EcoServ-GIS v3.3

Technical Report: "Carbon Storage Service"

1. Ecosystem Service Definition and Description

Short definition:

The storage of carbon in above and below ground biomass (vegetation and soils).

Long definition:

The storage of carbon in above and below ground biomass. The capacity of the natural environment is mapped by assigning potential carbon storage values per mapped habitat type based on peer-reviewed literature. Values map typical storage levels within habitat vegetation and levels within the upper 30 cm of soils. The demand (need) for carbon storage is considered to be constant across the entire study area, as there are global benefits in the storage of carbon.

Descriptive text:

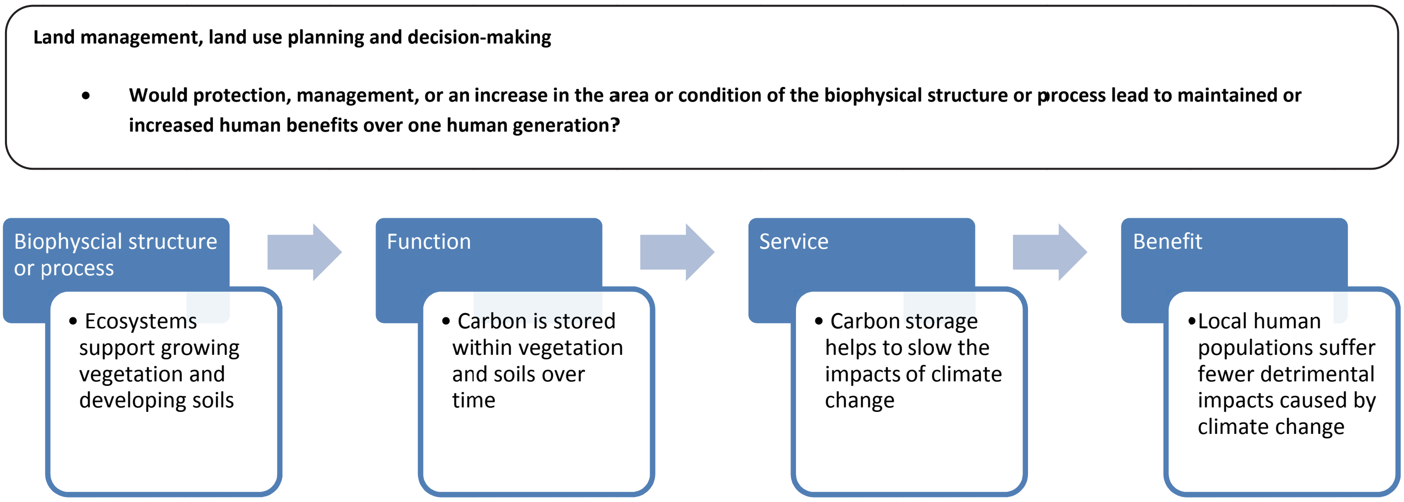
Ecosystems help to counteract the impacts of climate change by storing carbon within vegetation and soils, ultimately benefiting people. Some habitats have more potential to store carbon than others. The amount of carbon stored within the vegetation and top 30 cm of soil is known for a wide range of UK land uses and habitat types. All man-made structures or surfaces, water courses, water bodies, the sea, sand dunes, intertidal areas, rock and unclassified habitats are considered to store zero carbon.

Service benefits description

This service reflects the benefits that all people receive when carbon is stored away from the atmosphere, due to the resulting benefits in future climate change avoidance. The service illustrates that different habitat types store different levels of carbon per unit area. Ultimately the benefits are dependent on habitat management, and the service benefits occur over very long timescales. The links between the short-term management or extent changes in the area of the ecosystems, and the benefits to people, are weak. The links between the natural environment and human benefit are not easily mapped for this service, and demand is simply mapped as a constant high value to illustrate continuous high need for carbon storage across all areas.

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

The UK government has pledged to reduce greenhouse gas emissions by 80% by 2050, compared to 1990 levels, as part of the "Low Carbon Transition Plan" (HM Government 2011; HM Government 2009). The importance of managing land as a carbon store was recognised in this plan, which encourages woodland creation and sensitive land management to protect and increase this carbon store. Levels of carbon sequestration can be difficult to estimate, therefore, many studies have estimated and mapped the amount of carbon stored instead (Chan et al. 2006; CEP 2008; CEP 2007; CCW & Environment Systems 2012; Countryside Council for Wales 2010; Davies et al. 2011). There is now a growing body of published research using similar methods to map carbon levels.

There is an important distinction between a static measure of the carbon storage present in the existing ecosystem, and potentially lost to the atmosphere if the habitat is removed, altered or managed in certain ways, versus carbon sequestration which is the ongoing removal of carbon form the atmosphere over time. Using simple estimates of carbon storage may have limited interpretation compared to some more complex studies examining both storage and sequestration (Beaumont et al. 2014). However, it allows the rank importance, for carbon storage, of current ecosystem types to be examined, and shows which have the most capacity or potential to continue to store carbon under appropriate management regimes.

A recent study reviewed carbon storage values following a UK-based literature review which compared measurements of carbon storage within different land use classes recorded in the scientific literature (Cantarello et al. 2011). The authors grouped land use types into 11 classes and calculated the mean amount of carbon storage (t ha^{-1}) for each of these using the measurements reported by the studies reviewed. Five measurements per land use class were used, with a priority towards records made within 2000 – 2005 (to match Corine Land Cover 2000 that was used for mapping) in South West England, followed by the rest of England, the UK, and worldwide.

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

Capacity

- Reviews of the literature can be used to extract typical carbon storage values, per habitat type that can be used to map carbon storage levels via linkage to habitat or ecosystem maps (Cantarello et al. 2011).
- A number of habitats / ecosystem have no or few recorded measures of carbon, e.g. manmade structures or surfaces, water courses, water bodies, the sea, sand dunes, intertidal areas, rock and unclassified habitats (Cantarello et al. 2011; Milne & Brown 1997).
- A national scale study in Wales used available information and expert opinion to create a 0 to 3 scoring system to rank habitats by importance for carbon storage in soils, vegetation and a combined assessment (Countryside Council for Wales 2010). Both vegetation mapping and soils mapping were used to create the combined maps.
- Research at the city scale has shown that urban areas should not be discounted and that urban habitats and soils can store significant levels of carbon, therefore they should be considered in analysis (Davies et al. 2013; Edmondson et al. 2014).

Demand

- Research has examined the social value of carbon storage and sequestration of GB woodlands, illustrating the complexity required when assessing areas of existing habitat together with scenarios of land use change (Brainard et al. 2009).
- Most mapping studies have not graded levels of carbon storage demand, assuming high or constant demand across the study area (Bagstad et al. 2014), or only mapping capacity (Countryside Council for Wales 2010; Hölzinger et al. 2013; Cantarello et al. 2011; Newton et al. 2012).

A variety of studies have examined carbon storage levels in different habitats, ecosystems and scales. These can be used to compare values to the outputs of EcoServ-GIS analysis. Reported total carbon storage values for selected habitats and scales include:

Reference	Scale, location, ecosystems	Area	Carbon storage	Vegetation, soil or combined
(Milne & Brown 1997)	GB	230,000km^2	9,952 Mt C	Vegetation and soils
(Lindsay 2010)	UK	244,000km^2	3,121 Mt C	Peatlands
(Broadmeadow & Matthews 2003)	UK	244,000km^2	150 Mt C	Biomass of forests
(Milne et al. 2001)	GB	230,000km^2	113.8 Mt C	Vegetation and soils
(Hagon et al. 2013)	Lake district NP	/	22.68 Mt C	Peat soils
(Burrows et al. 2014)	Scottish marine	470,000 km^2	18.4 Mt C	Sediments (95%) plus living material
(Beaumont et al. 2014)	UK coastal habitats	/	9.4 Mt C	Vegetation and soils
(Hagon et al. 2013)	Lake district NP	/	3.403 Mt C	Woodlands
(Davies et al. 2013)	City, Leicester	73km^2	0.231 Mt C	Above-ground vegetation

Note: Mt = million tonnes, equivalent to Tg, Terragram

Values used to represent carbon storage per ecosystem type (Cantarello et al. 2011)

Habitat	Vegetation			Soils			Total		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Broadleaved forest	111	57.4	208	162	70.5	335	273	127.9	543

Complex cultivation patterns, fruit trees, land principally occupied by agriculture, transitional woodland-scrub	14.7	2	36.7	88.4	37.5	120	103.1	39.5	156.7
Coniferous forest	59.1	26.7	95.8	107	81.9	175	166.1	108.6	270.8
Green urban areas - sport and leisure facilities	8.32	2	25.1	91.3	40	142	99.62	42	167.1
Inland and salt marshes	8.44	1	15	143	37.4	235	151.44	38.4	250
Mixed forest	78	47.5	139	124	85.6	179	202	133.1	318
Moors - heathland	7.11	2	17.5	103	50.7	196	110.11	52.7	213.5
Natural grasslands - pastures	3.1	1	6.98	121	72	204	124.1	73	210.98
Non irrigated arable land	2.36	1	4.64	63.9	27.5	88.2	66.26	28.5	92.84
Bioenergy crops	2.9	1.56	4.47	74.6	69.8	80.2	77.5	71.36	84.67
Peat bogs	7.15	1.57	20	576	133	1170	583.15	134.57	1190

Values as Mg C ha-1, Mg = tonne (1,000 kg) (metric ton)

4. Summary of constructing the GIS mapping service model

This model maps where carbon is stored in different habitat types and shows which types store more carbon than others, including storage within typically expected soils, characteristic of established examples of each habitat type. A relatively good level of published studies allow carbon levels to be linked to habitat and land use types, however these are mostly to the broad habitat types rather than detailed habitat sub-categories. The maps show the carbon levels that can potentially be stored, because habitat age and condition are not considered. Habitats that have not matured, e.g. young woodland, or that have been heavily modified, e.g. drained wetland or bogs will differ greatly from the predictions of the model. The demand (need) for carbon storage cannot be quantified spatially and therefore we indicate the need as being high across the whole study area.

It should be made clear that by using typical carbon storage values to represent the "capacity" (cf. potential) of each habitat type for carbon storage, some of the issues regarding carbon sequestration are avoided. The values serve to give some indication of the capacity each habitat type has to store a typical level of carbon under typical conditions, for mature or well-managed examples of this habitat. Therefore, for example if the toolkit was used for scenario modelling of future land use changes from improved grassland to blanket bog, this will result in increased capacity, indicating the potential for the habitat to store more carbon as the bog develops, whilst conversely conversion of blanket bog to improved grassland results in a lower capacity to store carbon. Due to the very wide margins in the recorded levels the main use of such a method is to broadly indicate the rank order of habitat capacity for carbon storage.

Despite the range of available literature a large number of approximations and assumptions had to be made in constructing the model. The main literature identified rules used to build the models were:

- Carbon storage levels can be linked to broad habitat types / ecosystems and used to map carbon storage levels, although mean values are used, storage levels vary greatly within each type.
- The carbon storage capacity of an ecosystem results from both storage in vegetation and within soils.

- The availability of fine scale resolution habitat mapping via OS MasterMap and local scale greenspace data allows habitats within urban areas to be included in carbon calculations, which are often lost in regional scale analysis, or by using data sources that do not account for urban vegetation cover.
- In reality carbon storage values will vary greatly per habitat patch, due to factors such as management, elevation, topography and site history.

To build the capacity model the carbon storage values from (Cantarello et al. 2011) were used to populate the values in the data link / lookup tables. Where applicable the values were approximated to other broader habitat types, or to intermediate habitat types based on logical rules, or a best-fit strategy. The full range of values can be seen in the data link tables within the Toolkit.

5. Spatial occurrence and service flows

This service is provided by areas of natural and semi-natural habitat. The flow of the service is not explicitly mapped because all people potentially benefit from the carbon storage service, wherever they area. The mapping of the flows is therefore representative of the benefits to people, but is only influenced by variations in levels of capacity.

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, semi-natural habitats and vegetation types.
- The carbon stored in each habitat and sub habitat type and soils, and any variations due to management, condition or quality.

Demand / Service Flows and benefits

- The humans benefits of carbon storage at a particular site.

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, local habitat data, LCM 2007, 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 carbon stored in each habitat and sub habitat type and soils, and any variations due to management, condition or quality.
  - Values have been taken from the literature and matched to the most appropriate habitat type, or levels inferred when maps habitats fall between habitat types with recorded values.
  - Literature values for vegetation and soils were combined, therefore the model assumes that soils typical of the vegetation type occur at each cell.

Demand / Flows

- The humans benefits of carbon storage at a particular site.
  - Not possible to predict spatially, therefore constant high demand was mapped.

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

Limitation	Impact
Source data	Habitat mapping is often only available at the broadest level.
Literature	Published sources were available on which to base the mapping rule.
Mapping rules transferability	More information on carbon storage per sub habitat types or variations in levels from different communities would be useful
Study area extent	Very small study areas may not contain the full range of carbon storage capacity
Landscape composition	N/A
Buffer zone impacts	N/A
Landscape pattern	N/A
Topography	Topography will impact capacity due to influence on soil development, 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
Ton_cell_IndC	Capacity	Carbon stored within each cell. E.g. for 10m cells the values represent the Tonnes of carbon stored per 100 m^2.
FN_ZSc1_100_IndC	Capacity	The carbon stored per cell, standardised and re-scaled from 1 to 100

Detailed GIS Analysis steps

Model: ES1CarbonCapacity

Estimates the relative amount of carbon stored in vegetation and the top 30 cm of soil within each raster cell.

- 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).
- The BaseMap_FINAL data is made a feature layer, including a selection to include only areas where the TotCarb field has values > 0.
- This is converted to a raster dataset based on field TotCarb and with cell size set by the User (SA010 or SA050).
- The min and max values are reported, using *Get Raster Properties.*
- The raster is divided by a user input value in order to convert the carbon stored value to per cell values (100 for 10 m cells and 4 for 50 m cells).
- The value is then saved as an indicator – Ton_cell_IndC.
- Values greater than 0 are extracted. Extract by mask is applied (default Study Area buffer).
- 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 CarbonStorage_Capacity and CarbonStorage_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: ES2CarbonDemand

Illustrates the (homogeneous) demand for carbon storage across the study area.

- 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).
- A constant raster of 100 was created across the Study Area.
  Extract by mask is applied (default = Study Area buffer).
- Datasets (raster) saved as CarbonStorage_Demand.
- A sub model converts the raster data to vector shapefiles.

Model: ES3CarbonStorageFlows

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

<u>The service flow model is the same for each service.</u>

For carbon the entire area of demand is considered to be the highest quintile.

- 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).
- 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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