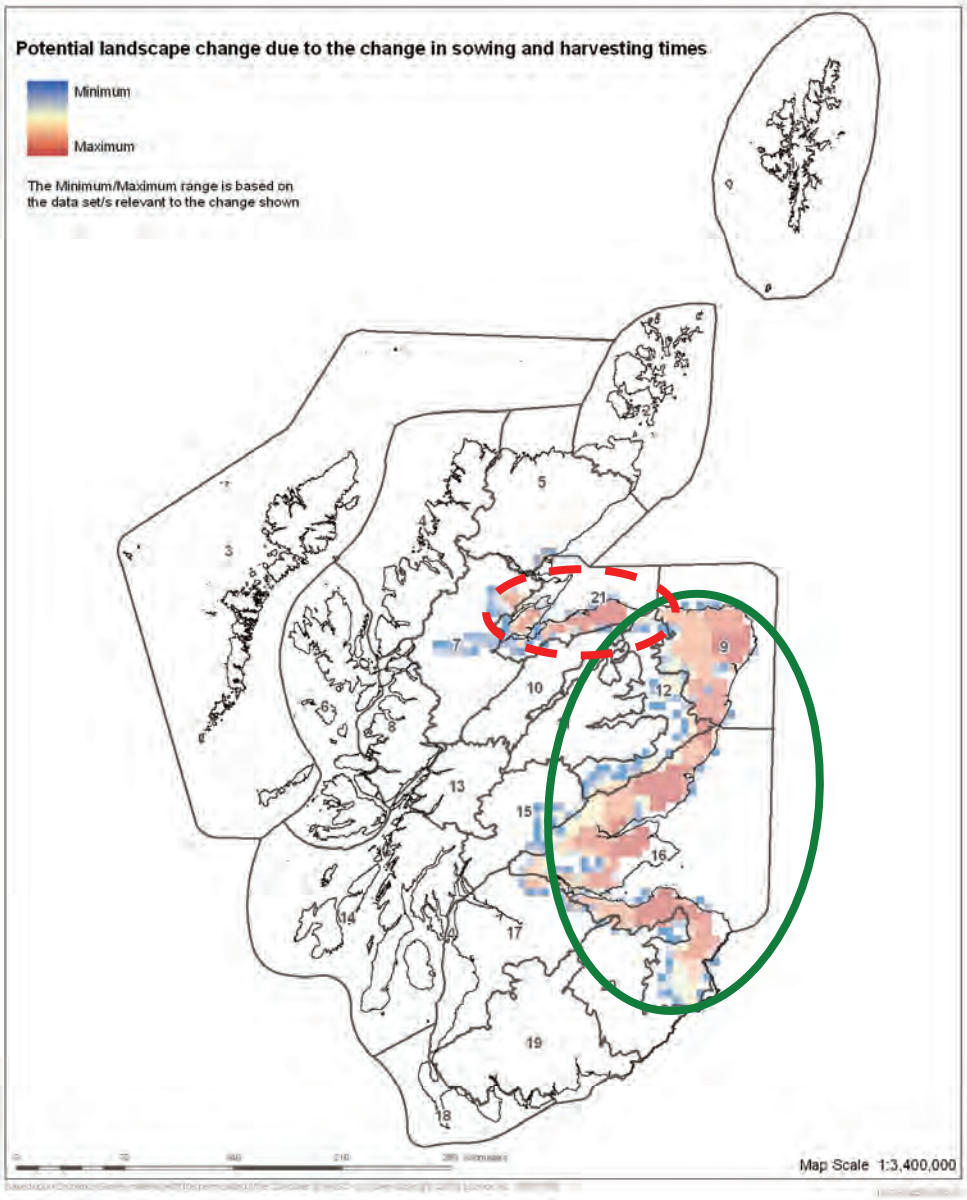

Figure 4.32b, Change 94

▸Change distribution based on comparison of arable farmland areas (including cereals, general cropping, horticulture and mixed farming farm types) with climate change variable P1: Average change in winter precipitation (UKCP09)

UKCP09 Climate Change Probability Level: **50%**

Emission Scenario: **Medium**

Time Period: **2050s (2040 - 2069)**

Areas projected to experience less change under UKCP09 than UKCIP02

Areas projected to experience greater change under UKCP09 than UKCIP02

Table 4.13: Analysis of changes to Figure 4.32b

Landscape change				
Change 94 Figure 4.32b Sowing and harvesting affected by wetter winters – possible shift from autumn to spring sowing resulting in more winter stubbles or move to ground cover crops.				
Key differences between the 02 and 09 national maps				
The extent of areas affected by the change is similar between UKCIP02 and UKCP09, however these is a reduction in the extent of areas experiencing the maximum degree of change under UKCP09.				
Differences between 02 and 09 national analysis				
Areas where change is less under UKCP09		Areas where change is greater under UKCP09		
North east Scotland, Aberdeenshire, Angus, lowland Perthshire, Fife, Lothians and eastern parts of the Borders.		Moray coast		
Regional analysis - differences between the effects of 02 and 09 projections on landscape				
Region	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Lowland Perthshire	Potential shift from autumn to spring sowing, and increase in ground cover crops in winter months.	Slightly reduced shift from autumn to spring sowing, and smaller increase in ground cover crops in winter months.	None	No significant change
Highland Perthshire	Minor shift from autumn to spring sowing, and increase in ground cover crops in winter months, though limited to lower glens and not noted as significant influence on character.	Slightly reduced shift from autumn to spring sowing, and smaller increase in ground cover crops in winter months likely.	None	No significant change

Local analysis - differences between the effects of 02 and 09 projections on landscape				
Location	Change identified under UKCIP02	Less landscape change under UKCP09	Greater landscape change under UKCP09	Broad conclusions
Killiecrankie	Impacts on agricultural crops are not an issue for this area.	None	None	No change
Strathmore	Potential shift from autumn to spring sowing, and increase in ground cover crops in winter months.	Slightly reduced shift from autumn to spring sowing, and smaller increase in ground cover crops in winter months.	None	No significant change
Firth of Tay	Potential shift from autumn to spring sowing, and increase in ground cover crops in winter months.	Slightly reduced shift from autumn to spring sowing, and smaller increase in ground cover crops in winter months.	None	No significant change
Perth	n/a	n/a	None	No change

Table 4.14 Landscape changes mapped at a national level including data sources used for mapping (Table 4.1 in Phase 1 Interim Report, updated to describe the implications of the UKCP09 projections)

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
Forests and woodlands	62	Mixed broadleaves – species mix – increase in beech and sycamore – outcompeting oak, ash and elm resulting in changing woodland composition – loss of native species, increase in new species	Figure 4.2a and 4.2b	Broadleaves, National Inventory of Woodlands & Trees (NIWT)	T2: Autumn temperature change (TEMP)				High	High certainty of trend for increased temperature, plus lower variance between probabilistic projections.	Direct, high	Increase in the degree of change in southern Scotland.	Pattern of change broadly similar
Forests and woodlands	63	Damage to woodlands caused by summer drought resulting in early leaf fall and dying trees	Figure 4.3a and 4.3b	National Inventory of Woodlands & Trees (NIWT)	P2: Average decrease in summer precipitation (PREC)				High	Medium-high certainty for trend in decreased summer precipitation. Higher variance between	Direct, high	Pattern of change broadly similar Areas now experiencing a greater decrease in summer precipitation	Slight decrease in the degree of change, but the pattern of change broadly similar.

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
										probabilistic projections.		under UKCP09 do not have high concentrations of woodland.	
Forests and woodlands	64	Damage to woodlands caused by winter flooding resulting in early leaf fall and dying trees especially on poorly draining soils and where linked to summer drought – most evident in eastern Scotland	Figure 4.4a and 4.4b	National Inventory of Woodlands & Trees (NIWT)	P1: Average change in winter precipitation (PREC)				High for precipitation, medium for soil moisture	High certainty of trend for increase in winter precipitation. Medium-high variance between probabilistic projections.	Direct, high	Pattern of change broadly similar Exception - no longer higher degree of change in the north eastern fringes of the Cairngorms.	Pattern of change broadly similar
Forests and woodlands	65	Wind throw damage to woodland caused by extreme winds,	Figure 4.5a and 4.5b	National Inventory of Woodlands & Trees (NIWT)	P1: Average change in winter precipitation (PREC)				High for precipitation, medium for soil moisture,	High certainty of trend for increase in winter	Direct, high	Pattern of change broadly similar Exception - no	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		exacerbated by wetter winters			W1: average wind speed change in the winter (WIND)				low for windspeed (averaged as medium)	precipitation. Medium-high variance between probabilistic projections.		longer higher degree of change in the north eastern fringes of the Cairngorms.	
Forests and woodlands	66	Fire damage and prevention measures in response to increased risk of fire damage to woodlands (greatest in eastern and southern Scotland), linked to increase in recreation activity	Figure 4.6a and 4.6b	National Inventory of Woodlands & Trees (NIWT) All areas except remote, SE Urban-Rural classification	T2: Autumn temperature change (TEMP) P2: Average decrease in summer precipitation (PREC) T4: change in daily max. temperature in Summer-Autumn (TMAX)				High	High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic projections. Medium-high certainty for trend in decreased summer precipitation. Higher	Direct, high	Increase in the degree of change, particularly in southern Scotland.	Slight increase in the degree of change

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
										variance between probabilistic projections. High certainty for trend in increased daily max temperature summer and autumn. Medium variance between probabilistic projections.			
Forests and woodlands	48	Riparian woodlands – more frequent and extensive with increase in lowland flooding – a part of flood management	Figure 4.7a and 4.7b	National Inventory of Woodlands & Trees (NIWT)	SEPA Fluvial Flooding risk SEPA Coastal Flooding risk				High		Direct and adaptation, high		

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
Freshwater systems	1	Flood management comprising – upland land management (closing drains, woodland establishment), temporary flood storage, diversion of flood flows away from urban areas, green roofs, SUDS, one way valves, raising floor levels, increasing drain capacity, flood resilient design and materials, doubling flood defences	Figure 4.8a and 4.8b	Urban, SE Urban-Rural classification Moorland, Landcover	P1: Average change in winter precipitation (PREC) SEPA Fluvial Flooding risk				High	High certainty of trend for increase in winter precipitation. Medium-high variance between probabilistic projections.	Adaptation, medium	Pattern of change broadly similar Exception - increase in the degree of change for the north western coast and islands, reflecting higher projected winter rainfall under UKCP09. However changes in upland land management to mitigate flooding will be most focused in areas closest to urban areas.	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
Freshwater systems	5	Increase in river flooding severity and frequency, especially in Western Scotland. Events resulting in damage to property, crops, habitats. Human response of flood protection, catchment management.	Figure 4.9a and 4.9b	SEPA Fluvial Flooding risk	P1: Average change in winter precipitation (PREC)				High	High certainty of trend for increase in winter precipitation. Medium-high variance between probabilistic projections.	Direct, high	Reduction in areas experiencing a higher degree of landscape change.	The extent and degree of change is reduced.
Freshwater systems	6	Flood damage to river banks and flood plains resulting in scouring and erosion of river valleys and floodplains and deposition	Figure 4.10a and 4.10b	SEPA Coastal Flooding risk SEPA Fluvial Flooding risk	P1: Average change in winter precipitation (PREC)				High	High certainty of trend for increase in winter precipitation. Medium-high variance between	Direct, high	Pattern of change broadly similar	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		downstream								probabilistic projections.			
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.11	Sea level rise	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Sea level rise data				n/a		Direct		
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.12	Surge risk	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Surge risk data				n/a		Direct		
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.13	Wave fetch	SNIFFER FRM 10 Coastal Flooding in Scotland a Scoping Study Wave fetch data				n/a		Direct		
Coast, estuaries and sea	n/a	Coastal erosion and inundation	Figure 4.14	Combined risk	SNIFFER FRM 10 Coastal Flooding in Scotland a				n/a		Direct		

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
					Scoping Study Combined risk data								
Coast, estuaries and sea	3	Flooding in inner estuaries and erosion of mudflats and shingle banks	Figure 4.15a and 4.15b	Estuaries, digitised Intertidal Area, Landcover Mudflats-saltmarsh, landcover	SEPA Coastal Flooding risk P1: Average change in winter precipitation (PREC) W1: average wind speed change in the winter (WIND)				High	High certainty of trend for increase in winter precipitation. Medium-high variance between probabilistic projections.	Direct, high	There is a slight reduction in the extent of areas experiencing a greater degree of change around the Dornoch Firth and the Firth of Forth, particularly along the Fife coast.	There is a slight reduction in the degree of change in the inner Tay estuary, but no change in the uplands.
Urban	9	Stress on green infrastructure caused by summer drought and high temperatures,	Figure 4.16a and 4.16b	Urban-Peri Urban, SE Urban-Rural classification	P2: Average change in summer precipitation (PREC) T2: Autumn temperature				High	Medium-high certainty for trend in decreased summer precipitation. Higher	Direct, high	The degree of change for eastern Scotland may be slightly reduced.	Slight reduction in the degree of change

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		winter rainfall, pests and disease and increased use resulting in damage or modification of urban greenspace			change (TEMP)					variance between probabilistic projections. High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic projections.			
Urban	8	Increased demand and use of green and blue infrastructure in urban areas. Increased provision, use and management.	Figure 4.18a and 4.18b	Urban-Peri Urban, SE Urban-Rural classification	T2: Autumn temperature change (TEMP) T4: change in daily max. temperature in Summer-Autumn (TMAX)				High	High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic	Adaptation. medium	The degree of change for southern Scotland may increase slightly	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
										projections. High certainty for trend in increased daily max. summer and autumn temperature. Medium variance between probabilistic projections			
Tourism	14	Changing tourism products, destinations. Increasing provision of outdoor recreation infrastructure and associated facilities. Including increased	Figure 4.17a and 4.17b	All areas except remote, SE Urban-Rural classification	T1: Average annual temperature increase (TEMP) T2: Autumn temperature change (TEMP) T3: Increased difference between summer-				High (for temperature and precipitation predictions) Medium for snow cover and low for cloud cover	High certainty of trend for increase in mean annual temperature. Lower variance between probabilistic projections.	Adaptation, medium	Pattern of change broadly similar	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		erosion in upland areas, and increased pressure on coastal resources			winter (TEMP) P2: Average decrease in summer precipitation (PREC) C1: Increased cloud cover (TCLW) SN1: Change in snowfall (SNOW) T4: change in daily max. temperature in Summer-Autumn (TMAX)					High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic projections. Medium-high certainty for trend in decreased summer precipitation. Higher variance between probabilistic projections. High certainty for trend in			

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
										increased daily max. summer and autumn temperature. Medium variance between probabilistic projections			
Infrastructure	19c	Further development of wind energy at domestic and commercial scales	Figure 4.19	Scottish Natural Heritage Windfarm Footprint and Turbine datasets					n/a		Mitigation, high		
Infrastructure	18	Increase in water infrastructure associated with export resulting in new large reservoirs, aqueducts etc	Figure 4.20a and 4.20b	Upland areas (200m+) in the Borders, OS Panorama height data	P1: Average change in winter precipitation (PREC) P2: Average decrease in summer precipitation				High	High certainty of trend for increase in winter precipitation. Medium-high variance between	Adaptation, High	Pattern of change broadly similar	Not relevant

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
					(PREC)					probabilistic projections. Medium-high certainty for trend in decreased summer precipitation. Higher variance between probabilistic projections			
Infrastructure	21	Biomass power plants resulting in industrial type buildings in rural locations	Figure 4.21	Coniferous forests, NIWT Arable Farmland, digitised farm types					n/a		Mitigation, medium		
Habitats (natural and semi natural)	72	Damage to peatland – quicker erosion, gullying and	Figure 4.22a and 4.22b	Peat, Landcover	P1: Average change in winter precipitation (PREC)				High	High certainty of trend for increase in winter	Direct, high	Central Highlands, the Cairngorms and Breadalbane	Slight reduction in the degree of change

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		bogbursts								precipitation. Medium-high variance between probabilistic projections.		experience less change. The Outer Hebrides experience greater change.	
Habitats (natural and semi-natural)	39	Changes in peat accumulations – growth where temp and rainfall increase, decay where rainfall decreases	Figure 4.23a and 4.23b	Blanket Bog, Landcover Peat, Landcover	T1: Average annual temperature increase (TEMP) P1: Average change in winter precipitation (PREC) P2: Average decrease in summer precipitation (PREC)				High	High certainty of trend for increase in mean annual temperature. Lower variance between probabilistic projections. High certainty of trend for increase in winter	Direct, high	Argyll and the Shetland Isles experience less change. Caithness and Sutherland, parts of the Highlands, the north west coast, Skye and the Outer Hebrides experience greater change.	Slight reduction in the degree of change

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
										precipitation. Medium-high variance between probabilistic projections. Medium-high certainty for trend in decreased summer precipitation. Higher variance between probabilistic projections.			
Habitats (natural and semi-natural)	36	Biodiversity – more rapid decomposition and nutrient recycling – affecting nutrient status of some	Figure 4.24a and 4.24b	Upland areas (600m+), OS Panorama height data Heather Moorland,	T2: Autumn temperature change (TEMP)				High	High certainty of trend for increase in mean autumn temperature. Lower	Direct, high	north western coastal edge of Caithness and Sutherland, Dumfries and Galloway and the Scottish	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		habitats – montane and moorland – resulting in invasion of grasses		Landcover						variance between probabilistic projections		Borders experience greater change. .	
Habitats (natural and semi-natural)	31	Loss of arctic-alpine species resulting in changing micro character of highest uplands	Figure 4.25a and 4.25b	Upland areas (600m+), OS Panorama height data	T2: Autumn temperature change (TEMP)				High	High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic projections	Direct, high	Pattern of change broadly similar	Pattern of change broadly similar
Habitats (natural and semi-natural)	27	Impact on heather moorlands from damage through fire and change in extent and distribution	Figure 4.26a and 4.26b	Heather Moorland, Landcover	T1: Average annual temperature increase (TEMP) T2: Autumn temperature change (TEMP)				High	High certainty of trend for increase in mean annual temperature. Lower variance	Direct, high	Slight increase in the degree of change for the whole of Scotland, and particularly in south eastern	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
					T3: Increased difference between summer-winter (TEMP)					between probabilistic projections High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic projections		Scotland.	
Agriculture	41	Shelter belts to shade and shelter livestock and crops in farmed areas – especially those with livestock and with sensitive crops	Figure 4.27a and 4.27b	Intensive farming (all areas except LFA), digitised farm types	T2: Autumn temperature change (TEMP) P1: Average change in winter precipitation (PREC) W1: average wind speed change in				High (for temperature and precipitation) Low for windspeed	High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic	Adaptation, medium	North and eastern Scotland experience less change. Ayrshire experiences greater change.	Slight reduction in the degree of landscape change.

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
					the winter (WIND)					projections. High certainty of trend for increase in winter precipitation. Medium-high variance between probabilistic projections.			
Agriculture	43	Loss of field boundary and other farmland trees due to storm damage and stress resulting in more open farmland landscapes	Figure 4.28a and 4.28b	Intensive farming (all areas except LFA), digitised farm types	T1: Average annual temperature increase (TEMP) P1: Average change in winter precipitation (PREC) P2: Average decrease in summer precipitation				High (for temperature and precipitation) Low for windspeed	High certainty of trend for increase in mean annual temperature. Lower variance between probabilistic projections. High	Direct, high	North east Scotland, the east coast, east Fife, Lothian and Borders experience less change.	Slight reduction in the degree of change

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
					(PREC) W1: average wind speed change in the winter (WIND)					certainty of trend for increase in winter precipitation. Medium-high variance between probabilistic projections. Medium-high certainty for trend in decreased summer precipitation. Higher variance between probabilistic projections.			
Agriculture	75	Flood damage to agricultural crops – from rainfall, sea	Figure 4.29a and	Intensive farming (all areas except LFA),	P1: Average change in winter precipitation				High for precipitation, medium for extreme sea	High certainty of trend for increase in	Direct and adaptation, high	North east Scotland, Fife, Lothian and Borders,	The landscape change is greater and

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		and flood storage projects	4.29b	digitised farm types	(PREC) SEPA Fluvial Flooding risk SEPA Coastal Flooding risk				level	winter precipitation. Medium-high variance between probabilistic projections.		Ayrshire and Dumfries and Galloway experience greater change	more extensive.
Agriculture	87	Arable – potential increase in productivity if nitrogen and soil moisture – requirement for greater on-farm storage of crops resulting in new, larger farm buildings	Figure 4.30a and 4.30b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	T2: Autumn temperature change (TEMP)				High	High certainty of trend for increase in mean autumn temperature. Lower variance between probabilistic projections.	Direct and adaptation, high	The Lothians experience a slight increase in change.	Pattern of change broadly similar
Agriculture	88	Increased requirement for irrigation of arable resulting in irrigation infrastructure –	Figure 4.31a and 4.31b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm	T3: Increased difference between summer-winter (TEMP) P2: Average decrease in				High	Medium-high certainty for trend in decreased summer precipitation.	Adaptation, medium	Slight decrease in the degree of change particularly in Angus and	Slight decrease in the degree of change.

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		sprays and booms		types	summer precipitation (PREC) SM1: Change in soil moisture during summer-autumn (SMOI)					Higher variance between probabilistic projections.		Fife.	
Agriculture	94	Sowing and harvesting affected by wetter winters – possible shift from autumn to spring sowing resulting in more winter stubbles or move to cover crops	Figure 4.32a and 4.32b	Cereals, General Cropping, Horticulture & Mixed farming, digitised farm types	P1: Average change in winter precipitation (PREC)				High	High certainty of trend for increase in winter precipitation. Medium-high variance between probabilistic projections.	Adaptation, medium	North east Scotland, the east coast and Fife experience a less change The Moray coast experiences greater change.	Slight decrease in the degree of change.
Agriculture	98	New or novel crops and potential conversion from pasture to	Figure 4.33a and 4.33b	Cereals, General Cropping, Horticulture & Mixed	T2: Autumn temperature change (TEMP)				High	High certainty of trend for increase in mean	Adaptation, medium	Slight increase in the degree of change for southern	Pattern of change broadly similar

Topic	Number (ref Appendix 5, Tables 5.4 and 5.5)	Landscape change	Map figure number	Data		Timeframe (yrs)			Climate change certainty (for climate change variable) UKCIP02	Climate change certainty (for climate change variable) UKCP09	Landscape change certainty (direct or adaptation or mitigation)	Commentary on the likely national pattern and degree of landscape change under UKCP09 50% probability level	Commentary on the likely pattern and degree of landscape change in Tayside
				Topographic\ Landscape data	02 Climate\ Flooding data	<10	10-100	100+					
		arable		farming, digitised farm types						autumn temperature. Lower variance between probabilistic projections.		Scotland.	

5 UNCERTAINTY AND RISK

5.1 This section reviews the implications of the UKCP09 probabilistic projections for the level of uncertainty associated with different climate change variables. Whereas the UKCIP02 projections provided a single value for each emissions scenario / timeframe, the UKCP09 projections provide a range of probabilistic values[17]:

- The 10% probability projections indicate that the probability that the change in question will be less than the value shown is 10%. UKCP uses the term 'very unlikely to be less than' (and therefore very likely to be more than) to describe such changes indicating a higher level of confidence of the effect occurring.

- The 90% probability projections indicate that the probability that the change in question will be less than the value shown is 90% - it is very unlikely to be greater than that shown and therefore very likely to be less.

- The 50% probability projections indicate that the projected change is just as likely to be greater as it is to be less than the value shown. This is the central estimate and, importantly, does not indicate the projection that is most likely to occur.

5.2 Analysis of the more extreme probabilistic projections (e.g. 90% and 10%) allows the variation in potential changes to be explored, helping to inform the way in which the projections should be applied. For example, if there is relatively little difference between the scales of change which have a 90%, 50% and 10% probability of being exceeded, any conclusions based on the projections are likely to be reasonably reliable, providing a firm foundation for policy or other responses. On the other hand, if there is a significant difference between either the 90% or 10% projections and the 50% projection, the conclusions will be more tentative and, importantly, a judgment will need to be made about the level of risk that any subsequent response should adopt. Using the example of 'winter precipitation change' for the three UKCP regions in Scotland, Table 5.1 shows how the information from the probabilistic projections was used to explore these differences. The results are set out in Table 5.2.

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[17] http://ukclimateprojections.defra.gov.uk/content/view/1338/543/

Table 5.1: Calculating variance between probabilistic projections for 'change in winter precipitation' variable (UKCP09 2040-2069 timeframe, medium emissions scenario)

Step 1: review the scale of the 50% probabilistic change (taken from UKCP09[18] and included as Figures A1.7 to A1.9 in Annex 1 of this Appendix in graphic format) Eastern Scotland +10.0% (lower change) Northern Scotland +12.5% Western Scotland +15.0% (higher change)
Step 2: calculate the difference between 90% (Table 5.2 - Column C) and 10% (Table 5.2 - Column E) probabilistic projections Eastern Scotland 20.0% - 0.1% = 19.9% (lower variance) Northern Scotland 24.5% - 4.0% = 20.5% Western Scotland 28.5% - 5.0% = 23.5% (higher variance) This records the variations between projections – showing that, in Eastern Scotland, there is a difference of around 20% between the 90% and 10% probabilistic projections, compared with a figure of 23.5% for Western Scotland. This suggests that there is slightly greater uncertainty about the projections for Western Scotland. The results are set out in Column F of Table 4.2.
Step 3: calculate these difference as percentage of the 50% probabilistic projection (Table 4.2 - Column D). This shows the scale of the variance relative to the projected change in question. Eastern Scotland (19.9/10) x 100 = 198.5% (higher variance relative to projected change) Northern Scotland (20.5/12.5) x 100 = 164.0% Western Scotland (23.5/15) x 100 = 156.7% (lower variance relative to projected change) For Eastern Scotland it shows that, although the projected change is less than that for other parts of Scotland, the difference between the 90% and 10% projections is relatively high at 198% of the 50% probabilistic projection. The results are set out in Column G of Table 4.2.
Step 4: To assist in judging the significance of these findings, the figures in Column G were classified as follows: Less than 100% = lower variance indicating higher certainty in the projected change 100% - 200% = medium variance More than 200% = higher variance indicating lower certainty in the projected change

5.3 Table 5.2 sets out the 90%, 50% and 10% probabilistic projections for projected changes in temperature and rainfall (Columns C, D and E respectively). The table shows the difference between the 90% and 10% projections (°C for temperature, % change for precipitation) (Column F) and this difference as a proportion of the 50% projection (Column G). **The lower the figures in Columns F and G, the less difference between the projections at different levels of probability, and thus the lower the likelihood that outcomes will be significantly different.**

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[18] http://ukclimateprojections.defra.gov.uk/content/view/1338/543/

Conversely, the higher the figures, the greater the difference and the likelihood that outcomes associated with a given variable will be significantly different.

Table 5.2: Analysis of differences between UKCP09 10%, 50% and 90% probabilistic projections
(based on data from http://ukclimateprojections.defra.gov.uk/content/view/1338/543/)

A	B	C	D	E	F	G	
2040-2069, medium emis-sions	UKCP region	90% probability that change will be less than	50% probability that change will be less than	10% probability that change will be less than	Difference between the 90% and 10% probabilistic projections (Column C minus Column E)	Column F as a proportion of the 50% probabilistic projection (Column D)	Commentary
					Low figures = less difference between probabilities = higher certainty in the projected change		
Mean annual temp change (°C)	Eastern Scotland	3.1	2	1.2	1.9°C	95.0%	**LOWER VARIANCE** indicating that, relative to other climate change variables, there is higher confidence that mean annual temperature will rise by between 1.9 and 2.1°C.
	Northern Scotland	2.8	1.9	1.1	1.7°C	89.5%	
	Western Scotland	3.1	2.1	1.3	1.8°C	85.7%	
Summer temperature change (°C)	Eastern Scotland	4	2.3	1.1	2.9°C	126.1%	**MEDIUM VARIANCE** indicating that, relative to other climate change variables, there is moderate confidence that mean summer temperature will rise by between 2 and 2.5°C.
	Northern Scotland	3.4	2	0.9	2.5°C	125.0%	
	Western Scotland	3.8	2.5	1.1	2.7°C	108.0%	
Autumn temperature change (°C)	Eastern Scotland	3.4	2.2	1	2.4°C	109.1%	**MEDIUM TO LOWER VARIANCE** indicating that, relative to other climate change variables, there is medium to higher confidence that mean autumn temperature will rise by 2 to 2.4°C. There is greater certainty for Western Scotland.
	Northern Scotland	3.2	2	1	2.2°C	110.0%	
	Western Scotland	3.4	2.4	1.5	1.9°C	79.2%	

A	B	C	D	E	F	G	
2040-2069, medium emis-sions	UKCP region	90% probability that change will be less than	50% probability that change will be less than	10% probability that change will be less than	Difference between the 90% and 10% probabilistic projections (Column C minus Column E)	Column F as a proportion of the 50% probabilistic projection (Column D)	Commentary
Winter temperature change (°C)	Eastern Scotland	2.9	1.6	0.7	2.2°C	137.5%	**MEDIUM VARIANCE** indicating that, relative to other climate change variables, there is moderate confidence that mean winter temperature will rise by between 1.6 and 2°C.
	Northern Scotland	2.8	1.7	0.7	2.1°C	123.5%	
	Western Scotland	3	2	1	2°C	100.0%	
Change in mean daily max temperature summer (°C)	Eastern Scotland	5.4	3	1.1	4.3°C	143.3%	**MEDIUM VARIANCE** indicating that, relative to other climate change variables, there is moderate confidence that the change in mean daily max temperature in summer mean summer will rise by between 2.6 and 3°C.
	Northern Scotland	4.6	2.6	0.9	3.7°C	142.3%	
	Western Scotland	5.2	3	0.9	4.3°C	143.3%	
Change in mean daily max temperature autumn (°C)	Eastern Scotland	3.7	2.2	1	2.7°C	122.7%	**MEDIUM VARIANCE** indicating that, relative to other climate change variables, there is moderate confidence that the change in mean daily max temperature in summer mean autumn will rise by between 2 and 2.2°C.
	Northern Scotland	3.4	2	0.9	2.5°C	125.0%	
	Western Scotland	3.6	2.2	1	2.6°C	118.2%	
Change in summer precipitation (%)	Eastern Scotland	0.1	-13	-27.5	27.6%	212.3%	**HIGH VARIANCE** indicating that, relative to other climate change variables, there is lower confidence that the reduction in summer rainfall will be between 11 and 13%.
	Northern Scotland	0.2	-11	-24	24.2%	220.0%	
	Western Scotland	0.1	-13	-27	27.1%	208.5%	

A	B	C	D	E	F	G	
2040-2069, medium emis-sions	UKCP region	90% probability that change will be less than	50% probability that change will be less than	10% probability that change will be less than	Difference between the 90% and 10% probabilistic projections (Column C minus Column E)	Column F as a proportion of the 50% probabilistic projection (Column D)	Commentary
Change in winter precipitation (%)	Eastern Scotland	20	10	0.15	19.85%	198.5%	**MEDIUM VARIANCE** indicating that, relative to other climate change variables, there is moderate confidence that increases in winter precipitation will be between 11 and 13%.
	Northern Scotland	24.5	12.5	4	20.5%	164.0%	
	Western Scotland	28.5	15	5	23.5%	156.7%	

5.4 The figures suggest that there is greater difference for precipitation during both winter and summer than for temperature changes. **This suggests that climate related landscape changes associated with temperature are, all other things being equal, more likely to occur than those associated with changes in rainfall.**

5.5 It should be noted that the difference between upper and lower projections increases over time (graphs are presented in Annex1).

5.6 This information was used to explore and hopefully reduce uncertainty within the revised Phase 1 report. This takes the form of a commentary to sit alongside the discussion of uncertainty. It makes clear that this commentary focused solely on the UKCP09 projections, but should help clarify areas of uncertainty or risk in relation to particular types of change covered in the report. We also used the findings to qualify any overall conclusions based on these broad aspects of climate change.

6 AUDIT OF IMPLICATIONS FOR PHASE 1 INTERIM REPORT

Introduction

6.1 This section of the report includes an overview of the updates required to the Phase 1 Interim Report, and the implications for the key findings.

Audit process

6.2 Having identified the key differences between the UKCIP02 and UKCP09 projections, then re-run the national map analysis where appropriate and identified issues of uncertainty associated with different climate change variables, the next task was to conduct an audit of the Phase 1 Interim Report to identify where revision was required to reflect the updated analysis. This was carried out in a number of ways:

- an analysis of where general findings and conclusions need to be updated;
- an analysis of the key findings from the study to confirm whether any need to be revised;
- an analysis of the requirement to modify any of the three photomontages prepared for the Tayside case studies and, if necessary, the reworking of the images as appropriate.

6.3 Table 6.1 below provides a summary of the updates required to each chapter of the Phase 1 Interim Report. Table 6.2 explores the implications for the key findings in greater detail.

Table 6.1 Summary of updates to Phase 1 Interim report

Section	Summary of Phase 1 content	Summary of updates required
Executive Summary	Executive summary	Update key conclusions based on changes outlined below.
Section 1: Introduction	This chapter includes a summary comparison of UKCIP02 and UKCP09	This text should be expanded and updated based on the implications set out in the UKCP09 Stage 1 report. This should also include commentary on the UKCP09 data and uncertainty. Include a short section on 'how to use this report' which explains that the local implications of the 09 data are only mapped for winter precipitation, and other differences are not mapped at a local level. Other provisos particularly stating that the data should not be interpreted at the local level. Para 1.4 reference to UKCP09 report as annex.

Section	Summary of Phase 1 content	Summary of updates required
Section 2: Methodology	This chapter explains the methodology for the study.	The methodology overview diagram should be updated to reflect the review of UKCP09 data, and the descriptive text updated to reflect where UKCP09 data has been used to update the National level mapping
Section 3: Future Climate Change in Scotland	This chapter explores the implications of climate change under the UKCIP02 scenarios.	The UKCP09 Stage 1 report sets out a comparison of UKCPI02 and UKCP09 climate change variables and this commentary should be used to update this section, including comment on changes to the confidence attached to the changes described.
Section 4: Scotland-wide Pattern of Climate Related Change	This section provides a descriptive overview of the key climate related landscape changes that were explored at a national level. It includes Table 4.1 which provides a summary of the landscape changes mapped at a national level.	Table 4.14 in this report to replace Table 4.1 from the Phase 1 report.
	General commentary is included on the implications of climate change, provided by topic, and specific conclusions are drawn based on the results of the mapped analysis.	Tables set out in Section 4 of this report provide a detailed summary of the required changes to the national, regional and local conclusions in relation to the maps re-run with UKCP09 data. The revised maps will be inserted into the document, replacing those based on UKCIP02 data, as appropriate. The text should be updated in light of these findings.
	The maps include a commentary on certainty associated with the climate change data.	Include reference to Tables 5.1 and 5.2 from this report which provide analysis of certainty associated with the climate change variables based on UKCP09 climate change data.
	Table 4.2 and summary text provide an overview of the degree of change by Natural Heritage Zone.	Table 4.2 in the Phase 1 report requires to be updated and the text requires to be reviewed in light of the revised conclusions based on the UKCP09 mapping.
	Commentary is provided on population and multiple deprivation.	This is a high level summary and the broad landscape changes described are unchanged.

Section	Summary of Phase 1 content	Summary of updates required
	Commentary is provided on the influence of climate related landscape change on designated landscapes.	This text should be reviewed and updated where spatial reference is made to key landscape changes affected by altered patterns under UKCP09.
Section 5: Tayside Pilot Area	This section of the report focuses on Tayside to provide a more detailed analysis of the implications of climate change for the landscape and the cultural ecosystem services it provides	Tables set out in Section 4 of this report provide a detailed summary of the required changes to the national, regional and local conclusions in relation to the maps re-run with UKCP09 data. The text should be updated in light of these findings.
	Commentary and conclusions are set out in relation to each of the four case study areas of Killiecrankie, Strathmore, Firth of Tay and Perth.	Tables set out in Section 4 of this report provide a detailed summary of the required changes to the national, regional and local conclusions in relation to the maps re-run with UKCP09 data. The text should be updated in light of these findings.
	Photomontages are provided for Killiecrankie, Strathmore and Firth of Tay	Conclusions in Section 6.7 (Table 6.3) of this Appendix do not identify a requirement to modify the photomontages.
	Commentary is provided for each case study area on the impact of climate related landscape change on cultural ecosystem services	Review and update of commentary to reflect differences between UKCIP02 and UKCP09, as summarised in Chapter 4 of this report. This is a high level commentary and changes are likely to be minor in nature
	Commentary is provided for each case study area under the four socio-economic scenarios	Review and update of commentary to reflect differences between UKCIP02 and UKCP09, as summarised in Chapter 4 of this report. This is a high level commentary and changes are likely to be minor in nature
	Description of impacts of landscape related climate change on Loch Tummel National Scenic Area	Review and update of commentary to reflect differences between UKCIP02 and UKCP09, as summarised in Chapter 4 of this report. This is a high level commentary and changes are likely to be minor in nature

Section	Summary of Phase 1 content	Summary of updates required
Section 6: Conclusions	This section of the report summarises the areas of most significant climate related landscape change and explores the spatial and topic based variations in relation to direct impacts, human adaptation and mitigation activities at a national level	Spatial references to areas experiencing the greatest level of change should be reviewed against the changes set out in Section 4 of this report.
	References	Update reference list to include 09 references.
Appendix 1 Ecosystem services	Description of ecosystem services	No change
Appendix 2 UKCIP Socio Economic Scenarios	Description of UKCIP socio economic scenarios	No change
Appendix 3 Workshop	Summary of issues discussed at workshop	No change
Appendix 4 Literature review	Literature review key findings	No change
Appendix 5 Significant Landscape Changes	Summary tables of significant landscape changes identified from literature review	Changes in tables 5.2 and 5.3
Appendix 6 Landscape character descriptions for Tayside detailed study area, existing and with climate change	Detailed landscape character descriptions drawing on the information in the Tayside Landscape Character Assessment (1999) and Fife Landscape Character Assessment (1999) exploring changes under UKCIP02	Review and update of landscape character descriptions to reflect differences between UKCIP02 and UKCP09, as summarised in Chapter 4 of this report.

Section	Summary of Phase 1 content	Summary of updates required
Appendix 7 Cultural ecosystem services tables – current, with climate change, with climate change and socio-economic scenarios	Sets out the impacts of climate change on the cultural ecosystem services for each pilot area example	Review and update of ecosystem services analysis to reflect differences between UKCIP02 and UKCP09, as summarised in Chapter 4 of this report. Only minor changes likely to be required.
Appendix 8 Socio-economic scenarios – detailed descriptions	Description of how each of the four socio economic scenarios would affect the likely landscape changes identified in each of the pilot areas	Review and update of socio-economic scenario analysis to reflect differences between UKCIP02 and UKCP09, as summarised in Chapter 4 of this report. Only minor changes, if any, likely to be required.
Appendix 9 Climate change maps	Climate change maps which illustrate the maximum and minimum change for the UKCIP02 climate change scenarios for key weather variables	Update to include winter precipitation maps for UKCP09
Appendix 10 Mapping methodology	Description of mapping methodology	Include update to mapping methodology on use of 09 data and combination of 02 and 09 data

Ecosystem services and socio-economic scenarios

6.4 As indicated in Table 6.1, the alterations to the pattern of landscape changes resulting from the updates of the UKCP09 data will not significantly impact on the conclusions provided in relation to the ecosystem services described under each case study, nor the descriptions provided under the socio-economic scenarios. The detail of the analysis will be reviewed but the broad changes described are likely to remain unchanged.

6.5 In relation to the socio-economic scenarios, the changes noted under the UKCP09 are typically greatest for direct impacts. The extent to which landscape change varies under the socio economic scenarios is more strongly focused towards adaptation and mitigation impacts. Furthermore these summaries focus on broad trends which remain unchanged between UKCIP02 and UKCP09. Again, the detail of the analysis will be reviewed but the broad changes described are likely to remain unchanged.

Summary of implications of UKCP09 for Phase 1 key findings

6.6 Table 6.2 provides a summary of the implications of the changes identified under UKCP09 for the Phase 1 key findings. This illustrates: the change identified in the key findings:

- the theme to which it relates (see Table 4.14);
- a summary comparison of the implications of UKCIP02 and UKCP09
- the implications for the key findings.

Table 6.2 Summary of implications for Phase 1 key findings

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Direct changes			
An increase in coastal flooding and erosion, including loss of low lying areas of land to the sea;	Coasts, estuaries and sea	Spatial pattern of sea level rise likely to remain the same, but degree of change may be higher. Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Emphasise greater degree of potential change as coastal areas affected by increased sea level rise and similar or higher winter rainfall.

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Potential dramatic landscape changes in sections of coast or catchments where flooding and land stability are already issues.	Coasts, estuaries and sea Freshwater	Spatial pattern of sea level rise likely to remain the same, but degree of change may be higher. Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Emphasise greater degree of potential change as coastal areas affected by increased sea level rise and similar or higher winter rainfall. Some catchments may experience similar or reduced winter rainfall.
An increase in river flooding, erosion and slope instability;	Freshwater	Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Some catchments may experience similar or reduced winter rainfall, others may experience higher winter rainfall.

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Changes to semi natural habitats as species' climate space moves north with particular implications for heather moorland, peat bogs, native woodlands and montane plant communities.	Habitats (natural and semi natural)	Increase in degree of average annual temperature increase Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions. All of Scotland experiences decrease in summer precipitation but extent of areas experiencing greatest decrease is reduced Increase in average autumn temperatures remains similar	Higher temperatures could accelerate changes in semi-natural habitat changes, but overall conclusion unchanged.

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Direct effects on trees and forests more widely, resulting from changing patterns of rainfall, increases in storm damage and a potential increase in the pests and disease. This could be most evident in agricultural areas, woodlands, designed landscapes and in settlements.	Forests and woodlands	Increase in average autumn temperatures remains similar All of Scotland experiences decrease in summer precipitation but extent of areas experiencing greatest decrease is reduced Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Possible changes in the extent of this change – higher temperatures could increase stress on trees, but less pronounced reductions in summer rainfall and a mixed pattern of winter precipitation change could result in more localized effects
Changes to the pattern of snowfall and snow lie	Tourism	Increase in average winter temperatures changes in the spatial pattern of winter precipitation with some areas experiencing potential decline	Possible that some upland areas will experience further reduction in snow lie as consequence of reduced precipitation and higher winter termperatures
Mitigation measures			
Continuing trend for onshore and offshore wind energy	Infrastructure	n/a	No change
Cultivation and processing of biomass including short rotation coppice and energy crops.	Infrastructure	n/a	No change

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Development of tidal and marine based renewables, and the wider take up of small scale or micro-renewables such as solar panels on buildings	Infrastructure	n/a	No change
An expansion of productive and native or semi-natural woodland for carbon storage	Forests and woodland	n/a	No change
Restoration of natural upland habitats for carbon storage	Habitats (natural and semi natural)	n/a	No change
Planned adaptation			
A range of responses to the increased risk of riparian and coastal flooding. Catchment wide measures could include the restoration of natural floodplains and the expansion of woodland to intercept rainfall and slow the speed of run-off.	Habitats (natural and semi natural) Forests and woodland	Spatial pattern of sea level rise likely to remain the same, but degree of change may be higher. Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Increased sea level rise means there is likely to be a requirement for more extensive coastal flood defence measures Changing patterns of winter rainfall could increase the requirement for catchment wide measures in some areas, particularly in western Scotland where settlements located on river corridors.

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Requirement for engineered flood defences, particularly where settlements, historic properties, infrastructure or more productive farmland are at risk. Similar responses are likely along the coast, including estuaries and sea lochs.	Freshwater systems Coasts, estuaries and seas	Spatial pattern of sea level rise likely to remain the same, but degree of change may be higher.	Increased sea level rise means there is likely to be a requirement for more extensive coastal flood defence measures Changing patterns of winter rainfall could increase the requirement for catchment wide measures in some areas, particularly in western Scotland where settlements located on river corridors.
Managed realignment and strengthening of coastal flood defences and resulting loss of inter-tidal landscapes	Coasts, estuaries and seas	Spatial pattern of sea level rise likely to remain the same, but degree of change may be higher.	Increased sea level rise means there is likely to be a requirement for more extensive coastal flood defence measures .
Other measures could include the upgrading of infrastructure to make it better able to deal with higher rainfall	Infrastructure	Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Spatial pattern of vulnerable areas may change but overall finding unchanged.
Changes in forest and woodland management, including the use of different tree species, restructuring to avoid higher and more exposed locations and, where opportunities exist, a move towards continuous cover forestry techniques in preference to clear fell.	Forests and woodlands	Increase in average autumn temperatures remains similar Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Spatial pattern of areas subject to change may alter, but overall finding unchanged.

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Timing of forestry activity may also change reflecting the impact of wetter winters.	Forests and woodlands	Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	This is likely to be more significant in the west of Scotland and less significant in the Cairngorms, Grampians and Southern Uplands
Development of habitat networks including new woodlands	Habitats (natural and semi natural) Forests and woodlands	Increase in average autumn temperatures remains similar Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Spatial pattern of areas subject to change may alter, but overall finding unchanged.
Unplanned adaptation			
Agricultural intensification of existing production in existing core areas, the introduction of different crops and expansion into currently more marginal areas where soil quality allows. This could result in trends such as field enlargement, the requirement for improved farm buildings and the need for on farm water storage and irrigation.	Agriculture	Increase in average autumn temperatures remains similar All of Scotland experiences decrease in summer precipitation but extent of areas experiencing greatest decrease is reduced.	Spatial pattern of areas subject to change may alter, but overall finding unchanged.

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
The need for shelter and shade could be reflected in the creation of shelter belts, while increased stress, allied to field enlargement could result in the loss of field boundary trees and hedges, together with features such as drystone dykes.	Agriculture	Increase in average autumn temperatures remains similar Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Spatial pattern of areas subject to greatest degree of change may alter, but overall finding unchanged.
Higher winter rainfall could influence the timing of sowing and other operations and could result in a range of detailed measures to reduce the risk of soil erosion and damage.	Agriculture	Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.	Greatest differences are likely to occur in the west, least in the east where arable most common, so overall finding unchanged.
Impact on patterns of tourism and recreation, as people adapt to warmer and drier summers. Scotland could see an expansion in recreation activity, particularly in more accessible areas around settlements and in protected landscapes	Tourism Urban	All of Scotland experiences decrease in summer precipitation but extent of areas experiencing greatest decrease is reduced	Spatial pattern of areas subject to greatest degree of change may alter, but overall finding unchanged.

Phase 1 Interim report key finding	Theme	Implications of UKCP09 data compared to UKCIP02	Implications for key findings
Conversely, an increase in winter rainfall and reduction in snow lie could have an impact on winter recreation, reinforcing existing patterns of seasonality. These changes could result in pressure on accessible recreation facilities during the summer, with possible increases in erosion and fire risk, and pressure for tourism related development	Tourism Urban	Changes in spatial pattern of winter precipitation – with some areas experiencing larger increases, and some areas showing lower rates of increase or slight reductions.All of Scotland experiences decrease in summer precipitation but extent of areas experiencing greatest decrease is reduced	Spatial pattern of areas subject to greatest degree of change may alter, and overall degree of change may be less but overall finding unchanged.

IMPLICATIONS FOR TAYSIDE PHOTOMONTAGES

6.7 The Phase 1 report included a series of four local case studies drawn from locations across Tayside. Three of these were illustrated using photomontages showing potential effects of climate change on the landscape. The three locations in question were:

- Killiecrankie with the Loch Tummel National Scenic Area;
- Strathmore;
- Firth of Tay.

6.8 It was identified that the differences between the UKCIP02 and UKCP09 projections could have implications for these photomontages. However it should be noted that the photomontages were designed to illustrate landscape change rather than an accurate prediction of the changes that will occur. A summary of the illustrated changes for each photomontage is provided in Tables 6.3 - 6.5 with more detail provided in Annex 3.

6.9 Comment is provided on the possible impacts for the illustrated landscape changes as a result of the altered projections under UKCP09.

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Table 6.3 Killiecrankie implications for photomontage

Landscape changes illustrated under UKCIP02	Possible alterations to illustrated landscape changes under UKCP09	Implications for photomontage under UKCP09
Increase in the incidence of fires affecting moorlands and woods (DIRECT)	Possible slight increase in degree of change	No alteration to photomontage required.
Increase in recreation activity including demand for upland paths (ADAPTATION)	Pattern of change remains similar	No alteration to photomontage required.
Increase in erosion along burns and rivers (DIRECT)	Pattern of change remains similar	No alteration to photomontage required.
Loss of heather moorland and increase in grassland (DIRECT)	Erosion and loss of peat may be less pronounced than previously anticipated in the UKCIP02 conclusions.	Subtle differences in the pattern of vegetation change however there is no scientific basis for calculating the degree of change.
Expansion of woodland to increase carbon sequestration (MITIGATION)	Mitigation activity – no change	
Expansion of woodland as part of catchment wide flood management (ADAPTATION)	The extent of rewilding may be less than anticipated within the valley and upland areas. No significant change.	No alteration to photomontage required.
Expansion of woodland to create habitat networks and shelter stock (ADAPTATION)	Possible slight reduction in degree of change	No alteration to photomontage required.
Possible intensification of agriculture in currently marginal areas (ADAPTATION)	Pattern of change remains similar	No alteration to photomontage required.
Measures to deal with increased runoff and risk of landslides (ADAPTATION)	Slight reduction in extent and degree of change.	No alteration to photomontage required.
Conclusion: Landscape changes between UKCIP02 and UKCP09are subtle or relate to degree of change, and no basis for altering the photomontage is identified.		

Table 6.4 Strathmore implications for photomontage

Landscape changes illustrated under UKCIP02	Possible alterations to illustrated landscape changes under UKCP09	Implications for photomontage under UKCP09
Reinforcement of the National Grid to serve renewable energy schemes (MITIGATION)	Mitigation activity – no change	
Windfarm to provide low carbon power (MITIGATION)	Mitigation activity – no change	
New farm buildings required to store new and higher yields from existing crops (ADAPTATION)	Pattern of change remains similar	No alteration to photomontage required.
New woodland belts to create habitat networks, shelter and shade for crops, and a source of woodfuel (ADAPTATION)	Possible slight reduction in degree of landscape change.	No alteration to photomontage required.
Biomass crops to provide low carbon heat and power (MITIGATION)	Mitigation activity – no change	
Installation of micro-renewables including roof mounted solar equipment (MITIGATION)	Mitigation activity – no change	
Loss of field boundary trees accelerated by summer drought, winter waterlogging and storm damage (DIRECT)	Smaller increases in winter rainfall could result in the loss of fewer field boundary trees.	No alteration to photomontage required.
Field enlargement resulting from intensification of agriculture (ADAPTATION)	Pattern of change remains similar.	No alteration to photomontage required.
Conclusion: The majority of landscape changes focus on adaptation and mitigation responses, and alterations to landscape change between UKCIP02 and UKCP09 are subtle resulting in no requirement for alteration to photomontage.		

Table 6.5 Firth of Tay implications for photomontage

Landscape changes illustrated under UKCIP02	Possible alterations to illustrated landscape changes under UKCP09	Implications for photomontage under UKCP09
Reduction on snow lie on distant mountains (DIRECT)	No data	
Expansion of woodland to increase carbon sequestration (MITIGATION)	Mitigation activity – no change	
Reinforcement of the National Grid to serve renewable energy schemes (MITIGATION)	Mitigation activity – no change	
Windfarm to provide low carbon power (MITIGATION)	Mitigation activity – no change	
New flood defence embankments adding to the loss of natural estuary shoreline (ADAPTATION)	Sea level projections are increased, however the impact of increased winter precipitation in combination with sea level rise resulting in flooding in inner estuaries is slightly reduced. The changes are illustrative rather than representing an accurate picture of projections for a given date. The pattern of change is unlikely to alter.	No alteration to photomontage required.
Rise in sea level resulting in loss of reedbeds, island and riparian trees (DIRECT)	See above	No alteration to photomontage required.
Introduction of new crops including biomass (ADAPTATION)	Pattern of change remains similar	No alteration to photomontage required.
Further intensification of farming – loss of hedges, introduction of new buildings (ADAPTATION)	The extent of loss of hedgerows and trees as a result of stress from higher winter rainfall may be reduced. The factors influencing introduction of new buildings do not significantly change.	No alteration to photomontage required.
Conclusion: None of the illustrated changes would be significantly altered by the differences between the 02 and 09 projections.		

Implications for conclusions

6.10 Phase 1 of the research concluded that ‘overall, human mitigation and adaptation measures may have a more significant influence on landscape character than the direct effects of climate change’. The report also concluded that: ‘the combined influence of these direct, mitigation and adaptation changes may be greatest in lowland and coastal landscapes reflecting the dominance of land management, settlement and land use in shaping landscape character and the likely impact of changing sea levels’.

6.11 The UKCP09 projections suggest that some changes (notably temperature increases and sea level rise) are likely to be more pronounced than previously indicated, that others (notably winter rainfall increases) are likely to show a mix of higher and lower impacts in different parts of the country, and some may show less pronounced patterns of change (notably summer rainfall decreases). Our analysis suggests that these differences are likely to influence a number of the potential landscape changes explored within the Phase 1 Interim Report, but that any differences are likely to relatively localised. In some cases the direct impacts are likely to be less pronounced, though around the coast they are likely to be more severe, particularly in the west where there is likely to be greater sea level rise, higher temperatures and higher winter rainfall than previously suggested. In the east (away from the coast), it is likely that the effects will be less pronounced, with higher temperatures being countered in some cases with less severe changes in rainfall.

6.12 Overall, we believe that these two key conclusions remain valid, though some of the detail underpinning them has changed.

6.13 Conclusions about the effects on wildland qualities also remain valid, though again some of the detail of the changes is now slightly different. These areas are potentially affected by warmer summers and winters, less snow but less pronounced changes in rainfall, except in the west.

6.14 Overall conclusions about the effects on ecosystem services remain largely unchanged, as does the conclusion that ‘climate related landscape change will have some of the greatest impacts in those areas where people live and work’.

7 PRESENTATION OF UKCP09 DATA IN UPDATED PHASE 1 INTERIM REPORT

7.1 There are a number of options for highlighting the inclusion of UKCP09 data in the updated Phase 1 report. The option chosen must be clear enough to consistently alert the reader to the different data source, but not unnecessarily distracting.

- Use of colour highlighted text or *italicised text*

  Use of boxed text

- **Use of symbols surrounding updated text**
- Inclusion of additional columns in tables (as used in this report)
- Colour coded highlighting within tables
- The addition of a symbol in the margin (and in table column headings and on figures) to indicate where the findings are based (fully or partially) on the UKCP09 data. Candidates for such a symbol are presented in the right hand margin.

7.2 The use of colour highlighting or tables could make it difficult for the document to be photocopied. However, due to the size of the Phase 1 report, and current extent of colour use it is anticipated that the majority of users would use an electronic version of the report in preference to a hard copy. We are also concerned that the use of italics, boxed text or symbols within the body of the text could be distracting to the reader and disrupt the flow of the document. Our recommendation was the use of a symbol in the margin and our preference was for the '09' icon. These recommendations were accepted by the steering group.

References

UKCIP02 Climate change projections - http://www.ukcip.org.uk/index.php?id=161&option=com_content&task=view

UKCP09 Climate change projections - http://ukclimateprojections.defra.gov.uk/

SNIFFER (2008) Coastal Flooding in Scotland: a Scoping Study (project FRM10)

SNIFFER (2008) Coastal Flooding in Scotland: Updated Summary Nov 09 (project FRM10)

ANNEX 1

UKCP09 Probabilistic Projections

Figure A1.1: Mean temperature, medium emissions, Eastern Scotland, UKCP09,

Eastern Scotland

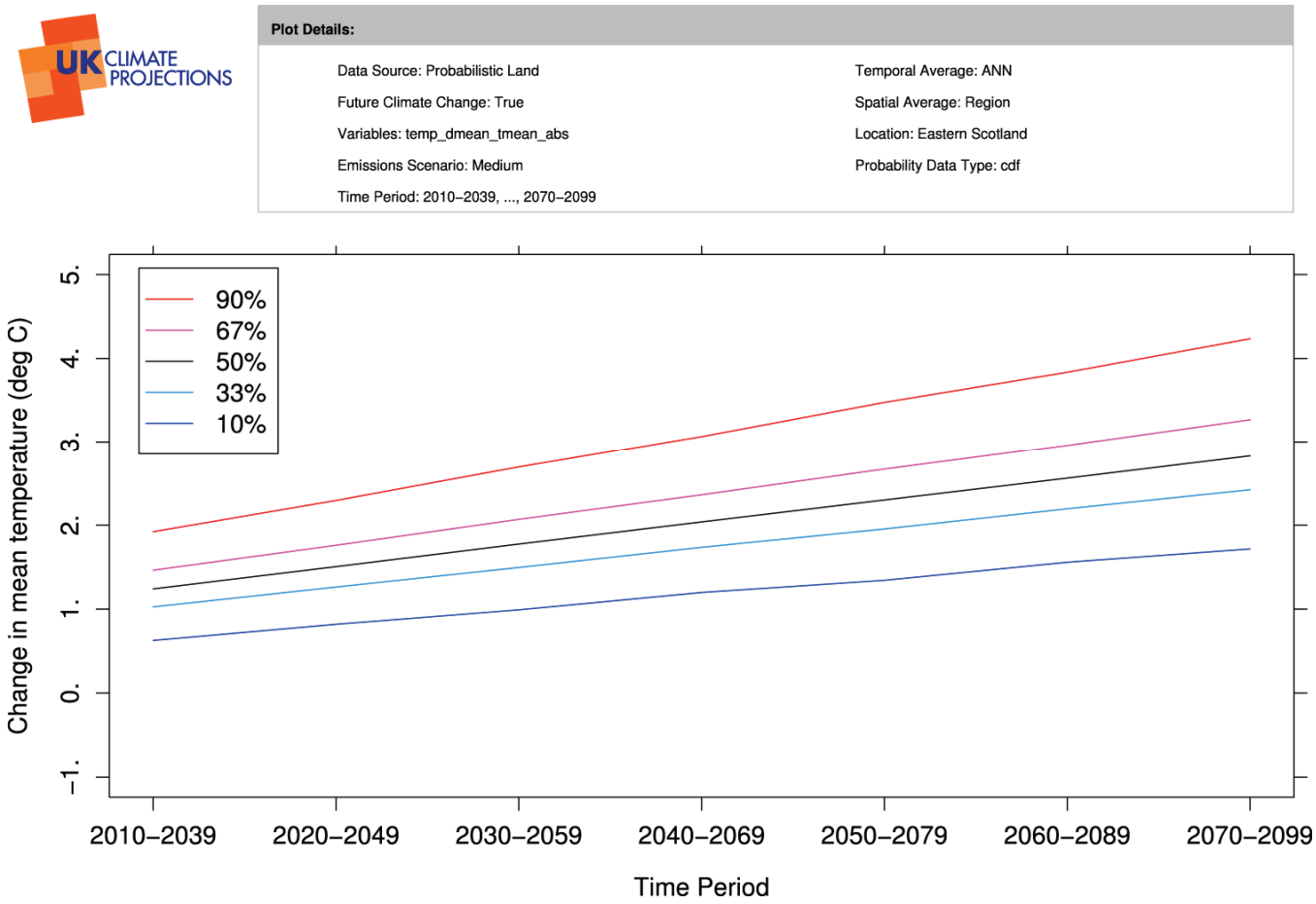


Figure A1.2: Mean temperature, medium emissions, Northern Scotland, UKCP09

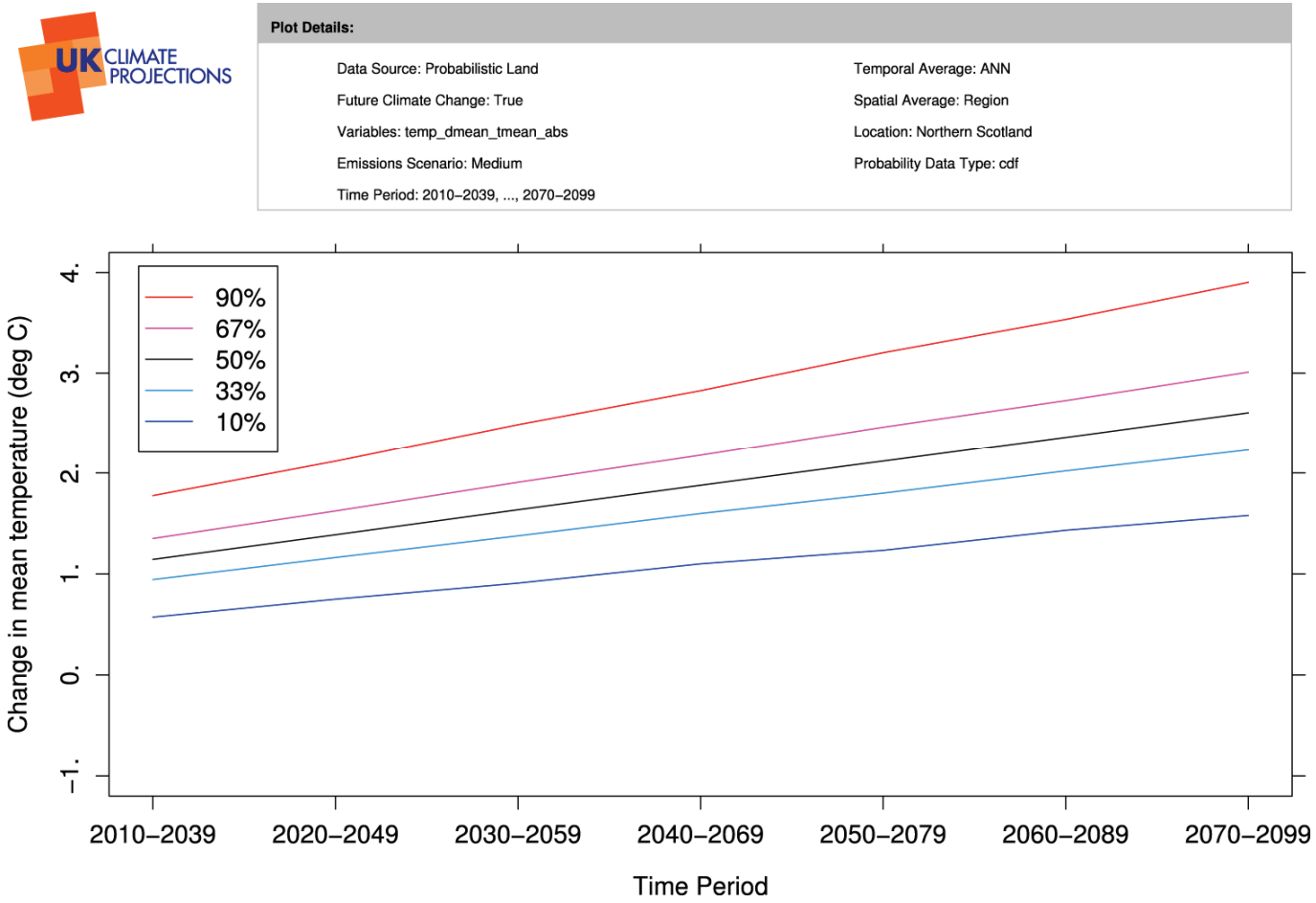


Figure A1.3: Mean temperature, medium emissions, Western Scotland, UKCP09

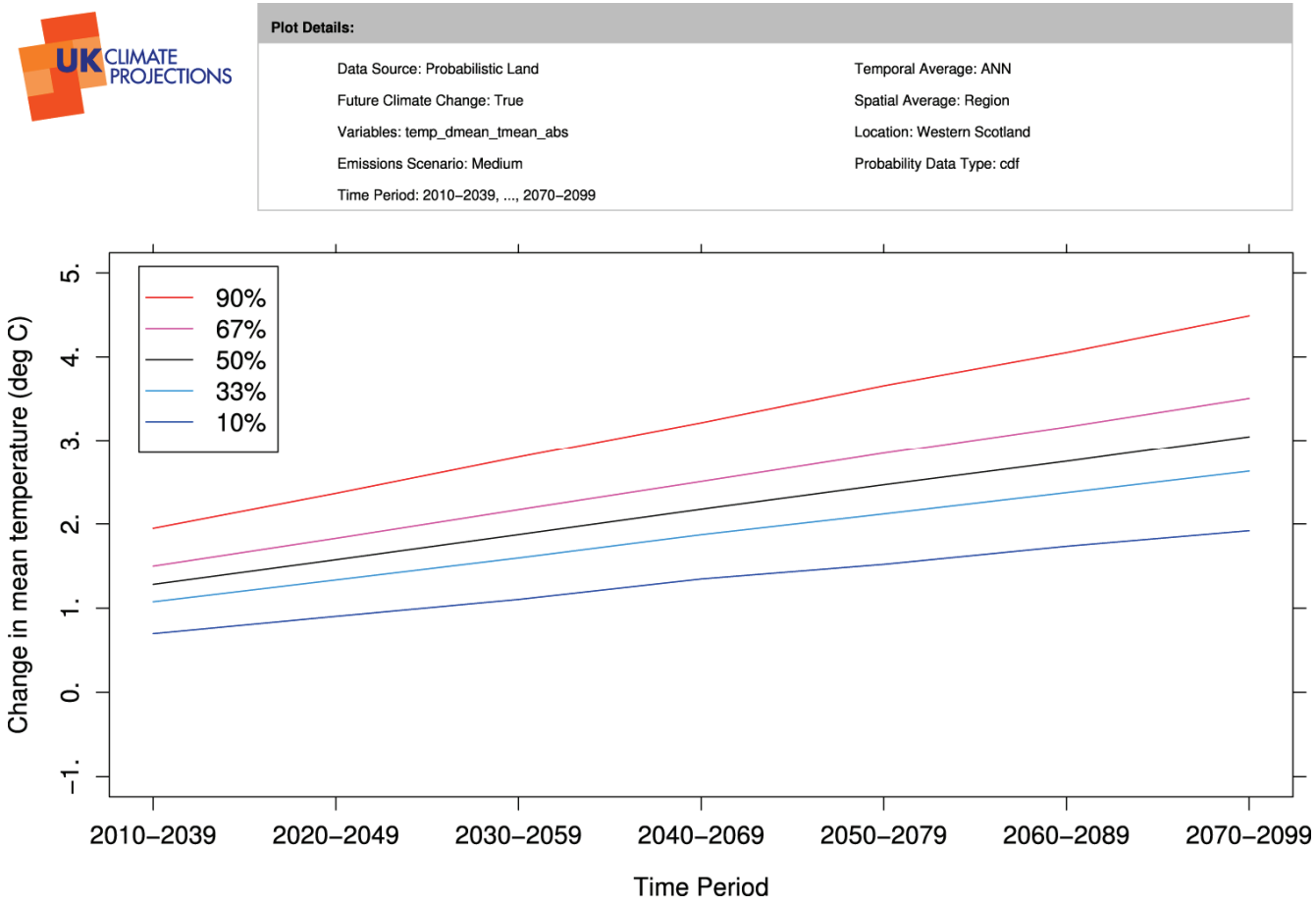


Figure A1.4: Summer precipitation, medium emissions, Eastern Scotland, UKCP09

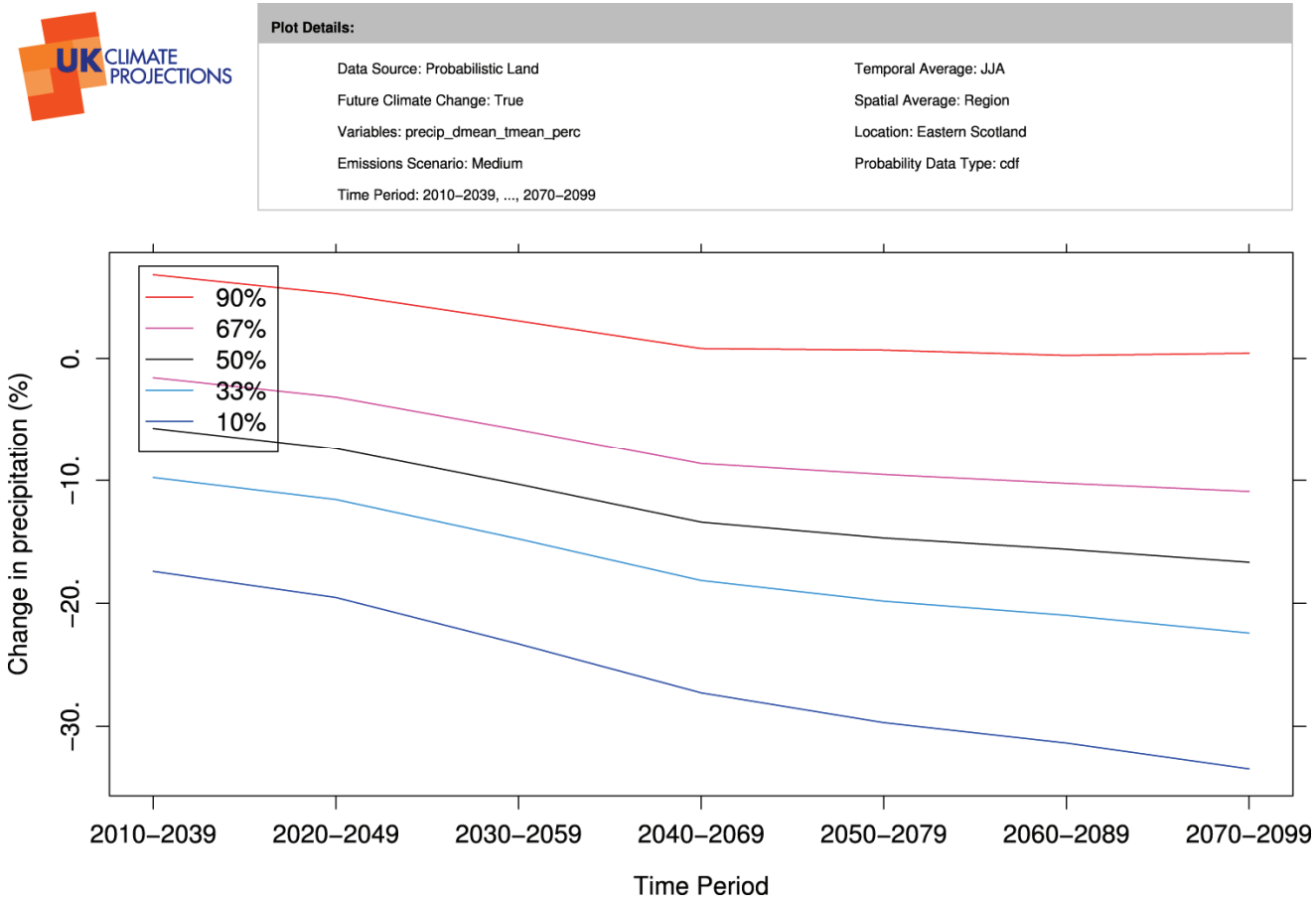


Figure A1.5: Summer precipitation, medium emissions, Northern Scotland, UKCP09

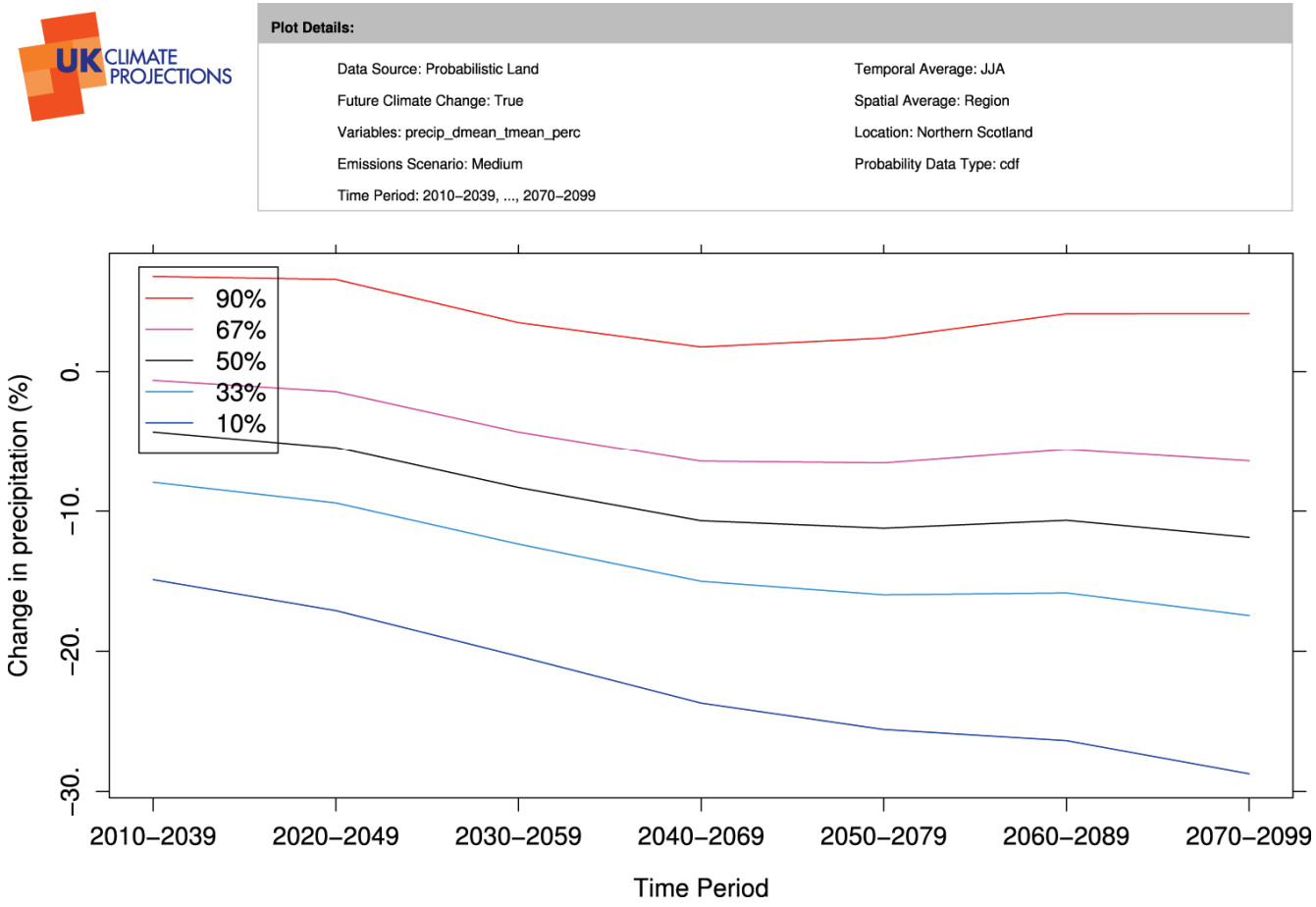


Figure A1.6: Summer precipitation, medium emissions, Western Scotland, UKCP09

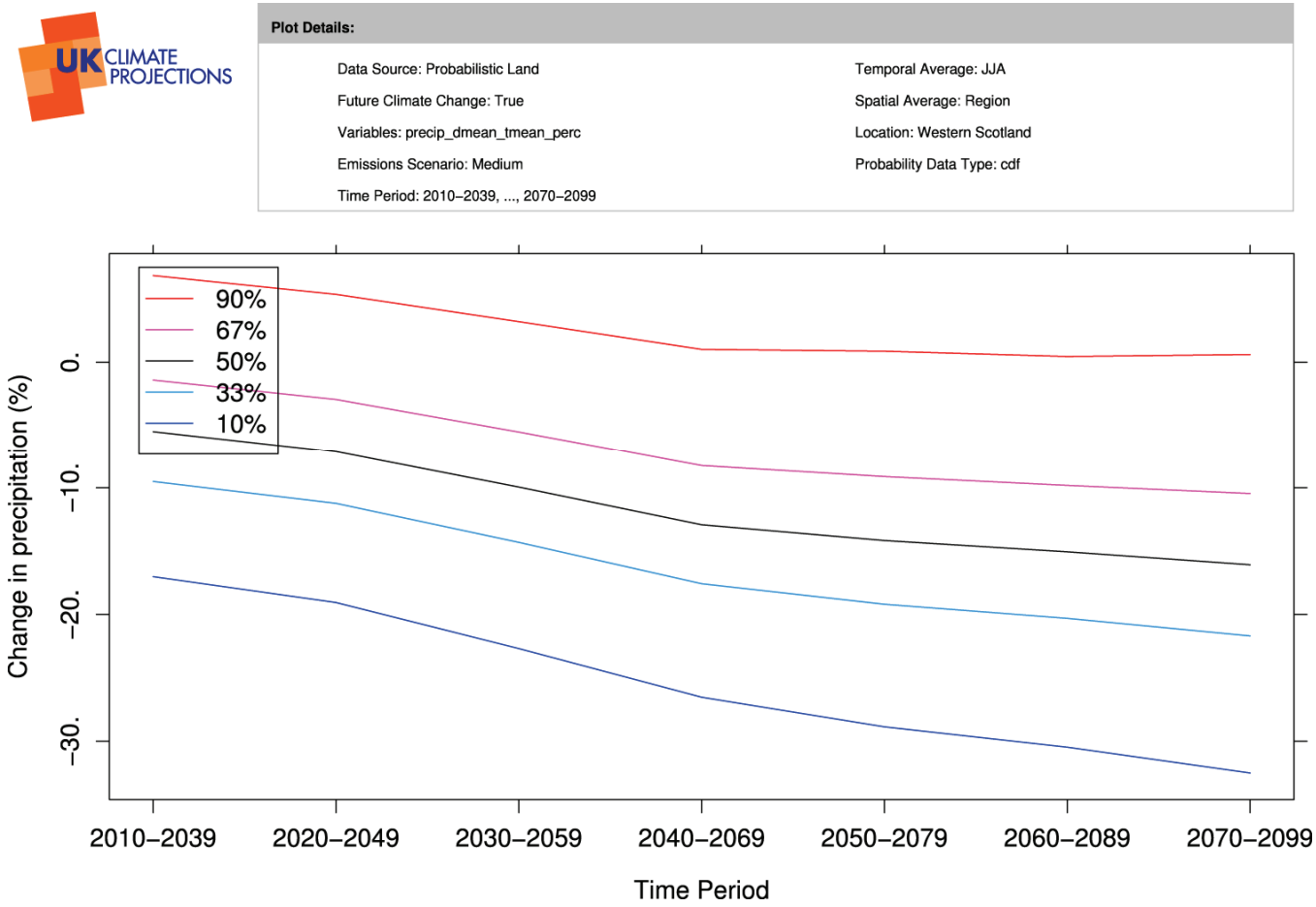


Figure A1.7: Winter precipitation, medium emissions, Eastern Scotland, UKCP09

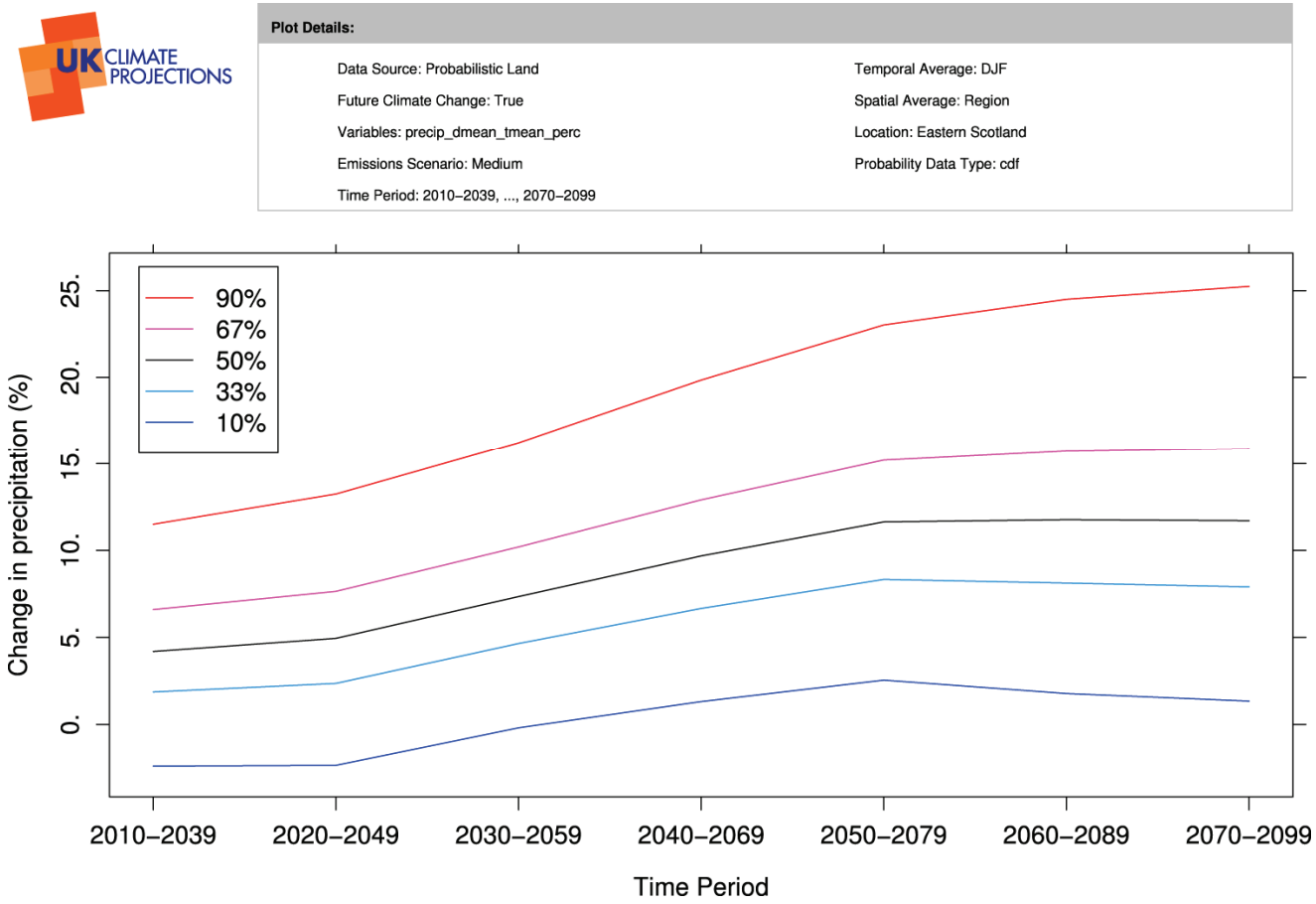


Figure A1.8: Winter precipitation, medium emissions, Northern Scotland, UKCP09

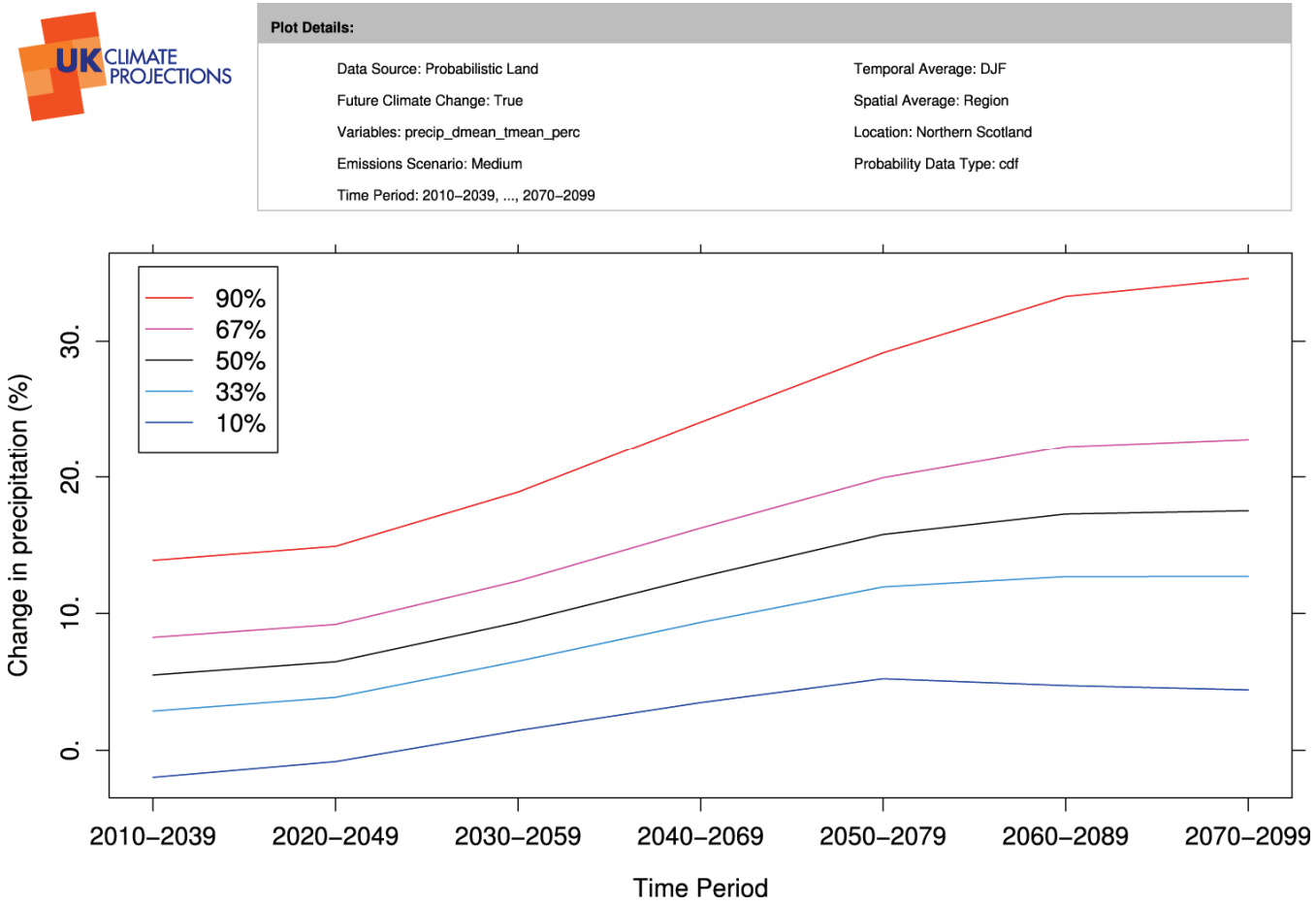
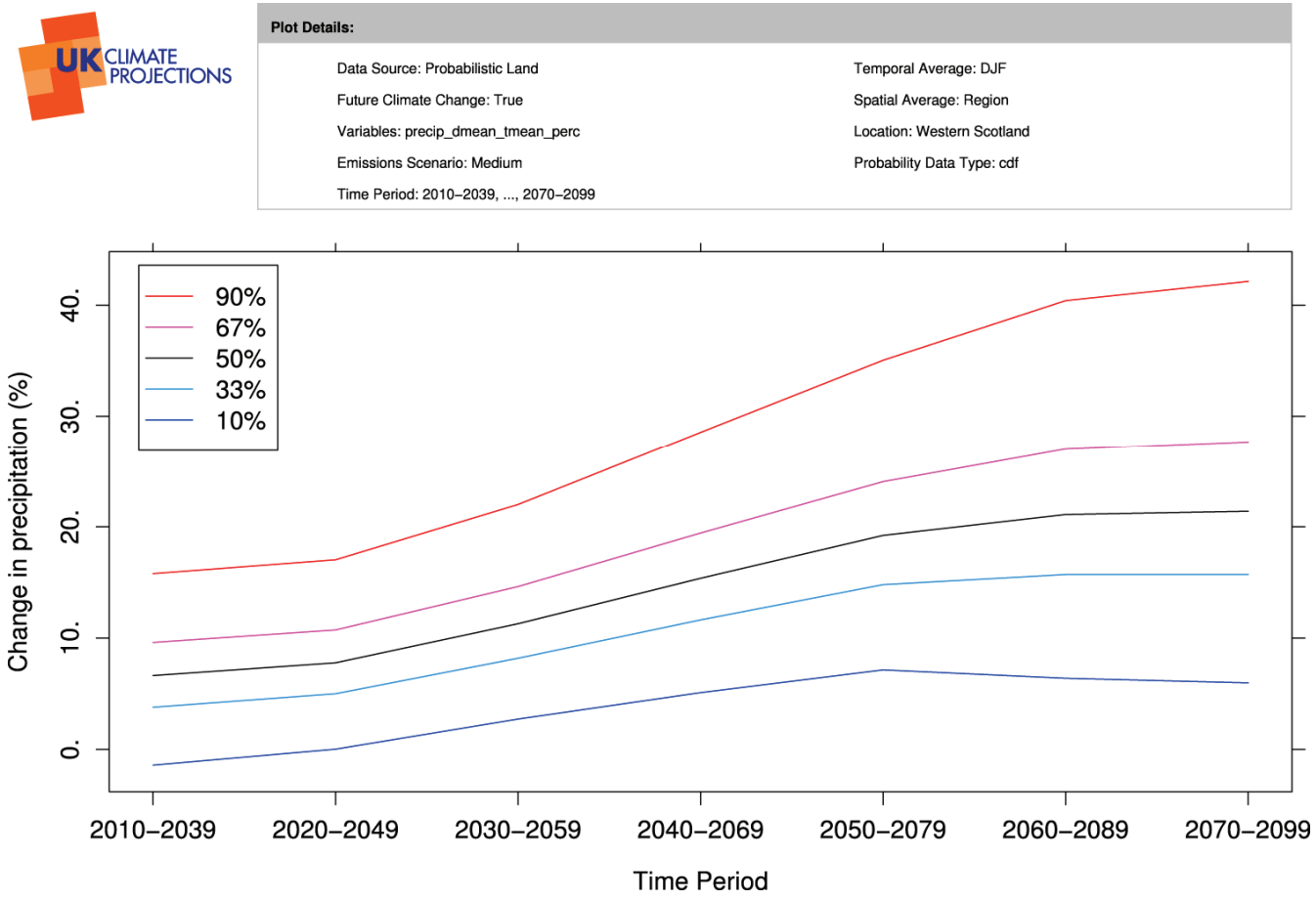


Figure A1.9: Winter precipitation, medium emissions, Western Scotland, UKCP09



ANNEX 2

Advice from Scottish Climate Change Impacts Partnership

Box 1 : Initial queries from LUC (black, normal text) and advice from SSCIP (italic, red text)

Dear Joe
Your name has been given to me by Deb Munro and Clive Mitchell at SNH. I wondered if you would be able to provide some advice on research we have been carrying out using UKCIP02 projects which we now need to review in the light of the 09 projections.

Land Use Consultants (LUC) carried out a research project in 2008/9 for SNH into the likely implications of climate change on the Scottish landscape at national, case study regional and local levels.
Our national analysis drew on UKCIP02 climate change projections. We carried out a comparatively simple analysis based on:
- the identification of potential impacts of climate change (e.g. summer drought affecting some tree species) based on literature review and input from our steering group
- GIS mapping of the landscape feature in question (e.g. deciduous woodland)
- GIS mapping of relevant climate change variables (e.g. summer rainfall and summer temperatures)
- combination of these layers to identify areas where there are concentrations of the landscape feature and the most pronounced climate change

Our mapping converted all data to a 5km grid and placed climate change variables on a percentage scale. We recognise that this was a simplistic approach and have used it to illustrate rather than predict where and how much change could occur.

You need to take extra caution when using UKCP09 in this kind of situation… especially due to the lack of spatial coherence between grid cells and should you try to combine variables. Hard to comment further without knowing more about your methodology

We are now moving into the second phase of the study and our first task is to review the above work in the light of the UKCP09 projections and to rerun any GIS analysis where there are significant differences between the two sets of projections.

My initial reading of the UKCP09 website suggests that:
- the two sets of projections are not directly comparable since the 09 data are presented as probabilistic projections, but the 50% likelihood projections are most 'similar' to the 02 data

You are right, they are not directly comparable. While the 50% likelihood may be roughly 'similar', the UKCIP02 numbers were from a single model run, and their equivalent might fall anywhere… although this is usually (hopefully!!) towards the centre of the UKCP09 distribution… in Scotland there is a greater divergence between the central estimate in 09 and the 02 value… so you will need to be careful.
http://ukclimateprojections.defra.gov.uk/content/view/617
NB: check the emissions scenarios used are compatible as well.

- some 09 data variables are higher or lower than those in 02. Our initial proposal is that we provide a commentary on these rather than rework the maps which would show little difference in the spatial patterns of change

This seems reasonable if the difference in 02 09 doesn't seem to have significant consequences for your project.

However, I'd encourage you to consider what impact the wider range of uncertainties included in the UKCP09 projections might have (e.g. 67% or 90% prob. levels)… this will depend on the sensitivity and risk tolerance you have in your systems. Using just a 'central

estimate' as a single (deterministic) value can lead to 'brittle' adaptation strategies… one of the key advantages of UKCP09 is that it allows you to address a range of climate scenarios.

- some 09 data show different spatial patterns (e.g. winter rainfall where some areas such as the Cairngorms now show a decrease). We think these variables are the key ones for us to concentrate on in any reworking of our GIS analysis since the interaction with 'landscape features' is likely to be different from that previously identified.

Again, seems reasonable approach… but would encourage also looking at impact of range of uncertainties / probability levels.

It would be very helpful if you were able to provide any advice you may have on updating or reviewing previous analysis in the light of the new projections.
Have there been any systematic comparisons of climate change variables from the two projections (subject to qualifications of course)?

UKCIP is working on something that looks at this a little… we'll probably try and do something from SCCIP as well, but this may take some time.

Are there any views on the rights or wrongs of partial updating (i.e. relying on data from both 02 and 09)?

As long as you are clear as to which you are using, and preferably have justified why you've decided it's not necessary to update everything to UKCP09, then this shouldn't be a problem. Many users will find it's not viable/justifiable to rerun models etc if there is unlikely to be much change. Of course in the end it comes down to the judgement of the individual organisation.

Are you aware of other researchers undertaking this kind of updating exercise?

AQWA (?) or something along those lines has produced something, but only available to members. I'm sure others are looking at this, natural England for example, but I don't know what progress they have made, or if they've begun.

Box 2 Comments from SCCIP on LUC draft report

It's really interesting to see someone evaluate the differences in UKCIP02 and UKCP09 in this way, I'm not sure too many people have attempted this yet. As we discussed, it appears that there is a far greater need for such evaluation in Scotland (compared to southern England for example). I have had discussions with Roger Street (technical director) and others at UKCIP about this over the last few weeks, and we will look to provide some further guidance on this in the near future.

I haven't had a chance to look carefully at your evaluations/analysis, but they generally seem to be along the right track (winter precipitation and summer temperatures). I do think there is much more that could be got out of using probabilistic data from UKCP09 in this area (e.g. risk and thresholds), but obviously that is beyond the scope of this project (perhaps something for SNH to consider in the future).

I've made a few quick notes on the report as follows:

[1.6] The 'decades' in UKCIP02 were also for the centre of a 30-year interval (i.e. 2020s = 2011-2040)* it just provided three time slices rather than 7 overlapping ones.

[1.6] The emissions scenarios are based on IPCC SRES* the high (A1F1) and low (B1) scenarios are the same in '02 and '09* the medium scenarios are different.

[1.6] I realise that you get this concept, but don't think you should use 'most similar', at least not with likely in front of it (maybe similar?)

http://ukclimateprojections.defra.gov.uk/content/view/617

[1.10] One of the most interesting things that UKCP09 allows is for risk to be associated with key 'thresholds' in your system* for something like ecosystems this would be a very interesting aspect* although quite possibly beyond the scope of your project.

[2.ALL] General comment * be clear if you are using the central estimate from UKCP09 * and it is not necessarily the 'most likely'* we try to encourage the presentation of a range as well if possible (for example put it in brackets after the central estimate).

[2.Figs] Not entirely sure how these were generated in the end* I'll just reiterate that you shouldn't average/interpolate values between UKCP09 grid cells as there is not spatial coherence* I presume these are using your own 5km grid.

[2.31] The central estimate doesn't have a 50% probability of occurring* it is just the centre of the distribution* may seem like a technicality, but it is important.
http://ukclimateprojections.defra.gov.uk/content/view/534/9/

[3.3] It will be interesting to see how/if this works* but yes, as a pragmatic response it seems reasonable* also note, that there are difficulties if you try and combine variables using UKCP09 data, I'm not sure it you are trying to do this* the met office is currently producing a technical note on wind speed from UKCP09, as you may of noticed they are not present at this time.

Box 3: Further issues and questions raised by LUC in response to Steering Group comments on the draft report. LUC (black, normal text) and advice from SSCIP (italic, red text).

I think there are two substantive issues for us to address:

- the first is how we go about translating the UKCP09 data onto our 5km grid. Recognising that interpolation between grid cells is a no-go, we are proposing an alternative based on taking the relevant 09 figure from the centrepoint of each of our 5km cells. I suppose this may blur the transition a little, but we are interested in fairly strategic patterns, so think this may be ok?

That is the same approach that I've been using in GIS. I imagine that it will be rare that this causes significant problems, perhaps only where the centre point is near the boundary of '02 cells, and topography/scaling is highly variable. For your purposes I don't think this would be much of an issue.

- the second concerns the combination of different 09 variables. From your email I understand that it is not appropriate to combine different variables to illustrate, for example, where it is likely to be drier and hotter? This does have some implications for our analysis since we used GIS to identify areas where the degree of change for one or more climate change variables was combined with the presence of a particular feature. The only way around this would be to present separately maps of the relevant 02 and 09 variables and a commentary on what the differences mean for our 02 analysis. Does this seem like the most sensible way forward?

The issues arise from the additional information in UKCP09 probabilistic distributions for variables. Taking a probability level for one, does not necessarily mean that the same level (or even direction of change) will be appropriate for another… kind of difficult to explain… but say 85% temperature does not necessarily relate to 85% level for precipitation, which could go the other way…

To explore variation of multiple variables, UKCP09 has 'Joint Probability' function which lets you look at combinations of two variables…

http://ukclimateprojections.defra.gov.uk/content/view/1932/517/

I believe you can also explore multiple variable combinations using the LINK 11-member RCM data, but this will be beyond the scope of you current project.

Producing separate maps, and commenting on any difference you observe seems reasonable for your current project, again limited if you use only central estimates…

Our original analysis focused on the 02 medium/high emissions scenario. Our analysis to date has focused on comparing this with the 09 medium emissions scenario, recognising that the two are not directly compatible. While we could carry out a limited comparison (perhaps based on the more comparable High and High emissions projections) to highlight where there are significant differences in the projections for Scotland, the issue becomes a little trickier for any rerun of our earlier analysis, since they are all based on the 02 medium/high emissions scenario...

We are not going to be able to re-run all this analysis again, so I think the pragmatic alternatives are:

a) to keep the comparison of 02 medium/high and 09 medium emissions scenarios, but to highlight the compatibility issues in the accompanying text. This could underplay any increases and overplay any decreases in the 09 projections;
b) to bracket the 02 medium/high emission scenario with comparison of the 09 medium and high projections. Differences between the 02 and 09 based analysis would be based on 'eyeball' analysis of these maps rather than anything more GIS based. This feels like the most robust solution, though visually will be less powerful. It also sits more comfortably with your advice about not combining different 09 variables.

It does make things a little tricky when doing this kind of comparison that the emissions scenarios have changed. Figure 2.13 is a good illustration of the differences. It is worth noting that there is not much divergence due to emissions scenarios until after 2050 or so… see figure 2.14 on the same page.

http://ukclimateprojections.defra.gov.uk/content/view/2032/

A number of people in our steering group have questioned the validity of using the 90 and 10% probabilistic projections to test the robustness or brittleness of our conclusions. I had understood this was one of the benefits of the probabilistic approach and also taken this from our phone discussion, and have included as per the attached paragraph. Could you confirm you are happy with this general approach?

UKCP09 advises against using probability levels outside of 10% and 90%.

http://ukclimateprojections.defra.gov.uk/content/view/1935/517/

It is quite a complex methodology used to create the probabilistic projections, and due to the way it is produced I understand that there is less information provided by the model runs to constrain extreme values outside this range. It is worth noting that it is not the same as distributions generated by sampling from a natural population (say as an ecologist would do) where extreme values would have greater validity. Full explanation would be quite technical, and probably require discussion with modellers themselves.

Looking at range of probability levels does indeed provide a more robust assessment of risk… results outside the 10-90% range are considered very unlikely. If you only use 50% level, then even if it passes, you don't know at what level it might fail (say 65%?).

The choice of what probability levels to use is really dependent on the user and their attitude to risk, 10/90% is commonly used as these are the widest recommended levels, but you may find some other level more appropriate.

ANNEX 3

Tayside Photomontage Analysis

Note: columns 1 and 2 are taken from the Phase 1 Interim Report. Column 3 has been added as a commentary on the implications of UKCP09 projections

Table A3.1 Killiecrankie: Description of climate change influenced landscape change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Topography and Geology: Extensive upland area with spurs orientated south, separating main glens. Hills are generally more rounded than to the west and rocky outcrops are fewer. Hill summits range from 400 to 1000m AOD. Glens with wide flood-plains (around 0.5-1km across). Valley floor is around 50-200m AOD and valley sides are elevated to around 500m AOD. Harder rock has created a number of gorges and falls. A number of glacial deposition features.	**Topography and Geology:** The physical structure of this landscape may remain largely unchanged, though the localised patterns of erosion and deposition may change.	**Topography and Geology:** Minor implications for local patterns of erosion and deposition as a result of slightly different rainfall projections
Forests and woodlands: In the uplands there are a few areas of semi-natural broadleaf woodland up to 600m AOD. Small areas of coniferous plantation are generally limited to below 450m AOD. Within the glens, extensive broad-leaf woodland (semi-natural on steeper slopes and managed estate woodland), mixed and coniferous woodland on valley sides, much of it associated with estates.	**Forests and woodlands:** The uplands may see some expansion of semi-natural woodland reflecting the improved climatic conditions.	**Forests and woodlands:** Less extreme reductions in summer rainfall, allied to higher summer temperatures could support further woodland expansion.

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Freshwater Systems: Large rivers meander across the floodplain and flows down incised narrow channels, most notably the pass of Killiecrankie. Networks of smaller burns and tributaries draining upland areas.	**Freshwater Systems:** Within the main glen, flood management includes the rewilding of some areas of floodplain to provide storage for flood water, and the use of engineered measures to protect property and infrastructure, particularly around settlements such as the village of Killiecrankie. In the upland area, some rewilding has been undertaken to reduce the speed of run-off, but there is evidence of increased erosion along stream corridors and the loss of some peat where damage has occurred as a result of summer drying and winter erosion.	**Freshwater Systems:** Winter rainfall increases will be lower than previously suggested, potentially reducing the requirement for upland and lowland flood management and defence measures.
Urban and Peri-Urban: Within the glens, well settled villages, large estates and some planned villages. Some uniform style and layout settlements. Small estates of distinctive landscape and architecture. General traditional use of building materials including granite, schist, slate and some sandstone.	**Urban and Peri-Urban:** Small settlements within the glen may make increased use of small scale renewables.	**Urban and Peri-Urban:** no change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Tourism and Recreation: Historically the area has attracted tourists from 19th Century onwards. Estates, castles and settlements are popular tourist destinations. The Pass of Killiecrankie itself is an important attraction, and the landscape of the Loch Tummel NSA an important recreation resource. Upland paths provide opportunities for informal recreation, walking and climbing. Appreciated for its panoramic scenic and wild views. Landscape used for game and stalking. Some cross-country skiing opportunities.	**Tourism and Recreation:** Better summer weather may mean the uplands are increasingly used for informal recreation.	**Tourism and Recreation:** Summers are likely to be warmer but not quite as dry as previously projected. This could reduce the expansion of informal recreation.
Infrastructure: The glen provides important communication routes through the Highlands (A9(T) and railway). Several telecommunication masts. Electricity transmission lines pass along the glen.	**Infrastructure:** Further measures are likely to be implemented along both the A9 and the railway corridors to minimise the risk of disruption through landslides, including slope engineering and debris shelters.	**Infrastructure:** Possible reduction in the requirement for slope stabilisation measures along transport corridors to cope with increases in winter rainfall.

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Natural and semi-natural habitats: Within the uplands, below 600m AOD, heather moorland of dry and wet heath is the dominant habitat. Above 600m AOD montane heaths and grasslands predominate, with some areas of rich arctic-alpine flora. Gentle slopes tend to have blanket bog, with the peat at least 1m deep. Vegetation patterns closely reflect altitude, exposure and underlying geology, and the area is managed for grouse shooting, red deer and sheep grazing. Native ancient and semi-natural woodland is concentrated within the glens, particularly on steeper and less accessible slopes. Some gorge vegetation is found within the Pass of Killiecrankie.	**Natural and semi-natural habitats:** Likely enhancement of woodland based habitats within the glens and expanding onto middle hill slopes. Below 600AOD, the amount of heather within the moorland vegetation declines as soil conditions change, and tree planting also causes some loss of heather moorland. Above 600 AOD the rich arctic-alpine flora has disappeared or is much reduced with grasses invading these habitats. There is a noticeable movement of flora and fauna to elevations and latitudes not previously tolerated. However there is uncertainty relating to the interaction of direct and adaptation responses on habitats.	**Natural and semi-natural habitats:** Increase rates of warming and less pronounced rainfall changes could have subtle influence on this. However, the level of uncertainty about the response of semi-natural habitats is such that it is not possible to draw any conclusion about the implications of the differences between UKCIP02 and UKCP09 projections
Agriculture: Some arable farming on lower/mid valley sides and drained valley floor. Pasture on glen floor and upper slopes. Large and rectilinear fields occupy glen floor. Medium and rectilinear fields occupy gentler glen slopes. Shelterbelts and post-and-wire fences act as field boundaries on the floodplain. Hedges, trees and walls are used as field boundaries on glen slopes. The general structure of field boundary trees is in decline. Upland areas are characterised by rough and unimproved pasture giving way to heather moorland managed for grouse, deer and sheep.	**Agriculture:** Farming is not likely to be significantly changed.	**Agriculture:** No change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Historic Environment: Within the glens there are numerous historic features including castles, fortified manor lodges and estate features e.g. Blair Castle and Blair Atholl and the associated gardens and designed landscapes. There are traces of General Wade's Military Road and, within the upland areas, evidence of historic routeways, former shielings and historic field patterns.	**Historic Environment:** The expansion of woodland may have an impact on the historic structure of the landscape and, potentially, on historic sites such as shielings, trackways and other remains. The introduction of wind turbines and electricity transmission lines will impact on the setting of historic structures, buildings and landscapes.	**Historic Environment:** No change.
Protected Landscapes: The landscape includes part of the Loch Tummel National Scenic Area.	**Protected Landscapes:** The impacts on the identified 'special qualities' of the Loch Tummel NSA are explored in more detail at the end of this section. The conclusions of this exercise identified that although there will be some changes to the landscape character, diversity is one of the qualities of the landscape which also makes it more resilient to potential climate related landscape change.	**Protected Landscapes:** conclusions remain unchanged

Table A3.2 Strathmore: Description of climate change influenced landscape change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Topography and Geology: Glacial erosion has formed broad straths and a complex landscape of glacial deposition including outwash terraces, eskers and dry valleys. Strathmore is up to 10km wide.	**Topography and Geology:** The physical structure of this landscape may remain largely unchanged.	**Topography and Geology:** No change
Forests and woodlands: Overall there is a limited extent of woodland. Broad-leaf woodland is limited to inner policy woodland and a few areas of unimproved land. Coniferous plantations can be found on areas of poorer land, especially glen sides. Native birch woodland is located on pockets of unimproved land. Existing policy and estate woodland. There is a trend of tree loss due to lack of management and replacement planting.	**Forests and woodlands:** Strathmore could experience an accelerated loss of its characteristic field boundary trees as a result of the stress caused by drier and warmer summers and wetter winters. They could also be lost as a result of agricultural intensification, particularly if it results in further field amalgamation. On the other hand, the area could see the development of shelterbelts and forest habitat links, designed to connect habitats across the intensively farmed strath, and provide shading and shelter for crops and stock. The choice of tree species may change with an increasing use of beech and sycamore. Where productive forestry occurs it is less likely to comprise sitka spruce. The overall effect may a change from a well treed arable landscape, to a landscape comprising contrasting areas of open arable farmland and more wooded corridors or belts.	**Forests and woodlands:** The loss of characteristic field boundary trees may differ as summers become even warmer, but less dry. The extent of this difference is uncertain and may not be substantial. Other changes are unlikely to be affected.

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Freshwater Systems: Undersized glacial misfit rivers occupy the glen floor. Existing flood defences are located along rivers.	**Freshwater Systems:** The risk of flooding along key river corridors, part-icularly those draining upland areas to the north, may increase, leading to a combination of hard flood defences around settle-ments and rewilding of river floodplains where this is compatible with inten-sive agriculture. Patterns of erosion and deposition, together with localised river alignments, may change. In summer, low flow conditions may be more common, with inc-reasing levels of pollution, and implications for fisheries and other fresh-water habitats and species as a consequence.	**Freshwater Systems:** The risk of flooding may be reduced as a result of less substantial increases in winter rainfall, though extreme events are likely to remain an issue. Summer low flow issues are likely to be slightly less severe.
Urban and Peri-Urban: Settlements are small, often planned villages, and some small market/processing towns and larger market towns. The 19th century saw a growth in market towns, e.g. Coupar Angus, Forfar. Some recent modern house building expansions are found on settlement edges. Outside settlements, development is limited to scattered farmsteads and agricultural buildings. Vernacular building materials are predominantly red sandstone.	**Urban and Peri-Urban**: Settlements are generally small and rural, so measures to improve urban liveability in the face of rising temperatures may be limited. There may be an increase in the use of micro-renewables throughout the area, most visibly taking the form of roof-top solar collectors and small scale wind turbines. The use of solar collectors could have a local impact on the character of traditional buildings within the landscape. Small turbines would increase the area's 'developed' character. The emphasis on energy efficiency may result in novel building styles or materials, especially outwith Conservation Areas.	**Urban and Peri-Urban**: No change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Tourism and Recreation: Generally limited opportunities for tourism and recreation reflecting intensive agriculture, although some use for golf. Occasional historic features provide tourist destinations.	**Tourism and Recreation:** Strathmore is not a major recreation area, though improved summer weather conditions could lead to an increase in local informal recreation activity and creation of local access routes. New recreation facilities may be created inland to replace resources such as golf courses lost as a result of sea level rise and coastal erosion. However, issues such as competition for land for agricultural production may affect recreation provision.	**Tourism and Recreation:** Minor changes in emphasis due to warmer but slightly less dry summers than previously projected, but the potential for greater knock-on effects with increased levels of sea level rise.
Infrastructure: Some important road connections, e.g. A94, pass through this landscape. There is a network of relatively long straight minor roads between fields. Roads are relatively visible within this flat, open agricultural landscape. Electricity transmission lines are present.	**Infrastructure:** The area could see the development of single turbine or small to medium size windfarms and the upgrading of electricity transmission lines. Close to settlements there is also potential for small or medium sized biomass plants, food processing centres, and combined heat and power plants. However, there is uncertainty surrounding the energy mix in 2050.	**Infrastructure:** No change
Natural and semi-natural habitats: Habitat interest is limited to a few unimproved areas. Most land is cultivated for arable production with some field boundary trees and hedgerows.	**Natural and semi-natural habitats:** The creation of woodland belts would contribute to habitat networks, though the biodiversity of this intensively farmed area could remain comparatively low.	**Natural and semi-natural habitats:** No change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Agriculture: Arable agriculture dominates this landscape – cereals, potatoes and oil seed rape. Some arable cultivation has occurred on floodplains. There is limited pasture (mostly of pig farming). Fields are medium sized and regular, some enlarged, most dating back to parliamentary enclosure. Field boundaries are characteristically hedges with a high density of mature hedgerows, however intensification of farming has led to some removal. Agriculture has led to large modern agricultural buildings (especially potato stores) which are often light in colour.	**Agriculture:** the existing pattern of arable and horticultural cultivation is intensified. It is possible that there is a changing composition of crops, with heavily water dependent crops such as potatoes, moving away from drier areas, and a wider range of crops, including oil seed rape and energy crops such as miscanthus grass, increasing in extent. Market conditions, and the levels of incentive for biomass and bioenergy crops will influence the relative balance of crops. It is likely that productivity will increase, leading to a requirement for new, larger storage and processing buildings. Warmer, drier summers may result in the wider use of irrigation equipment including mobile booms. Demand for water may exacerbate low flow conditions in water courses in summer.	**Agriculture:** Potential for slightly reduced need for summer irrigation, and less severe low flow in water courses.

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Historic Environment: Limited number of landscape features due to intensity of agriculture. Some historic houses, estates and surviving Pictish standing stones and other monuments, also historic villages. The structure of this landscape dates back to the enclosure and agricultural improvement movements of the eighteenth and nineteenth centuries.	**Historic Environment:** Agricultural intensification could result in the weakening of the historic structure of this landscape as field boundaries and trees are lost. Modern infrastructure and buildings would underline the intensive, almost industrial nature of this landscape. There may also be changes to the fabric of historic buildings resulting from management of rainwater, increased salt contamination and accelerated decay of vulnerable stone, and increased biological growth on stone.	**Historic Environment:** Minor differences resulting from less pronounced increases in winter precipitation.

Table A3.3 Firth of Tay: Description of climate change influenced landscape change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Topography and geology: The Carse of Gowrie is predominantly flat with a bank marking the south edge before the Firth of Tay. Landform is around 10-50m AOD. The Sidlaws beyond comprise hard volcanic rocks and form a line of smooth rounded hills up to 300m AOD. The southern hills are most distinctive, where the vertical scarp of Braes of the Carse face south-east. To the north the hills subside to farmland plateau.	**Topography and geology:** The overall structure of this landscape would remain unchanged, but sea-level rise, particularly if more extreme scenarios are accurate, could have a significant influence on the balance of land and water, depending on the nature of human responses to flood management.	**Topography and geology:** Sea level rise is likely to be greater than previously indicated (comparing a medium emissions scenario, the increase could be between 0.5 and 23 cm greater than suggested by the UKCIP02 projections – based on figures for Edinburgh).
Forests and woodlands: There is limited tree cover on the Carse. Broad-leaf trees are limited to field boundaries, shelterbelts and policy woodlands. Very limited areas of coniferous policy woodland. History of orchards means some apple trees still remain. The Sidlaw hills are more wooded, with a combination of broadleaf and productive coniferous forestry.	**Forests and woodlands:** On the Carse it is possible that traditional orchards would be reinstated or expanded. It is likely that the current pattern of gappy and outgrown hedges further deteriorates in response to agricultural intensification and stress from higher winter rainfall and drier summers. This could also affect woodland around Carseland settlements and designed landscapes. Woodland on the Sidlaws is diversified, with an expansion of native woodland and the management of coniferous plantations on a continuous cover basis but with increased evidence of damage from storms, summer fires, summer drought and pests and diseases. The high value of agricultural land on the Carse may preclude the expansion of wet woodland in this location.	**Forests and woodlands:** Stress impacts on woodlands likely to be more to do with summer temperature increases and less to do with wetter winters and drier summers.

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
Freshwater Systems: A series of short burns drain the southern slopes of the Sidlaws and the Carse of Gowrie.	**Freshwater Systems:** An increase in flood protection along streams and burns where there is a risk that increased storm flows from the Sidlaws could flood settlement on the Carse, particularly with high or surge tides. Within the Sidlaws there is some evidence of increased erosion, but the expansion of woodland helps to mitigate run-off.	**Freshwater Systems:** The risk of flooding associated with increases in winter rainfall is likely to be reduced, though the risk associated with extreme weather events will remain.
Coast, estuaries and sea: The tidal Tay dominates the landscape of the Firth area, particularly when viewed from higher ground. The river turns through a series of meanders before broadening and straightening to the east of its confluence with the River Earn. The river is fringed with intertidal mudflats and reedbeds, though it is likely that these are already more limited in extent due to existing flood protection embankments along its northern side.	**Coasts, estuaries and seas**: The effects of climate change on the Tay Estuary would depend upon human adaptation and mitigation responses. Sea level rise and the increase risk of storm surge tides suggest that the estuary, like many others on the east coast of Scotland, will be at increased risk of flooding. Existing flood defences mean that rising sea level in particular would result in coastal 'squeeze' and the loss of intertidal mudflats and reedbeds which are of ecological, landscape and cultural significance. It is likely that existing flood defences would be upgraded in some areas in response to the increased risk to properties, settlement and possibly the most productive farmland. Alternatively, a process of managed realignment could see the removal or repositioning of flood defences to allow the migration of intertidal areas as sea levels rise. This would result in loss of	**Coasts, estuaries and seas**: Possible increase risk of coastal flooding, coastal squeeze and loss of land associated with sea level rise.

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
	farmland and would also change the landscape of the Firth. It is also possible that the tidal based renewable energy developments are brought forward in the form of a tidal barrage or a series of tidal lagoons, although it is acknowledged that the tidal range in this area may not be sufficiently large. The former would significantly modify the pattern of tides, with knock-on implications for upstream habitats and landscapes.	
Urban and Peri-Urban: On the Carse, settlement tends to be located on slightly raised ground, or along the foot of the Sidlaws' slopes. A scatter of large farmsteads and hamlets are located on tracks leading from principal roads. Recent housing demand has led to settlement expansion and some ribbon and dispersed development. Traditional building materials include red sandstone, harder igneous rocks from the Sidlaws, and also brick around Errol.	**Urban and Peri-Urban**: There may be an increase in the use of micro-renewables throughout the area, most visibly taking the form of roof-top solar collectors and small scale wind turbines. Solar collectors could have a local impact on the contribution of traditional buildings within the landscape. Small turbines would increase the area's 'developed' character. The emphasis on energy efficiency may result in novel building styles or materials, especially outwith conservation areas.	**Urban and Peri-Urban**: No change
Tourism and Recreation: Generally limited opportunities for tourism and recreation, although the hills are more popular recreational areas. Occasional historic features provide tourist destinations.	**Tourism and Recreation:** Improved summer weather conditions could lead to an increase in local recreation activity along the Carse and more particularly in the Sidlaws and hills to the south of Newburgh.	**Tourism and Recreation:** Minor changes in emphasis due to warmer but slightly less dry summers than previously projected
Infrastructure: The Carse is a communication corridor (A90 (T) and the Perth to Aberdeen railway line). There is a geometric pattern	**Infrastructure:** The area could see the development of small or medium size windfarms and the upgrading of national grid transmission	**Infrastructure:** No change

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
of roads and railways. Several transmission lines cross this landscape. A disused airfield is located at Errol.	lines. There is also potential for small or medium sized biomass plants and close to settlements, or food processing centres, combined heat and power plants. However, there is uncertainty surrounding the energy mix in 2050.	
Natural and semi-natural habitats: Ecological interest is concentrated within the intertidal mudflats and reedbeds, and along some of the Tay's tributaries. Grass and heather moorland is found in some higher parts of the Sidlaws.	**Natural and semi-natural habitats:** Sea level rise and the increase risk of storm surges, together with human responses, could have a significant impact on natural and semi-natural habitats along the Tay and its tributaries. The creation of woodland belts would contribute to habitat networks on the Carse and into the Sidlaws, though the biodiversity of this intensively farmed area could remain comparatively low. There may also be loss of heather moorland to grassland on the upper slopes and summits of the Sidlaws as a result of changes in moorland management.	**Natural and semi-natural habitats:** Potential increase in loss of semi-natural habitats along the Tay as a result of increased rates of sea level rise
Agriculture: On the Carse extensive arable land and limited pasture occupy large rectilinear fields. Field boundaries comprise gappy hedges, post-and-wire fences and wet ditches. There is a decaying structure of hedgerow trees. Recent years have seen a significant expansion in the use of polytunnels to provide controlled conditions for fruit cultivation.	**Agriculture:** the existing pattern of arable and horticultural cultivation is intensified. It is possible that there is a changing composition of crops, with a wider range of crops, including oil seed rape and energy crops such as miscanthus grass, increasing in extent. Alternatively, the area could further specialise in fruit growing, with re-establishment of orchards and other fruit trees, and expansion of polytunnel growing. Market conditions,	**Agriculture:** Possible reductions in the requirement for irrigation.

Current landscape	With climate change (UKCIP02 projections)	Likely implications of UKCP09 projections for previous analysis of climate change
	and the levels of incentive for biomass and bio-energy crops will influence the relative balance of crops. It is likely that productivity will increase, leading to a requirement for new, larger storage and processing buildings. Warmer, drier summers may result in the wider use of irrigation equipment including mobile booms.	
Historic Environment: On the Carse, historic features are limited due to the intensity of agriculture but include castles, historic houses and designed landscapes. The Sidlaws include some historic field systems, burial sites, hill-forts and castle sites.	**Historic Environment:** Agricultural intensification could result in the further weakening of the historic structure of this landscape as field boundaries and trees are lost. Modern infrastructure and buildings would underline the intensive, almost industrial character of this landscape. There may also be changes to the fabric of historic buildings resulting from management of rainwater, increased salt contamination and accelerated decay of vulnerable stone, increased biological growth on stone, impacts on and potential loss of unique coastal historic sites due to sea level rise or the risk of subsidence to historic structures.	**Historic Environment:** Minor differences resulting from less pronounced increases in winter precipitation.

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