

Carbon management and scenario planning at landscape scale with GIS at the Southwest England

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ABSTARAC:

Climate change is real, and causal link to increased greenhouse gas emissions is now well established. Globally, the ten hottest years on record have occurred since 1991, and in the past century, temperatures have risen by about 0.6 °C. The potential for soil organic carbon (SOC) sequestration, energy savings and the reduction of the emission of greenhouse gases are investigating for a range of changes in the management of land use and land cover. So, we outline a framework for considering uncertainty in estimates of emissions of greenhouse gases (GHG_s) where the objective is to determine least cost adaptations to reduce emissions of the land use and land cover level at the Southwest England. Land use soils, having been depleted of much of their native carbon stocks, have a significant CO₂ sink capacity. Management practices to build up soil and / or decrease soil organic matter decomposition rates at the UK. In this paper an attempt has been made to develop a geographical information system (GIS) based methodology for distribution and quantify the soil organic carbon and emissions from a land use and land cover level.

1. INTRODUCTION:

It is now widely believed that globally averaged temperatures will rise significantly over the next 100 years as a result of increasing atmospheric concentrations of greenhouse gases such as carbon dioxide (IPCC, 2007). Increased average temperatures are likely to be associated with a variety of other climate changes including variations in the seasonality, amount and intensity of precipitation, and shifting location and strength of wind patterns. The impacts of future climate change include rising sea levels and effects on water supply, agriculture, infrastructure and human health. Impacts may be both beneficial and detrimental but the net global impact will be negative economically and environmentally (Stern, 2006). Responses to

the threat of future climate change are both adaptations to new climate conditions, and mitigation of the magnitude of change. Mitigation can be achieved both through reducing emissions of greenhouse gases and by increasing storage of carbon in the earth system. The most successful mitigation strategy will be based on multiple approaches, using as many opportunities for emissions reduction and increased carbon storage as possible. In particular it is thought that there is potential for increased storage of carbon on land in soils and growing vegetation. In the UK, the major direct emissions of greenhouse gases (GHG_s) such as from land use are methane (CH₄) from enteric fermentation by ruminant livestock and manure management, and nitrous oxide (N₂O) from soils and manures. Methane has a global warming potential 21 times greater than carbon dioxide; figure for nitrous oxide is 310 times that of CO₂ (IPCC,2001). Using figures from the UK submission to the Framework on Climate Change (Salway et al., 2001), agriculture accounted for 8% of total net UK GHG emissions in 1999.

Emission estimates for land use systems are subject to a large amount of uncertainty. There can be uncertainty concerning our understanding of how systems work and interact, the validity of possible outcomes and the distribution of possible outcomes and creating different scenarios with GIS system. There is now a need for research on the potential impacts of changing land use on terrestrial carbon storage.

This project aims to develop a methodology for estimating the impacts of future land use change on terrestrial carbon storage under a range of different scenarios. This project use contrasting regions of the UK (Southwest England) as case studies but the methodology developed will be adaptable to other areas of the world.

Future carbon storage on land will depend on a complex range of factors and interactions including the amount of carbon held in different soil, vegetation and land use types, the reaction of these carbon stores to future climate change, and socio-economic drivers of land use change (government policy, food supply, values, planning constraints etc). The main objective of this paper is to GIS-based approach for the quantification of carbon storage at the landscape scale using land use, soil, vegetation cover and climate as the principle determinants of carbon storage (e.g. Milne and Brown, 1997).

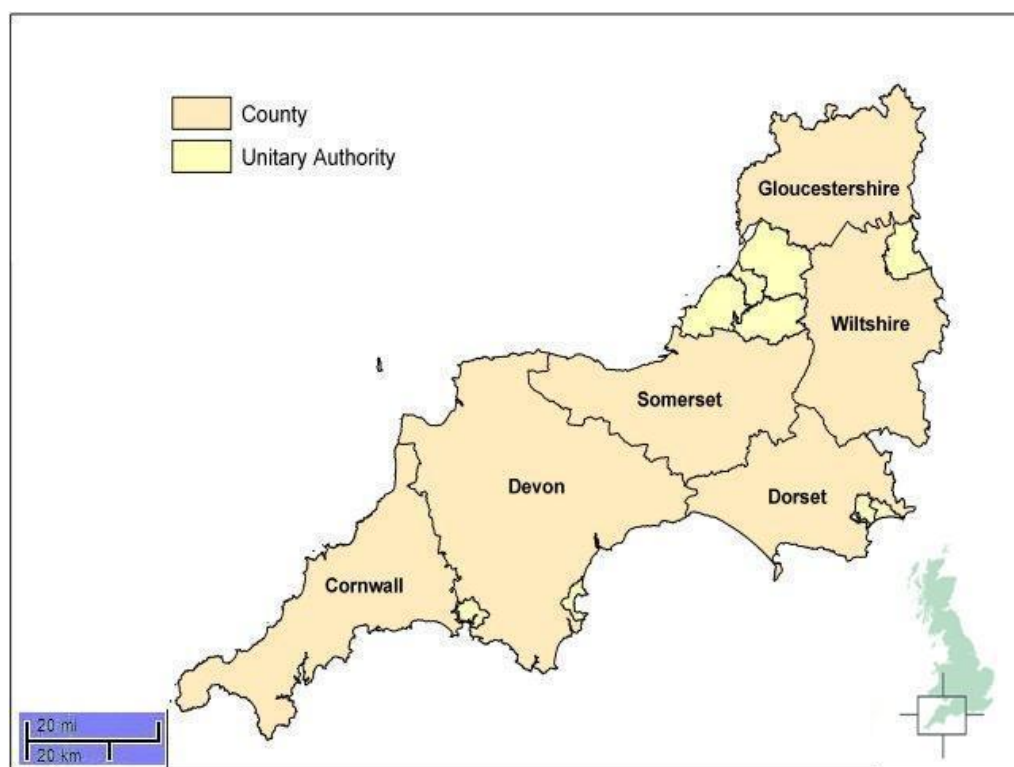
To determine the impacts of policy scenarios on carbon storage and to evaluate their effectiveness as climate change mitigation strategies for the region.

2. MATERIALS AND METHODS:

2.1. Study area

The study area covers the Southwest part of England. The Southwest is the largest region in England in terms of area, and extends from the counties of Gloucestershire, Avon, Wiltshire, Dorset, Somerset, Devon and Cornwall (Figure1). The region is nearly 400 km from end to end, covers almost 24,000 km² and has a coastline about 1,100 km long. The small native population is enhanced by growing numbers of retired people and, particularly in Devon and Cornwall, by large numbers of seasonal visitors attracted by the mild climate, beautiful coastline and unspoiled countryside.

Figure 1: The region of Southwest of England.



2.2. Modelling

The understanding of SOC dynamics and SOC distribution at a regional level is an essential step when quantifying regional and global C budgets (Paustian *et al.*, 1997). The modelling of SOC content is a way of indirectly assessing C sequestration to complement direct measurements. Modelling may also help in the identification of areas with a large potential for increased SOC sequestration as well as making it possible to predict and understand future changes due to changing climate, altered land use and different land management

practices. To be successful, these models need to incorporate both human and environmental factors when predicting regional SOC changes.

Recently articles published have addressed measures that may either sequester carbon within the soil or save CO₂ emissions from reduced energy use. Those thought to be most suitable and likely to be tried in England are listed in Table 1.

At any given location, soil carbon stocks are largely a result of management practices and crop residue inputs resulting from rotations over several years (King et al., 2004). Therefore the impact of changes in cultivation and management practice needed to be assessed on the same basis.

Table 1. Changes in land use and management practice assessed for carbon sequestration and saving potential within the arable and managed grassland sector of farming in England (King et al., 2004).

Changes in land use and management practice to arable land	Changes in land use and management practice to managed grassland
Change to permanent woodland	Change to permanent woodland
Change to willow energy crop	Change to willow energy crop
Change to miscanthus energy crop	Change to miscanthus energy crop
Conventional to zero tillage	Change to clover based pastures
Conventional to reduced tillage	
Addition of straw residues	
Addition of livestock manure to arable land rather than grassland	
Set-aside field margins on arable land	
Extensification scenario of converting break crops in rotation	
Extensification scenario with outdoor pig breeding on grass in rotation	
Conversion stockless organic management	Conversion of conventional to organic dairy management system
Conversion to organic management with livestock	

2.3. Methodology for using GIS

It should be mentioned here clearly that GIS does implicitly improve the accuracy of various input data. GIS is greatly help in interpretation of the results obtained in terms of high-resolution spatial distribution. To estimate total land use and land cover organic carbon content and its distribution within the Southwest, spatial analysis will be used. To achieve

this, representative measurements of total mass of carbon in the vegetation will be estimated by land use classification totals by plotting for each 1 km x 1 km square the average vegetation carbon density of the land class of the square with GIS modelling system. This will enable calculation of estimated total carbon distribution in different land class.

First, the carbon conservation and storage map will be constructed by a set of environmental attributes considered most important for forest and agriculture land production, and by identifying the spatial distribution of highly ranked sites. The sequestration of carbon in woody biomass is one of the most important mechanisms for removing carbon from agriculture to forest is associated with significant gains in soil carbon over losses attributable to decomposition and / or mineralization (Lal, 2002; Lal et al., 2004a).

Second, the study will examine the degree to which lands on highly-ranked sites for carbon storage and conservation are considered as areas for protection in the long-term and long-range Southwest region. The GIS modelling and planning support system intended for this research conceptually divide into two main components or subsystems.

3. RESULTS :

a) *Estimated top soil and total soil organic carbon*

This presents data and preliminary findings from a GIS analysis of the 920 km² Tamar catchment in South-west England. This study has estimated soil organic carbon (SOC) density [i.e. the amount (kg OC ha⁻¹) in a defined depth layer] in all soils in the Tamar Valley catchment. Organic carbon (OC) levels [i.e. the density of OC in the soil (kg OC ha⁻¹) soil] in the Ap horizon (top soil) and total soil layers are determined using published data on soil depth, bulk density and percentage of organic carbon.

Results of the analysis from the GIS are presented of maps for soils and summary statistics are presented in a series of tables 2, 3.

The database of analytical results from GIS determinations SOC mass for depths up to 20 cm and all depth range in soil component and this provides a preliminary assessment of this information. This result has been separate calculation for topsoil and total soil depth. The topsoil is more vulnerable to management change such as ploughing and carbon storage and GHG emission.

This area SOC mass which has been quantified for **top soils** is 2.45 Mt C and mass of **total soil** types as using GIS method is 5.32 Mt C (Table 2, 3). These values can be considered as

the sum of the products of an area and a mean carbon density for each soil groups. Existing databases have prove to be a valuable data source in calculating estimates for size and distribution of carbon pools in soils type at Tamar Valley catchment.

The figure 2, 3 is shows soils organic carbon densities at Tamar valley catchment.

Table 2: Soil carbon density and total carbon in Tamar Valley soils. Only values for the top soil (top 20 cm) have been calculated.

Soils Types	Depth (0-20 cm)	Density of C (t / ha ⁻¹)	Area (ha)	Total Carbon (t)
Neath	0-20	27.5	20311	558552.5
Hallsworth 1	0-20	12.7	13895	176466.5
Hallsworth 2	0-20	12.7	6450	81915
Denbigh 2	0-20	10.2	11499	117289.8
Denbigh 1	0-20	10.2	67774	691294.8
Parc	0-20	3.9	801	3123.9
Hafren	0-20	22.8	1739	39649.2
Moor Gate	0-20	17.1	3085	52753.5
Winter Hill	0-20	5.2	200	1040
Hexworthy	0-20	3.7	4892	18100.4
Wilcocks 2	0-20	13.5	1265	17077.5
Powys	0-20	12.3	1950	23985
Yeollandpark	0-20	13.8	1232	17001.6
Princetown	0-20	43	4708	202444
Larkbarrow	0-20	6.3	914	5758.2
Trusham	0-20	7.4	10309	76286.6
Laployd	0-20	35.4	129	4566.6
Nordrach	0-20	9.7	951	9224.7
Moretonhampstead	0-20	6.6	2656	17529.6
Raw china clay spoil	0-20	0	872	0
Onecote	0-20	14.3	119	1701.7
Sportsmans	0-20	9.9	2723	26957.7
Halstow	0-20	8.4	5785	48594
Teme	0-20	4.9	1486	7281.4
Conway	0-20	27.5	903	24832.5
Malvern	0-20	11.3	1566	17695.8
Manod	0-20	11.4	11449	130518.6
Alun	0-20	6.4	165	1056
Crowdy 2	0-20	14.8	4878	72194.4
Total			184706	2444891.5

Table 3: Soil carbon density and total carbon for the full depth of soils in the Tamar Valley Catchment.

Soils Types	Depth (0-13 cm)	Density of C (t/ha ⁻¹)	Area (ha)	Total Carbon (t)
Neath	0-100	44.34	20311	20355.4
Hallsworth 1	0-100	25.71	13895	357240.5
Hallsworth 2	0-100	25.71	6450	165829.5
Denbigh 2	0-100	33.81	11499	388781.2
Denbigh 1	0-100	33.81	67774	2291439
Parc	0-100	21.23	801	17005.3
Hafren	0-54	31.76	1739	55230.7
Moor Gate	0-120	38.14	3085	117661.9
Winter Hill	0-63	11.8	200	2360
Hexworthy	0-87	35.92	4892	175720.7
Wilcocks 2	0-74	40.17	1265	50815.1
Powys	0-102	24.18	1950	47151
Yeollandpark	0-63	18.39	1232	22656.5
Princetown	0-120	21.5	4708	101222
Larkbarrow	0-77	21.41	914	19568.8
Trusham	0-120	23.83	10309	245663.5
Laployd	0-71	81.44	129	10505.8
Nordrach	0-85	26.06	951	24783.1
Moretonhampstead	0-58	40.96	2656	108789.8
Raw china clay spoil	0	0	872	0
Onecote	0-92	17.59	119	2093.2
Sportsmans	0-90	19.19	2723	52254.4
Halstow	0-130	15.15	5785	87642.8
Teme	0-127	26.31	1486	39096.7
Conway	0-91	79.19	903	71508.8
Malvern	0-77	20.94	1566	32792.1
Manod	0-95	32.91	11449	376786.6
Alun	0-127	29.46	165	4860.9
Crowdy 2	0-100	87.4	4878	426337.2
Total			184706	5316152.5

Figure 2: Tamar Valley Catchment Top Soils Carbon Density Map

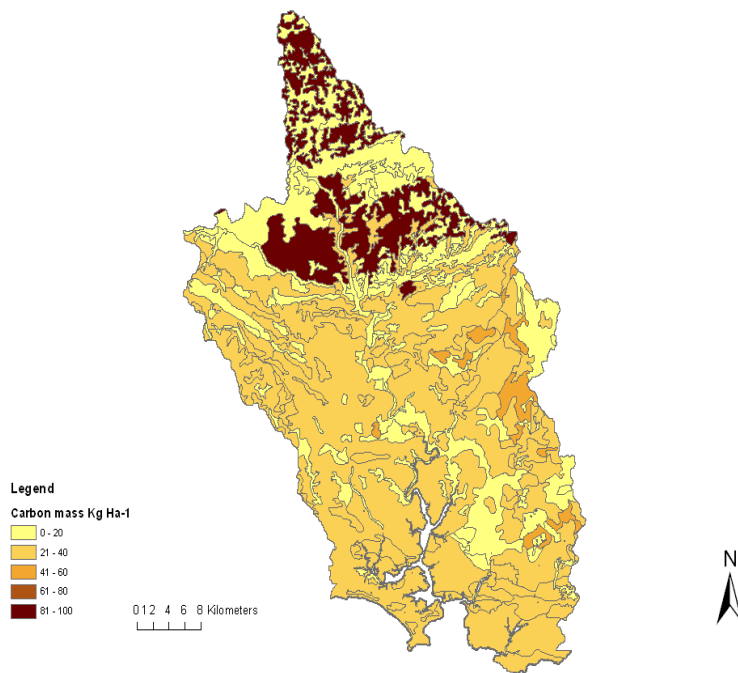
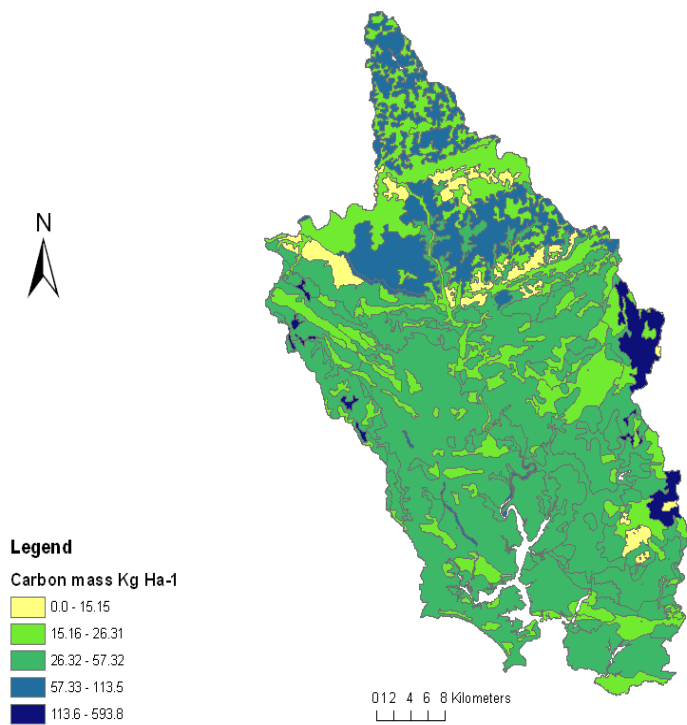


Figure 3: Tamar Valley Catchments Total Soils Carbon Density Map



b) Estimates of carbon in vegetation

In support of the UK's commitment under the Framework Convention on Climate Change, researchers have been developing an inventory of carbon in the vegetation and soils of Great Britain (Milne and Brown, 1995). Forest and other vegetation are an important part of the sink of carbon and changes in size and productivity of the sink may act as a sink or source for carbon dioxide. The total amount of carbon held by vegetation in Great Britain is estimated to be 114 M tonnes.

In part of pilot site study (Tamar Valley) the carbon store in the forest and non-forest vegetation of the Tamar Valley was estimated by combining published studies of biomass partitioning (Milne and Brown, 1995) and land classification and digital map of land cover on Geographical Information System (GIS) (table 4).

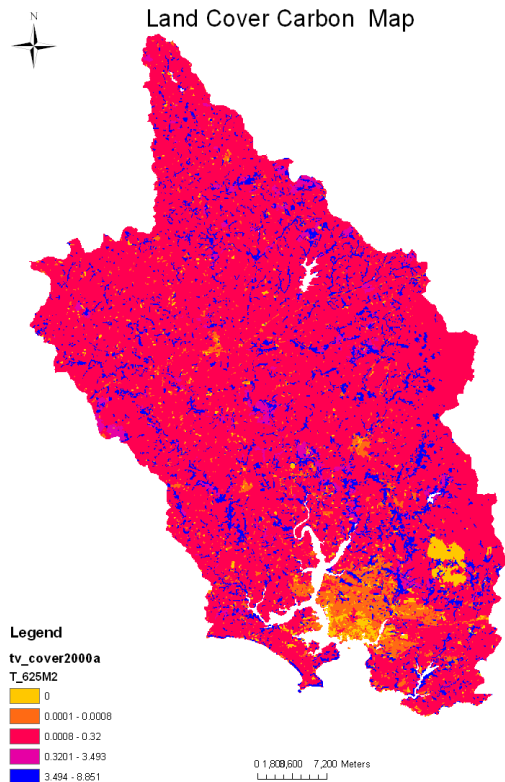
Table 4 and Figure 4 show the Land Cover Carbon density. Carbon storage in vegetation has been calculated by multiplying the area each of land cover types within the study site (Tamar Valley) by estimates for their carbon content. The total mass of carbon in vegetation on land in each land class was calculated by summing the products of carbon density and total area for each cover type. The average density for each land class was then calculated by dividing by the total area of land in each land class with considering Milne and Brown, 1995. It also has been calculated carbon storage for each square kilometre of the study site by determining the area of different vegetation types in each 1-km² square.

Therefore, vegetation carbon stores have been calculated by multiplying carbon density by the true surface area. Total mass of carbon in the vegetation of Tamar Valley was estimated to be **1.24** M tonnes (table 4) by adding the land class totals.

Table 4: Land covers carbon density in Tamar Valley catchment. The land cover types are matched with the cover types of Milne and Brown, (1995).

Land Cover Type (GIS)	Cover Type (Milne and Brown,1995)	Vegetation Carbon Density (t/ha ⁻¹)	Land Cover Area (ha)	Total Land Cover Carbon Mass (t)
Bread-leaved woodland	Broadleaf	5532	178.4	986964.1
Coniferous woodland	Conifer woodland	2183	45.7	99709.9
Arable Cereals	Crops	100	204.4	20442.8
Arable horticulture	Crops	100	172.2	17218.7
Improved grassland	Unimproved grass	100	807.9	80790.7
Neutral grass	Unimproved grass	100	40.5	4050.3
Calcareous grass	Unimproved grass	100	80.6	8060.7
Acid grass	Unimproved grass	100	102.6	10256.2
Bracken	Heath	200	0.01	1.3
Dwarf shrub heath	Heath	200	2.8	566.5
Open dwarf shrub heath	Heath	200	28.6	5714.8
Inland bare ground	-	0	4.4	0
Bog	Bogs, etc	200	16.7	3326.8
Suburban/rural development	-	0.5	96.4	48.2
Salt marsh	Maritime	200	1.2	247.5
Continuous urban	-	0	23.8	0
Littoral rock	-	0	8.5	0
Total			1814.7	1237398.1

Figure 4. Land Cover Distribution Carbon of Biomass.



4. CONCLUSION:

The carbon stored in vegetation of Tamar catchment has been estimated to be **1.24 Mt** (Table 4) and in top soils and total soils to be **2.45 Mt** and **5.32 Mt** (Table 2, 3). These values can be considered as the sum of the products of an area and a mean carbon density for each land cover group and each soil group.

Existing databases have proved to be a valuable data source in calculating estimates for the size and distribution of the carbon pools in the vegetation and soils of Tamar Valley catchment (Southwest England). However, existing databases do not always have all the required information and future work is necessary to provide this. Forests are the main sink of carbon but their density and productivity varies and changes in land use due to policies and schemes may also result in particular places will becoming significant sources or sinks for carbon throughout the country. Therefore, the challenge now is to extent the work on the pool size to include rates of change of stored carbon.

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