Development of Jules for soils/ecosystem research

Bridget Emmett, David Robinson, David Cooper, Ed Rowe
Countryside Survey soils team
Defra soils threat project team

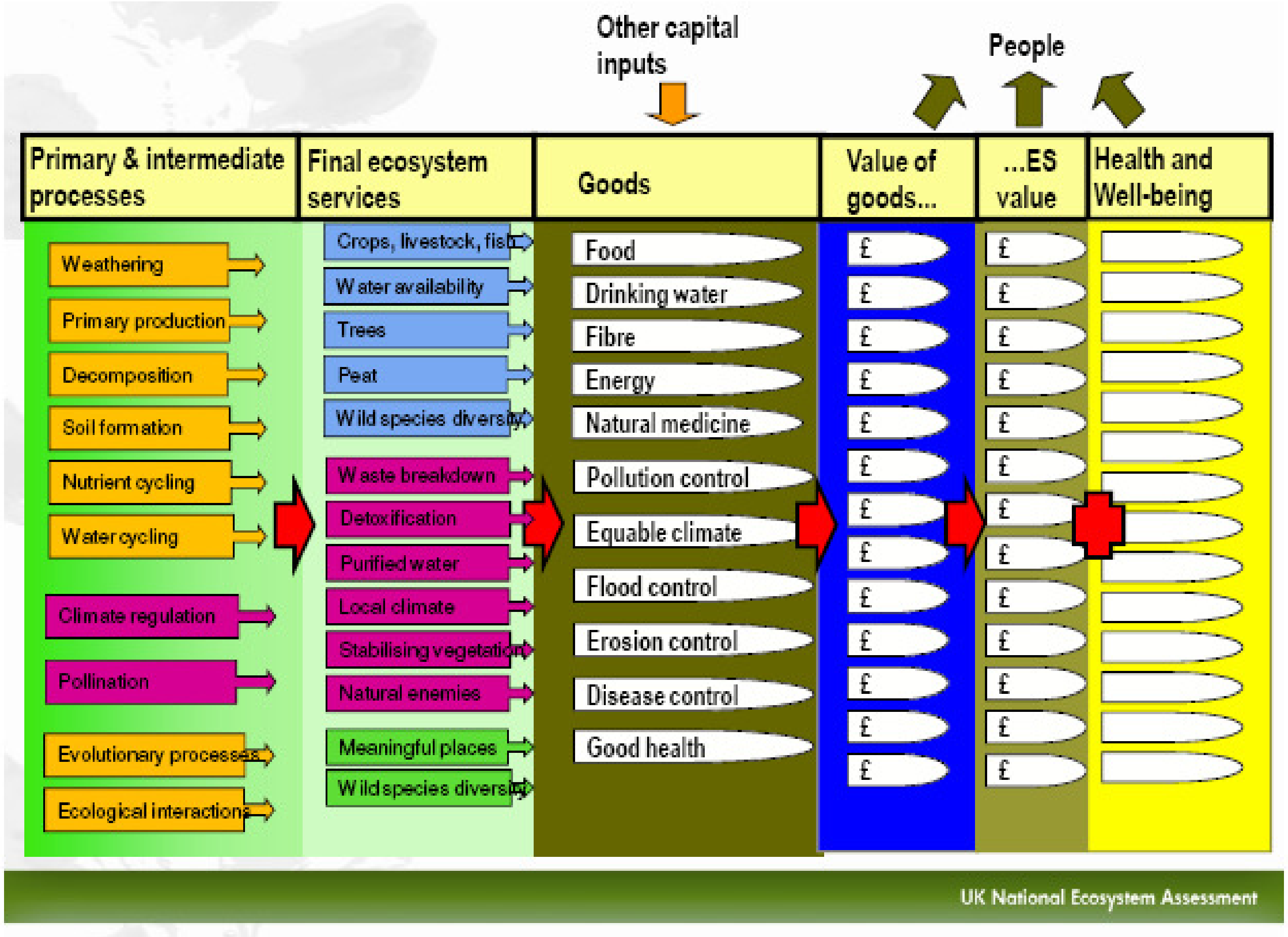
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Classification of Ecosystem Goods and Services (after MA, 2003)

Provisioning Services	**Regulating Services**	**Cultural Services**
Products obtained from ecosystems •Food •Fresh Water •Fuelwood •Fiber •Biochemicals •Genetic resources	*Benefits obtained from regulation of ecosystem processes* •Climate regulation •Disease regulation •Water regulation •Water purification •Pollination	*Nonmaterial benefits obtained from ecosystems* •Spiritual and religious •Recreation and ecotourism •Aesthetic •Inspirational •Educational •Sense of place •Cultural heritage
Supporting Services *Service necessary for the production of all other ecosystem services* • **Soil Formation** • **Nutrient cycling** • **Primary Production**		

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

National Ecosystem Assessment recognises major role of soils in delivering many ecosystem services



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

UK National Ecosystem Assessment approach to services Primary, intermediate and final services are mapped onto Millenium Assessment services as: Regulating services (pink); Supporting servicecs (yellow); Provisioning (blue); Cultural (green). Draft June 2010

Soils as a finite resources

We consistently mine the soil resource.

But we rely on it for the provision of food, feed, fibre, and the regulation of the Earth System through gas exchange, filtering, buffering, waste disposal etc.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

EU recognizes the importance of protecting the soil resource

Soil Thematic Strategy
The Communication (COM(2006) 231)
Establishes a ten-year work program for the European Commission."

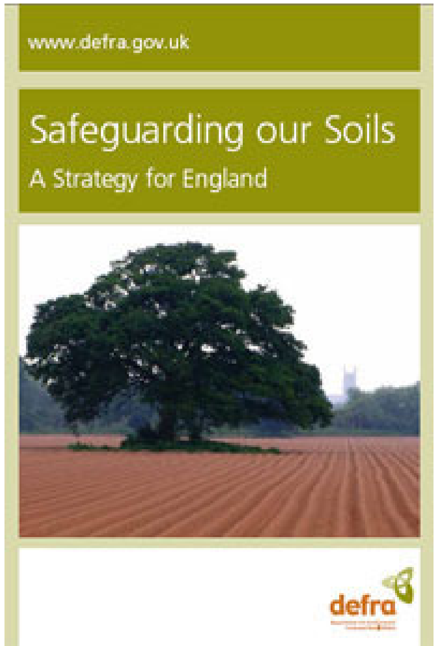
The proposal for a framework Directive (COM(2006) 232)
Sets out common principles for protecting soils across the EU.

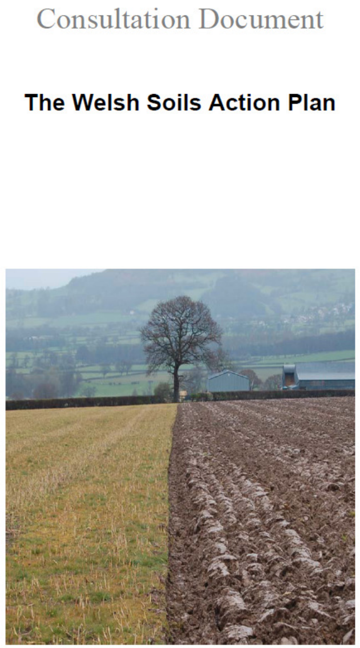
The Impact Assessment (SEC (2006) 1165 and SEC(2006) 620)
Contains an analysis of the economic, social and environmental impacts.

8 threats:

1) erosion:	€0.7 – 14.0 billion
2) organic matter decline:	€3.4 – 5.6 billion
3) compaction:	no estimate possible,
4) salinisation:	€158 – 321 million
5) landslides:	up to €1.2 billion per event
6) contamination:	€2.4 – 17.3 billion
7) sealing:	no estimate possible
8) biodiversity decline:	no estimate possible

Soils are a major policy focus in Defra and EU





SPICe briefing

7 July 2006

06/53

SOIL PROTECTION IN SCOTLAND

DR NICOLA MCLOUGHLIN

This briefing explains the nature and importance of Scotland's soil resources. Sustainable soil management is vital to the farming and forestry sectors and for supporting protected habitats, animals and unique landscapes. Current threats to Scottish soils include: soil erosion, compaction, contamination, sealing, loss of soil biodiversity and declining organic carbon content. The drivers of these threats are climate change, urban development and changing land management practices. The Scottish Executive is currently gathering evidence on the state of and threats to soils in Scotland. In addition strategies or policies are being developed to promote conservation and enhancement of biodiversity interests.

Scottish Parliament Information Centre (SPICe) Briefings are compiled for the benefit of the Members of the Parliament and their personal staff. Authors are available to discuss the contents of these papers with MSPs and their staff who should email spice@scottish.parliament.uk. Members of the public or external organisations may comment on this briefing by emailing us at spice@scottish.parliament.uk. However, researchers are unable to enter into personal discussion in relation to SPICe Briefing Papers. If you have any general questions about the work of the Parliament you can email the Parliament's Public Information Service at spinfo@scottish.parliament.uk.

Every effort is made to ensure that the information contained in SPICe briefings is correct at the time of publication. Readers should be aware however that briefings are not necessarily updated or otherwise amended to reflect subsequent changes.

www.scottish.parliament.uk

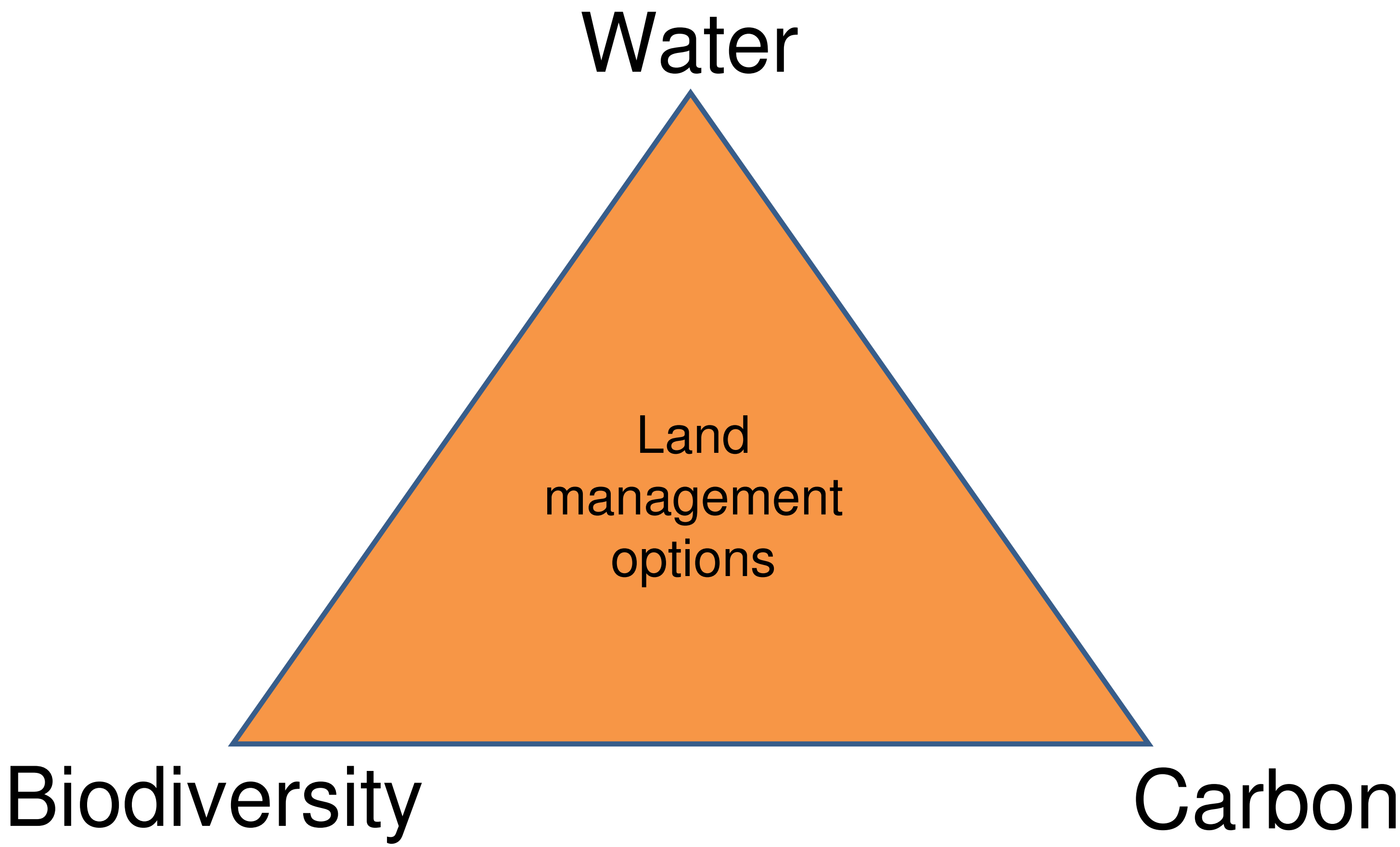
1

The Scottish Parliament

But moving away from mapping and static measurements to understanding processes and function

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

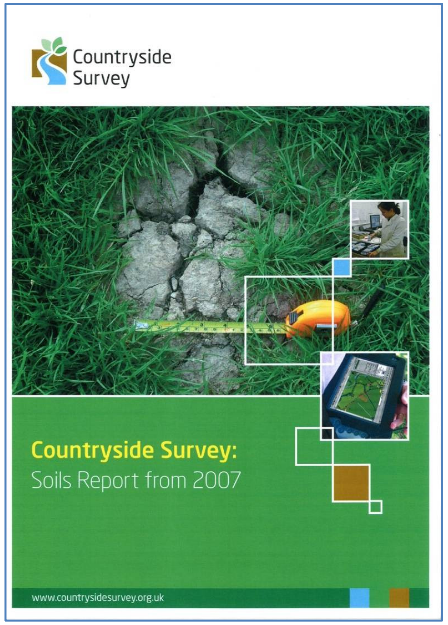
Managing land for ecosystem services



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Current questions

- How is soil changing?
- If so, what is driving the change?
- What does that mean for soil function and ecosystem service provision?
- Does soil biodiversity matter?
- Does our ‘classic’ soil classification work for new challenges (or even old ones)? What is needed to forecast future change?
- How can we better manage land to protect soil natural capital and the services they provide

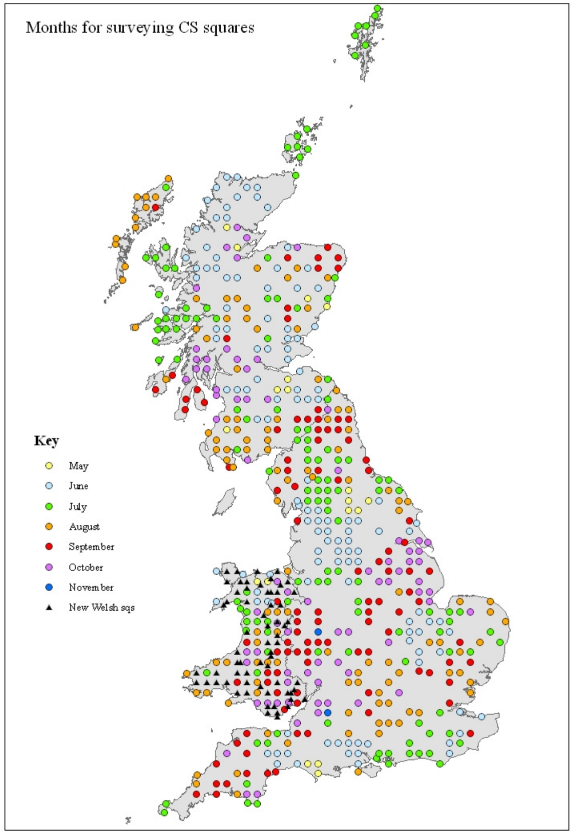


Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Emmett et al. 2010;
www.countrysidesurvey.org.uk

Countryside Survey Soils

- A national integrated monitoring programme
- Land use, vegetation, linear features, waters, **soils (0-15cm)**, landcover map
- Unique 30 year record with 3 data points
- New for 2007
  - Molecular microbial diversity
  - Soil functions (C and N rate functions)
- Integrated analysis to determine change in ecosystem services:
  - Soil C sequestration
  - Soil health
  - Biodiversity
  - Water quality
  - Food and fibre production



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Emmett et al. 2010; www.countrysidesurvey.org.uk

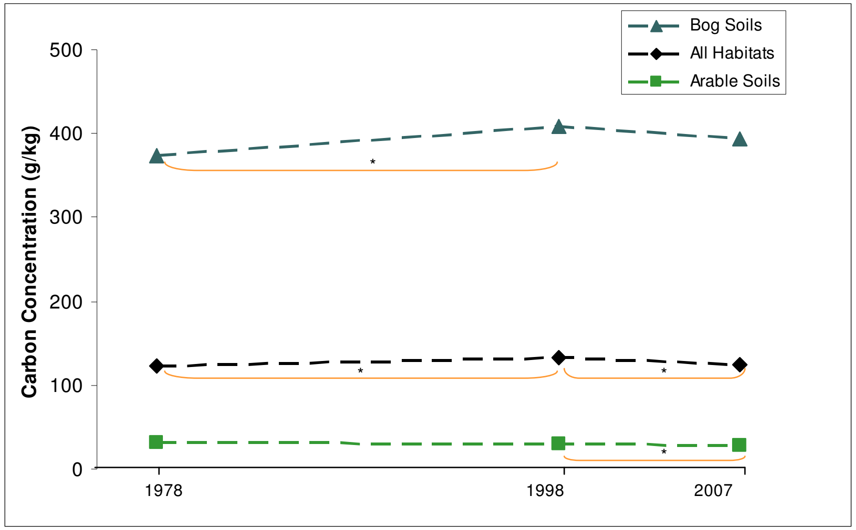
Countryside Survey topsoil (0-15cm) measurements

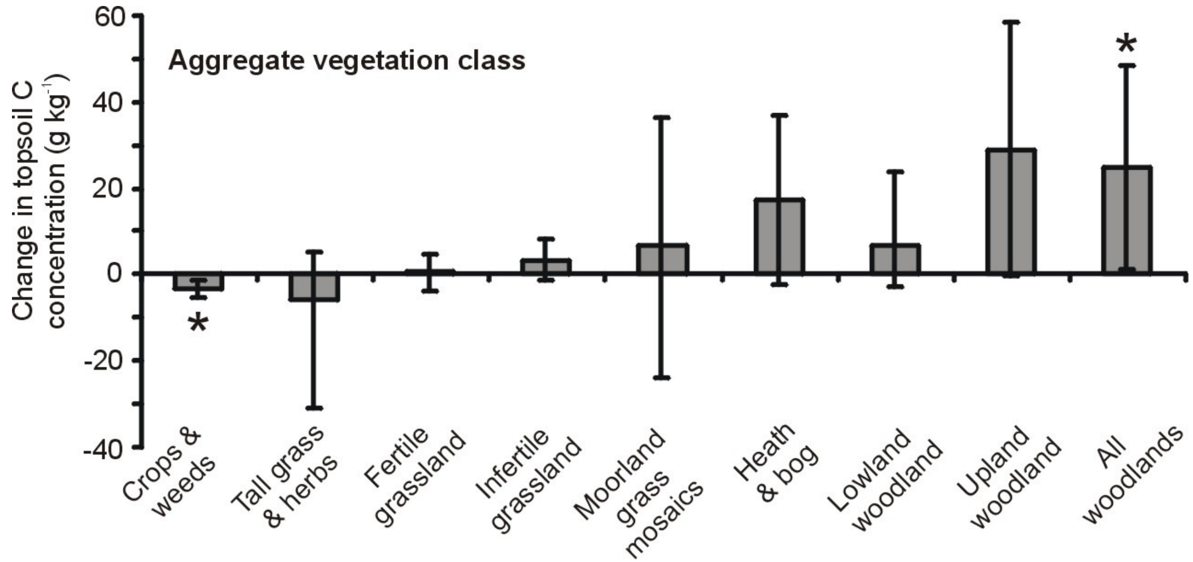
Physical	Chemical	Diversity	Activity/Function
Moisture	pH	Mesofauna	Potential N mineralisation
Soil type	LOI	Bacterial	Potential C mineralisation (respiration)
Soil organic thickness	%C		Basal soil respiration
Hand texture	%N		Microbial biomass
Bulk density	Olsen P		Plant C turnover
	42 metals		DOC/DON turnover
	POPs		Metabolic quotient ($C_{resp}/C_{biomass}$)
			Microbial quotient ($C_{biomass}$/SOC)

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Emmett et al. 2010;
www.countrysidesurvey.org.uk

No change in topsoil carbon concentration (0-15cm) at GB scale (1978 – 2007)





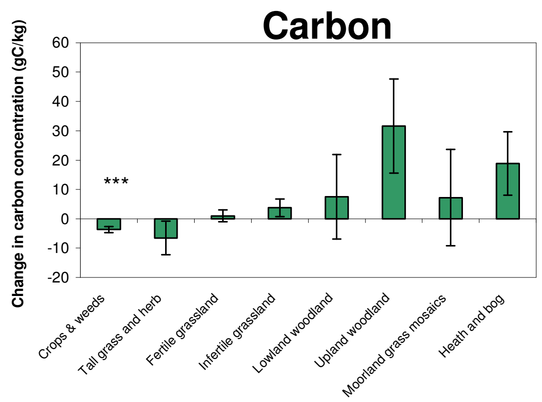
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

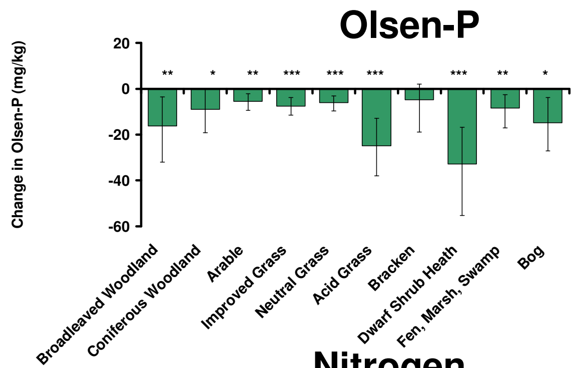
Emmett et al. 2010; www.countrysidesurvey.org.uk

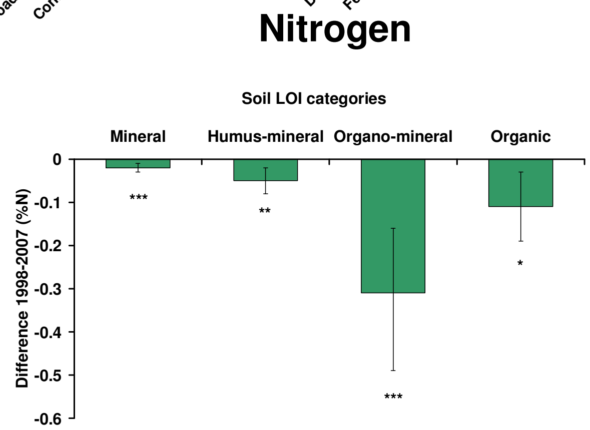
Headline Results

Report published Feb 2010. All data available on line (3 time points (1978 – 2007), 591 1 km2, 2614 samples)

- Is soil carbon (0-15cm) changing and what are the drivers?
  - ***No (spatial patterns linked to decline in S depn and climate)***
- Is recovery from acidification continuing?
  - ***Yes (but only in less acidic environments)***
- Is there robust evidence of a decline in soil biodiversity as stated by the EU?
  - ***No (decline in no. of taxa noted but further work needed)***
- Is N-enrichment continuing or is recovery starting?
  - ***No (increased carbon is diluting the signal)***
- Can the trend of increasing P status be confirmed?
  - ***No (broadscale decline in Olsen P)***
- Is the decline atmospheric metal deposition reflected in soil metal concentrations
  - ***Depends on the metal***







Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Emmett et al. 2010; www.countrysidesurvey.org.uk

Major surprises

- Dilution of nitrogen signal with carbon (increase in C:N)
  - Nitrogen remains a problem to include in models as conflicting results in the literature with respect to effects on decomposition
- Decrease in available phosphorus even in semi-natural habitats
  - Why?
- Most consistent predictor of spatial patterns of change in soil carbon is change in soil pH
  - Should acidity be included in models such as Jules?

Question: How does N, P and pH influence soil carbon rate functions?

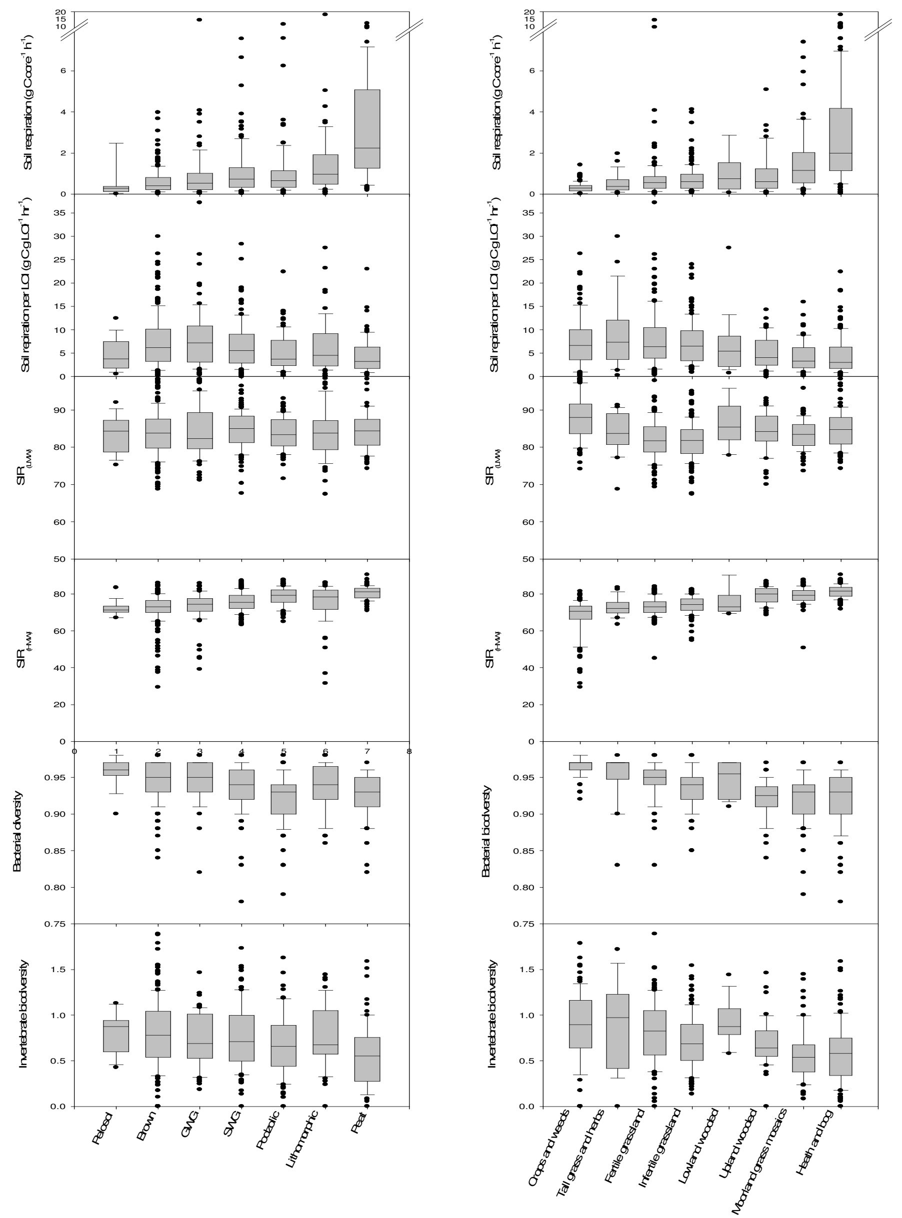
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Emmett et al. 2010; www.countrysidesurvey.org.uk

What best predicts soil carbon rate functions

By soil type

By vegetation type



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Simfukwe et al, in prep
Report to Defra.

Vegetation type is a best single predictor of soil C and N rate functions.

Simfukwe et al. In Prep

Factor	**Potential N mineralisation**	**Basal soil respiration**	**Substrate indiuced respiration (LMW)**	**Substrate induced respiration HMW)**	**Biodiversity (bacteria)**	**Biodiversity (invertebrates)**
Soil Class	0.166	0.145	0.009	0.141	0.124	0.022
Vegetation Class	0.32	0.226	0.007	0.335	0.35	0.06
Stepwise regression (all soil variables)	0.53	0.42	0.13	0.44	0.57	0.08

LOI, BD, pH, Olsen P, %N, %C, Al, Ca, Ec, humics, phenol, amino acids, absorbance at 254nm, biodiversity, field capacity……

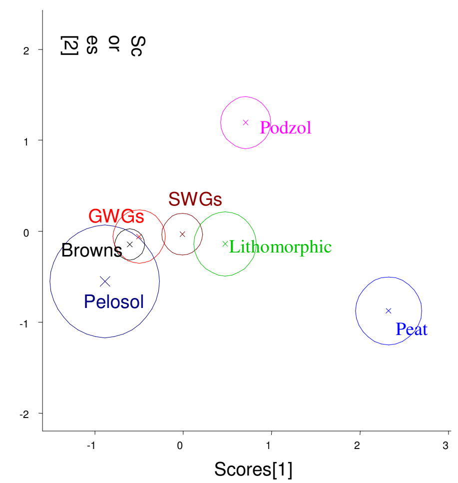
So we're not great at predicting rates even under controlled conditions.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

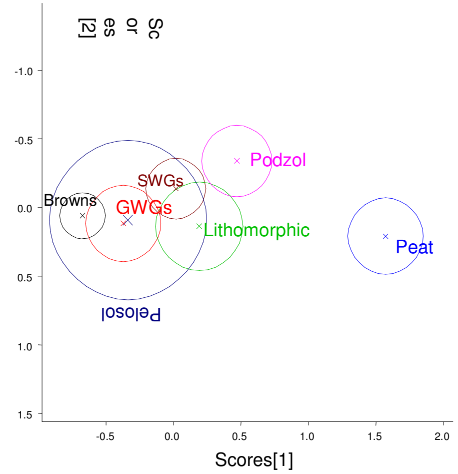
Simfukwe et al. In Prep. Report to Defra.

Discrimination analysis suggests vegetation has greatest influence on topsoil physico-chemistry, function and biodiversity

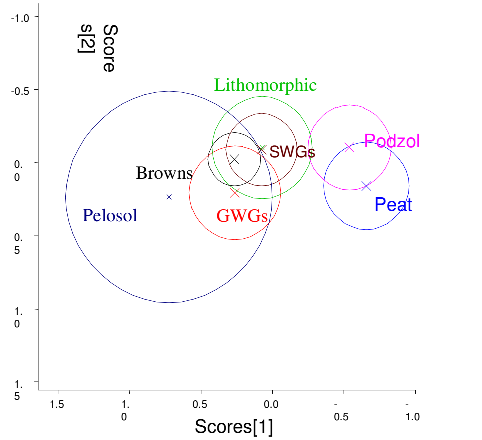
(a) Groups discriminated by physico-chemimical variables



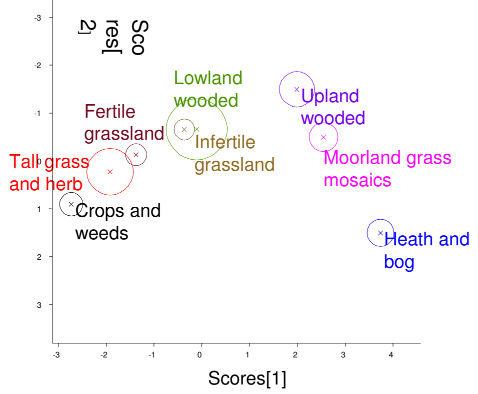
(b) Groups discriminated by function variables



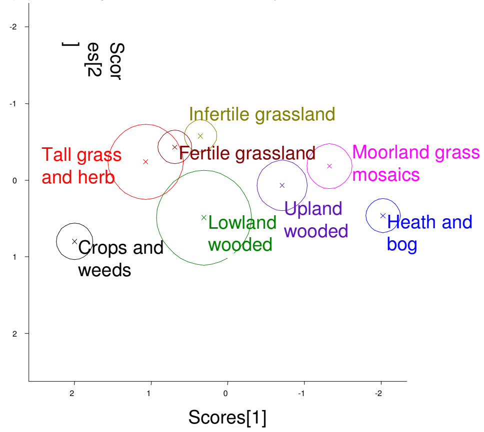
(c) Groups discriminated by Biodiv(bact) and Biodiv(invert) variables



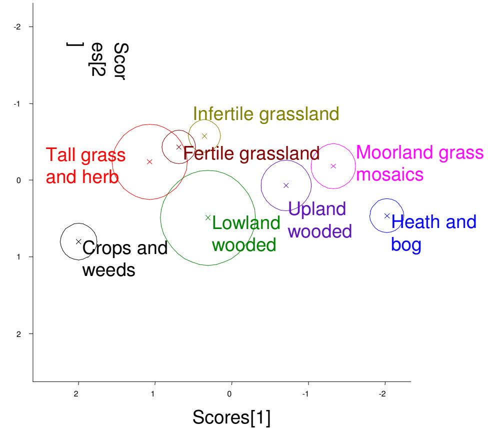
(d) Groups discriminated by physico-chemical variables



(e) Groups discriminated by function variables



(e) Groups discriminated by function variables



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Simfukwe et al. In Prep. Report to Defra.

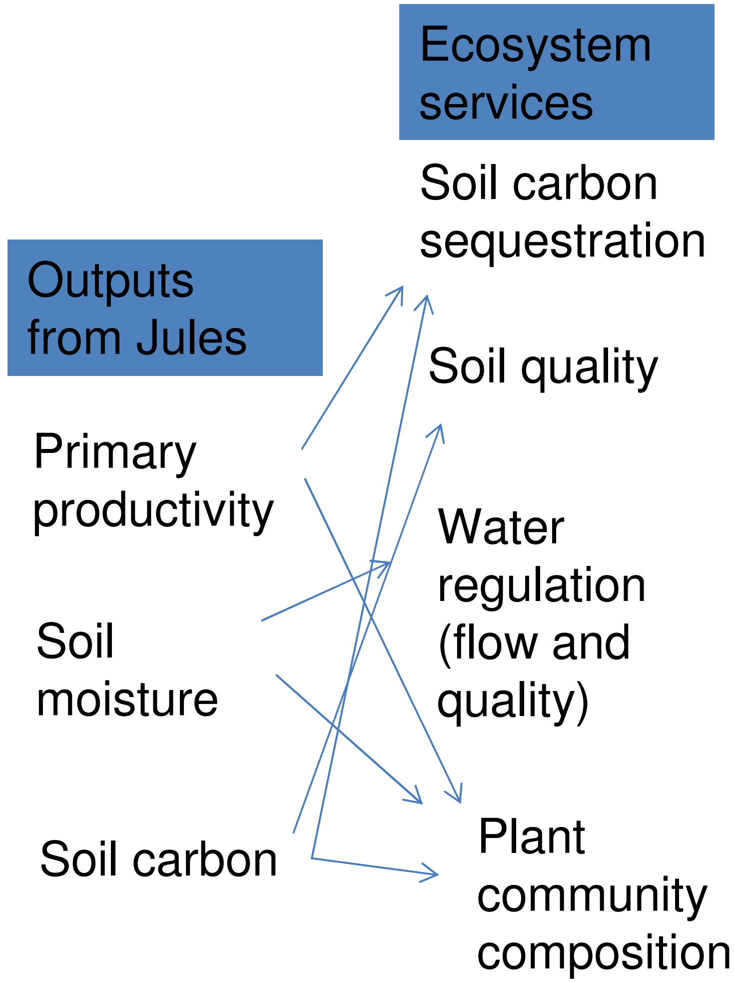
Slide of unpublished data deleted

Jules for soils and ecosystem services research

1. Providing driving variables (e.g. primary production and SMD) for specialist soils models

2. Providing driving variables for plant ecological niche models (now available for > 1000 UK higher plants) based on max, min temp, soil moisture, light (primary prodn), C:N and pH

3. Exploring feedbacks and interactions in ecosystem experiments (EPRECOT project) and EU ecosystem observatories (new EU EXPEER project)



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

1. Use of 'UKCIP08 Scenarios' to determine the potential impact of climate change on thepressures/threats to soils in England and Wales

- Threats to soils are:organic matter decline, erosion, compaction, salinisation, landslides, sealing, contamination and declining biodiversity

- Review and identify criteria for selecting candidate models

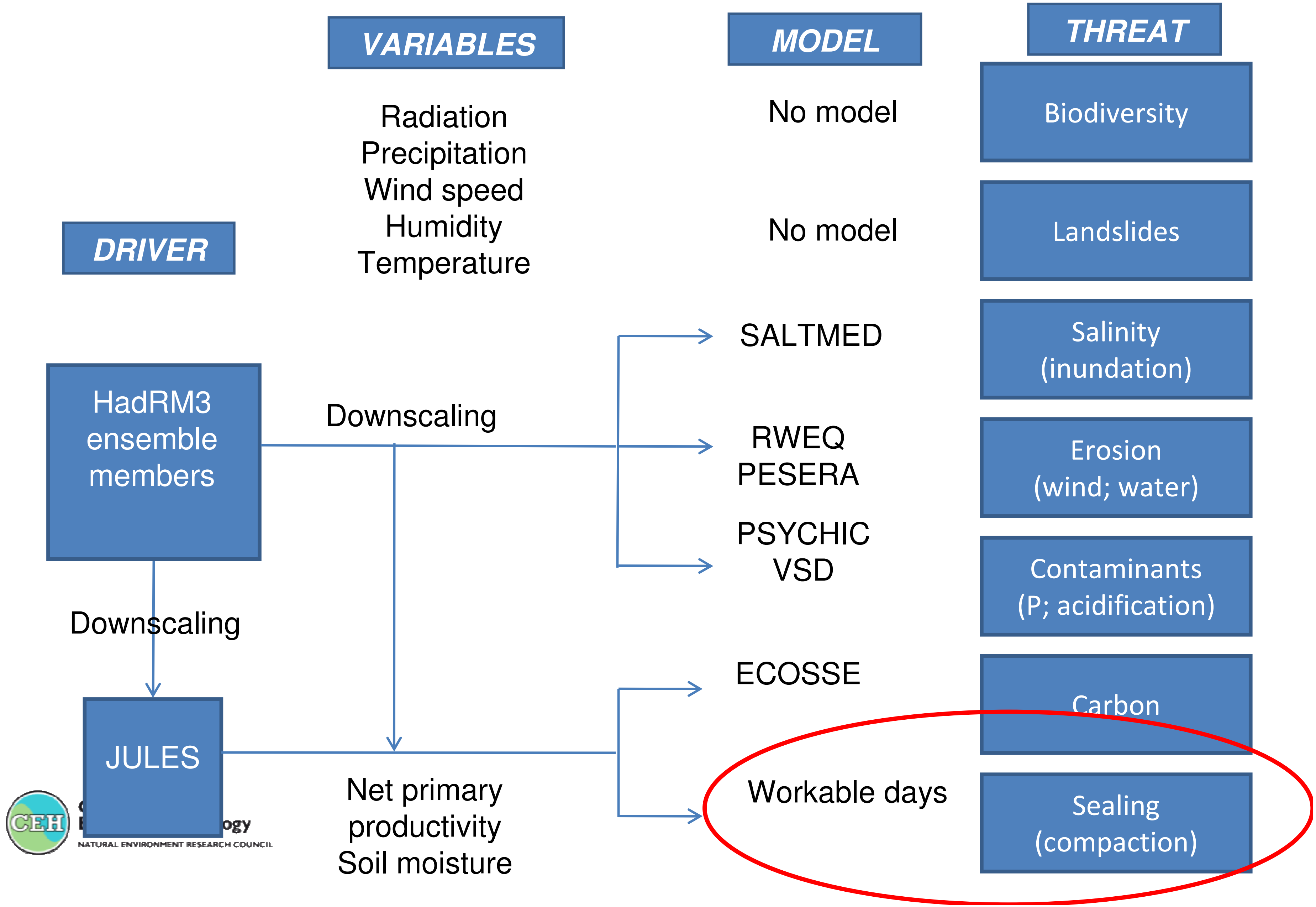
- Modify UKCIP09 scenarios for input to models and use to assess likely response of soil functioning

- Collaboration between Centre for Ecology and Hydrology, Bangor; ADAS Wolverhampton;Scottish Crop Research Institute (SCRI); Leeds University; Centre for Ecology and Hydrology, Wallingford; British Geological Survey; Aberdeen University

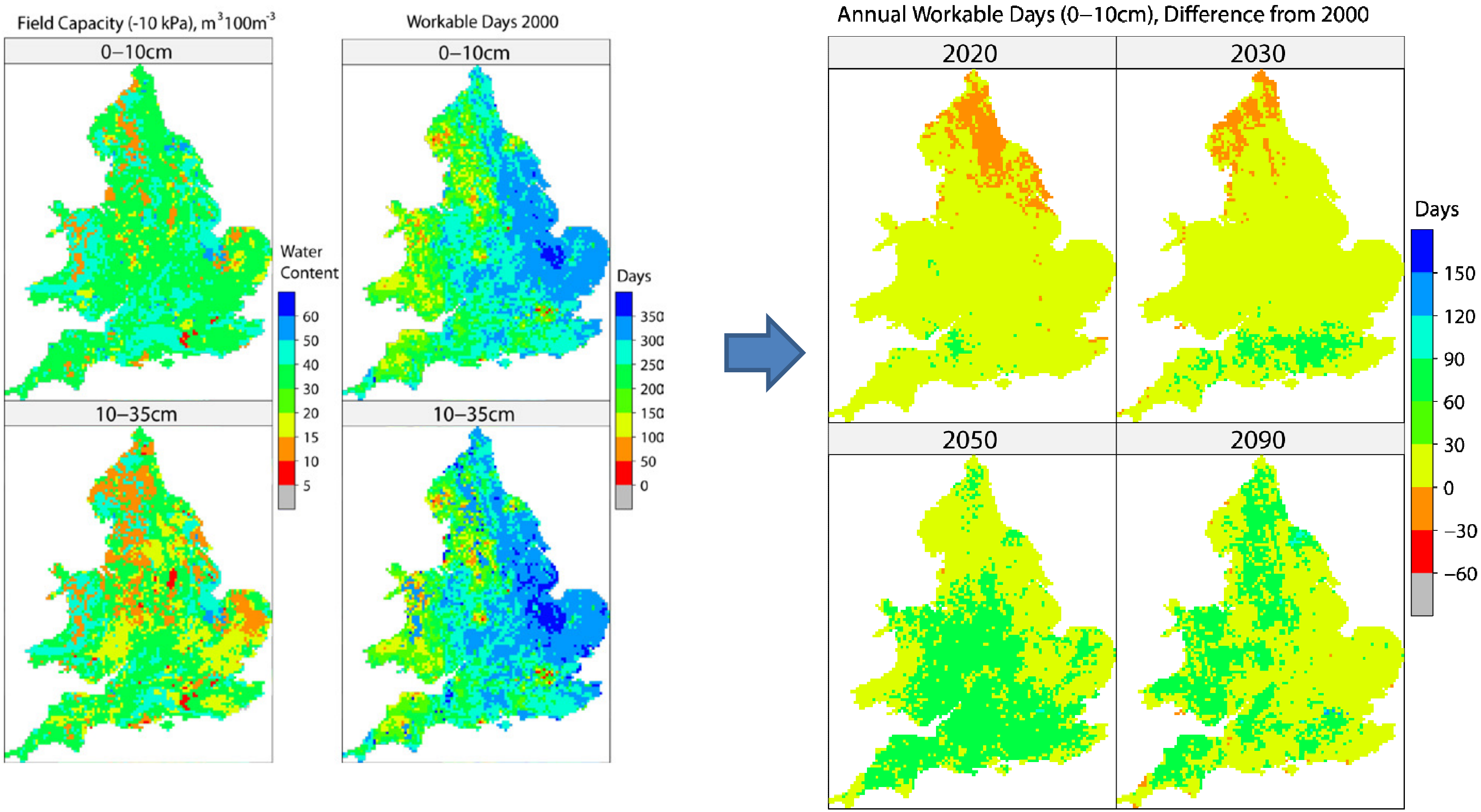
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Cooper et al. 2010 Use of 'UKCIP08 Scenarios' to determine the potential impact of climate change on the pressures/threats to soils in England and Wales: Final report to Defra

Jules as a source of driving variables for specialist soil models



Use of Jules to provide soil moisture data to forecast change in workable days



Cooper et al. 2010 Use of 'UKCIP08 Scenarios' to determine the potential impact of climate change on the pressures/threats to soils in England and Wales: Final report to Defra

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

2. Proving driving variables for predicting vegetation change

Empirical niche models for predicting plant species composition change in terrestrial vegetation in response to multiple drivers are now available for most higher plants in GB and many lower plants

defra

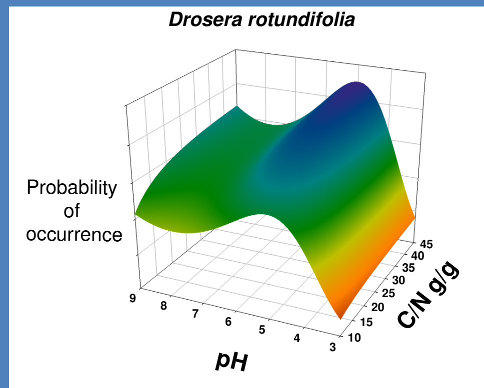
DRIVERS

- N deposition
- Grazing/succession
- Recovery from acidification
- Climate change
- Drainage/flooding

ABIOTIC/CLIMATE VARIABLES

- Soil C:N ratio
- Canopy heigh
- Soil pH
- min Jan, max precipitation
- % soil moisture

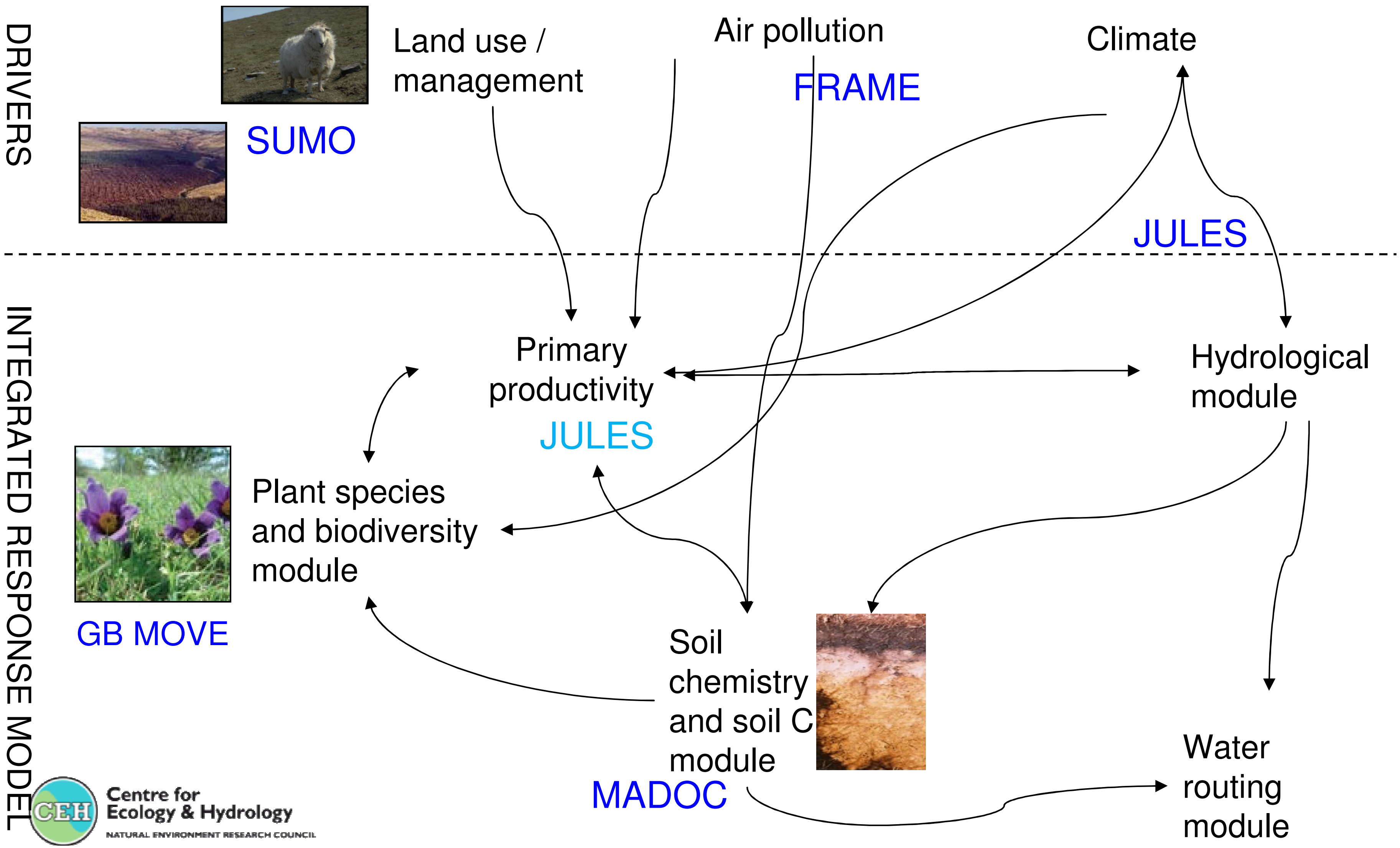
Niche models of species occurrence (2 of 8 axes only)



Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Smart et al. (In Press)

Next steps – more soil parameters into Jules and introduce more ecological feedbacks



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

3. A potential tool for ecosystem observatory and experimental scientists. Mutual benefit as data to test performance of models

- ESF funded ClimMani project is building database of all climate change manipulation experiments in EU

Linked to

- N America 'Interface' project which brings together N America climate change experimental scientists (Feb meeting)

- Meta-analysis underway for all precipitation experiments

- EPRECOT prroject tested four ecosystem models against experimental data across different climatic zones

CEH Ce Ec NATU

Beier et al. 2004 Ecosystems 7:583-597

Exploration of sensitivity of four ecosystem models models using experimental data

Global Change Biology (2008) **14**, 2365–2379, doi: 10.1111/j.1365-2486.2008.01651.x

Modelled effects of precipitation on ecosystem carbon and water dynamics in different climatic zones

DIETER GERTEN*, YIQI LUO†, GUERRIC LE MAIRE‡, WILLIAM J. PARTON§, CINDY KEOUGH§, ENSHENG WENG†, CLAUS BEIER¶, PHILIPPE CIAIS‡, WOLFGANG CRAMER*[1], JEFFREY S. DUKES‖, PAUL J. HANSON**, ALAN A. K. KNAPP††, SUNE LINDER‡‡, DAN NEPSTAD§§, LINDSEY RUSTAD¶¶ and ALWYN SOWERBY‖‖

*Potsdam Institute for Climate Impact Research, Telegrafenberg A62, 14473 Potsdam, Germany, †Department of Botany and Microbiology, University of Oklahoma, Norman, OK 73019, USA, ‡Laboratoire des Sciences du Climat et de l'Environnement, UMR CEA-CNRS-UVSQ, L'Orme des Merisiers, Bat. 712, 91191 Gif-sur-Yvette, France, §Natural Resource Ecology Laboratory, University of Colorado, Campus Mail 1499, Fort Collins, CO 80523, USA, ¶Risø National Laboratory for Sustainable Energy, Biosystems Department, Building BIO-309, Frederiksborgvej 399, 4000 Roskilde, Denmark, ‖Department of Biology, University of Massachusetts Boston, Boston, MA 02125, USA, **Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN 37831-6422, USA, ††Department of Biology and Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO 80523, USA, ‡‡Southern Swedish Forest Research Centre, Swedish University of Agricultural Sciences, PO Box 49, SE-23053 Alnarp, Sweden, §§Woods Hole Research Center, PO Box 296, Woods Hole, MA 02543, USA, ¶¶USDA Forest Service, Northeastern Research Station, 35 Crystal Lane, Cumberland, ME 04021, USA, ‖‖Centre for Ecology and Hydrology, Orton Building, Deiniol Road, Bangor, Gwynedd LL57 2UP, UK

Abstract

The ongoing changes in the global climate expose the world's ecosystems not only to increasing CO_2 concentrations and temperatures but also to altered precipitation (*P*) regimes. Using four well-established process-based ecosystem models (LPJ, DayCent, ORCHIDEE, TECO), we explored effects of potential *P* changes on water limitation and net primary production (NPP) in seven terrestrial ecosystems with distinctive vegetation types in different hydroclimatic zones. We found that NPP responses to *P* changes

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Global Change Biology (2008) **14**, 1986–1999, doi: 10.1111/j.1365-2486.2008.01629.x

Modeled interactive effects of precipitation, temperature, and [CO_2] on ecosystem carbon and water dynamics in different climatic zones

YIQI LUO*, DIETER GERTEN†, GUERRIC LE MAIRE‡, WILLIAM J. PARTON§, ENSHENG WENG*, XUHUI ZHOU*, CINDY KEOUGH§, CLAUS BEIER¶, PHILIPPE CIAIS‡, WOLFGANG CRAMER†‖, JEFFREY S. DUKES**, BRIDGET EMMETT††, PAUL J. HANSON‡‡, ALAN KNAPP§§, SUNE LINDER¶¶, DAN NEPSTAD‖‖ and LINDSEY RUSTAD***

*Department of Botany and Microbiology, University of Oklahoma, Norman, OK 73019, USA, †Potsdam Institute for Climate Impact Research, Telegraphenberg A62, D-14473 Potsdam, Germany, ‡Laboratoire des Sciences du Climat et de l'Environnement, UMR CEA-CNRS-UVSQ, L'Orme des Merisiers, Bat. 712, 91191 Gif-sur-Yvette, France, §Natural Resource Ecology Laboratory, University of Colorado, Campus Mail 1499, Fort Collins, CO 80523, USA, ¶Biosystems Department, Risø National Laboratory for Sustainable Energy, Technical University of Denmark, Building BIO-309, Frederiksborgvej 399, 4000 Roskilde, Denmark, ‖Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement (CEREGE), BP 80, F-13545 Aix en Provence cedex 04, France, **Department of Biology, University of Massachusetts, Boston, MA 02125, USA, ††Centre for Ecology and Hydrology, Orton Building, Deiniol Road, Bangor, Gwynedd LL57 2UP, UK, ‡‡Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6422, USA, §§Department of Biology, Colorado State University, Fort Collins, CO 80523, USA, ¶¶Southern Swedish Forest Research Centre, Swedish University of Agricultural Sciences, PO Box 49, SE-230 53 Alnarp, Sweden, ‖‖Woods Hole Research Center, PO Box 296, Woods Hole, MA 02543, USA, ***USDA Forest Service, Northern Research Station, 271 Mast Road, Durham, NH 03824, USA

Abstract

Interactive effects of multiple global change factors on ecosystem processes are complex. It is relatively expensive to explore those interactions in manipulative experiments. We conducted a modeling analysis to identify potentially important interactions and to stimulate hypothesis formulation for experimental research. Four models were used to quantify interactive effects of climate warming (*T*), altered precipitation amounts [doubled (DP) and halved (HP)] and seasonality (SP, moving precipitation in July and August to January and February to create summer drought), and elevated [CO_2] (*C*) on net primary production (NPP), heterotrophic respiration (R_h), net ecosystem production (NEP), transpiration, and runoff. We examined those responses in seven ecosystems, including forests, grasslands, and heathlands in different climate zones. The modeling analysis showed that none of the three-

Reasonable consistency for response to different rainfall scenarios

Directions of change in Net Primary Production under different rainfall scenarios, for the seven experimental sites in water limited (“Lim.”) and water-unlimited seasons (“Unlim.”)

The symbols refer to: ↑,ΔNPP ≥ +10 %; ↓, ΔNPP ≤ –10 %; •, +10 % < ΔNPP < –10%. For each case, the results from the four models are indicated (order: LPJ, ORCHIDEE, TECO, DAYCENT).).

Scenario	Season	Clocaenog	Flakaliden	Mols	Walker Branch	Konza	Jasper Ridge	Tapajós
Double Precipn	Limited	••••	↑↓↑↓	••↓↓	••••	↑↑••	••↑↑	•↑••
	Unlimited.	••••	↑•↑↑	↑↑•↑	↑••↑	↑↑↑↑	↓↑↑↑	↑•↑↑
Half Precipn	Lim.	••••	↓↓↓↓	•↓↓↓	↑••↓	↓↓•↓	••↓↓	•↓↓•
	Unlim.	•↓•↓	↓↓↓↓	↓↓↓↓	↓↓↓↓	↓↓↓↓	↑↓•↓	↓↓↓↓
Double freq	Lim.	••••	↓↑••	•↑↓•	••••	••••	•••↑	•↑↑•
	Unlim.	••••	•••↑	•↑••	•••↑	••••	↓↑↑↑	↑↑↑↑
Half freq	Lim.	••••	••••	••••	••••	••••	••••	••••
	Unlim.	••••	••••	••••	••••	••••	••••	••↑•
Sseasonal Precpn	Lim.	•↑••	↓↓↑↓	↑••↓	↑••↓	↑↓↓↓	••••	••••
	Unlim.	•↓•↓	↓↓↓↓	↓↓•↓	↓↓•↓	↓↓↓↓	•↓••	↓••↓

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

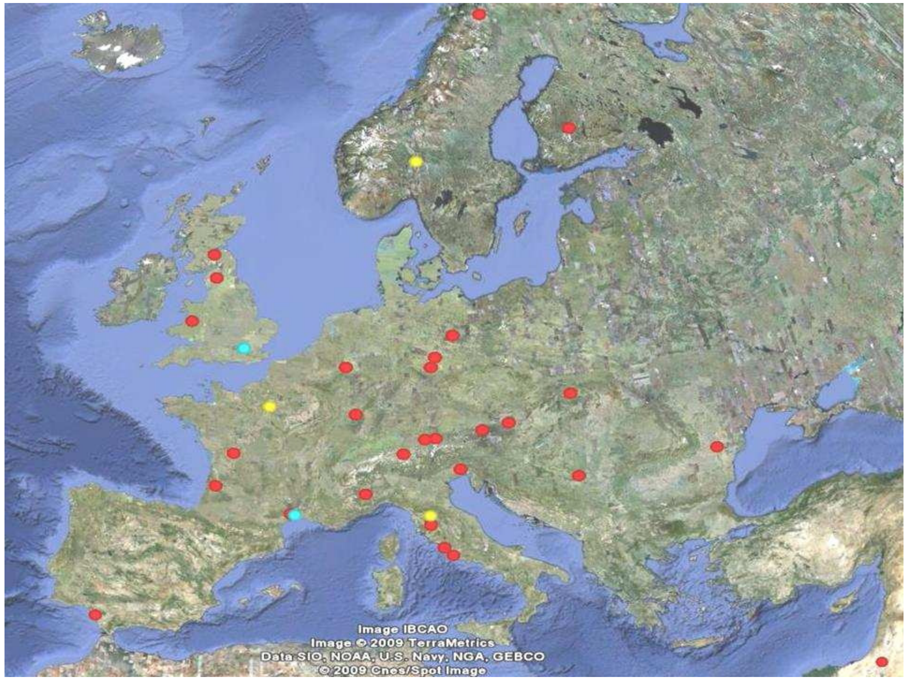
Gerten et al. (2008) GCB 14:2365 - 2379

Proposed Jules application to 33 new EU ecosystem observatories (EXPEER project)

All sites have:

- At least 10 years data
- A manipulation in place
- Adopt an ecosystem approach and have data on hydrology, ecology and biogeochemistry

- Modelling component will include application of one of 3 ecosystem models selected to each sites, creation of parameter libraries and development of a dynamic vegetation component



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Why Jules?

- Runnable at multiple scales
- Not limited to particular habitats or soils
- Integrates well with climate data
- Established community model
- Includes fundamental ecosystem components and enables feedbacks for integrated ecosystem science
- Lots of infrastructure and routines available