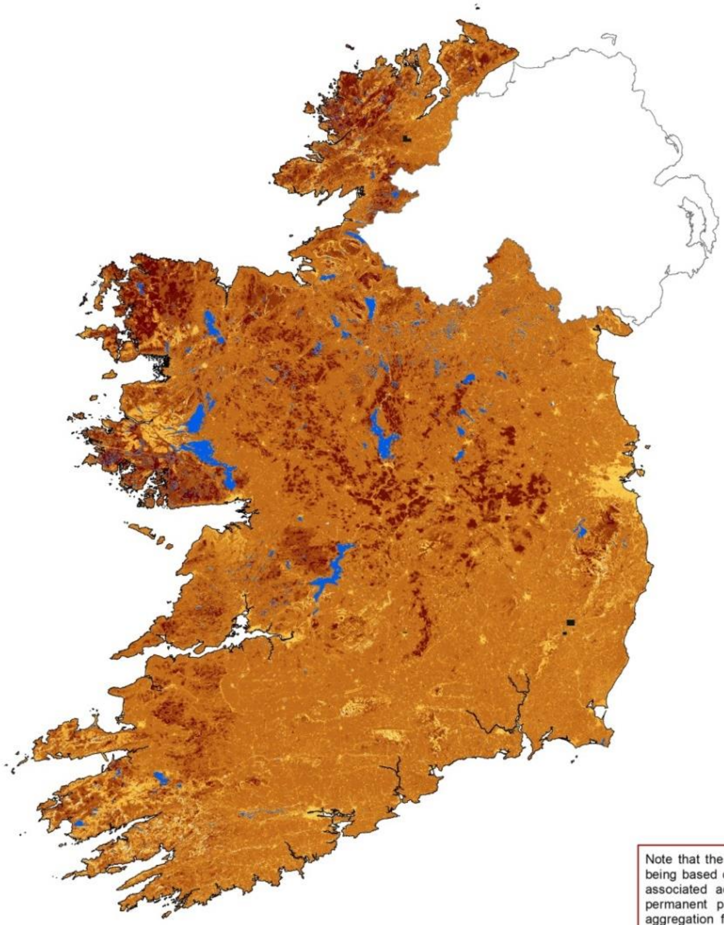
Soil carbon: Indicator document - Ecosystem Service Modelling & Rule-base development

Soil Carbon

Ecosystem service: **Regulation of greenhouse gases (carbon)**

29/03/2016



Legend

Higher contribution to carbon sequestration

Moderate contribution to carbon sequestration

Lower contribution to carbon sequestration

Freshwater

Compromised data in urban input

How to interpret the map:
The darkest colours represent areas with high level of organic soil carbon overlain by vegetation which is actively helping the soil to store carbon. Lighter colours represent sandy soils with little organic carbon, which are regularly disturbed where carbon is released into the atmosphere.

Ecosystem service:
Climate change (regulation) - storage of carbon within soils

What the service is:
Soil organic matter is a heterogeneous mixture of organic compounds that are highly enriched in carbon, ranging in decomposition from fresh plant residues (leaf litter), to highly decomposed material known as humus. Organic carbon levels of different soil types are directly related to the amount of organic matter contained in soil from growth and death of plant roots and foliage, as well as indirectly from the transfer of carbon-enriched compounds from roots to soil microbes. Peat based soils contain the most carbon whilst sandy soils contain much less.

Why it is important:
Carbon storage in the soil is known as a major carbon sink; the more carbon stored in the soil, the less greenhouse gases are released into the atmosphere. Soil carbon storage results from interactions of different ecological processes.

How the map was created:
Information about soil type, landform and vegetation together with the management information (ploughing, for example, reducing potential for holding soil carbon), that are available, have been weighted (valued) and combined. The map has been created using existing datasets; including the Teagasc national soils and subsoils datasets and the derived habitat map. This does not include information on disturbance, which is particularly relevant on peatlands. The map should be interpreted as showing the best information with the current data available. The map is intended for use at a strategic scale. If exact carbon budgets are required for a specific site, field work should be carried out.

Valuation example:

Ecosystem Service Typology	Significant effects	Data used	Example attributes	Indicative scoring
Soil carbon resource: Organic carbon stored in soils	Presence of organic carbon in the soil	Soils and subsoils	Organic soils	high
			Mineral soils	low
	Topography suitable for soil carbon accruement	Slope	Little slope	high
			Steep slopes	low
	Vegetation cycle accrues / releases soil carbon	Land cover	Semi-natural wetlands	high
			High intensity agriculture	low

0 20 40 60 80 100
Kilometres

N

Note that the Habitat Asset Register (HAR) has, whilst being based on the best data currently available, some associated accuracy limitations, particularly regarding permanent pasture and other information based on aggregation from the LPIS information and an under-estimate of species rich grassland and heath. For details, please refer to the section on data gaps and the section on the preparation of LPIS data for usage in the HAR.

Cartography by Environment Systems Ltd, May 2016.
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Contains data prepared by the Environmental Protection Agency based on Ordnance Survey Ireland information.
For full list of datasets used for this map, please refer to the final project report.

An Roinn Ealaíon, Oidhreachta agus Gaeltachta
Department of Arts, Heritage and the Gaeltacht

National Parks & Wildlife Service

Environment SYSTEMS evidence and insight

Indicator	**CICES classification**
SOIL CARBON (REGULATION OF GREENHOUSE GASES (CARBON))	**Section**: Regulation & Maintenance **Classes:** Global climate regulation by reduction of greenhouse gas concentrations **CICES IE Sub-class:** Areas important for emissions reduction
Scale	**CICES Cascade Level**[1]
Strategic/National. ~~Regional/Local~~	~~Structure/Function/~~Service/~~Benefit/Value~~

[1] Potschin, M. and R. Haines-Young (2016): Frameworks for ecosystem assessments. In: Potschin, M., Haines-Young, R., Fish, R. and Turner, R.K. (eds) Routledge Handbook of Ecosystem Services. Routledge, London and New York, pp 125-143.

What the service is

Soil carbon storage is an important ecosystem service as it can help mitigate climate change by storing CO_2 and preventing its release into the atmosphere. It occurs as the result of the interactions between different ecological processes. The amount of organic matter present within the soil profile is an important component of the service. Soil organic matter is a heterogeneous mixture of organic compounds that are highly enriched in carbon, ranging in decomposition state from fresh plant residues (leaf litter), to highly decomposed material known as humus.

The soil organic carbon levels of different soil types are directly related to the amount of organic matter contained in the soil from growth and death of plant roots and foliage, as well as indirectly from the transfer of carbon-enriched compounds from roots to soil microbes. Inorganic carbon from the mineral component of the soil is not readily released to the atmosphere or water from the soil so it has not been considered in this analysis.

Service indicator(s) mapped

Soil type, habitat, landform and land management were the indicators used to map the service.

Soil data were used to identify areas of mineral, organo-mineral and organic soils. Mineral soils have the lowest carbon content, while organic soils (including peat) have the highest carbon content. Soil drainage was also assessed, as waterlogged, oxygen-poor soils have slower microbial cycling and therefore act as a carbon store (when they are actively forming peat), while dry, well-aerated soils have much faster carbon-cycling and tend to retain lower levels of carbon in the soil.

Habitat data were used to assess the contribution of the vegetation to below-ground carbon storage. Deep-rooted perennial species can facilitate an increase in soil carbon over time through root exudates and decay of leaf litter.

Landform data were used to indicate the effects of topography on soil depth; gentler slopes, which retain deeper soils, and are more likely to accumulate carbon in the soil than steeper slopes, where soils are shallower and water flow is faster. Where depressions occur, organic matter can accumulate due to wetter conditions.

Land management was assessed as positive or negative. Positive management includes reduction of grazing, retention of permanent pasture over cropping, and drain blocking. Negative management includes clear felling large areas, tillage or planting forestry on organic soils, ploughing and drainage of land.

Datasets used	**Dataset requirement**[2]
Habitat Asset Register[3]	Essential
Teagasc Soils	Essential
NextMap 5m DTM	Essential
Conservation Designations	Beneficial

[2] 'Essential' datasets are needed to map the service, whilst 'beneficial' datasets will increase model accuracy but are not necessary requirements for mapping.

[3] The Habitat Asset Register only contains habitats suitable for national scale mapping; for details, please refer to the project report.

How the map was created

Information about soil type, landform and vegetation, together with available management information have been weighted (scored) and combined. The map has been created using existing datasets; including the Teagasc national soils and subsoils datasets and the derived habitat map.

The map should be interpreted as showing ecosystem service information based on the data currently available; when new data become available the maps can be updated. The maps are intended for use at the strategic scale, and a field visit should be conducted before decisions are made regarding a particular location. If exact carbon budgets are required for a specific site, field work should be carried out.

Scoring

Significant Effects	Datasets used	Example attributes	Indicative scoring[4]
Level of topsoil disturbance, carbon cycling through roots and detritus	Habitat Asset Register	Semi-natural broadleaved woodland	High
		Semi-natural grassland	Medium
		Saltmarsh – Spartina mosaic	Low
		Build environment	Disbenefit
Slope gradient affecting soil depth	NextMap 5m DTM	None	High
		None	Medium
		None	Low
		11°-18°; >18°	Disbenefit
Carbon content, texture and drainage properties	Teagasc Soils	FenPt ; RsPt	High
		AminSP, GGr	Medium
		AlluvMIN, Asi	Low

[4]The indicative scoring in this table gives overview-type information on how the individual data layers were incorporated into the ES maps. For full scoring, please refer to the spreadsheet containing the full rules-base.

Data gaps associated with this map during the pilot project

Management and habitat condition are major factors in determining soil carbon storage, neither of which could be fully incorporated into mapping at this stage. Disturbance of peatlands is important, as these areas sequester high amounts of carbon when in good condition, but release carbon into the atmosphere when disturbed (a project looking at the condition of peatlands is currently underway).

Depth of the soil profile (in particular peat depth) should ideally be included for mapping of this service.

Erosion is a major factor in determining how stable the soil profile is. Slope and habitat in conjunction form an additional indicator which could be added to the model to increase the accuracy regarding the effect soil erosion has on soil carbon storage.

The manner in which the LPIS system categorises Permanent Pasture may lead to an overestimation of the amount of grassland that is actually heavily improved. The Guide to Land Eligibility Direct Payment Schemes 2015 states that “Permanent grassland includes productive ryegrass dominated swards, less productive swards that include rush and other non-grass herbaceous species and grassland that includes heather which is grazable and where grass and herbaceous species are not predominant". This may lead to areas that are not overlain by better resolution habitat data being categorised as Permanent Pasture when they may contain other habitats such as Heaths or Blanket Bogs.

Additionally, as the data does not record percentage cover of the individual classes, the classes used are conservative best estimates. In case of a mix of an arable class and a grassland type, the area will appear as arable, even though in reality 90% of the area could be grassland. However, in the final HAR only ~1.5% or Ireland's terrestrial extent are covered by mosaic classes from LPIS, making this a minor issue with regards to overall accuracy for ecosystem service mapping

Scientific framework for modelling Soil Carbon

Overview:	There is good evidence on the role of soil type, landform and habitats in soil carbon storage mainly from literature concerning the terrestrial environment. The most relevant material is summarised here. An important component of soil carbon storage is the amount of organic matter present within the soil profile (Six et al., 2002). Soil organic carbon (SOC) levels of different soil types are directly related to the amount of organic matter contained within the soil from growth and death of plant roots and foliage (Melillo et al., 1989; Rasse et al., 2005), as well as indirectly from the transfer of carbon-enriched compounds from roots to soil microbes (Helal and Sauerbeck, 1986; Wardle, 1992).
Soil systems	In temperate climates, it has been estimated that soils are more important for carbon storage than vegetation (Milne and Brown, 1997; Alonso et al., 2012). In Wetland systems which lack oxygen, organic carbon accrues faster than in most other systems. Due to few organisms being able to tolerate anaerobic environments, respiration rates are low, which causes low rates of CO_2 release (Brady and Weil, 2002; Bain et al., 2011). In addition, the low temperatures and acidic conditions present in wetlands further slow the decomposition rate, causing dead plant material to build up in layers of organic matter (Lindsay, 2010; Bain et al., 2011). In these waterlogged systems the most important vegetation contributors to soil carbon build up are species such as Sphagnum

	mosses (Lindsay, 2010; Bain et al., 2011). That Sphagnum sp. do not facilitate methane release in the way vascular plants do is an additional factor contributing to climate change mitigation by Sphagnum dominated peatlands (Frenzel and Karofeld, 2000; Lindsay, 2010). The significance of vegetation for soil carbon in these wetland systems is therefore scored based on the amount of Sphagnum present (or inferred from the habitat type) and on the likely perturbation of the system. The presence of vascular plants, or of particularly wet microclimates with no oxic zone above the water table, are indicators of peatlands with high methane emissions (MacDonald et al., 1998; Kayranli et al., 2010). Within dry soil systems, vegetation has a different interaction with soil types. Here, carbon is respired by plant roots, soil microbial communities and other communities that feed on plant litter (Singh and Gupta, 1977; Brady and Weil, 2002). Therefore, the depth and quantity of roots and depth of plant litter will be key features in scoring the carbon potential of these vegetation types. Within dry soil systems the likelihood of organic matter in the soil profile being used in respiration is related to its depth, with carbon deep in the profile less likely to be utilised (Singh and Gupta, 1977; Fontaine et al., 2007). This carbon at depth can be an important part of the carbon sink (Milne and Brown, 1997; Alonso et al., 2012). Where the habitats are disturbed (e.g. re-sown grassland) (Hagon et al., 2013), carbon is likely to be utilised, as exposure to oxygen in the perturbation allows micro-organisms to respire (Brady and Weil, 2002), input of new carbon promotes the usage of ancient, buried carbon (Fontaine et al., 2007) and micro aggregates stabilising soil organic matter are broken down (Six et al., 2002). Good information regarding soil composition, particle size, pore spaces, and peat content in Ireland have been recorded by Teagasc (Teagasc Soils Guide[5]; Teagasc, 2007).

[5] http://gis.teagasc.ie/soils/soilguide.php

Management	Negative management practices leading to the release of carbon include: • Drainage (Armentano and Menges, 1986, Bellamy et al. 2005, Holman 2009, Natural England 2010) • Ploughing (Holden et al. 2004, Bain et al. 2011) • Overgrazing (Britton et al. 2005) • Management causing soil erosion (Eswaran et al. 1993, Davari et al. 2010) • Management which causes soil compaction (Dominati et al. 2010) • Applying lime or fertiliser (West and McBride 2005, Biasi et al. 2008) • Clear felling large areas (Eswaran et al. 1993, Foley et al. 2005, Davari et al. 2010) • Tilling on organic soils (Dawson and Smith 2007) • Planting root crops which disturb the soil • Peat harvesting Positive management practices leading to increased storing of carbon include: • Improvement of species diversity of grassland through species management (Fornara and Tilman 2008, Mommer et al 2010) • Reduction of grazing to avoid overstocking (Britton et al. 2005) • Improvement of soil structure • Retention of permanent pasture over cropping where feasible • Drain blocking (Armentano and Menges, 1986, Bellamy et al. 2005, Holman 2009)

Supporting evidence: References

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