Quantifying Soil Natural Capital and Trade-Offs in Ecosystem Services from SoilTrEC and Countryside Survey

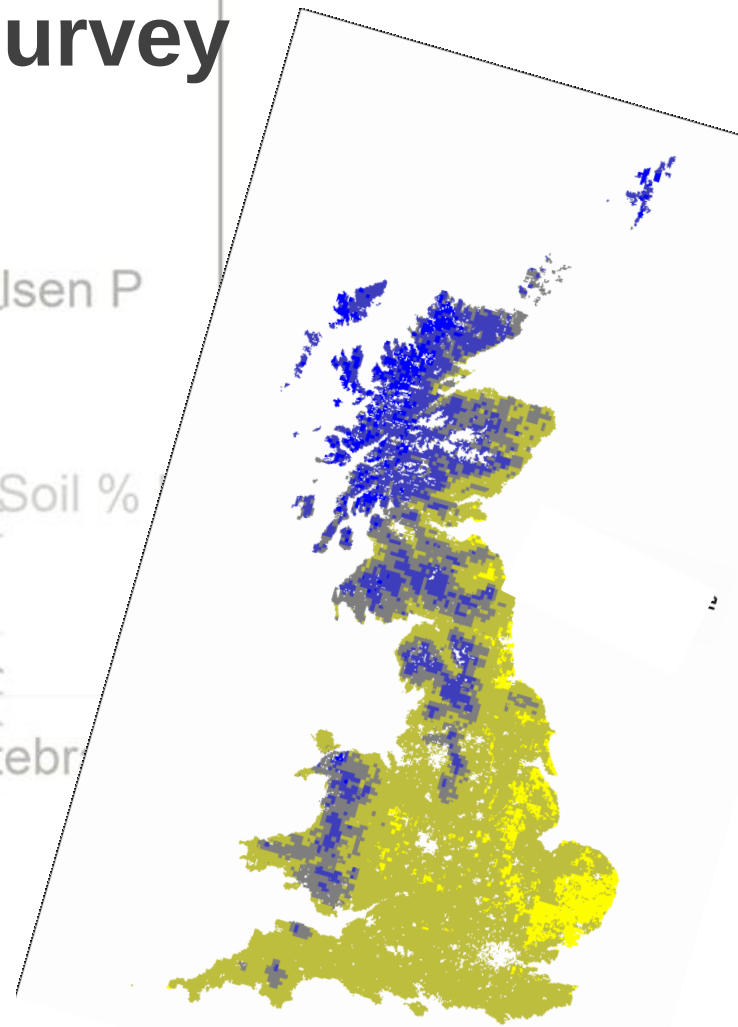
Aidan Keith

Centre for Ecology and Hydrology

Lancaster, UK

David Robinson, Jack Cosby,

Bridget Emmett, Lindsey Maskell



Centre for Ecology & Hydrology

NATURAL ENVIRONMENT RESEARCH COUNCIL

CONSIDERATIONS

- Soils often under appreciated leading to their abuse…
- Soils, where appreciated, are simplified…

CONSIDERATIONS

- Soils often under appreciated leading to their abuse…
- Soils, where appreciated, are simplified…

- Soils are not charismatic,
- Soils don't carry aesthetic appeal

CONSIDERATIONS

- Soils often under appreciated leading to their abuse…
- Soils, where appreciated, are simplified…

- Soils are not charismatic,
- Soils don't carry aesthetic appeal

How do we identify, acknowledge and promote the important functions soils fulfill?

How can we convey consequences of change at policy-relevant level?

Current and Emerging Themes

- Soil Thematic Strategy (EU)
  - 8 threats
- Soil Change
  - Soil change on anthropogenic time scales
- Ecosystems Approach to Land Management
  - Natural Capital and Ecosystem Services

Why Adopt an Ecosystems Approach in Soil Science?

- We need to recognise that soil is socio-ecological system
- Develop holistic approaches to ecosystem management at appropriate scales
- **Soil Quality** – But is primarily a **performance** indicator.
- **Soil Ecosystem Services** – Adds the concept of **value** within the context of the ecosystem in terms of **benefit** to human well-being.
- It is helpful for **Decision makers** to incorporate the value of goods and services delivered by ecosystems when considering land use and management changes.

Natural Capital (Environmental Assets!)

"..stock of natural assets yielding a flow of either natural resources or ecosystem services.."

Costanza & Daly, 1992

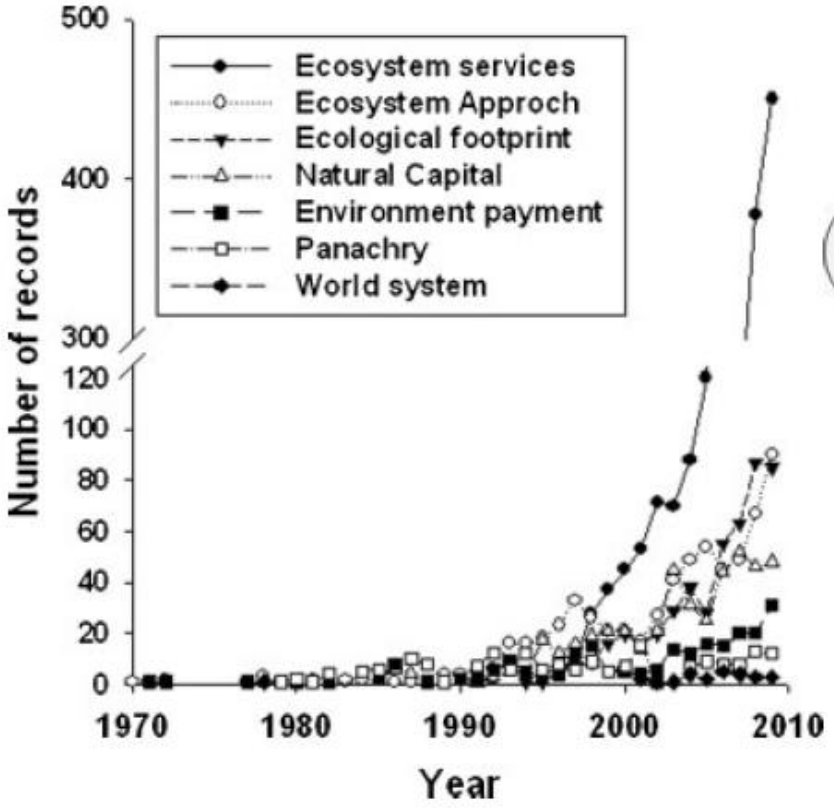
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

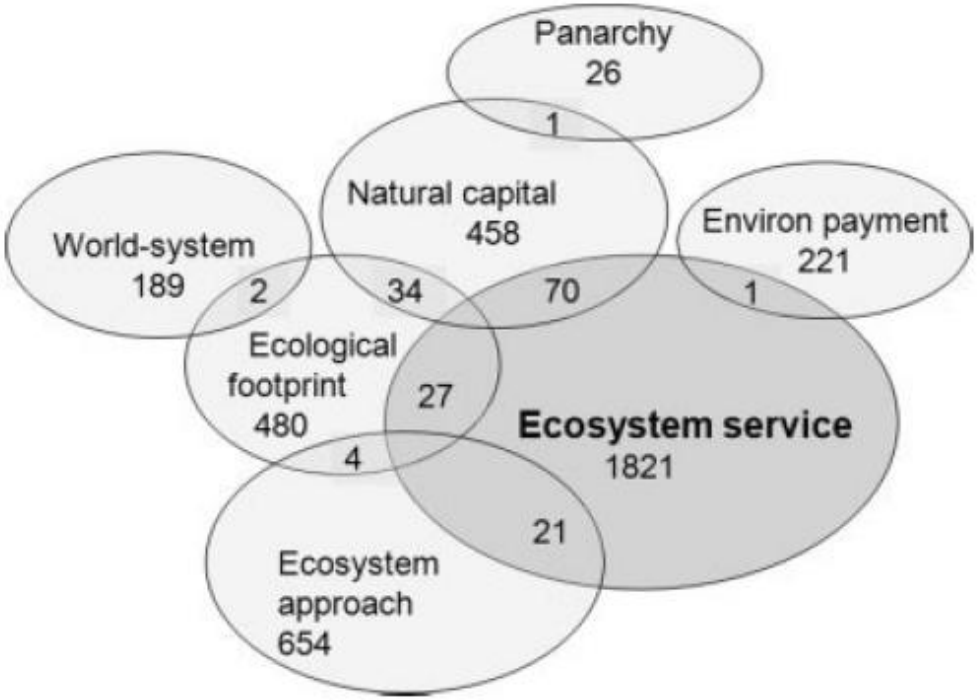
Ecosystem Services

Soils support food, feed and fibre production
Store carbon, nutrients and water
Regulate floods, droughts, heatwaves
Filter and recycle, water and waste
Habitat and genetic resource, e.g. Antibiotic extraction.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

CONCEPTS IN THE LITERATURE





Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

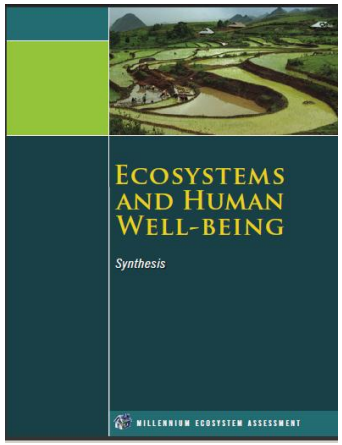
From Dick et al., 2011

Opportunities and Challenges:

1) Conceptual framework development, NC and ES;
2) Quantifying the soil resource, stocks, fluxes, transformations and identifying indicators of soil change;
3) Handling tradeoff's and developing decision support tools;
4) Valuing the soil resource.

Robinson et al., 2012

FRAMEWORKS - MEA

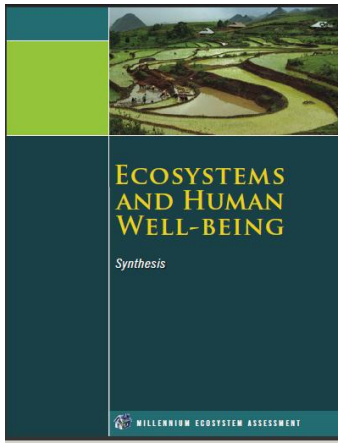


Ecosystem Service – Human Well-Being

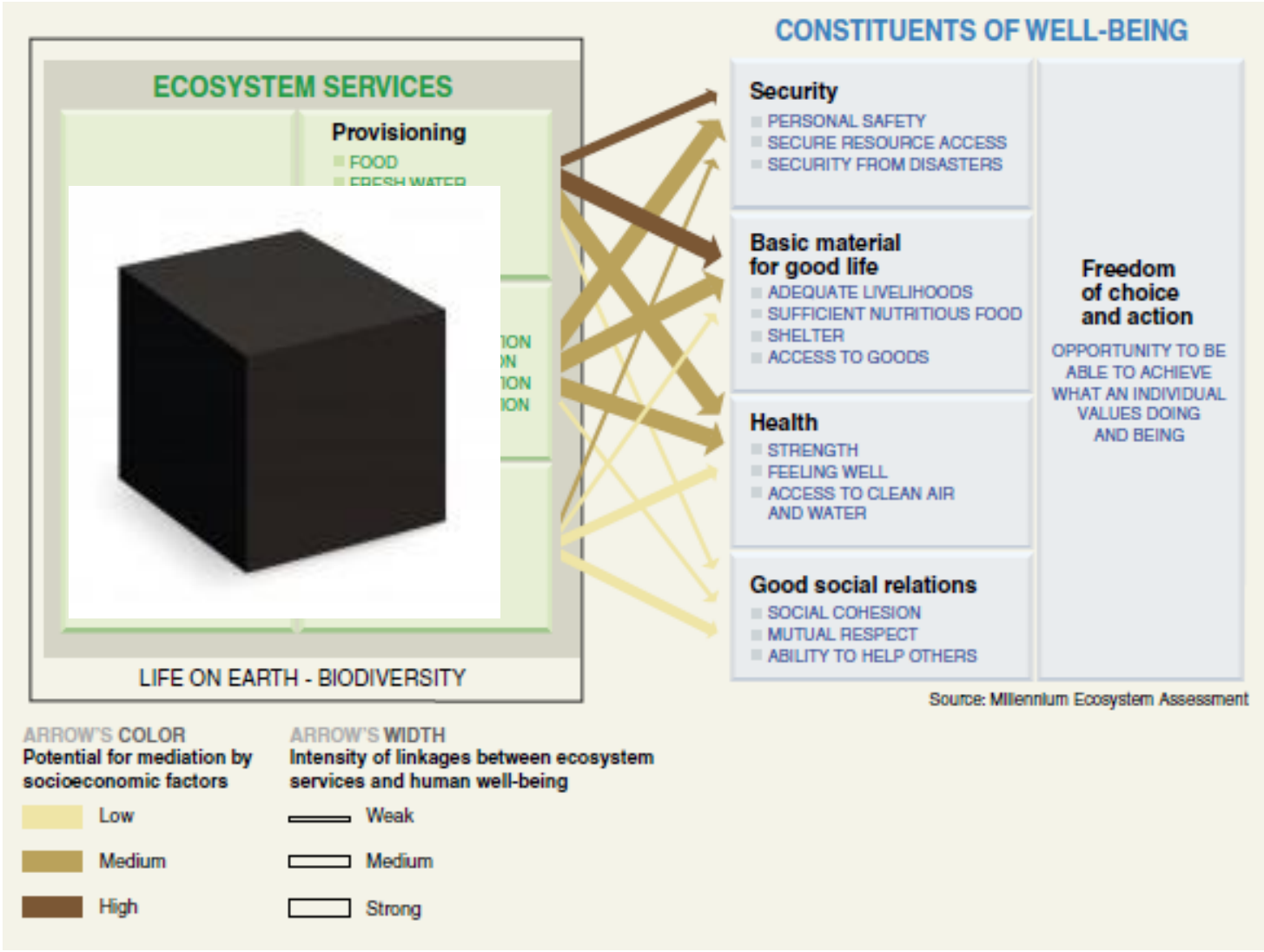
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Millennium Ecosystem Assessment (2005)

FRAMEWORKS - MEA



Ecosystem Service – Human Well-Being



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

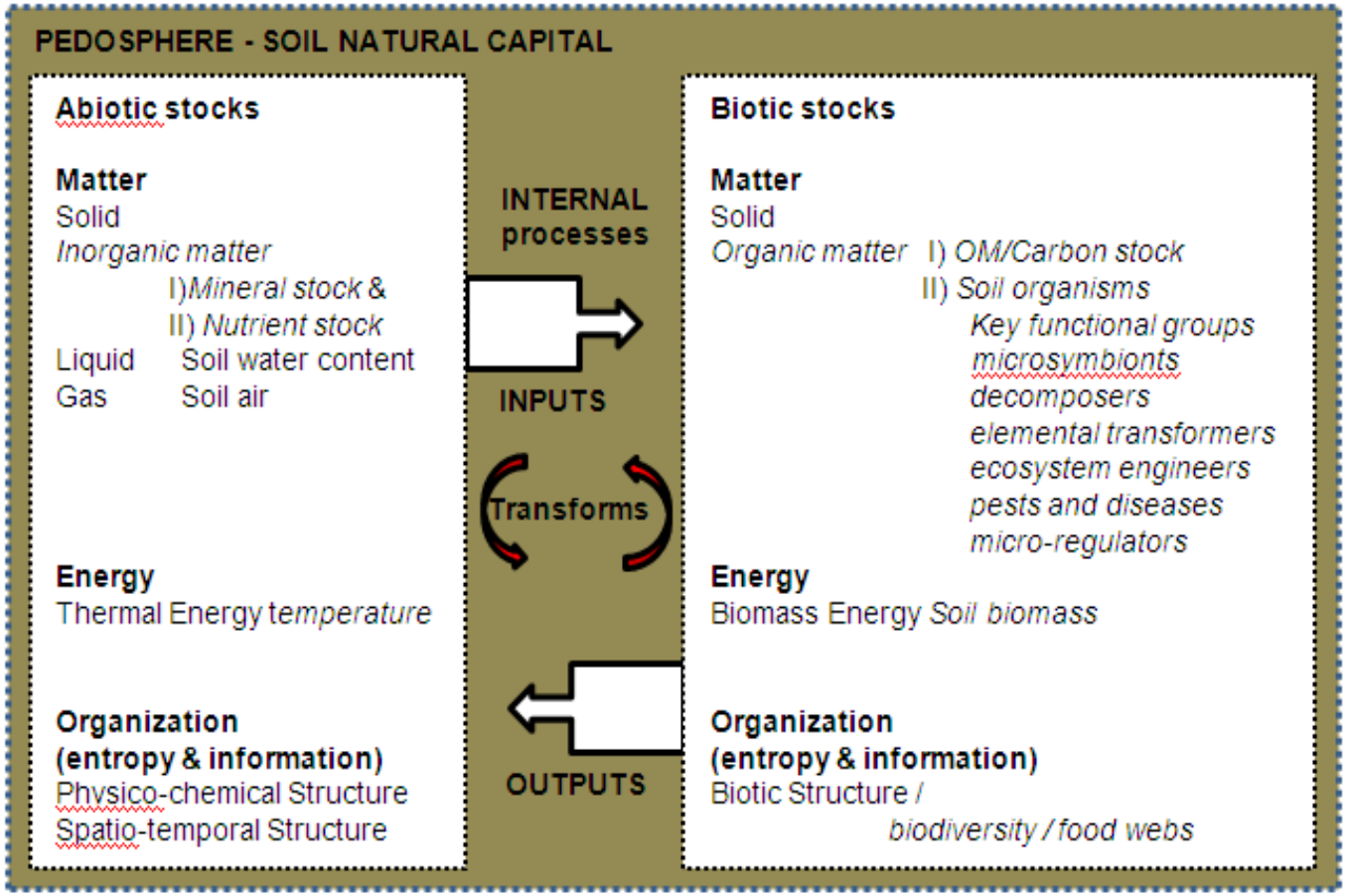
Millennium Ecosystem Assessment (2005)

FRAMEWORKS – Energy/Mass/Org

Soil Natural Capital

Matter
Energy
Organization/Structure

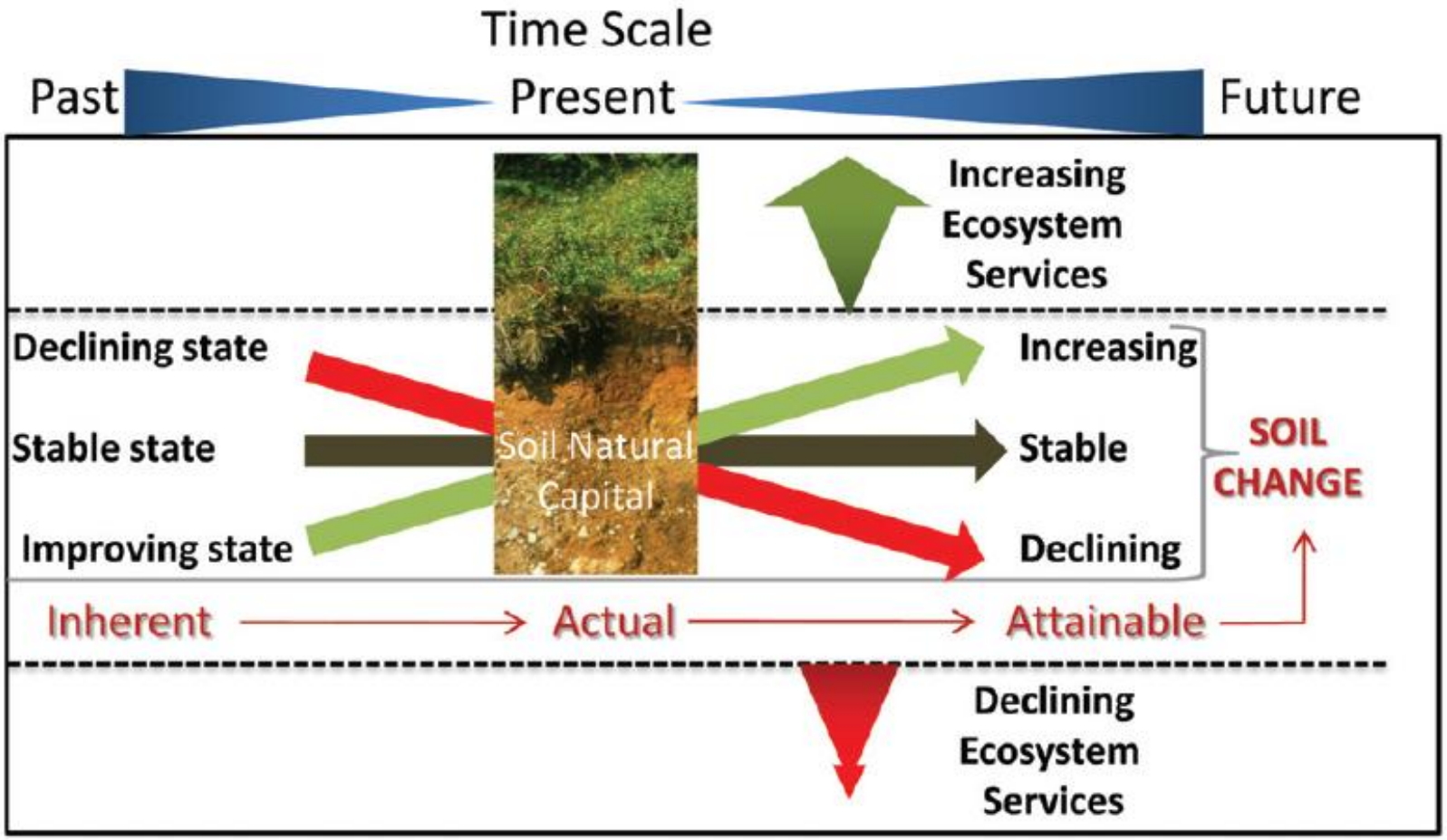
Natural Capital Stocks



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Robinson et al., 2009, 2013

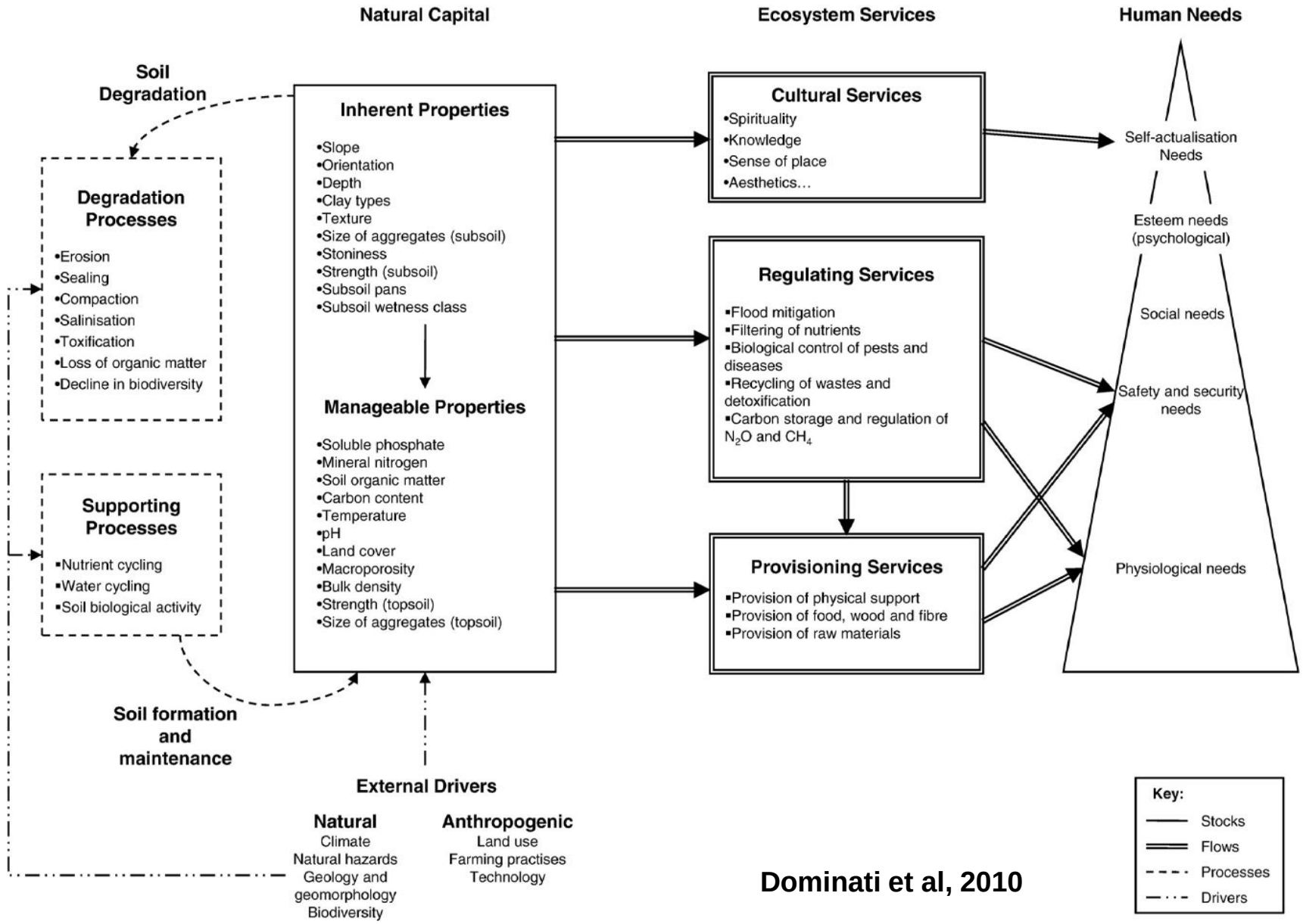
FRAMEWORKS – Soil change



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Robinson et al. 2013

FRAMEWORKS - Linking NC and ES



Dominati et al, 2010

FRAMEWORKS – Broader picture

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

McBratney et al, 2013

Countryside Survey

An ecosystems approach to monitoring

The UK Government is adopting an ecosystems approach, Countryside Survey forms part of this for measuring the '**state and change**' of British ecosystems.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

COUNTRYSIDE SURVEY - approach

Countryside Survey

- A national integrated monitoring programme over last 30 years (1978 – 2007)

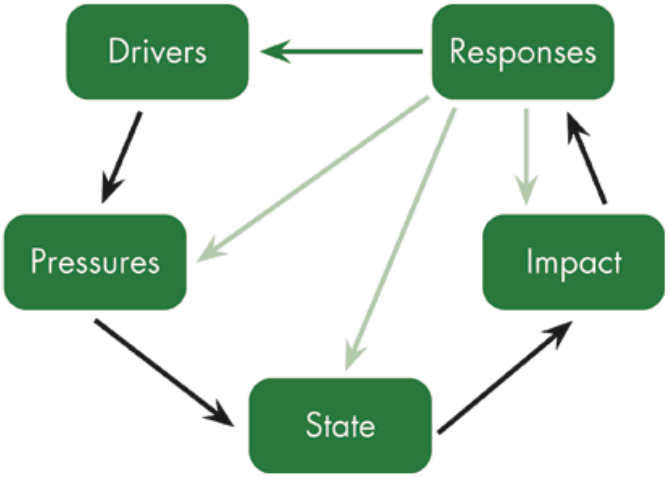
- Amount and quality change since last survey of:
  - Habitat
  - Plant species
  - Hedgerows and other linear features
  - Headwaters
  - Soils

Carey et al. 2008;
www.countrysidesurvey.org.uk

COUNTRYSIDE SURVEY - approach

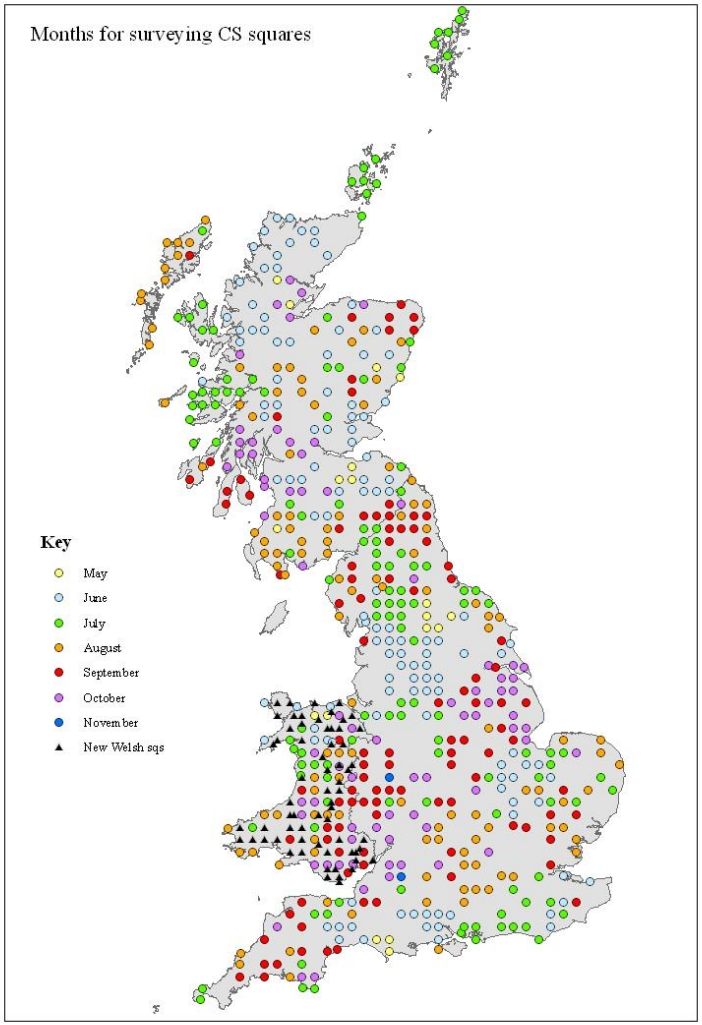
CS Philosophy

- The **D**riving forces that are responsible for change
- The resulting environmental **P**ressures on the **S**tate of the environment
- The **I**mpacts resulting from changes in environmental quality
- Society's **R**esponse to these changes



The DPSIR model helps us to answer four key questions, namely:

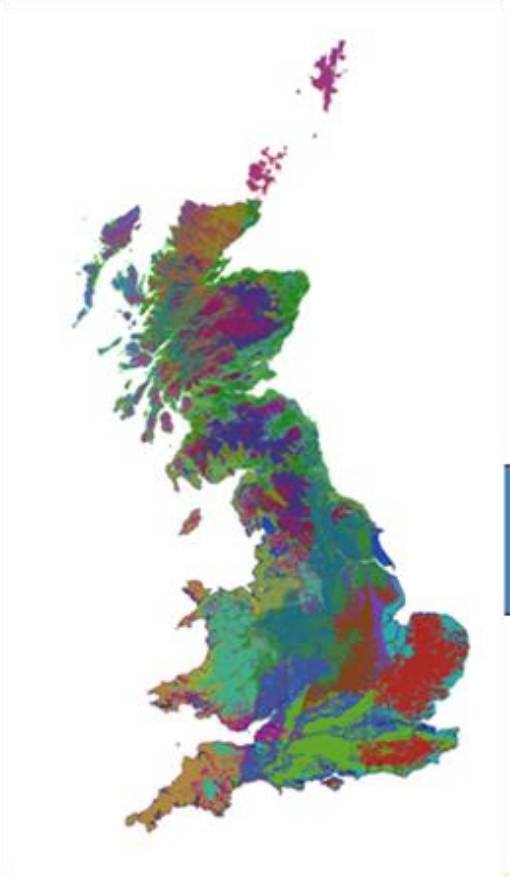
- What is happening in the environment?
- Why is it happening?
- Are the changes significant?
- What is, or could be, the response?



Stratified random sampling scheme, stratified by broad habitat

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

COUNTRYSIDE SURVEY - approach



stratified
random sample

Sample size (km squares)

1978	256
1984	384
1990	508
1998	569
2007	591

England, Wales and Scotland are divided into 'land classes', according to the major environmental gradients found at national scales.

COUNTRYSIDE SURVEY - gaps

MEASURABLE OR QUANTIFIABLE SOIL STOCK		
1) MATTER		
Solid	Inorganic material	I) Mineral stock & II) Nutrient stock
	Organic material	I) OM/Carbon stock & II) Organisms
Liquid	Soil water content	
Gas	Soil air	
2) ENERGY		
Thermal Energy	Soil temperature	
Biomass Energy	Soil biomass	
3) ORGANIZATION (ENTROPY & INFORMATION)		
Physico-chemical Structure	Soil physico-chemical organization, soil structure	
Biotic Structure	Biological population organization, food webs and biodiversity	
Spatio-temporal Structure	Connectivity, patches and gradients	

Monitoring emphasis at national scale

Measured

Nutrients
Carbon
Temperature
Soil spatial patterns

Missing

Soil moisture (COSMOS)
Soil gas
Soil biota (CS gathering information)

Technology limitations but also agronomic bias to nutrition

This framework has proved useful in identifying which stocks are sampled in national soil monitoring and which are missing. Soil physical stocks are often poorly represented.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Robinson et al., 2009, 2013

Soil carbon a headline indicator

Soils store 10 billion tonnes of the UK's terrestrial **carbon**, reducing greenhouse gas emissions, whilst enhancing soil structure.

A 1% change in soil carbon is equivalent to the UK's annual fossil fuel emissions

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

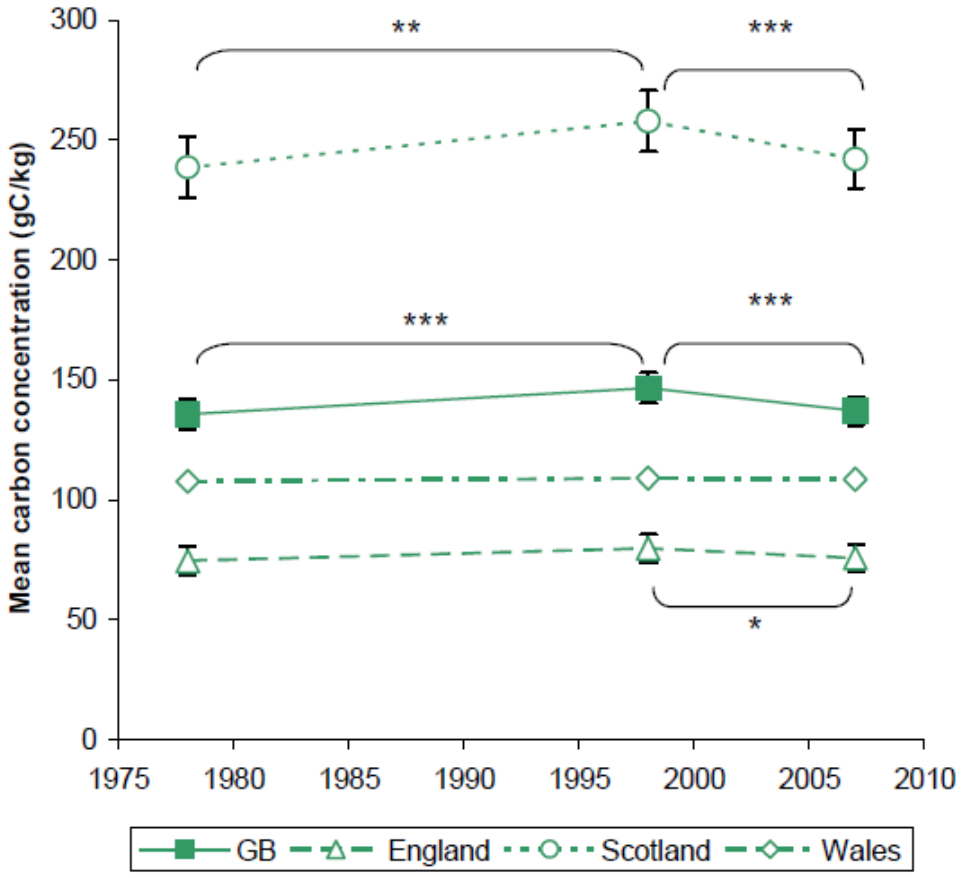
COUNTRYSIDE SURVEY – soil carbon

Figure 2.5: Change in soil C concentration (0-15cm) for GB and individual countries (a) over time and (b) net change between 1978 and 2007. Standard errors are indicated. Significant differences (* p<0.001, * p<0.01, * p<0.05) are shown between the years bracketed.**

a)

Significant C decrease over the last 10 yrs but no overall decline over the period of monitoring.

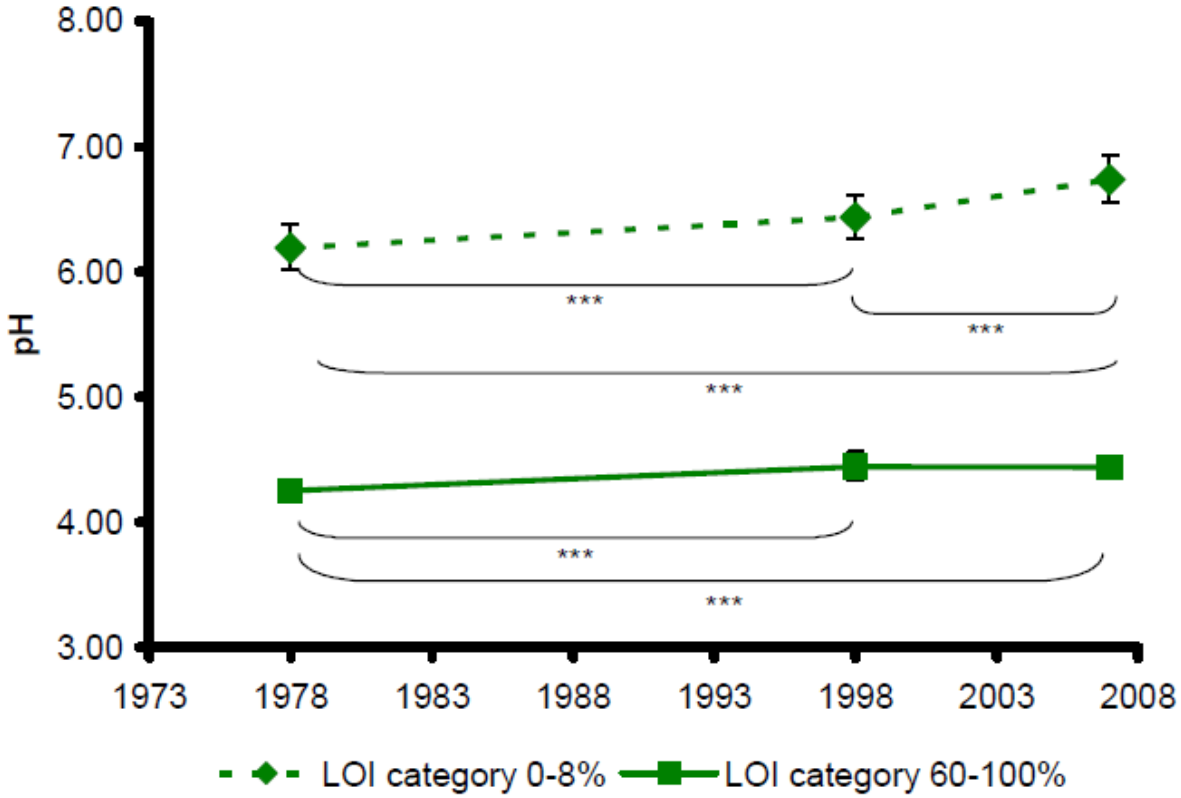
Hence we cannot confirm the 0.6 % yr^{-1} decline suggested by Bellamy et al (2005) reported in Nature.



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

COUNTRYSIDE SURVEY – soil pH

How is soil pH changing in GB soils?



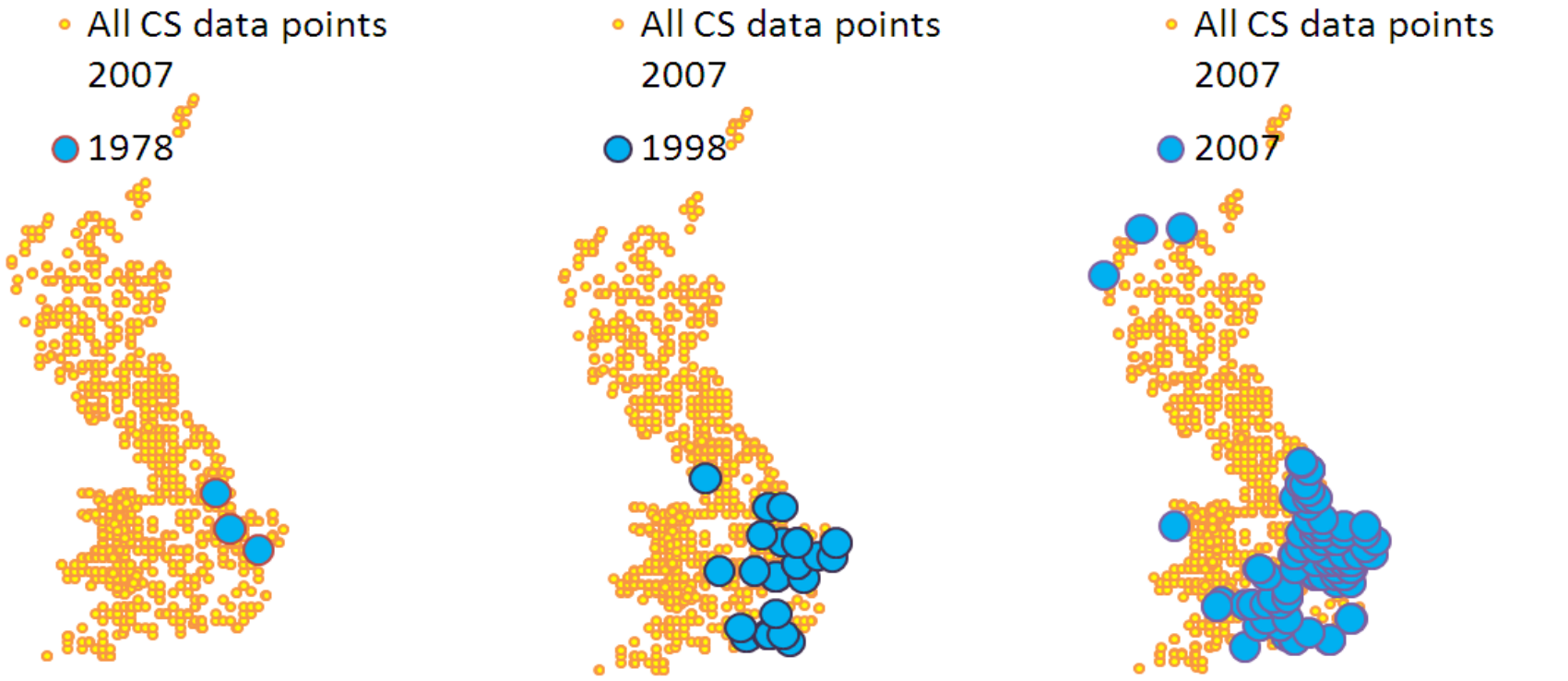
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

CS indicates significant increase in soil pH across GB between 1978 and 2007

COUNTRYSIDE SURVEY – soil pH

How is soil pH changing in GB soils?

Soil pH >8.3



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

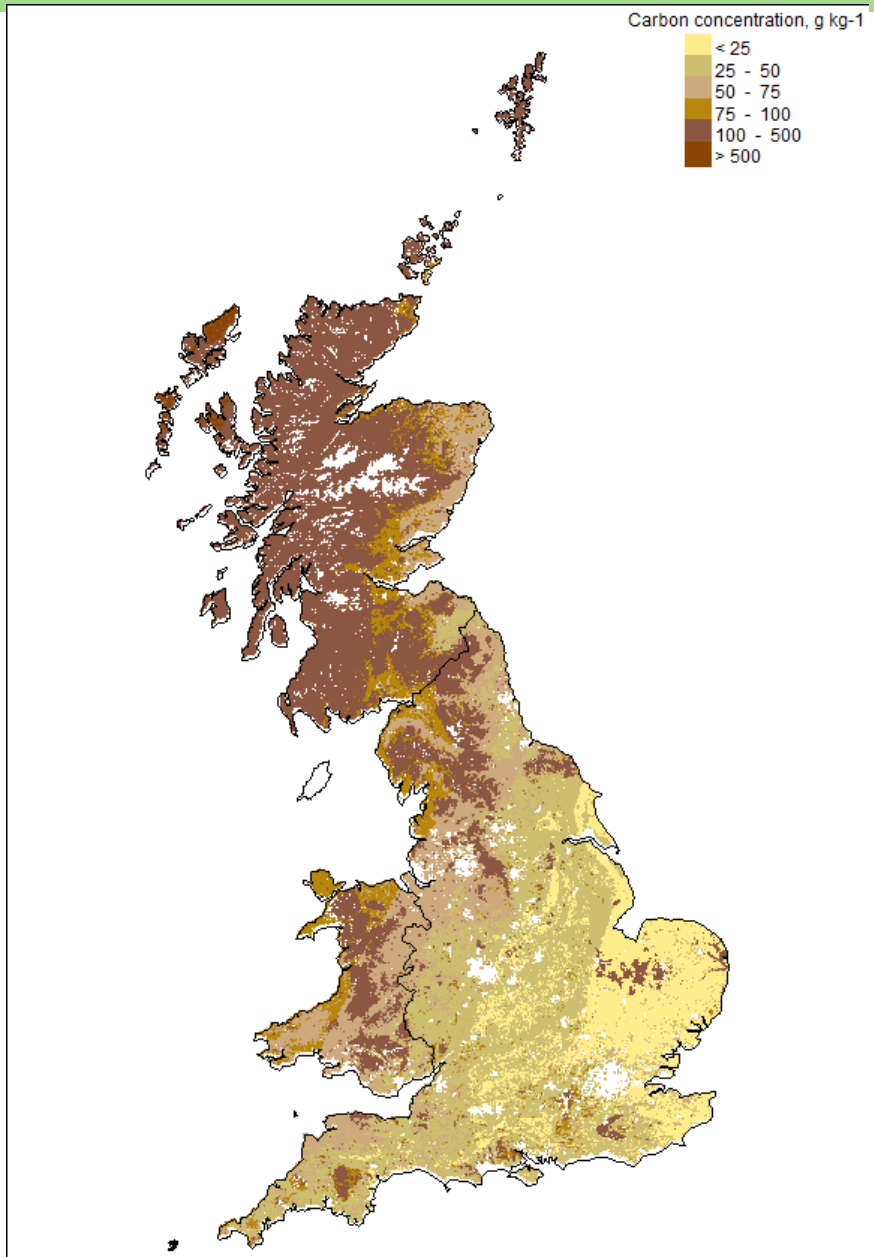
Thresholds in soils – breakdown in soil aggregates

COUNTRYSIDE SURVEY – mapping

Combine data from Land Cover Map & CS.

Model using chosen variables.

Map to 1km square or 25m resolution parcels.



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

UK Soils Observatory

Home » Soil maps » Countryside Survey maps

Soil Portal

- Soil data
- Soil maps
- Current projects
- Current publications

Countryside Survey maps

back | play | next

Carbon

C concn | C (t/ha) | % LOI (mean) | % LOI (krige)

Invertebrates

Total Invertbt | Mite: Springtail | Total taxa | Shannon Diversity

Nutrients

N Concn | C:N | Olsen P | Olsen P

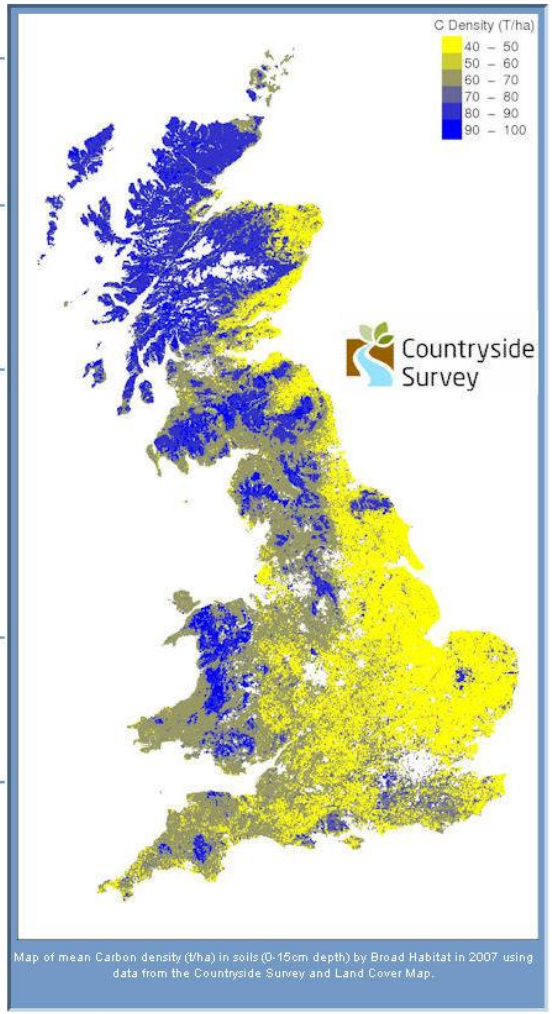
N mg/kg dry soil | N mg/kg dry soil | Nitrate/N

pH & Bulk Density

pH | pH Krige | Bulk Density

Metals

As Krige | Cu Krige



Map of mean Carbon density (t/ha) in soils (0-15cm depth) by Broad Habitat in 2007 using data from the Countryside Survey and Land Cover Map.

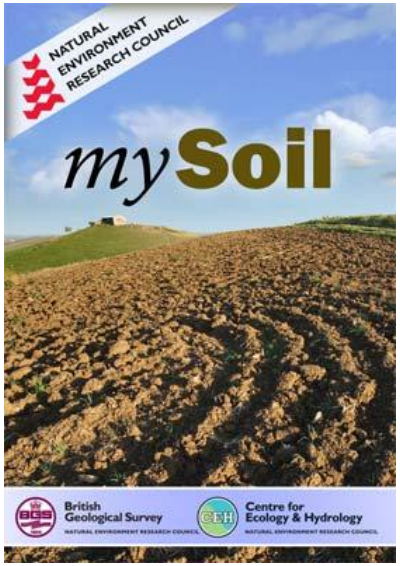
CEH Centre for Ecology & NATURAL ENVIRO

mySoil: engaging the public with soil information

The CEH & BGS KE teams launched mySoil app last year which now has more than **2 million** web hits and over **10,000** dedicated users highlighting real interest in soils information packaged in this format with crowd-sourcing capability.

Shelley et al., 2013. Crowd-sourced soil data for Europe. Nature

iphone
ipad



Engaging the public

Democratising data

Getting feedback

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Free to download mySoil at itunes

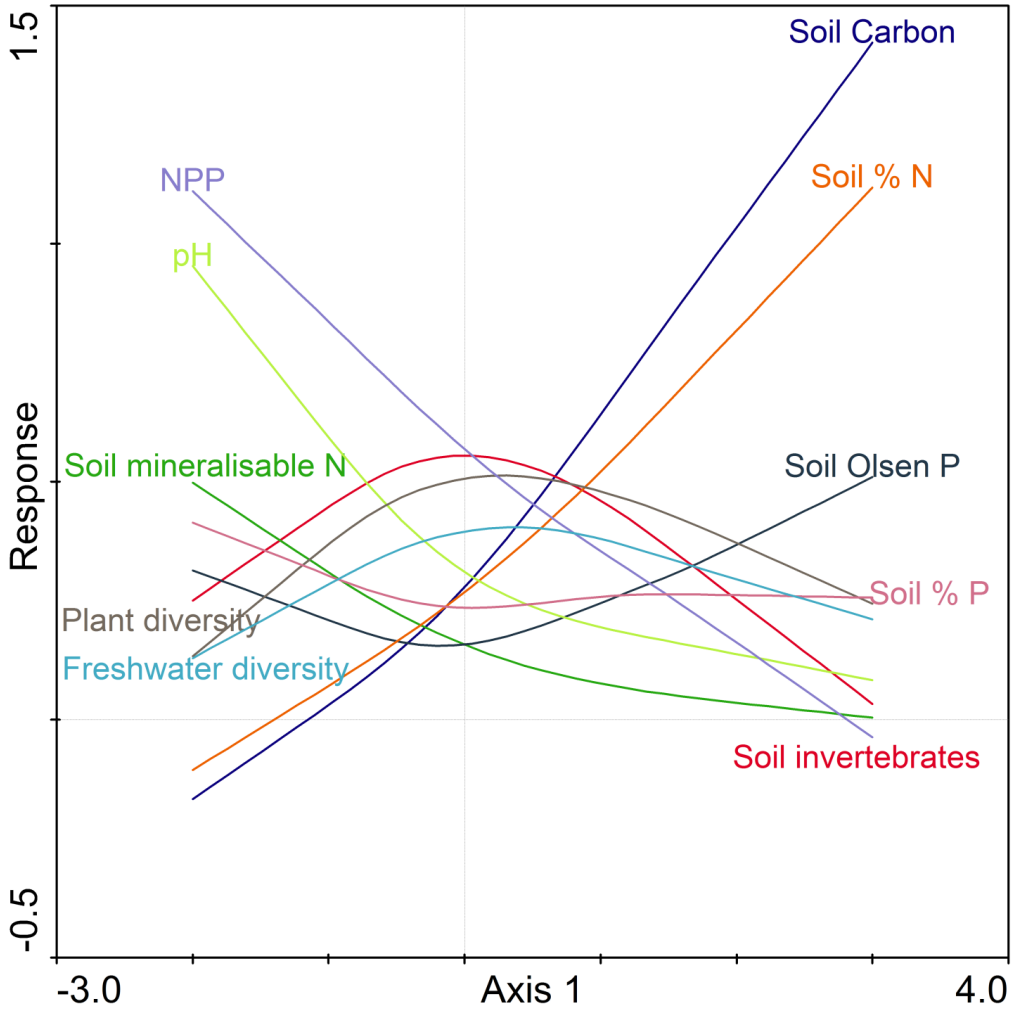
COUNTRYSIDE SURVEY – trade-offs

Integration using Countryside Survey

Ability to integrate with other indicators (biophysical measures)

Predict land use effects ….what about land management?

Scale?



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Maskell et al. 2013 Journal Of Applied Ecology

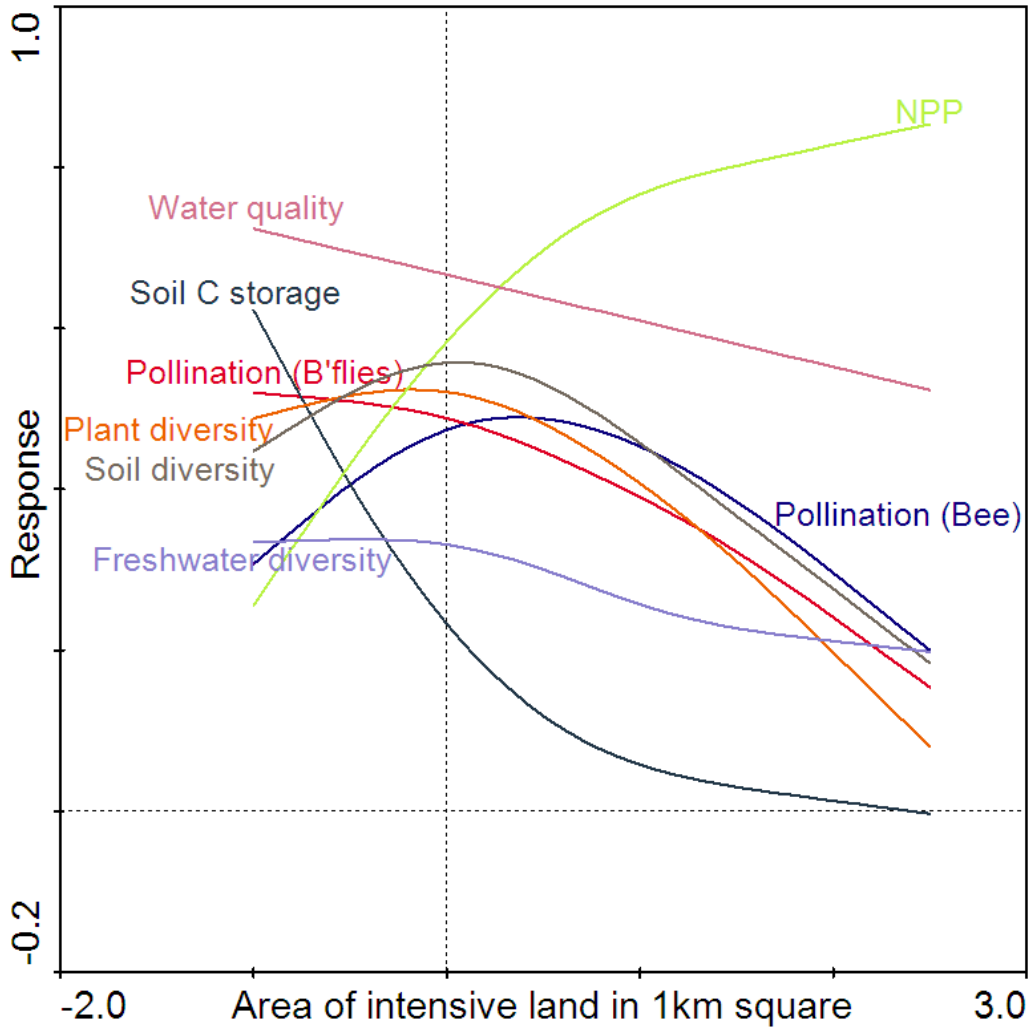
COUNTRYSIDE SURVEY – trade-offs

Integration using Countryside Survey

Ability to integrate with other indicators (biophysical measures)

Predict land use effects ….what about land management?

Scale?



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Maskell et al. 2013 Journal Of Applied Ecology

SoilTrEC – aims & approach

Address the priority research areas identified in the EU Soil Thematic Strategy and to provide leadership for a global network of Critical Zone Observatories (CZOs) committed to soils research.

Specific Objectives are:

1. Describe from 1st principles how soil structure impacts processes and function in soil profiles,
2. Establish 4 EU Critical Zone Observatories to study soil processes at field scale,
3. **Develop a Critical Zone Integrated Model of soil processes and function,**
4. Create a GIS-based modelling framework to delineate soil threats and assess mitigation at EU scale,
5. **Quantify Impacts of changing land use, climate and biodiversity on soil function and economic value,**
6. Form with international partners a global network of CZOs for soils research, and
7. Deliver a programme of public outreach and research transfer on soil sustainability.

SoilTrEC

SEVENTH FRAMEWORK PROGRAMME

The Critical Zone: Treetop to Bedrock

Photo courtesy of NERC Centre for Ecology and Hydrology, Bangor, Wales, UK

Soil Functions

- Food and fibre production
- Filtering water
- Transforming nutrients
- Carbon storage
- Biological habitat
- Gene pool

EU Thematic Strategy for Soil Protection, EC (2006) outlines soil functions and soil threats.

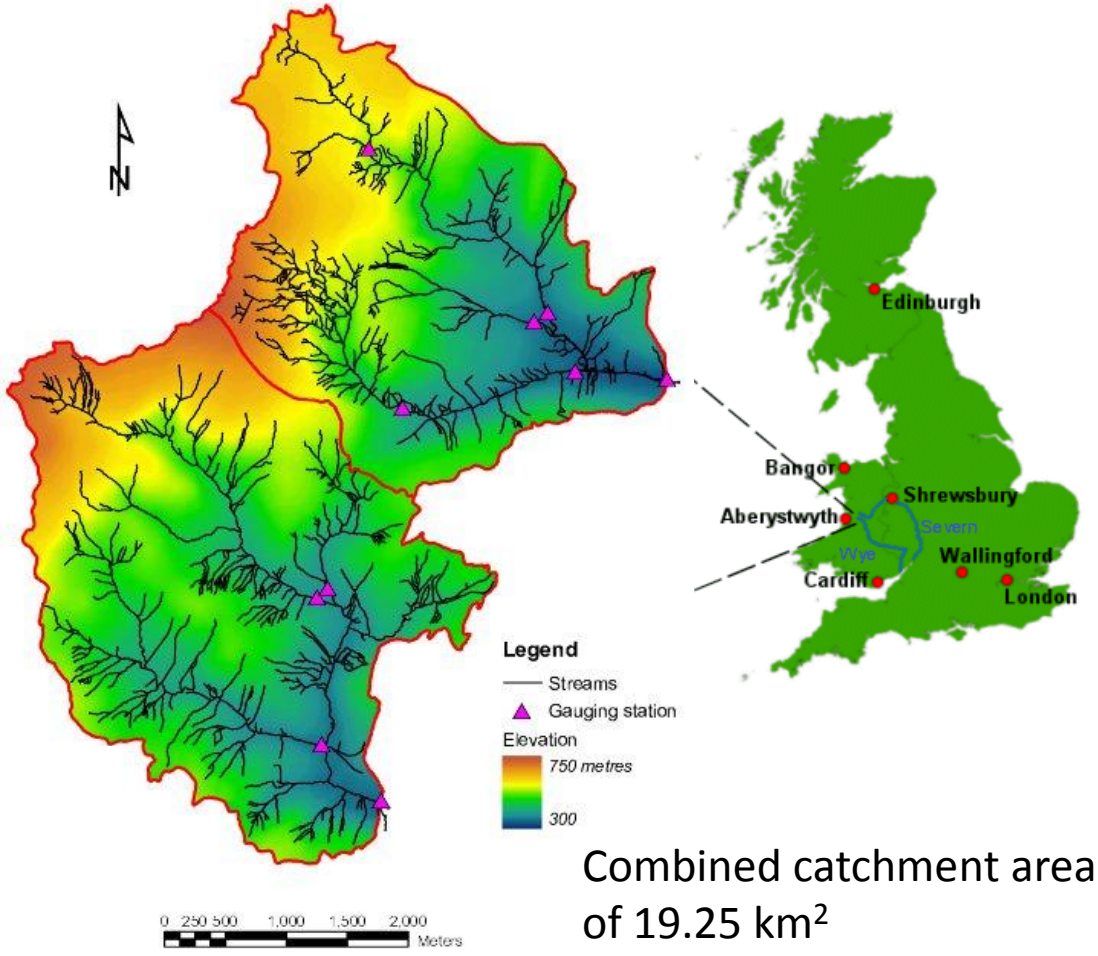
SoilTrEC – UK sites

Severn
(70% conifer plantation)

Wye
(Dwarf shrub heath plus acid & improved grassland)

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

The Plynlimon Research Catchments



Combined catchment area of 19.25 km^2
20 km from the coast

Landscape Modelling

LUCI (Land Utilisation and Capability Indicator)

Bethanna Jackson, Univ Wellington/CEH

Spatial modeling tools are required for the assessment of Ecosystem Service Delivery, hotspots and tradeoffs. InVEST, ARIES and LUCI are three such tools.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Decision making: LUCI, GIS modelling tool

- LUCI: Land Utilisation and Capability Indicator
- GIS toolbox of models to consider impacts of land use on:
  - flood risk
  - erosion and sediment transfer
  - agricultural productivity,
  - biodiversity,
  - Carbon,
  - *stakeholder wishes and requirements, water quality (N and P in 1st instance).*
- Subjectively values existing features and potential for change by "service" and explores where multiple benefits and financial incentives exist.
- Designed to work with widely available (national) data and update with local knowledge where possible.
- Designed to rapidly explore spatial trade offs and synergies with other ecosystem services
- Major advantage LUCI has is a routing algorithm, so the spatial location of interventions impacts predictions

Jackson et al. (2013)

LUCI conceptual framework

Ecosystem Service Production Function (Model)

Service f(x,y,z)

Carbon f(carbon model)

Mass balance where we're able to predict stock, flow and changes

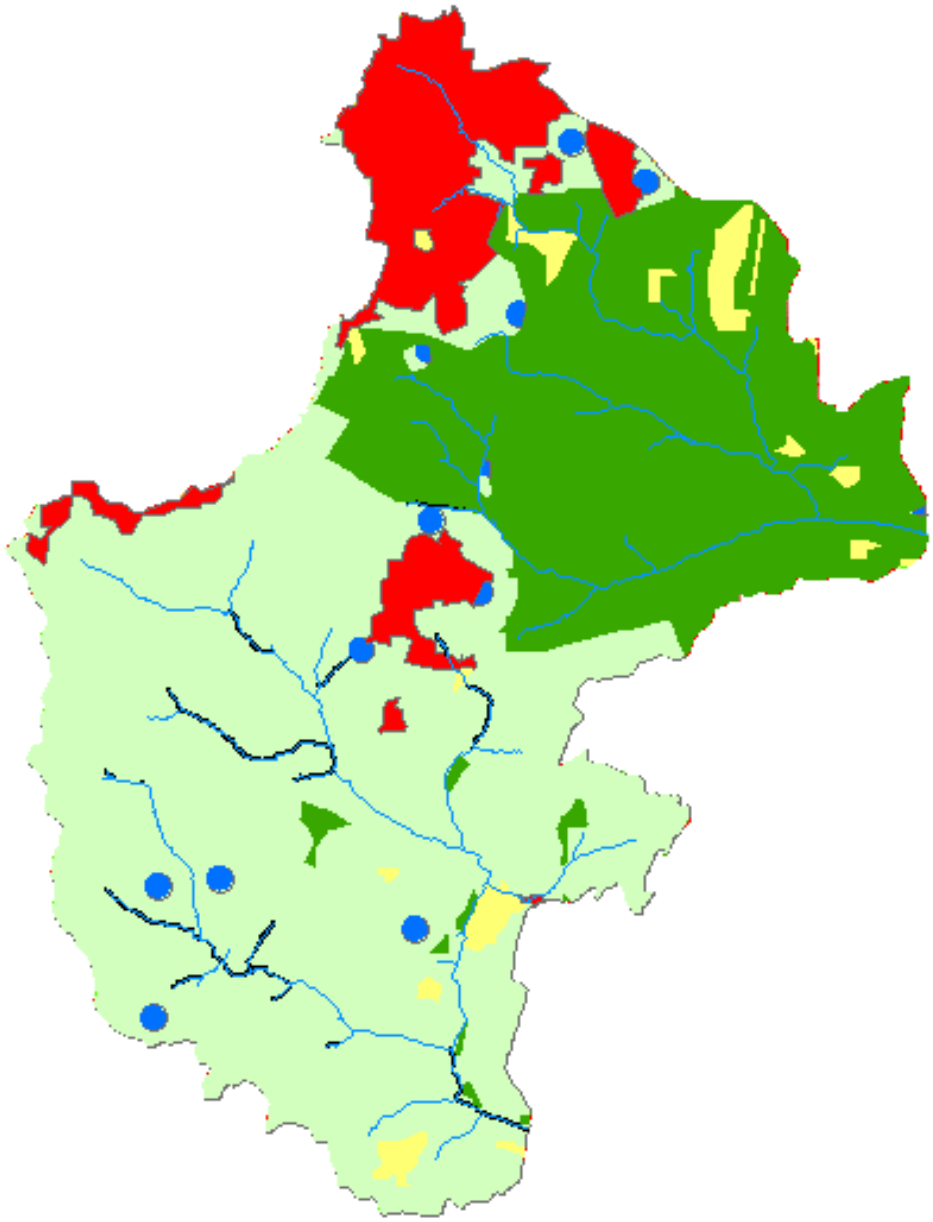
Each layer scored 1, 5 according to biophysical levels

Multiple layers scored, weighted and combined

Flood mitigation by trees

LAND COVER – LCM2007
SCENARIO PLACEMENT AREAS

SCENARIO
Riparian buffer strips vs random forest blocks of equivalent area



Land Cover

- Streams
- Conifers
- Acid grassland
- Boggy/peaty areas
- Other land cover
- Random Tree Placement
- Riparian Planting Placement

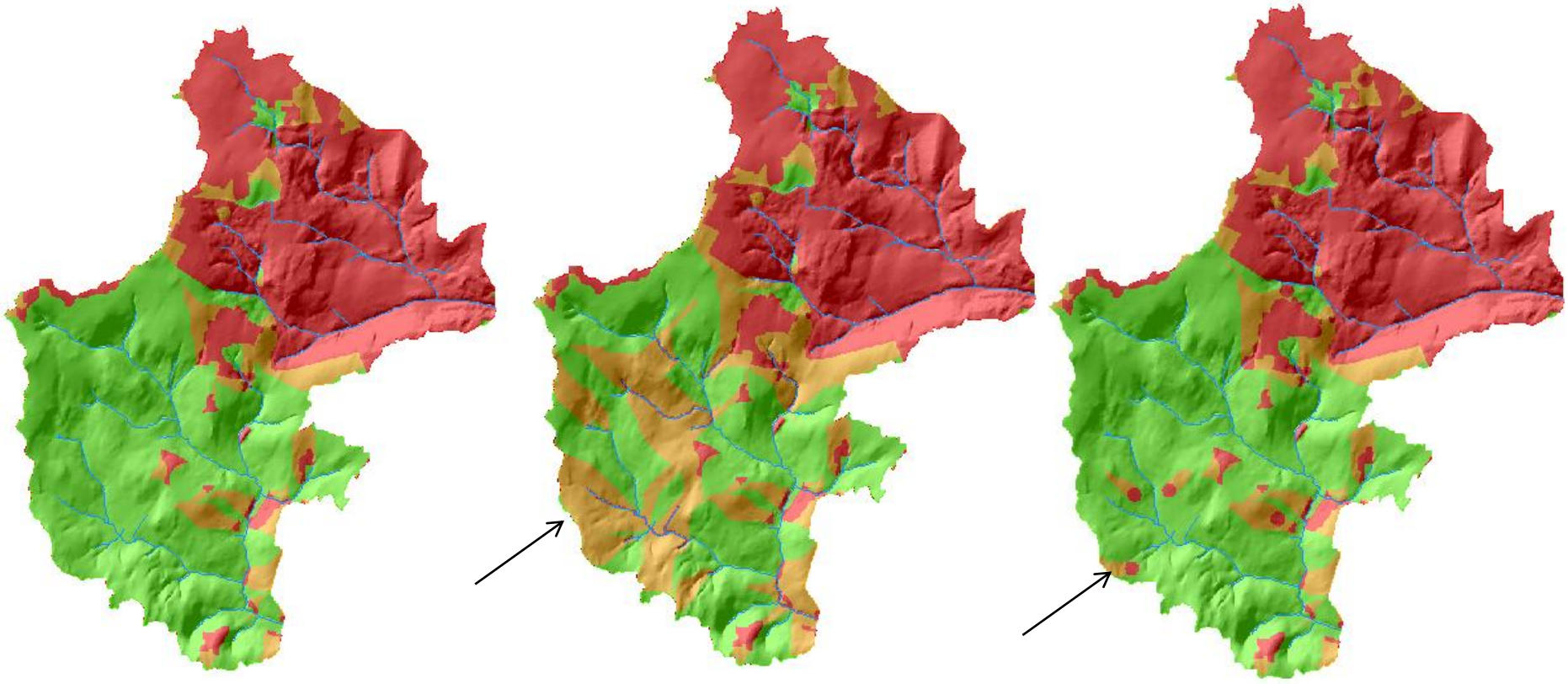
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

“Mitigation provision” by scenario

1) BASELINE

2) RIPARIAN

3) RANDOM BLOCKS



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Change in mitigation provision?

Scenario	% catchment with non-mitigated flood/sediment / nutrient delivering land	Change in landcover from baseline (%)	Area of catchment impacted by planting (%)	Ratio of area impacted to area directly modified (-)
Baseline (LCM2007)	49.2	- (baseline)	- (baseline)	- (baseline)
Random planting	47.7	0.9	1.5	1.7
Riparian planting	33.3	0.9	15.9	17.7

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Going forward..

Continue to develop/explore the conceptual framework

- Importance of stocks
- Consistency/Compatibility with broader frameworks

Gaps in data

- Stock-take of existing programmes/measures
- Gap-filling (Policy-driven?)

Follow-through to Decision Tools

- Trade-off's (based on simple weighting?)
- Linking LUCI with valuation

Thanks to our funders and partners

Countryside Survey

Countryside Survey - measuring change in our countryside

NATURAL ENVIRONMENT RESEARCH COUNCIL

CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

defra
Department for Environment Food and Rural Affairs

NATURAL ENGLAND

The Scottish Government

NIEA Northern Ireland Environment Agency
www.ni-environment.gov.uk

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

Scottish Natural Heritage
All of nature for all of Scotland

Forestry Commission

CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL