Soils and ecosystem services in relation to climate change and agriculture

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Outline

- Introduction - Soils pervade and influence all ecosystem services – soil type determines the balance of services available
- Soils, Climate Change and Agriculture – risks/opportunities
- Are we losing soil C? Results of the partial re-sampling of the National Soils Inventory of Scotland .
- How is the new data, information and knowledge useful to stakeholders and relate to present and future policies
- Conclusions

Science-Policy imperatives

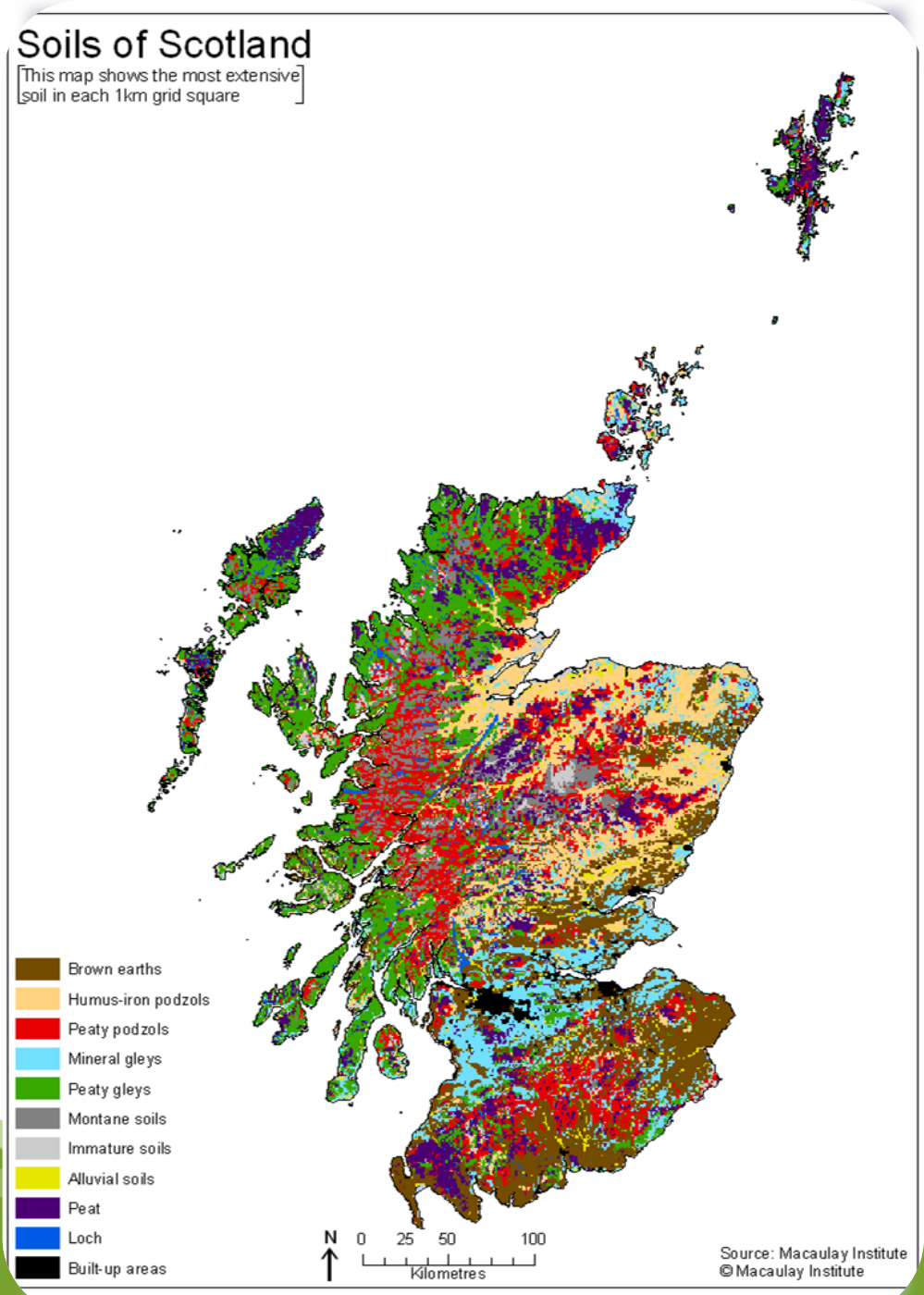
- International recognition of central role of soil in delivering ecosystem services
- EU WFD, Cross Compliance
- EU Soil Directive (2006)
- Scottish Government
  - 06 - Soil Monitoring System, Soil Strategy
  - 09 - Scottish Soils Framework published
  - 10/11- Land Use Strategy

Soils - high on the agenda

Not one but many soils

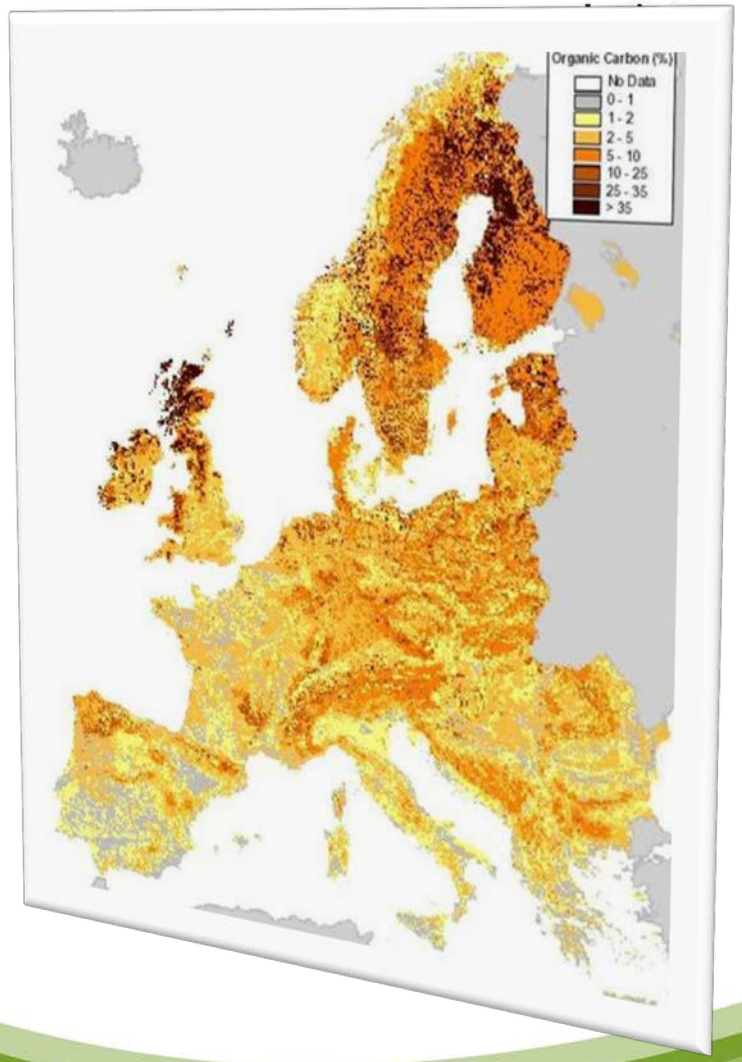
Soil formation *depends on rock type, vegetation, biodiversity, climate, topography, time and management*

This geodiversity *(soils and geology) determines the balance of soil-related functions in our landscape*



Scotland is a EU hot-spot for soil C

- Cool, wet climate, low pH and relatively young soils all contribute to natural accumulation of C from vegetation
- Not just our peats, our mineral soils used for farming are also higher than England and other parts of Europe



Functions of soil

Biomass production, agriculture and forestry

Storing, filtering & transforming nutrients, substances and water

Acting as carbon pool

Biodiversity pool, supporting habitats, species & genes

Archive of geological and archaeological heritage

Source of raw materials

Physical & cultural environment for humans and their activities

UK NEA classifies services along functional lines into the categories of:

Provisioning services:

The products obtained from ecosystems.

For example,
- **food**
- **fibre**
- **fresh water**
- **energy?**

Regulating services:

The benefits obtained from the regulation of ecosystem processes.

For example,
- **seed dispersal**
- **pollination**
- **regulation of climate**
- **noise regulation**
- **water regulation,**
- **regulation of some human diseases.**

Supporting services:

Ecosystem services that are necessary for the production of all other ecosystem services.

For example,
- **biomass production**
- **atmospheric oxygen production,**
- **soil formation and retention**
- **nutrient cycling**
- **water cycling**
- **provisioning of habitat.**

Cultural services:

The non-material benefits people obtain from ecosystems.

For example,
- **spiritual enrichment**
- **cognitive development**
- **reflection**
- **recreation**
- **aesthetic experience, including for example, knowledge systems, social relations, aesthetic values.**

Soil plays a role in them all

Scotland's soil….

Provisioning

- gross agriculture output of £1.75 billion in 2005 incl. in the past world record yields for cereals
- Forestry (incl. processing) ~ £650m p.a.

Regulating

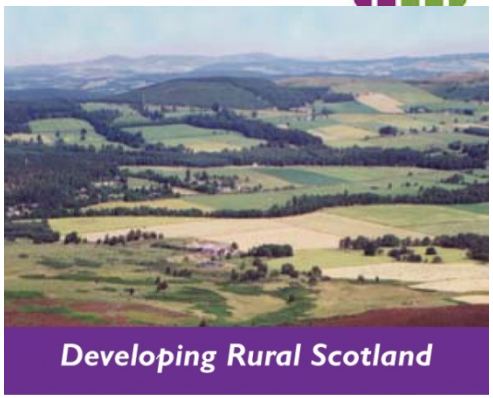
- Stores and filters our water. i.e. 40 billion m^3 of water in the top 1m when fully wet
- Filters out, transforms and degrades 1000s of different acidifying, potentially toxic elements and compounds
- Stores ~3000 Mt of C - equivalent of 186 y of Scotland's total carbon dioxide emissions

Supporting - habitats and biodiversity

- Flow Country, Machair
- 1 g of a typical soil can contain 10,000 different species of bacteria with an unexplored potential for new genes & enzymes

Cultural

- Are a record of our cultural history e.g. "plaggen" soils and harbours and protects archaeological artefacts.



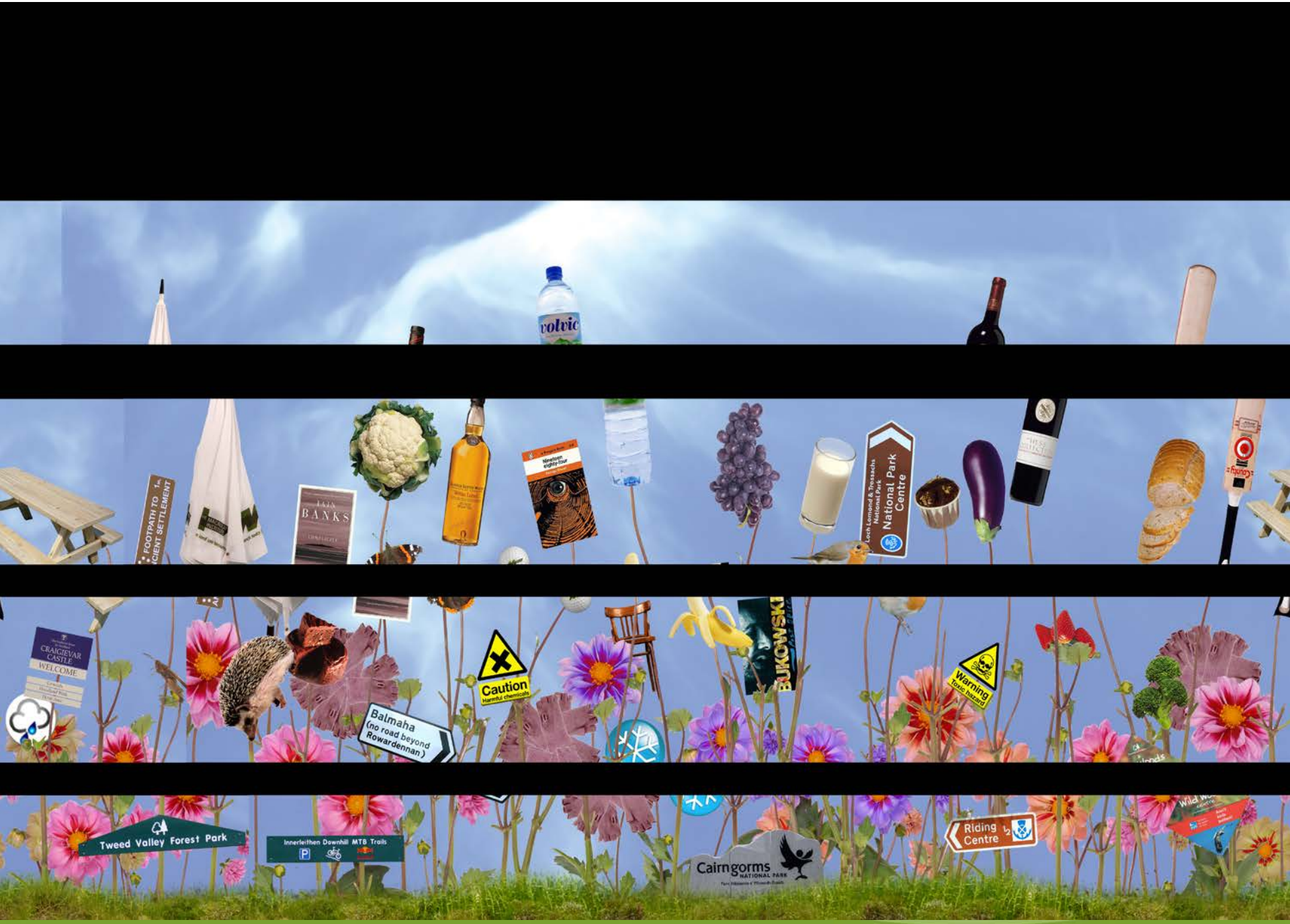
Valuing Soil Services

"… the city government of New York realised that changing agricultural practices meant it would need to act to preserve the quality of the city's drinking water."

Option 1 - install new filtration plants, at cost of $4-6 Billion with annual running costs of $250 M.

Option 2 - Spend $250 M on buying land to prevent development, and paying farmers $100 M a year to minimise water pollution.

'**Rachel Carson meets Adam Smith**'
The Economist 375, 8423:
pp 9; 74-76, April 23, 2005


volvic
FOOTPATH TO ANCIENT SETTLEMENT
BANKS
Kingdom Eighty-four
Loch Lomond & Trossachs National Park
National Park Centre
CRAIGIEVAR CASTLE
WELCOME
Caution
Harmful chemicals
BUKOWSKI
Warning
Toxic hazard
Balmaha
(no road beyond Rowardennan)
Tweed Valley Forest Park
Innerleithen Downhill MTB Trails
Cairngorms
NATIONAL PARK
Riding Centre

Soils as part of our natural capital - lessons of history

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- Poor soil management - main factor responsible for the collapse of settlements and civilisations in the past e.g. Antioch and Dust bowl of US in 1930's but also
- Soil erosion in the Viking settlements of Greenland and Iceland
- "Soils are the central pillar of sustainability" (Magnus Magnusson, 1996, Scottish and Icelandic historian, journalist)

"The history of every Nation is eventually written in the way in which it cares for its soil."

"The nation that destroys its soil destroys itself."

FRANKLIN D. ROOSEVELT
XXXII *President of the United States: 1933-1945*

Soil Degradation

- Soils are a fundamental part of each and every nation's natural capital
- In developing countries, they make up 70% of the value of natural capital (World Bank "Where is the Wealth of Nations").
- Soils are slow to form but they and their functions can be lost quickly as a result of extreme events, improper management or contamination.
- *Soil degradation* is a major global problem threatening the sustainability of terrestrial ecosystem services.

Extreme gully soil erosion in Kenya on land grazed by goats. (2010, CD Campbell).

Soils, Climate Change and Agriculture

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Adaptation/ Risks

- Organic matter turnover may be increased with feedbacks to climate forcing, e.g. from warmer drier soils. This will lead to losses in fertility and soil structure.
- Yields of agricultural and forestry products may be adversely affected by drought
- Trafficability and soil workability may be impacted at crucial times of the year, leading to a potentially increased risk of compaction.
- Erosion risk may increase if storm events occur more regularly.
- Some valued soils supporting specific habitats may be disproportionately at risk, e.g. Machair (from increased flooding /inundation) and montane soils (from warming/drying).

Soils, Climate Change and Agriculture

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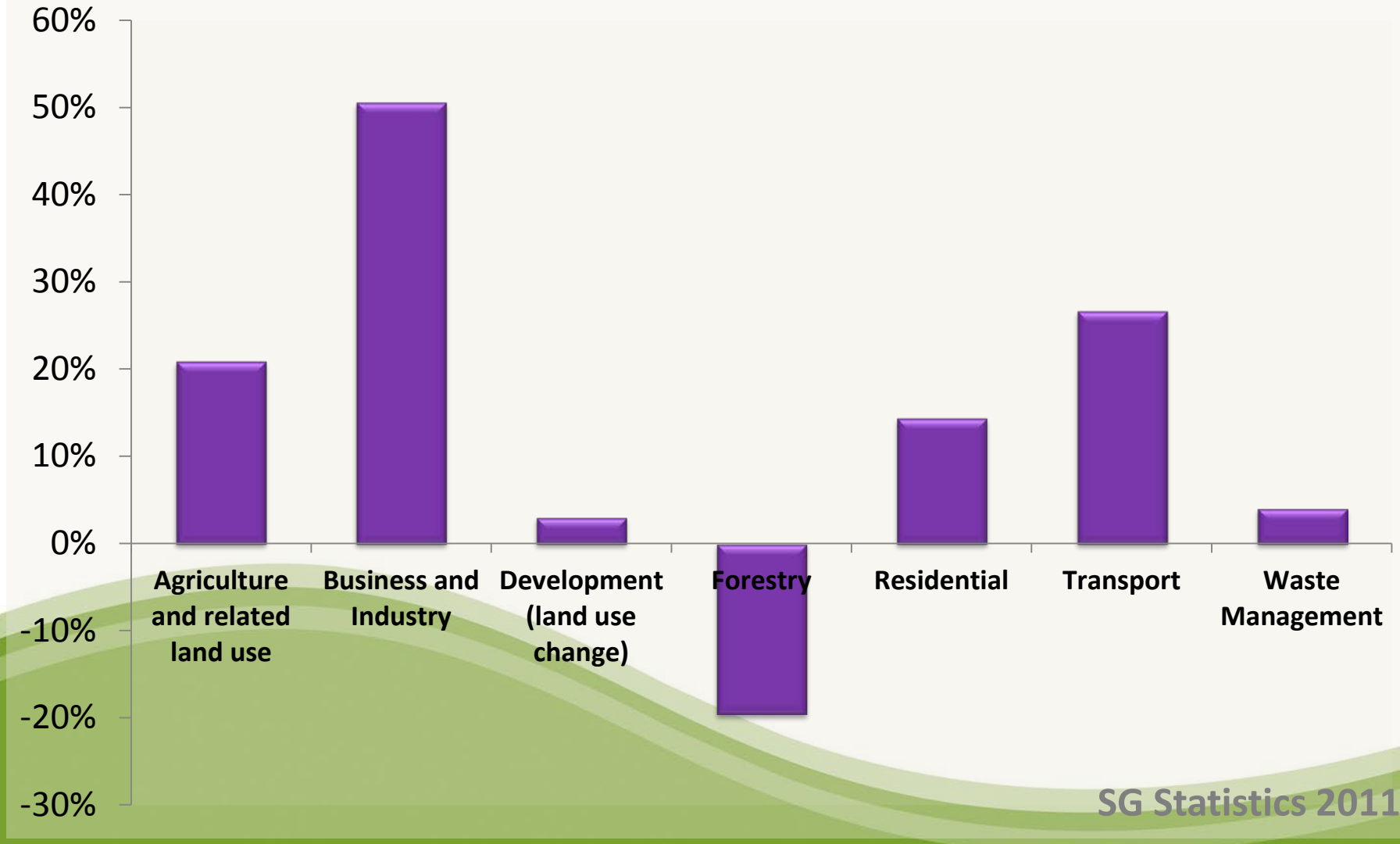
Mitigation/Opportunities

- Our soils may be able to support a wider range of food (e.g. maize) and fibre crops as climate constraints relax with the trade-offs for food/fibre versus other ecosystem services (C sequestration, biodiversity).
- Soils may be part of the solution to mitigate climate change through the adoption of management practices that reduce GHG emissions and sequester more C.
- Such practices may also have coincident benefits.

Emissions by sector as % of Total for 2009



SG Statistics 2011

Using ecosystem services to examine options for mitigating climate change

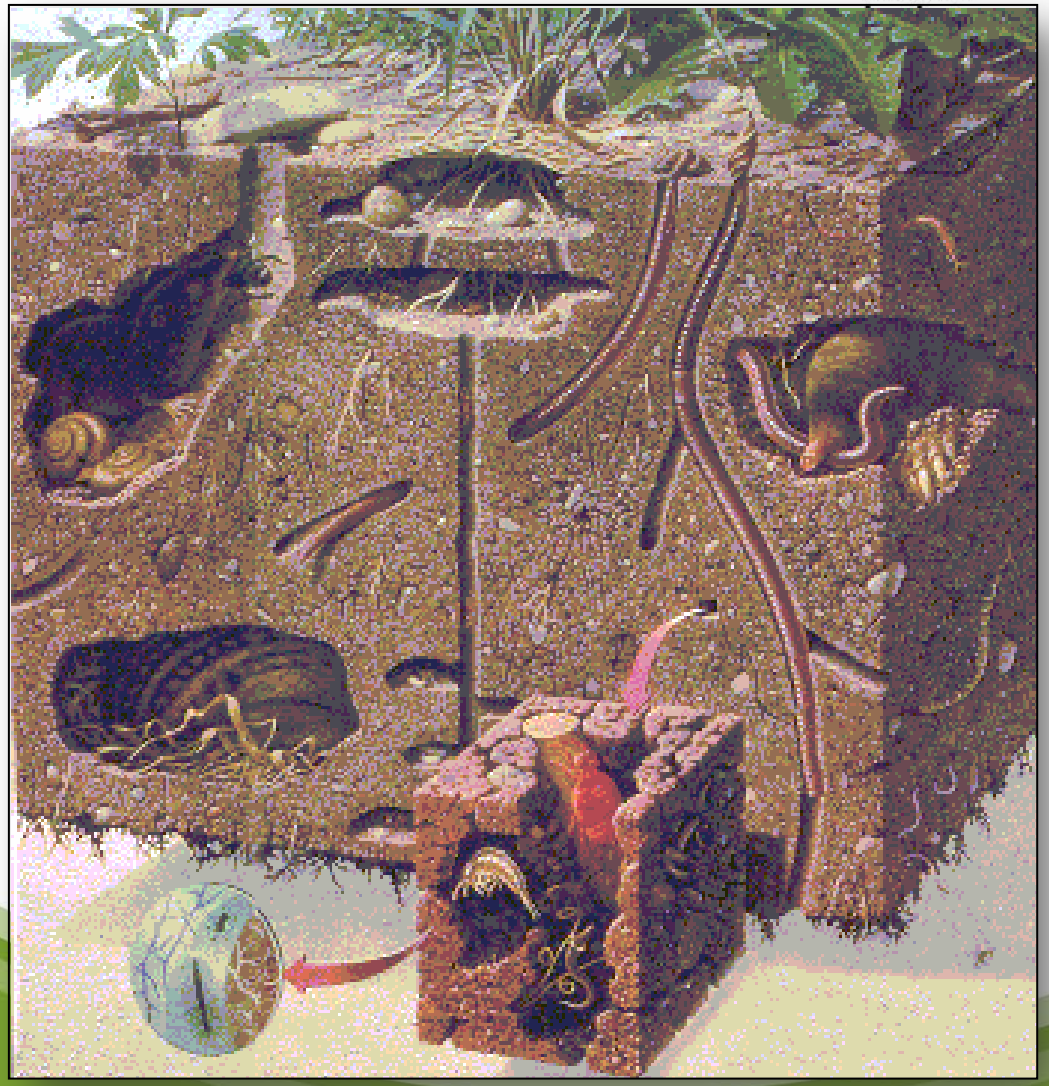
Option	Mitigation potential		Effect on services +, -, 0			
	Maximum abatement potential ($ktCO_2e$) in 2020	**Cost-effective-ness (£/tCO_2e abated)**	**Provisioning** • food • fibre • water • energy	**Regulating** • climate • noise • water • diseases	**Supporting** • Biomass • oxygen • soil formation • nutrient cycling • water cycling • habitat provision	**Cultural** • spiritual enrichment • Cognitive development • reflection • recreation • aesthetic experience
Supporting Anaerobic digestion	16	21	000+	+00+	+0+++0	00000
Restoring peatlands	48-2700[1]	27-68[2]	0 - +-	+0+0	++++++	+++0+
Increase soil organic matter (e.g. FYM)	162-2334[3]	NYQ	++++	+0++	++++++	00000

[1] Moran et al give 48 while IUCN (201) gives 2700 (geometric mean of 360)
[2] IUCN gives 27-68 but assumes one-off costs spread over 10 years.
[3] Chapman (2010)

Soil Organic Matter

The amount of carbon in soil (as organic matter) determines many of soil's ecosystem services

- Fertility
- Structure
  - Ability to retain water
  - Trafficability
  - Erodibility to wind and water
  - Workability under tillage
- The flow of nutrients and energy through the food-chain
- The amount and types of biodiversity
- Retention and transformation of pollutants



Transforming our soils

- In the last 50y, agricultural soils have changed, especially through increased mechanisation, use of agrochemicals, fertilisers, and new crop varieties.

- Increased frequency and depth of tillage, reductions in land under forage crops, and continuous use of grain cereals have all led to major concerns about declines in soil organic matter, with significant losses of top soil carbon in some circumstances (Johnson et al. 2009).

Photo: Paul Hallet

Are we losing soil C?

- Survey in England & Wales found decreases in **all** soils (Bellamy et al.)
  - Soils with C > 10%, the rate of decrease was 2% p.a.
- Countryside survey 2007 just reported – found no C loss overall but reductions in arable soils
- Different surveys use different approaches
- Highly relevant to Scottish soils especially with organic rich soils……

Re-Sampling National Soils Inventory of Scotland (NSIS) 2007-2009

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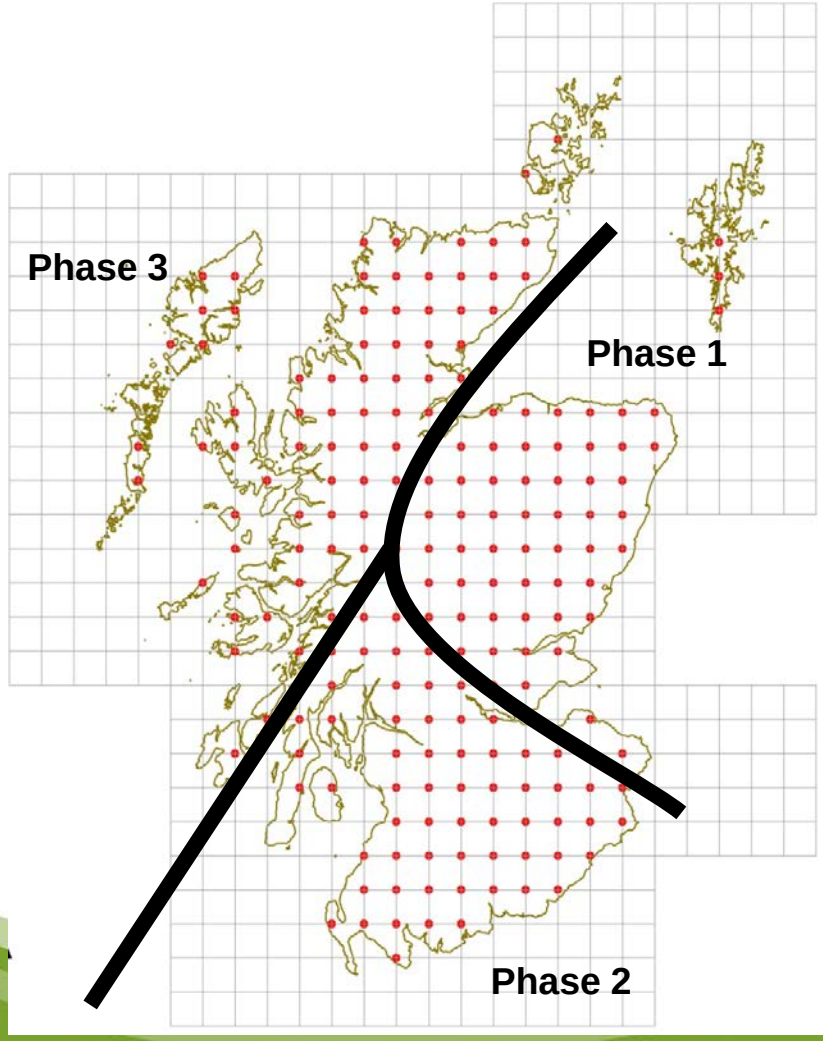
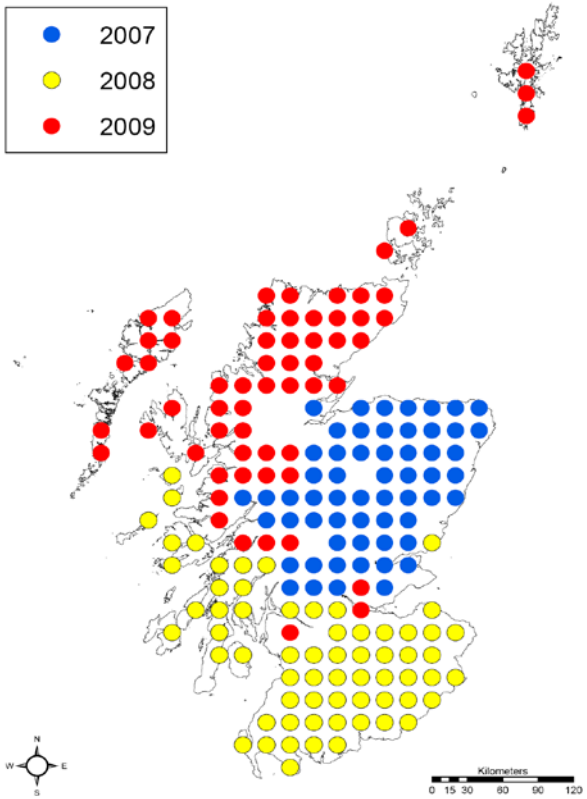
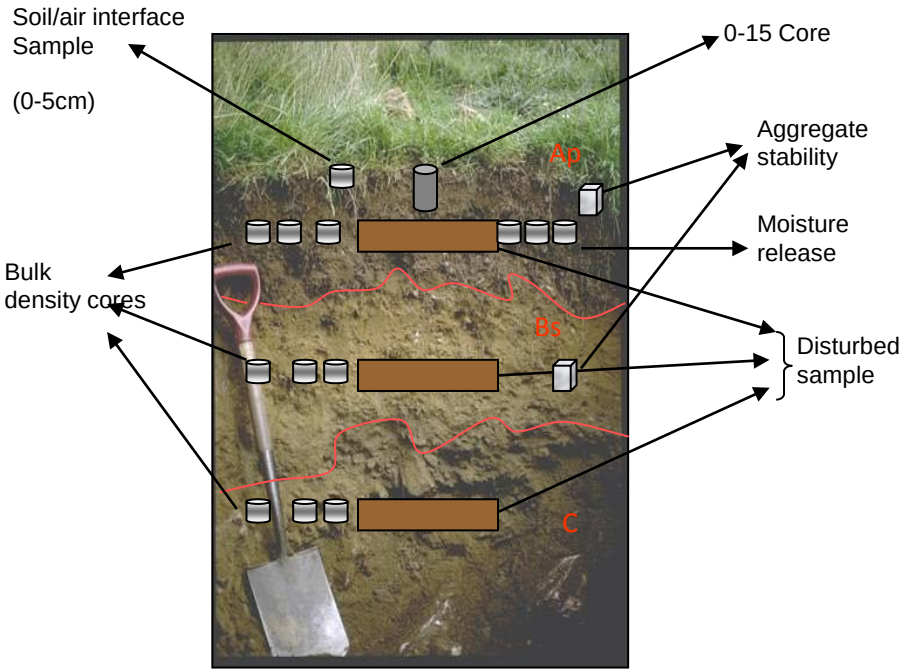
- A 20km grid aligned to previous 10km grid sampled 25 y ago
- Measure change in C
- Quantify local variability at each site
- Test sampling methods
  - Profile sampling (EU BioSoil, NSIS)
  - Composite auger (NSI- E&W, NSI-NI)
  - Single core 0-15cm (Countryside Survey)
  - Single 0-5cm core (UK Soil & Herbage Study)



Re-sampling the NSIS



Sampling – 20 km re-sampling grid by profile

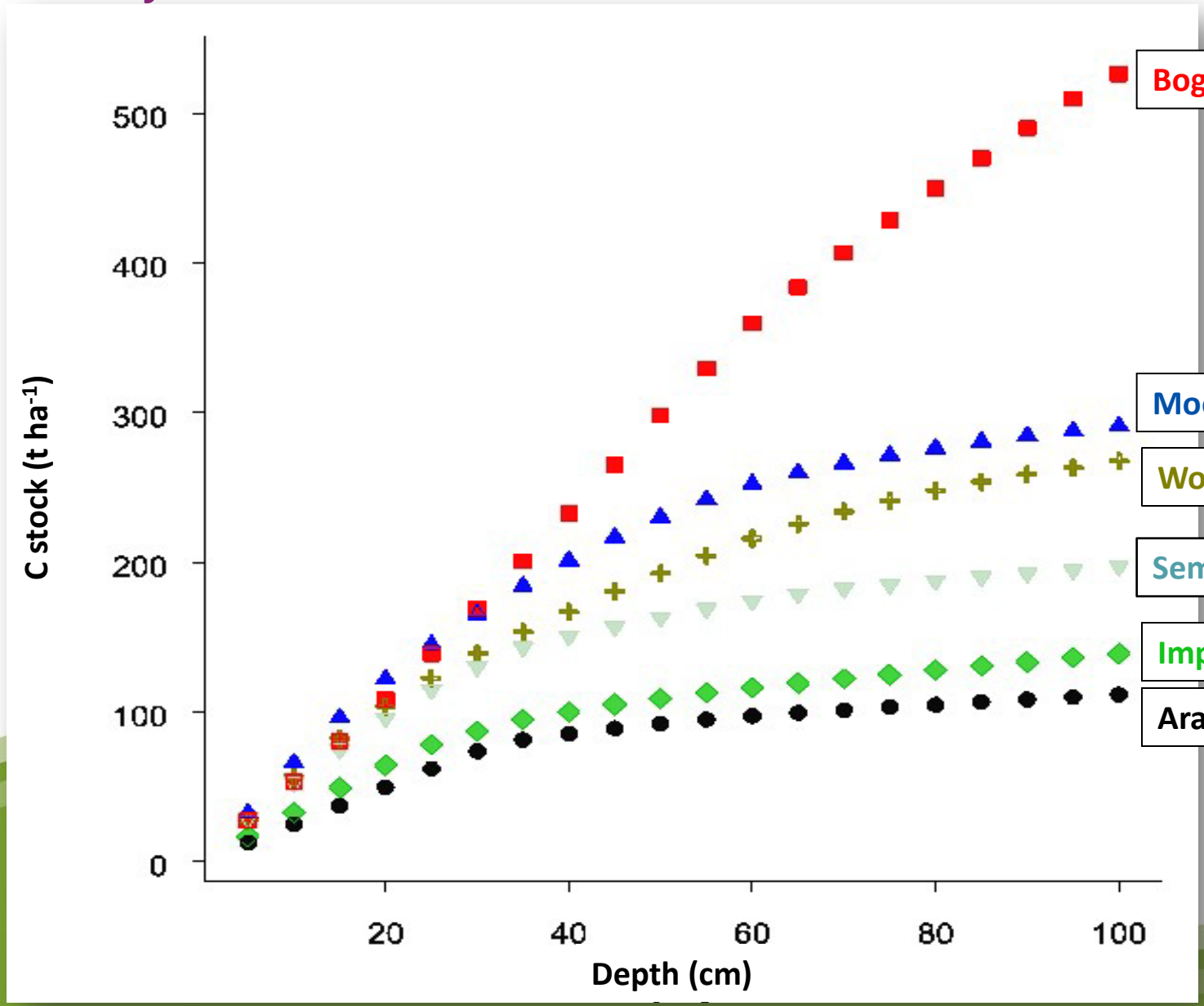


Analysis and Re-analysis

Outcomes

- Statistical and methodological insights to design new monitoring schemes
- Baseline to assess land use change (e.g. afforestation) and long term changes due to climate change and or management
- More robust evidence and accurate data on key attributes e.g. soil C
  - Derivation of minima, maxima and optima soil carbon levels in different soils and under different management would aid the setting of national targets for soil carbon (e.g. under GAEC).
- Risk analysis and mapping in relation to contaminants with new or changed baselines values.
- Risk analysis and mapping for soil compaction, loss of biodiversity and loss of carbon.
- New attributes and improved estimates of existing properties to model and predict changes in soil fertility and implications for plant, animal and human nutrition and health

Carbon by depth / thickness of horizons – National Soils Inventory of Scotland



Present and Future Policy drivers – how will stakeholders use the information?

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- Scottish Soil Framework and Land use strategy call for soil C to be protected
- Farmers are incentivised to protect soil carbon via Single Farm Payments under which GAEC must be maintained but no real specific mechanism for monitoring – yet?
  - direct payments to farming methods and measures to enhance and protect soil C e.g. the Welsh "Glastir" land management scheme, CAP post 2013?
  - In Australia - voluntary C credit schemes for farmers. Farmers recognise they must "grow the soil" before they grow any crops.
- United Nations Climate Change Conference *Cancun* - *COP* 16 REDD for peatlands
- Soils are key resource and part of National Natural Capital
- Soil C is the key indicator for soil health and sustainable management of soil then why not have it as a National Performance Indicator?

http://www.royalsoced.org.uk/enquiries/climate_change/index.htm

C sequestration potential of cultivated soils

Potential gain = 258 Mt

Max

Min

Un-constrained potential

Biophysically constraints (e.g. edaphic)

Management constraints

Social & Economical constraints

= "Actually achievable potential" between 1-3%

Potential loss =155Mt

Potential gain = 258 Mt

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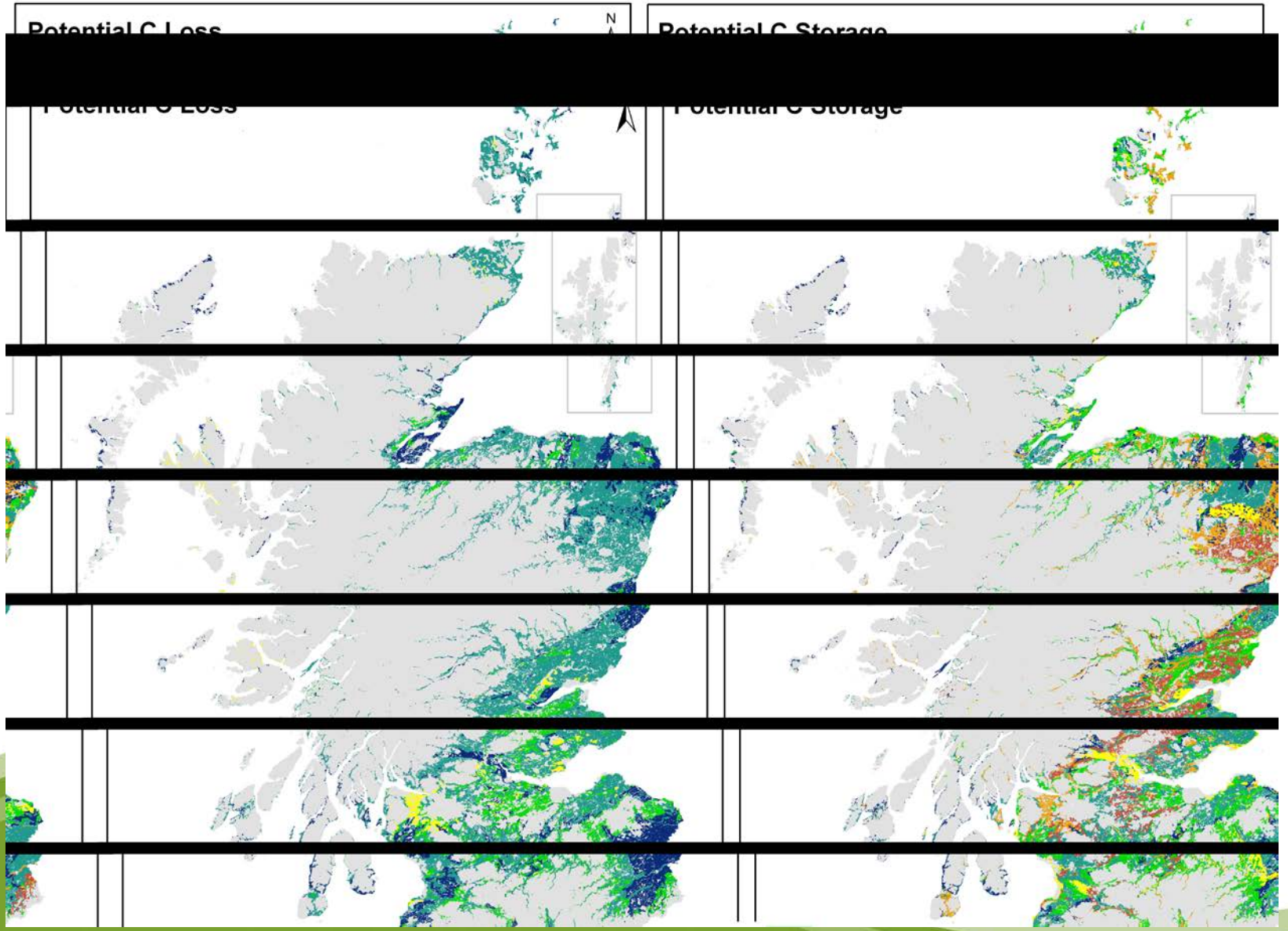


Top 30 cm of soil

Soil Indicators For Scottish Soils (SIFSS)

Select Local Authority

Dumfries and Galloway
Dundee City
East Ayrshire
East Dunbartonshire
East Lothian

Select Authority

Select Soil Map Unit for East Lothian

1
4
113
147
150

Select Soil Map Unit

Select Soil Series

Instructions

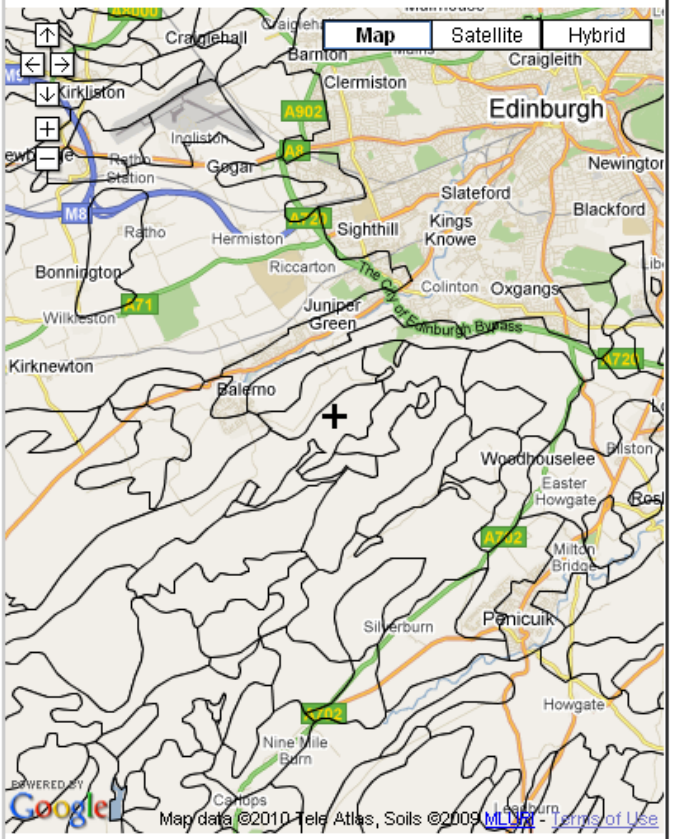
This site uses a series of menus to help you find information about soil. Selecting an object in one menu will generate a new menu with content which is determined by your selection. If you know your map unit you can select it from the menu, or use the Google(TM) map to have this website calculate the soil unit at its centre.

You can restart or step back in the process by selecting from any visible menu.

Firstly use the menu on the left to select your local authority, next you can find or select your soils unit and then you can select a series.

When you have done this new menus will appear and you can then select 'Cultivated' or 'Semi-natural' to describe your area of interest on the right. The process can be restarted by selecting an authority/soil unit/series again.

Select Soil Attribute



Get soil unit of map centre

Soil Indicators For Scottish Soils (SIFSS)

Select Local Authority

Aberdeen City
Aberdeenshire
Angus
Argyll and Bute
City of Edinburgh

Select Authority

Select Soil Map Unit for City of Edinburgh

445
446
447
467
470

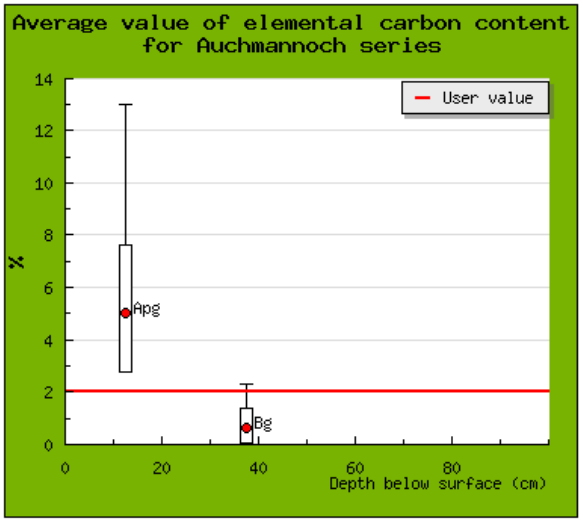
Select Soil Map Unit

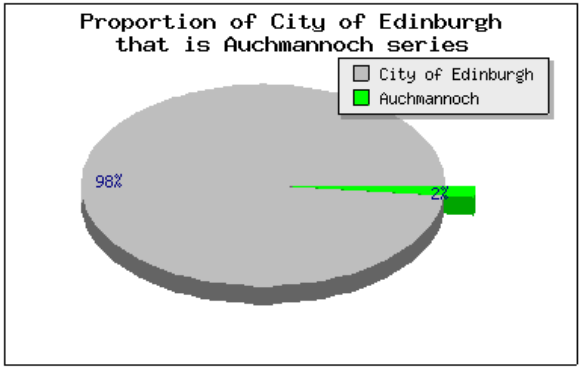
Select Soil Series for Soil Map Unit 470

Auchmannoch
Weitshaw

Select Soil Series

Results





Cultivated soils:

Semi-natural and woodland soils:
Weitshaw series belongs to the peaty gleys major soil subgroup. It is a poorly drained reddish soil with dull subsoil colours and a peaty surface layer.

Select Soil Attribute

Configure output

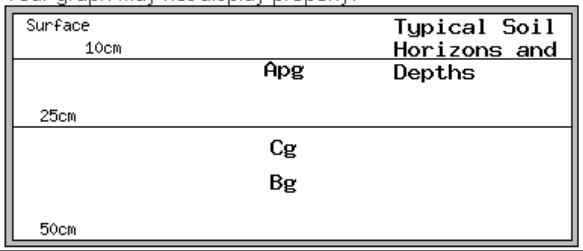
- (•) Cultivated soils
- ( ) Semi-natural soils

Average value of acetic acid extractable phosphate
Average value of the calcium content
Average value of elemental carbon content
Average value of the % clay (<2microns)
Average value H and Al content: exchangeable acidity
Average value of H ion equivalent of soil pH
Average value of the potassium content
Average value of the loss on ignition

Display Results

Your soil attribute value (or leave blank): 2
(no units please)

The following NULL values were encountered in the database query:
sd for horizon Cg
Your graph may not display properly.



Soil diversity and C sequestration

e.g. Arable land by soil type and location in the landscape

Soil type	Carbon contents Range Max-Min	Crop Potential Ranking
Mineral alluvial soils	9.96	3
Brown earth	11.26	2
Brown earth with gleying	12.26	1
Non-calcareous gley	13.07	5
Cult. Podzolic soils	12.03	3

Conclusions

- Soils…. are a valuable part of our natural capital……
- NSIS 2 has shown that
  - Choice of monitoring method has a large affect on estimates of C stock and change
  - Measures horizon thickness and depth are essential for highly differentiated Scottish soils
  - We now have more certainty in accuracy and reliability of our estimate of C stock
  - Overall C stock is stable since 1980's but given future projections of warmer soils and altered hydrology we need to maintain watching brief
  - Soil under woodland is accumulating soil C and this was significant at 15 cm depth.
  - Other changes are not significant statistically but are large in terms of CO2 equivalents, meaning that for more certainty (statistical significance) we need higher spatial sampling frequency
- We need a new approach that not just maintains our stock but seeks to grow this capital, C.f. Australian farmers – "Grow our soil before we grow our crops"
- Its an important message so don't let the complexity get in the way

Acknowledgments

- SG for funding 2006-2011 Research Programme and Soils Objective “Protecting the Nations Soils”.
- SG Soils Consultative Group
- Many, many colleagues at James Hutton Institute, BioSS and SAC
  - Esp. Willie Towers, Helaina Black, Allan Lilly, Steve Chapman, Rupert Hough
  - NSIS Re-sampling team and the Soil Survey of Scotland
- AVC Media

Not one soil, but many soils
Each with its own personality

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Sandy

Heather

Rusty

Claude

Monty

Rocky

Ally

Pete

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