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

Indicator	**CICES classification**
VEGETATION CARBON STORAGE Vegetation carbon (Regulation of greenhouse gases (carbon))	**Section**: Regulation & Maintenance **Class:** Global climate regulation by reduction of greenhouse gas concentrations Filtration / sequestration / storage / accumulation by micro-organisms, algae, plants, and animals **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

This is an important ecosystem service as it can help mitigate climate change by storing CO_2 and preventing its release into the atmosphere. Atmospheric carbon is sequestrated by, and stored in vegetation through the process of photosynthesis, resulting in vegetative growth. The more biomass present in the vegetation the more carbon that is stored, with mature woodland providing higher storage, grasslands providing little, and bare ground providing none.

The scientific framework outlined below helps to determine the type of data that could be used for modelling of this service, and provides general guidance which indicators are likely to have a positive or negative impact on service provision.

Scientific framework for modelling 'vegetated carbon storage'

Overview:	Atmospheric carbon is sequestrated by, and is stored in, vegetation through the process of osmosis and plant growth (FAO, 2001). There is good supporting evidence regarding the role of soils and habitats in vegetation carbon storage and the role of above and below ground processes. The most relevant material is summarised here.
Soil	Vegetation carbon storage is influenced by soil type, with properties such as soil texture, depth, organic matter/nutrient content as well as the context of the soil in the landscape affecting the type of vegetation likely to be present (Brady and Weil, 2002; Dominati et al., 2010). Additionally, human management of soil has a strong influence on vegetation carbon storage by altering the type of vegetation found in an area (Foley et al., 2005). This is of particular relevance when modifications of the soil (e.g. drainage or fertiliser input) promote growth of plants that would not naturally be sustained by the soil type present (Foley et al., 2005; Holman, 2009; McCracken et al., 2011). While vegetation is linked to broad groups of soil type (as discussed below), association between vegetation and subdivisions of soil type is low (Rankin et al., 2007). For example, mature woodland can even develop on quite shallow and wet soils. 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

Habitat and land use	The more biomass that is present in the vegetation layer, the more carbon is stored in the vegetation. Habitat type is a key determinant of vegetation carbon storage. As plant material, particularly woody tissue, contains up to 50% carbon (FAO, 2001; Thomas and Martin, 2012), a high biomass within the habitat is associated with large quantities of vegetation carbon. Consequently, on a per area basis, woodlands are the main contributor to vegetation carbon storage in temperate climates (Milne and Brown, 1997; Quine et al., 2011; Alsonso et al., 2012), with most carbon being stored in the trunks (Hagon et al., 2013). To assess the rate of carbon uptake, the age of the forest is important, as uptake is highest during the full-vigour phase (Quine et al., 2011; Alsonso et al., 2012) before levelling out in mature forests (Broadmeadow and Matthews, 2003). Most of the carbon stored in grasslands is in the soils (Bullock et al., 2011; Alonso et al., 2012; Hagon et al., 2013). Habitats managed for arable and horticultural crops store the least carbon in their vegetation (Milne and Brown, 1997; Alonso et al., 2012). An important difference between agriculturally managed and natural systems is that, in natural systems, part of the above ground biomass will be incorporated into the soil carbon store as plant litter (Melillo et al., 1989; Angers and Caron, 1998; Rasse et al., 2005). For example in heathlands, during the growth phase biomass increases, which leads to a net gain in vegetation carbon. However, after a certain time, between 18 and 27 years in Calluna vulgaris dominated heath, vegetation biomass (and carbon with it) levels out, as gain from growing plants and loss from dying plants balance out. During this time, however, stocks in the soil could keep increasing due to plant litter (Kopittke et al., 2013). Wetlands are considered a terrestrial carbon sink (Billett et al., 2010; Kayranli et al., 2010; Bain et al., 2011), but store the majority of the carbon in the underlying soils rather than in the vegetation (Ostle et al., 2009; Bain et al., 2011). A diverse community of soil invertebrates, particularly earthworms, can have a positive impact on soil structure by creating pores of various sizes that enable easy root penetration and increase oxygen content and water holding capacity (Brussaard, 1997; Wall and Moore, 1999; Lavelle et al., 2006). In habitats where this is the case, below ground species richness can have a positive impact on the maximum biomass that can be sustained above ground (Brussaard, 1997; Wall and Moore, 1999) and, hence, affect vegetation carbon.

Supporting Evidence: References

Alonso, I., Weston, K., Gregg, R., & Morecroft, M. (2012). Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources. (N. England, Ed.) Natural England. Retrieved from http://publications.naturalengland.org.uk/publication/1412347

Angers, D., & Caron, J. (1998). Plant-Induced Changes in Soil Structure: Processes and Feedbacks. Biogeochemistry, 55-72. Retrieved from http://www.jstor.org/stable/1469338

Bain, C., Bonn, A., Stoneman, R., Chapman, S., Coupar, A., Evans, M., Worrall, F. (2011). IUCN UK Commission of Inquiry on Peatlands. Retrieved from http://roar.uel.ac.uk/3591/1/IUCN%20UK%20Commission%20of%20Inquiry%20on%20Peatlands%20Full%20Report%20spv%20web.pdf

Billett, M., Charman, D., Clark, J., Evans, C., Evans, M., Ostle, N., others. (2010). Carbon balance of UK peatlands: current state of knowledge and future research challenges. Climate Research, 45, 13-29. Retrieved from http://www.int-res.com/articles/cr_oa/c045p013.pdf

Brady, N. C., and R. R. Weil. (2002) In The Nature and Properties of Soils (13th Edition). Upper Saddle River, NJ: Prentice-Hall, Inc.

Broadmeadow, M., & Matthews, R. (2003). Forests, carbon and climate change - The UK contribution. Tech. rep., Forestry Commission. Retrieved from http://www.forestry.gov.uk/pdf/fcin048.pdf/$FILE/fcin048.pd

Brussaard, L. (1997). Biodiversity and ecosystem functioning in soil. Ambio, 563-570. Retrieved from http://www.jstor.org/stable/4314670?seq=1&uid=3738032&uid=2&uid=4&sid=21104556804443

Bullock, J., Jefferson, R., Blackstock, T., Pakeman, R., Emmett, B., Pywell, R., others. (2011). UK National Ecosystem Assessment - Chapter 6: Semi-natural Grasslands. (J. Bullock, Ed.) UK National Ecosystem Assessment. Retrieved from http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx

Dominati, E., Patterson, M., & Mackay, A. (2010). A framework for classifying and quantifying the natural capital and ecosystem services of soils. Ecological Economics, 69(9), 1858-1868. Retrieved from http://www.sciencedirect.com/science/article/pii/S0921800910001928#

FAO (2001). Food and Agriculture Organisation of the United Nations. Plantations and Greenhouse Gas Mitigation: A short Review. Forest Plantations Thematic Papers, Working Paper FP/12. Retrieved from ftp://ftp.fao.org/docrep/fao/006/ac132e/ac132e00.pdf

Foley, J., DeFries, R., Asner, G., Barford, C., Bonan, G., Carpenter, S., others. (2005). Global consequences of land use. science, 309(5734), 570-574. Retrieved from http://www.sciencemag.org/content/309/5734/570.short

Hagon, S., Ottitsch, A., Convery, I., Herbert, A., Leafe, R., Robson, D., & Weatherall, A. (2013). Managing Land for Carbon - A guide for farmers, land managers and advisers. Retrieved from http://www.lakedistrict.gov.uk/caringfor/projects/carbon

Holman, I. (2009). An estimate of peat reserves and loss in the East Anglian Fens. Department of Natural Resources, Cranfield University / RSPB. Retrieved from http://www.rspb.org.uk/Images/Fenlandpeatassessment_tcm9-236041.pdf

Kayranli, B., Scholz, M., Mustafa, A., & Hedmark, A. (2010). Carbon storage and fluxes within freshwater wetlands: a critical review. Wetlands, 30(1), 111-124. Retrieved from http://www.jlakes.org/web/CARBONSTORAGE-FLUXES-FRESHWATERWETLANDS-W2010.pdf

Kopittke, G., Tietema, A., van Loon, E., & Kalbitz, K. (2013). The age of managed heathland communities: implications for carbon storage? Plant and soil, 369(1-2), 219-230. Retrieved from http://dare.uva.nl/document/480176

Lavelle, P., Decaens, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Rossi, J. (2006). Soil invertebrates and ecosystem services. European Journal of Soil Biology, 42, S3--S15. Retrieved from http://www.sciencedirect.com/science/article/pii/S1164556306001038

McCracken, D., Stoate, C., Goulding, K., Harmer, R., Hess, T., Jenkins, A., Williams, P. (2011). UK National Ecosystem Assessment - Chapter 7: Enclosed Farmland. (L. Firbank, & R. Bradbury, Eds.) UK National Ecosystem Assessment. Retrieved from http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx

Melillo, J., Aber, J., Linkins, A., Ricca, A., Fry, B., & Nadelhoffer, K. (1989). Carbon and nitrogen dynamics along the decay continuum: plant litter to soil organic matter. In Ecology of Arable Land — Perspectives and Challenges (pp. 53-62). Springer. Retrieved from http://link.springer.com/chapter/10.1007/978-94-009-1021-8_6

Milne, R., & Brown, T. (1997). Carbon in the Vegetation and Soils of Great Britain . Journal of Environmental Management, 49(4), 413-433. Retrieved from http://www.sciencedirect.com/science/article/pii/S0301479785701181

Ostle, N., Levy, P., Evans, C., & Smith, P. (2009). UK land use and soil carbon sequestration. Land Use Policy, 26, S274--S283. Retrieved from http://www.sciencedirect.com/science/article/pii/S0264837709000945

Quine, C., Cahalan, C., Hester, A., Humphrey, J., Kirby, K., Moffat, A., & Valatin, G. (2011). UK National Ecosystem Assessment - Chapter 8: Woodlands. (C. Quine, Ed.) UK National Ecosystem Assessment. Retrieved from http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx

Rankin, M., Semple, W., Murphy, B., & Koen, T. (2007). Is there a close association between 'soils' and 'vegetation'? A case study from central western New South Wales. Cunninghamia, 10(2). Retrieved from https://www.rbgsyd.nsw.gov.au/__data/assets/pdf_file/0010/89749/Cun102199Ran.pdf

Rasse, D., Rumpel, C., & Dignac, M. (2005). Is soil carbon mostly root carbon? Mechanisms for a specific stabilisation. Plant and soil, 269(1-2), 341-356. Retrieved from http://link.springer.com/article/10.1007/s11104-004-0907-y

Teagasc (2007). Creamer, R., Simo, I., Reidy, B., Carvalho, J., Fealy, R., Hallett, S., Jones, R., Holden, A., Holden, N., Hannam, J., Massey, P., Mayr, T., McDonald, E., O'Rourke, S., Sills, P., Truckell, I., Zawadzka, J. and Schulte, R. Irish Soil Information System – Synthesis Report (2007-S-CD-1-S1). Environmental Protection Agency, Wexford.

Thomas, S., & Martin, A. (2012). Carbon content of tree tissues: a synthesis. Forests, 3(2), 332-352. Retrieved from http://www.mdpi.com/1999-4907/3/2/332/pdf

Wall, D., & Moore, J. (1999). Interactions Underground: Soil biodiversity, mutualism, and ecosystem processes. BioScience, 49(2), 109-117. Retrieved from http://bioscience.oxfordjournals.org/content/49/2/109.short