EcoServ-GIS v3.3

Technical Report: "Noise Regulation Service"

1. Ecosystem Service Definition and Description

<u>Short definition</u>:

The absorption reflection and diffusion of anthropogenic noise by woodland and trees

<u>Long definition</u>:

Urban areas where vegetation may help to diffuse and absorb traffic noise. To map capacity, vegetation types are assigned a noise regulation score based on height, density, permeability and year round cover. Areas where vegetation helps to block noise are identified. Demand is mapped by estimating volume levels and the societal impacts of noise. Need for noise regulation is calculated based on Euclidean distance from roads, railways and airports. Noise volume is estimated based on distance from noise source, weighted according to source type. The societal impact is mapped based on population density and health IMD scores.

<u>Descriptive text</u>:

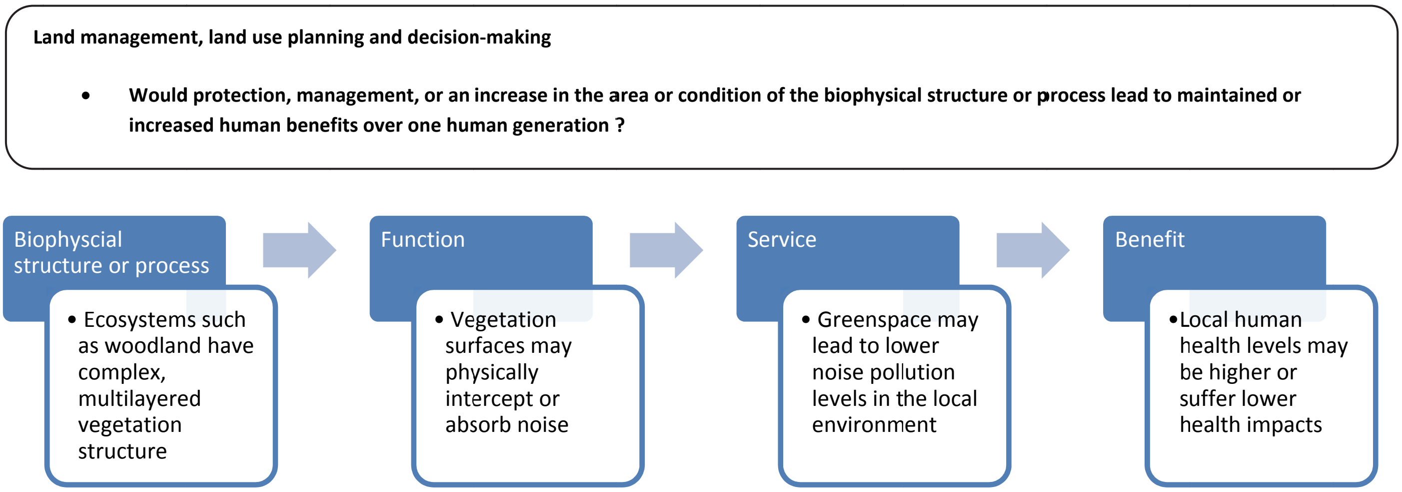
Trees and vegetation near to sources of noise such as roads and within urban areas may help to protect the most vulnerable people from the negative effects of noise pollution. People with existing health conditions may be at most risk of the detrimental impacts of noise pollution. Greenspace such as woodland and trees provide a service by intercepting, absorbing or dissipating noise pollution before it reaches people.

<u>Service benefits description</u>

People benefit from this service where local noise pollution levels may be reduced in areas where people live, recreate or regularly commute, such as within homes, walking or jogging in parks, cycle commuting or when relaxing or playing within gardens or yards. The link between the composition and status of the natural environment and positive impacts on local people's health is likely to be strongest in situations where people frequently undertake such activities in areas where there are high noise pollution problems. The benefits of existing vegetation cover, or of increased future cover are assumed to be higher where larger numbers of people live in, or near to, areas of predicted high noise pollution levels. People living at a far distance from noise pollution events are not considered to benefit from this service. The benefits are predicted to be higher for people who currently have poor health.

2. Service Cascade

As this toolkit is aimed at a county to regional scale the focus of land management and decision making is local. A timescale of one human generation (20 to 30 yrs.) is set within which to consider, assess or measure the impacts of land use planning decisions and management. This is logical in relation to the long-term planning decisions of local authorities, health boards and large infrastructure projects.



3. Literature review

Noise regulation is a recognised ecosystem service of vegetation and greenspace (Bolund & Hunhammar 1999) and has been noted as a benefit of greenspace occurring in towns and cities (Greenspace Scotland 2008).

Noise pollution is a recognised public health issue and may be more of an issue to different vulnerable sub groups of the population (Berglund et al. 1999; HPA 2010). Guidance exists for safe noise levels in specific situations and environments (Berglund et al. 1999). Significant proportions of the population may currently be impacted by noise pollution in European countries (Berglund & Lindvall 1995). In the UK about 10% of the population live in areas of excessive daytime sound levels, although up to 30% of the population express dissatisfaction in surveys of their local noise environment (HPA 2010).

Noise pollution can lead to various health impacts and has been implicated in increased stress levels and is thought to be an influencing factor in a range of mental health problems (Tzivian et al. 2015; HPA 2010). These impacts are greatest closer to the source of noise. Examples include a recent study that showed negative impact of noise on blood pressure in children (Liu et al. 2014). Reviews indicate that noise may impact cardiovascular heart disease and raise blood pressure (HPA 2010). In addition to impacting health, noise can have economic impacts such as being associated with lower house prices (Łowicki & Piotrowska 2015).

Noise can be produced from various sources, such as road traffic, air traffic, construction work, building noise and domestic activities, with varying resulting negative impacts on people (Berglund & Lindvall 1995). Several studies have examined and mapped noise levels in urban areas (Farcaş & Sivertun 2005; Fiedler & Zannin 2015; Foraster et al. 2011; Gan et al. 2012; Lin-hua et al. 2013). The importance of road noise is well known and various mitigation methods and strategies have been established (ARRB Group 2005; Cook & Haverbeke 1972). Advice suggests that government and planners adopt noise reduction strategies (Berglund et al. 1999), and mapping studies can be used to identify areas that may require noise action plans to deal with the resulting noise pollution levels (Ruiz-Padillo et al. 2014).

Various modelling software and methods for road noise assessment are recommended for use in planning and assessment of new developments e.g. as reviewed in (ARRB Group 2005), see also (Berglund et al. 1999; European Commission Working Group Assessment of Exposure to Noise (WG-AEN) 2006; Farcaş & Sivertun 2005; Gulliver et al. 2015). Many modelling methods require the use of detailed data such as building height (Gulliver et al. 2015). Detailed guidance is available on for example estimating noise pollution impacts from roads (Department of Transport 1998).

Greenspace provides varying levels of noise mitigation. An area's effectiveness as a noise barrier is related to the structure, size and density of the vegetation (Fang & Ling 2005). Trees and shrubs are best at scattering noise, with coniferous trees functioning all year round. Noise levels can be reduced by 5 – 10 decibels for every 30 m of woodland (Cook & Haverbeke 1972). It is also known that absorbent vegetation cover on the ground can also impact on noise levels, e.g. where grass cover occurs versus sealed surfaces (Department of Transport 1998).

Vegetation can be used in the design of development or roads to help reduce road noise levels (Van Renterghem et al. 2015). Studies have shown the positive and additive impact of tree canopy, tree stems and shrubs on road noise levels in relatively narrow 15 m wide tree belts (Van Renterghem et al. 2012). Noise reduction ability is relative to tree belt width (Van Renterghem 2014), although even narrow hedges can cause reduction in noise levels (Van Renterghem et al. 2014). Vegetated walls, lines of trees and green roofs may also have positive impacts on noise reduction (Van Renterghem et al. 2015).

The creation and maintenance of greenspace features or buffers can help to screen undesirable noise levels along roads (Bentrup 2008). Guidance in the US recommends that for moderate road speeds (<40 mph) a barrier of 6 to 15 m width is appropriate, and should be within 6 to 1 5m of the road edge (Bentrup 2008). For high speed roads a barrier of 20 to 30 m is advised, within 15 to 25 m of the edge of the road (Bentrup 2008). Buffers with evergreen species and with a mix of trees and shrubs are advised (Bentrup 2008). There will be a maximum distance beyond which additional cover of buffers, trees or woodland is no longer effective or necessary, this will depend on the level of noise pollution present but will be in the range of 300 to 500 m (Bentrup 2008).

Several insights from the following research were used to help construct the current GIS model:

Capacity

- Design guidance indicates that dense vegetation can reduce noise levels by 1dB(A) per 10 m depth, Nelson (1987) in (ARRB Group 2005).
- Advice in Australia summarises that noise reduction projects should aim for a minimum of >3 dB(A) and that levels of reduction of 3 to 5 dB(A) are attainable and likely to be noticeable by local communities, whilst in practice reduction levels of 10 dB(A) are difficult or expensive to achieve (ARRB Group 2005).
- Studies have shown reduced noise levels in urban parks compared to nearby streets (Cohen et al. 2014).
- Greenspace provides varying level of noise mitigation. An area's effectiveness as a noise barrier is related to the structure, size and density of the vegetation (Fang & Ling 2005; Van Tenterghem, Botteldooren & Verheyen 2012). Trees and shrubs are best at scattering noise, with coniferous trees functioning all year round.
- Noise levels can be reduced by 5 – 10 dB(A) for every 30 m of woodland (Crook & Haverbeke 1972), although recent guidance suggests more limited reductions of 1 dB(A) per 10 m width (ARRB Group 2005).
- Measurement of tree belt buffer strips in Taiwan indicated that both tree height and belt width positively impacted on noise reduction ability (Fang & Ling 2005).

Demand

- A study in Greece examined and modelled noise and found that transport networks are a primary source of noise pollution. Votsi et al. (2012) assumed that areas within 800 m of a high-quality carriageway (motorway), 600 m of a dual carriageway, 550 m of other regional roads, 650 m from railways and 1,500 m from major airports and 900 m around other airports represented noise hazard areas (Votsi et al. 2012). Land use was also used to identify industrial, domestic areas and likely construction sites.

- A study in Tehran found that indirect assessment of noise levels can match well with measured noise levels in urban areas. Research examined noise pollution and found road type to indicate potential noise levels, but also that street configuration and presence of passageway type was important in determining measured noise levels (Abbaspour et al. 2015).
- The presence of urban noise pollution can be related to complex patterns of land use and urban form, rather than simple distance measures (Ariza-Villaverde et al. 2014). Research in Cordoba, Spain indicated a correlation between noise pollution and a ratio of street width to building height (Ariza-Villaverde et al. 2014).
- Combined noise impact is important to consider, e.g. from multiple sources (Berglund et al. 1999).
- Vulnerable population sub groups, badly affected by noise pollution may include: those in ill health, the elderly and very young and at spatial locations such as schools and hospitals (Berglund et al. 1999).
- Guidance for undertaking noise mapping assessments indicates important elements as assessing road flow levels likely to cause noise levels, the ideal is to use measured or known vehicle use levels but in practice it may be acceptable to estimate road flow levels from road type (European Commission Working Group Assessment of Exposure to Noise (WG-AEN) 2006). Many detailed factors can influence modelled noise levels such as road surface type, gradient, building proximity, buffer distances (European Commission Working Group Assessment of Exposure to Noise (WG-AEN) 2006). Advice notes that in general for broad mapping purposes greenspace can be considered to absorb noise and man-made or sealed surfaces to reflect noise (European Commission Working Group Assessment of Exposure to Noise (WG-AEN) 2006).
- Detailed noise modelling methods tend to include building height data and require accurate vehicle movement data, and the presence or absence of barriers (Farcaş & Sivertun 2005).
- Noise mapping has been conducted for city areas and allows the assessment of the proportions of the population affected by noise pollution levels (Farcaş & Sivertun 2005; Gulliver et al. 2015).
- Mapping studies have used maximum road speed limits to estimate likely use levels and noise generated by traffic e.g. (Fiedler & Zannin 2015).
- A study found that measured noise levels in a city were positively correlated with degree of urbanisation, traffic density and distance to the street (Foraster et al. 2011).
- Work in Spain showed that noise levels are associated with the type or functionality or roads / streets (Gozalo et al. 2013).
- High percentage cover of sealed surfaces are likely to exacerbate noise pollution (Department of Transport 1998).

Despite insights from the literature in linking noise levels to health, caution must be applied to simplistic measures and assessment as studies indicate that there may be complex correlations between detrimental noise measures and air pollution impacts on health (Allen et al. 2009; Foraster et al. 2011; Gan et al. 2012; Kim et al. 2012; Morelli et al. 2015; Sørensen et al. 2014; Tzivian et al. 2015; van Kempen et al. 2012; Vlachokostas et al. 2012; Weber et al. 2014). There may also be complex associations between perception of noise impacts and visual links to local aesthetics or lines of sight to noise producing features (ARRB Group 2005). Additionally in reality many other sources of noise may contribute to perceived noise pollution levels, such as from commercial spaces or industry, including features such as wind turbines (Baker 2015). Finally, the exact detrimental health impacts of noise on particular diseases or conditions often requires further research to clarify short-term versus long-term impacts (HPA 2010). The current focus of this mapping model is on urban noise pollution, however noise can also negatively influence rural activities, such as recreation in a countryside setting (Iglesias Merchan et al. 2014).

4. Summary of constructing the GIS mapping service model

Sufficient information was available in the literature and sufficient detailed GIS data was available to build a simple logic based model of the service, however a large number of approximations and assumptions had to be made. The main literature identified rules used to build the models were:

Capacity

- Vegetation cover can help to reduce noise levels.
- Complex vegetation cover such as woodland, trees and scrub is most effective, although general cover of vegetation compared to artificial sealed surfaces are still effective.
- Wider belts of vegetation are more effective than narrow belts.
- There is both a maximum width of vegetation and distance from a noise source beyond which vegetation has no beneficial impact.

Demand

- Noise levels can be estimated by modelling the location of noise from multiple sources.
- Proportion of sealed surface, man-made urban cover can be correlated with noise levels.
- Noise levels are likely to be complex and not simply represented by distance from source due to the impact of street configuration and building height.
- The population impacted by noise pollution can be modelled and measured by relating the location to modelled noise maps, and by segmenting the population by health or age categories.

The following mapping rules were developed:

Capacity

Land cover is scored according to the ability to act as a barrier to anthropogenic noise. All man-made structures and bodies of water are assigned a score of 0. The remaining results are classified according to expert judgement. Woodland is assigned the highest score, then scattered trees and scrub, and finally grassland. The following scores are applied (see also the data link table, within the Toolkit):

Habitat	Noise regulation value
Woodland, Coniferous	100
Woodland, unknown	90
Woodland, mixed	90
Woodland, broadleaved	80
Scrub (all)	40
Scattered trees (all)	40
All other greenspace	10
Hedges and Walls	5
All manmade	0

In order to allocate higher scores to wider bands of vegetation a two-scale focal analysis is applied. A focal statistics analysis calculates a SUM score for the *short distance* neighbourhood (default 30 m). Another focal statistics analysis calculates a SUM score for the *local distance* neighbourhood (default 100 m). The scores are then summed to give a higher value to wider belts.

Demand

To illustrate areas which would most benefit from the presence of natural features that absorb and reflect anthropogenic noise, the number of residents and their mean health scores are estimated within a circular window (default 300 m) for each raster cell, using the average number of people per household reported in the 2011 census and the 2001 Index of Multiple Deprivation (IMD) health domain scores. Health is chosen as an indicator for societal demand because anthropogenic noise is believed to cause health-related issues. Noise mapping is conducted. This calculates the log10 inverse distance from each cell to the closest road, railway and airport because noise levels are higher closer to sources of anthropogenic noise. Maximum search distances were used based on the expected range of the noise produced from these sources (airports 1500 m, motorways 800 m, railways 650 m, major roads 600 m, minor roads 550 m). These distance bands were taken from a study conducted in Greece (Votsi et al. 2012). Because the effect of different sources is additive, the scores for each of these sources are summed. Finally, the societal demand (population and health) and regulatory need (noise map) scores are combined with equal weighting.

5. Spatial occurrence and service flows

This service is provided by areas of natural or semi-natural habitat or greenspace, primarily by woodland habitats. The flow of the service is considered to be largely in-situ. The benefits would be experienced therefore where people are resident in the area, or are walking, cycling or jogging within or adjacent to an area of greenspace. Currently the model includes all spatial areas and is not limited to publicly accessible areas.

6. Ideal Data

> The ideal data with which to map the service would be locally collected site measurements, at a relevant local spatial scale, compared to reference measures at a national scale. Data would be recently collected and updated regularly. Scientific research would be available which measures the impact of marginal changes in the extent, composition or condition of the natural capital asset on the level of the service delivered to people, and the benefits experienced. There would be detailed data on the number per socio-economic category, age or other suitable classification category of people who could benefit from the service, along with research on how changes in these social characteristics alter their relative levels of service demand over time. Finally there would be data on how levels of human use impact ecosystem condition.

In order to reliably map the service the following information would be required:

Capacity

- The type, location, extent, condition, quality and management status of greenspace.
- The extent to which noise pollution levels are reduced by the vegetation currently present.

Demand

- The number of people who live at, or visit each site, for how long and with what frequency.

- The vulnerability of the population to noise pollution, e.g. as indicated by age, socio-economic group and health status of the residents or visitors.
- The levels of noise pollution present at each locality, and its variation spatially and temporally .

Service flows and benefits

- The long-term health benefits of the reduced noise pollution levels compared to living at, or undertaking recreation, walking or cycling in other similar areas without such vegetation cover.

7. Proxies for ideal data

In the absence of the full range of ideal data to map the service, assumptions have been made, and additionally proxies have been used to represent selected elements of the ideal set of data.

Capacity

- The type, location, extent, condition, quality and management status of Greenspace.
  - *Type, location, extent*: BaseMap: A combination of local data and several (optional) national datasets including: OS MasterMap, priority BAP habitats, LCM 2007, local habitat data, local and national nature reserves, combined with Local Authority Open Space Survey / Green Infrastructure Survey (or equivalent).
  - *Condition, quality and management*: No consistent, reliable information .
- The extent to which noise pollution levels are reduced by the vegetation currently present.
  - A score is assigned to each habitat type in the link table "Noise" data field. This is used to represent the relative capacity of each habitat to ameliorate noise pollution. Analysis calculates the cumulative score within a search radius around each cell.
  - Analysis at two neighbourhood scales is used to capture the impact of vegetation belts of varying widths. These are set at defaults, *short* (30 m), *local* (100 m).

Demand

- The number of people who live at, or visit each site, for how long and with what frequency.
  - Number of people living within local scale walking distance (default 300 m).
- The vulnerability of the population to noise pollution, e.g. the age, socio economic group and health status of the residents or visitors.
  - Health score (IMD / WIMD / SIMD) (mean) of people within local scale walking distance (default 300 m)
- The levels of noise pollution present at each locality, and its variation spatially and temporally.
  - Roads, motorways, dual carriageways, railways and airports as the source of noise.
  - Distance, based on type of noise generating land use, to identify the area of noise impact.
  - Inverse distance, to map the change in impact over space.
  - Other sources of noise pollution are not included.

Service flows and benefits

- The long-term health benefits of the reduced noise pollution levels compared to living at, or undertaking recreation, walking or cycling in other similar areas without vegetation cover.
  - Spatial overlay of capacity and demand is used to indicate potential flow and benefits of the service.
  - Ranking by quintiles is used to identify areas of relative high priority, improvement areas and gaps.

8. Limitations to the model and potential future improvement (where relevant)

Because the model covers a subset of all sources of anthropogenic sound, the area over which the service is mapped will be under-represented. It may also be the case that levels of noise within demand areas are under-represented.

This is compounded by the inaccuracies in modelling population density and socio-economic characteristics. The ability of different habitat types to act as a barrier may not be accurately reflected by their score. Where woodland acts as a sound barrier local knowledge should be used to ground truth the map outputs, particularly where woodland is sparse. Finally, it is assumed that louder noise has a greater impact on physical and mental health, for example rather than the constancy or timing of noise pollution events.

Limitation	Impact
Source data	Habitat mapping is often only available at the broadest level. Fine scale variations in population demographics are masked. There may be errors in classification of households
Literature	There were relatively few sources on which to base the mapping rules, more information on noise pollution levels from different roads types, and impact distances are required.
Mapping rules	Ideally specific locations of different illness hotspots would be included rather than general health scores
transferability	
Study area extent	Very small study area may not contain the type of large roads predicted to cause noise pollution
Landscape composition	In rare cases of upland or entirely arable landscapes there may be no areas of mapped capacity
	Building height in urban areas will impact noise movement levels, but is not covered by the models
Buffer zone impacts	N/A
Landscape pattern	N/A
Topography	Topography will impact on the capacity and demand levels, but it not currently included in the models.

9. Final List of Indicators

Indicators with a suffix of _IndC or _IndD are saved in the Indicators Geodatabase.

Indicator Name	Type	Description
NoiseRegScore_IndC	Capacity	Cell based score showing the score of each patch cell for relative noise regulation capacity
Man Made IndD	Demand	Proportion of manmade surface within search distance
Health Score IndD	Demand	Health deprivation score (mean) within local search distance
Popn Density IndD	Demand	Population size (sum) within local search distance
Noise Score IndD	Demand	Predicted noise level score

Detailed GIS Analysis steps

Model: ES1NoiseRegCapacity

Models the capacity of patches of vegetation to act as barriers to anthropogenic noise.

- Defaults are set for cell size and extent, but can be altered by the user.
- Sub models delete all previously run data from Scratch, Outputs, Indicators, Shapefiles geo database and folders .(mainly required during model testing rather than the final models).
- BaseMap is converted to a raster based on "Noise" field.
- Focal statistics SUM conducted at short neighbourhood distance (default 30 m).
- Focal statistics SUM conducted at local neighbourhood distance (default 100 m).
- The two search scores are summed.
- Results extracted by mask to give results only the Study Area plus buffer (SA010).
- Values greater than 0 are extracted. Extract by mask is applied (default Study Area buffer).
- An area based threshold is applied to remove any sites / patches that occur below a "functional threshold" where small sites may not be considered capable of having capacity (default 500 m^2). This is achieved by conversion and reconversion of the raster data to feature class, selection by area, and then conversion back to raster, and then using this as a mask for the capacity score data.
- Values are re-scaled onto a 1 to 100 scale. A version of the dataset with No Data replaced by 0 is created.
- Datasets (raster) saved as Noise_Capacity and Noise_Capacity_0_100.
- A sub model converts the raster data to vector shapefiles. The values are grouped into simplified categories, e.g. 1-10 (10), 10-20 (20), 20-30 (30) etc.

Model: ES2NoiseRegDemand

Models the societal demand for Noise regulating ecosystem services based on the population density and the IMD health scores.

- Defaults are set for cell size and extent, but can be altered by the user.
- Sub models delete all previously run data from Scratch, Outputs, Indicators, Shapefiles geo database and folders (mainly required during model testing rather than the final models).
- Focal Statistics calculated on the socioeconomic points data. Summing the value of "House_popn" within each cell within a radius circle. Neighbourhood is set to a 300 m radius circle. Statistics type is set to SUM.
- Standardised to a 1-100 scale.
- Focal Statistics calculated on the socioeconomic points data "HealthScor". Mean value of Health scores within each cell within a radius circle. Neighbourhood is set to a 300 m radius circle. Statistics type is set to mean
- Standardised to a 1-100 scale.
- Distance scores created to each noise source.
- Calculates Euclidean Distance from cells to airports, Maximum distance set to 1500.
- Calculates Euclidean distance from cells to minor roads, Maximum distance set to 550.
- Calculates Euclidean distance from cells to railways, Maximum distance set to 650.
- Calculates Euclidean distance from cells to motorways, Maximum distance set to 800.
- Calculates Euclidean distance from cells to motorways A roads, Maximum distance set to 600.
- For each noise source, distance were converted to log values, after adding 1, then converted to inverse scores.
- Scores are summed to give a standard single noise score, then standardised and rescaled.
- Separate scores are produced for.
    - population density .
    - health scores.

    - predicted noise.
- These can each be weighted by the user (default 1), before they are combined (summed) to a single score.
- Extract by mask is applied (default = Study Area buffer). Values are re-scaled onto a 1 to 100 scale.
- Datasets (raster) saved as NoiseRegulation_Demand.
- A sub model converts the raster data to vector shapefiles. The values are grouped into simplified categories, e.g. 1-10 (10), 10-20 (20), 20-30 (30) etc.

Model: ES3Noise Regulation Flows

The capacity and demand data are converted to quintiles and overlaid to identify benefitting areas and gaps

The service flow model is the same for each service

- Defaults are set for cell size and extent, but can be altered by the user.
- Sub models delete all previously run data from Scratch, Outputs, Indicators, Shapefiles Geodatabase and folders (mainly required during model testing rather than the final models).
- Sub model takes the separate capacity and demand datasets and produces the following datasets for either the Study Area of the Study Area plus buffer.
    - Capacity quintiles based on area and value.
    - Demand quintiles based on area and value.
    - All areas where there is some level of demand.
    - When the quintiles are calculated for capacity these are only created for areas with Demand > 0.
- The service occurrence, demand and quintiles data are combined to create two sets of benefiting area data:
    - Ecosystem Service Benefiting Areas (ESBA) and gaps.
    - Ecosystem Service Benefiting Areas (ESBA) and gaps - prioritised.
- Ecosystem Service Benefiting Areas occur where Demand > 0 and Capacity > 0.
- Service Gaps occur where Demand > 0 and Capacity = 0.
- The prioritised data are defined by selecting the highest quintile (5) as high demand or high capacity, this allows the following categories to be produced:
    - A1 - Service Benefiting Area - High Demand (Q=5) and High Capacity (Q=5).
    - A2 - Service Benefiting Area - High Demand (Q=5) and Low Capacity (Q=1).
    - A - Service Benefiting Area - other (Demand Q>0<5 and Capacity Q>0).
    - B1 - Service Gap - High Demand (Demand Q=5 and Capacity Q=0).
    - B - Service Gap (Demand Q>0<5 and Capacity Q=0).
    - C1 - Restricted Service - High Demand (Demand (Q=5) and Capacity (Q>0 but restricted).
    - C - Restricted Service - other (Demand (Q>0<5) and Capacity (Q>0 but restricted).
- The ESBA and ESBA - prioritised datasets are each comprised of a single dataset to facilitate their use in later zonal statistics analysis.
- A sub model identifies "GI assets" by masking the service capacity maps to illustrate only those areas where there is a level of demand.
- A sub model exports the raster files to shapefiles. An optional patch area threshold allows small areas to be removed during the conversion process (default shape area > 200 m^2).

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