Bringing ecosystem services into economic analyses of land use

Presentation to:

Fondazione Eni Enrico Mattei (FEEM)

Isola di San Giorgio Maggiore, Venice, Italy

Thursday, 8th May 2014

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Royal Society Wolfson Professor, H.M. Treasury Natural Capital Committee, Defra Science Advisory Council

Bringing ecosystem services into economic analyses of land use

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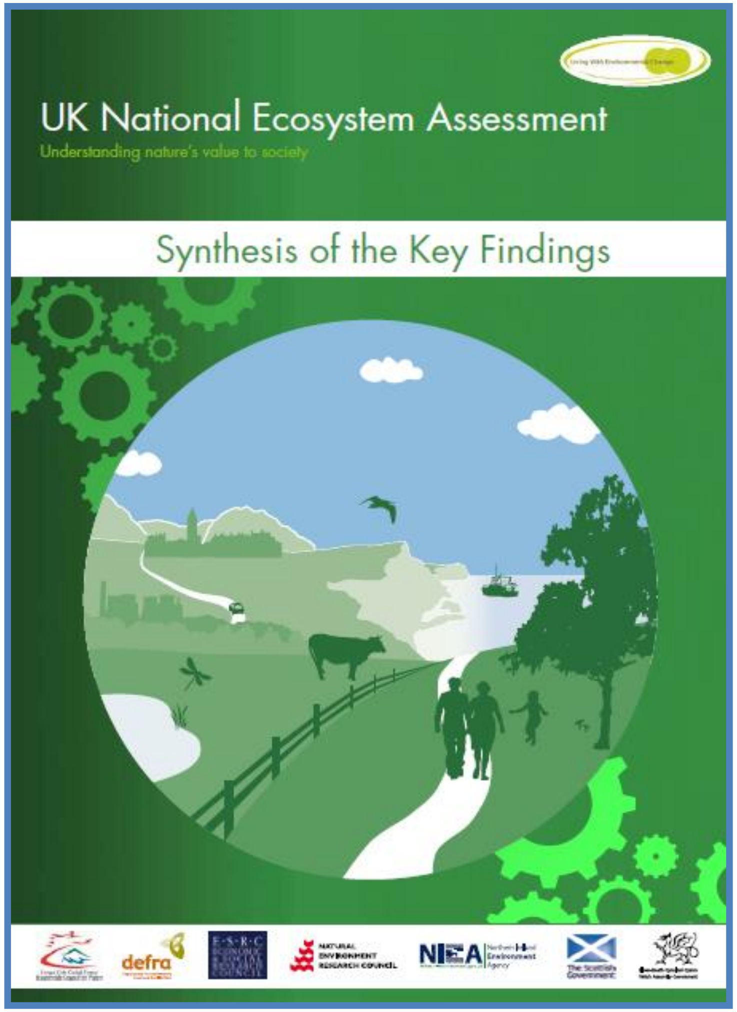
UK National Ecosystem Assessment

Making better land use decisions: UK Case Study



Available from UNEP or Defra: www.uknea.unep-wcmc.org

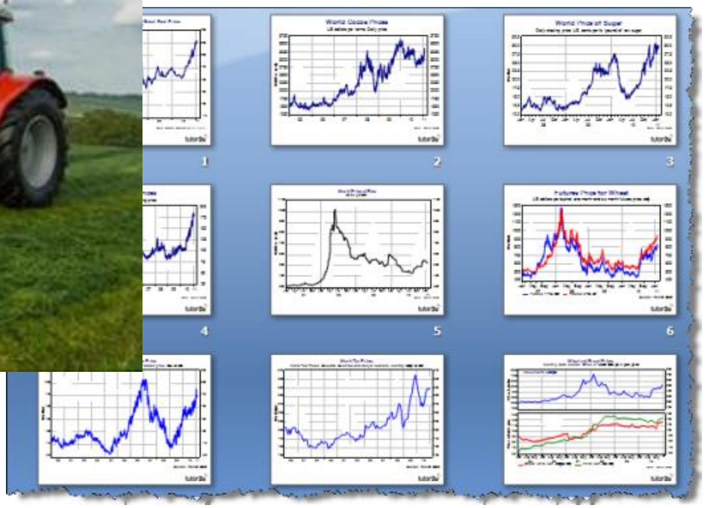
or Bateman et al. (2013) *Science*, 341: 45-50

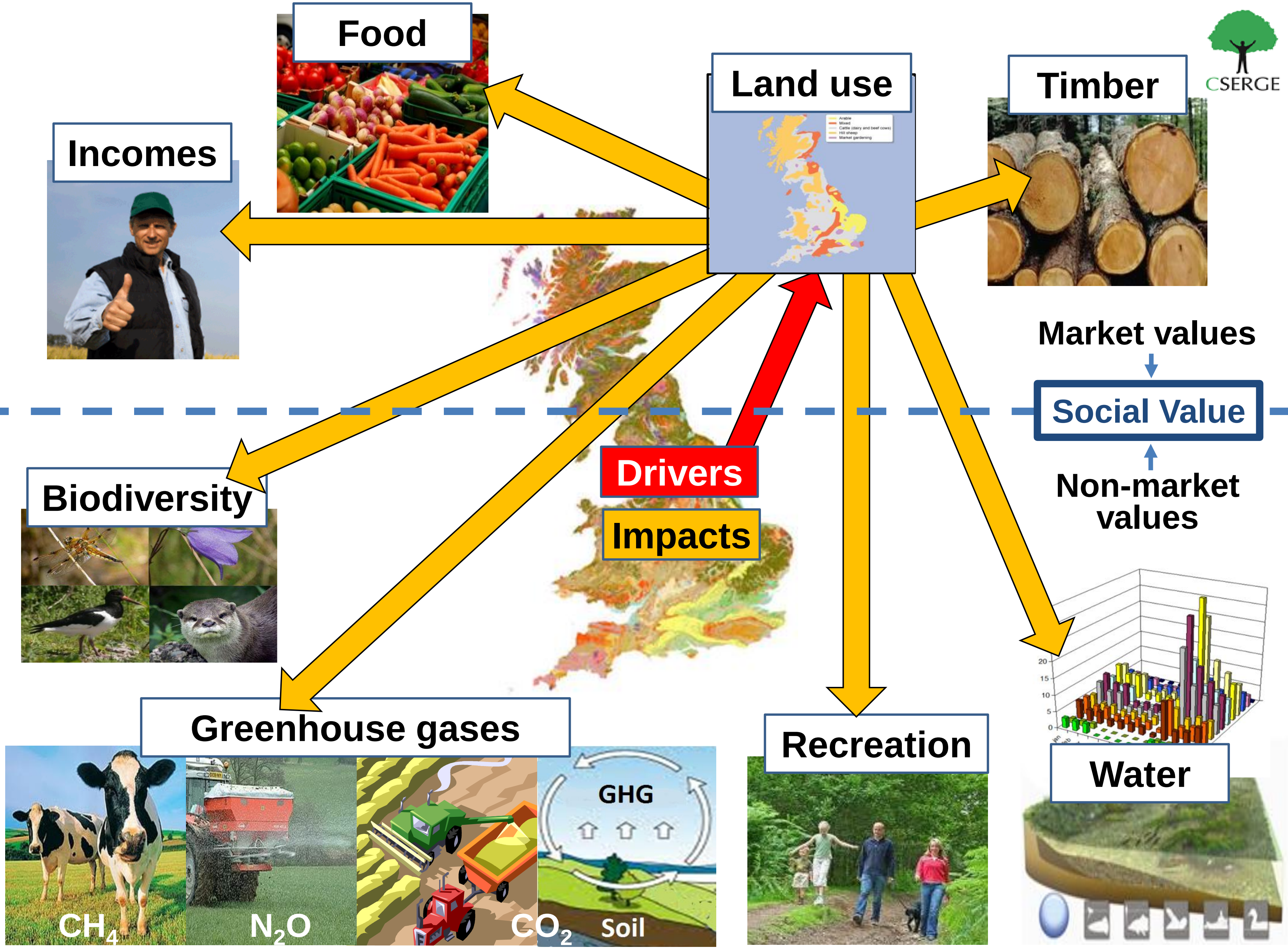
Making better land use decisions: UK Case Study

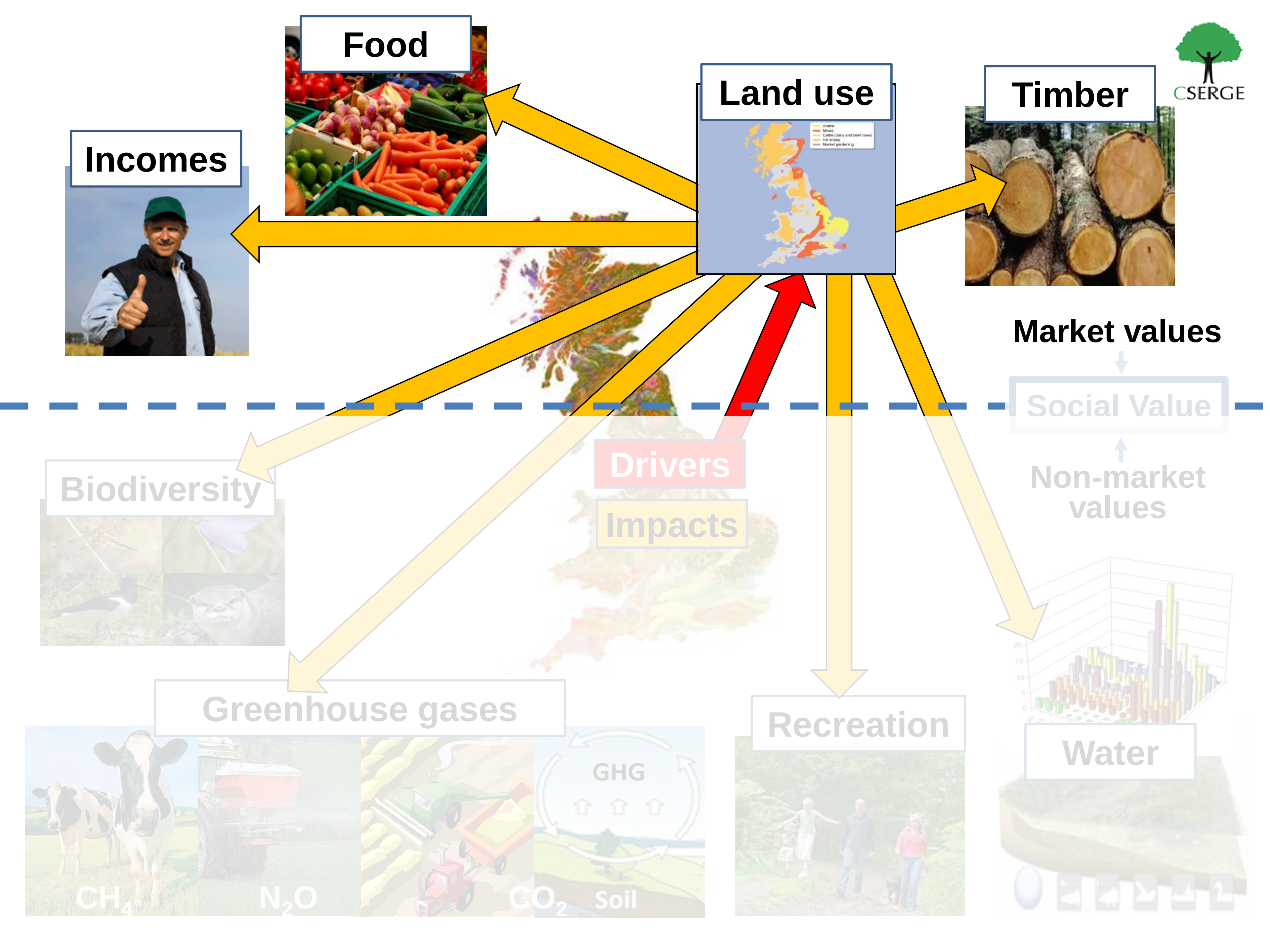
Drivers of land use change:

- Physical environment and its changes
- Changes in market forces, prices, costs, etc.
- Policy

Integrated analyses vital




Food
Land use
Timber
CSERGE
Incomes
Market values
Social Value
Non-market values
Drivers
Impacts
Biodiversity
Greenhouse gases
Recreation
Water
CH_4
N_2O
CO_2
GHG
Soil



CSERGE
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CH4
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CO2
Soil

Modelling agricultural land use: Data

Spatially referenced data for all of GB

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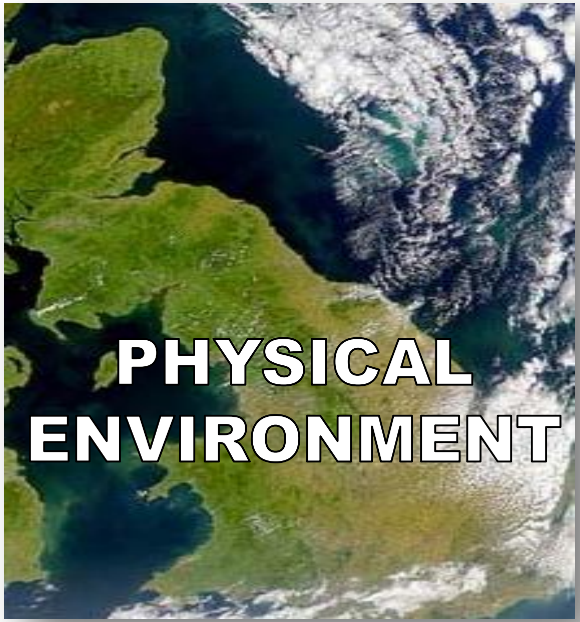
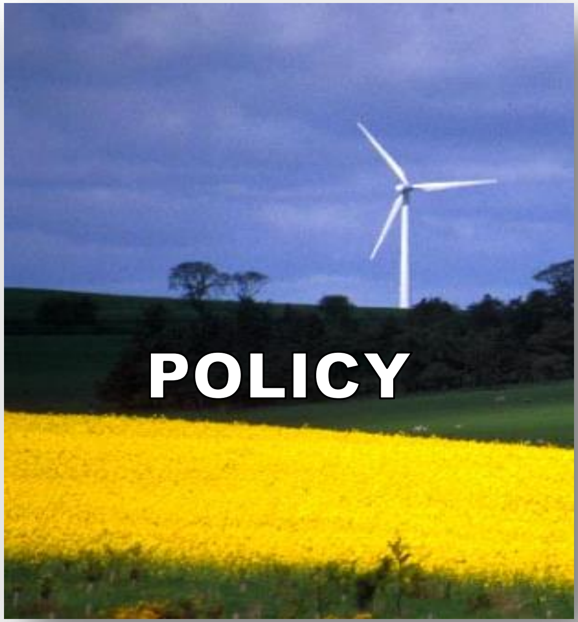




Soils	Output prices	Common Agricultural Policy
Temperature	Input costs	Environmental Policy
Rainfall	Technology	Intervention

2km square resolution; 55,000 cells; about 50 records per cell; data from 1972 to 2010

CSERGE

Agricultural land use model

Based on a joint (in inputs) multi-activity dual profit function (Chambers and Just, *AJAE,* 1989; Fezzi and Bateman, *AJAE,* 2011)

The farm objective function:

Fixed factors: soils, temperature, precipitation, policy, etc.

$$\pi(p, w, L, z) = \max_{l_1,\ldots,l_h}\{\pi(p, w, z, l_1, \ldots, l_h) : \sum_{i=1}^{h} l_h = L\}$$

profits

land use areas

output prices

input prices

total land

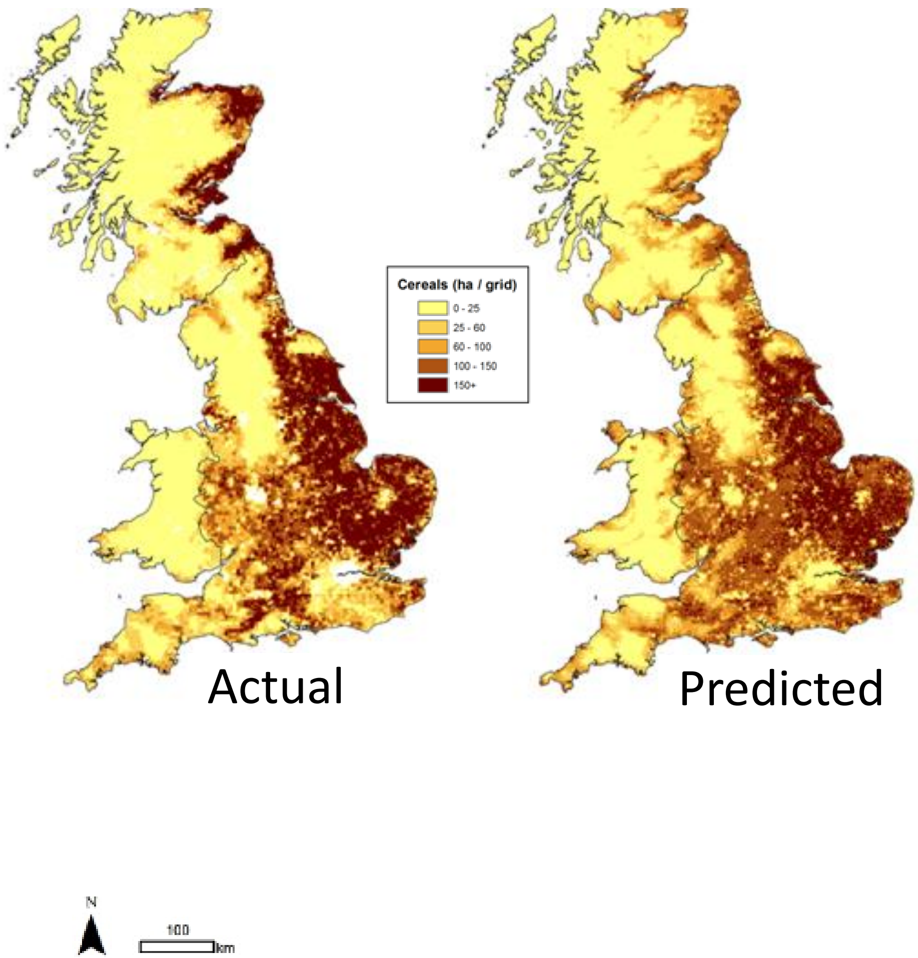
Very flexible specification allowing for full interactions.

Using duality we can derive a series of relations, including estimates of the amount of land allocated to each activity. This varies spatially due to variation in physical environment and allows us to compare predicted with actual land use in an out-of-sample test.

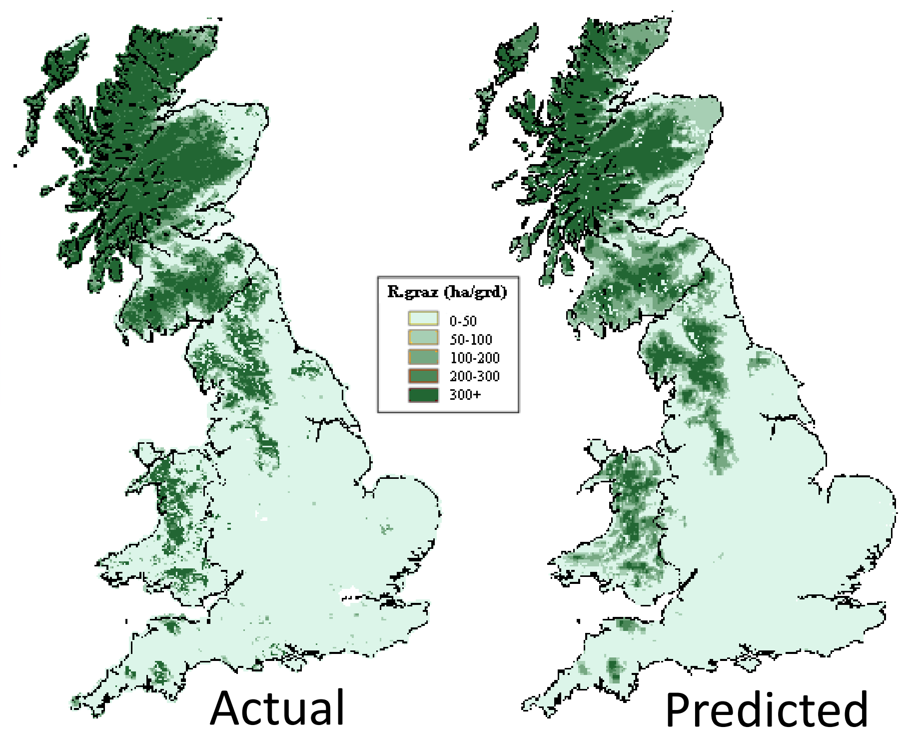
Validation

Out-of-sample, actual versus predicted tests

Cereals

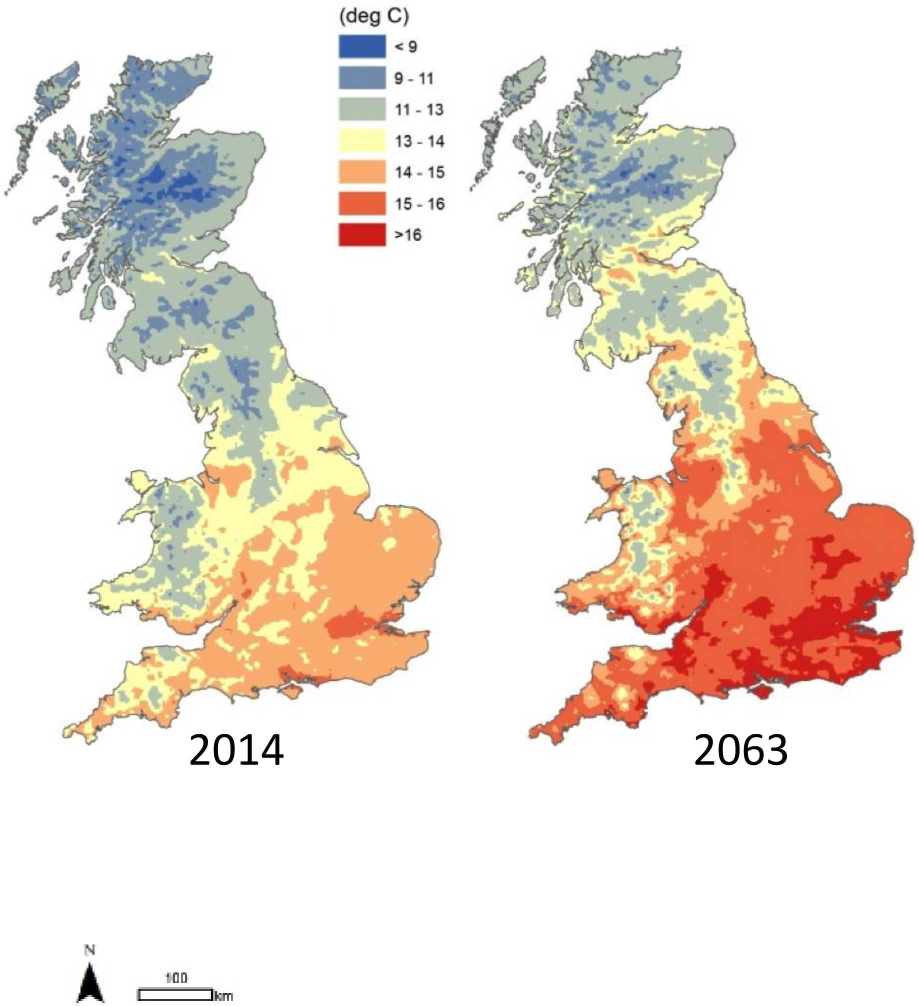


Grasslands

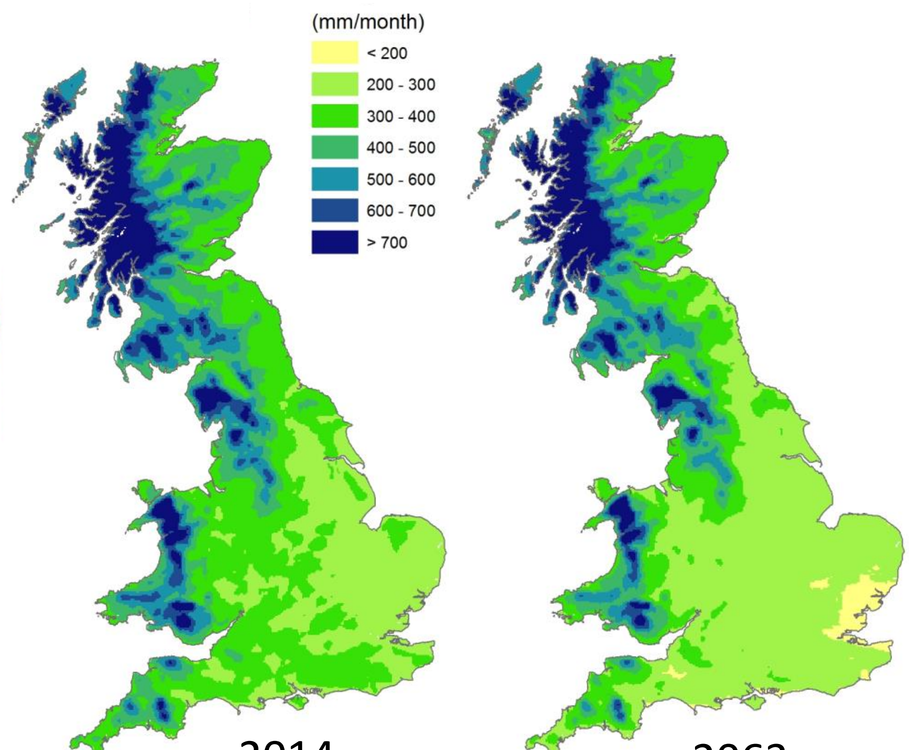


Drivers of land use: Climate change

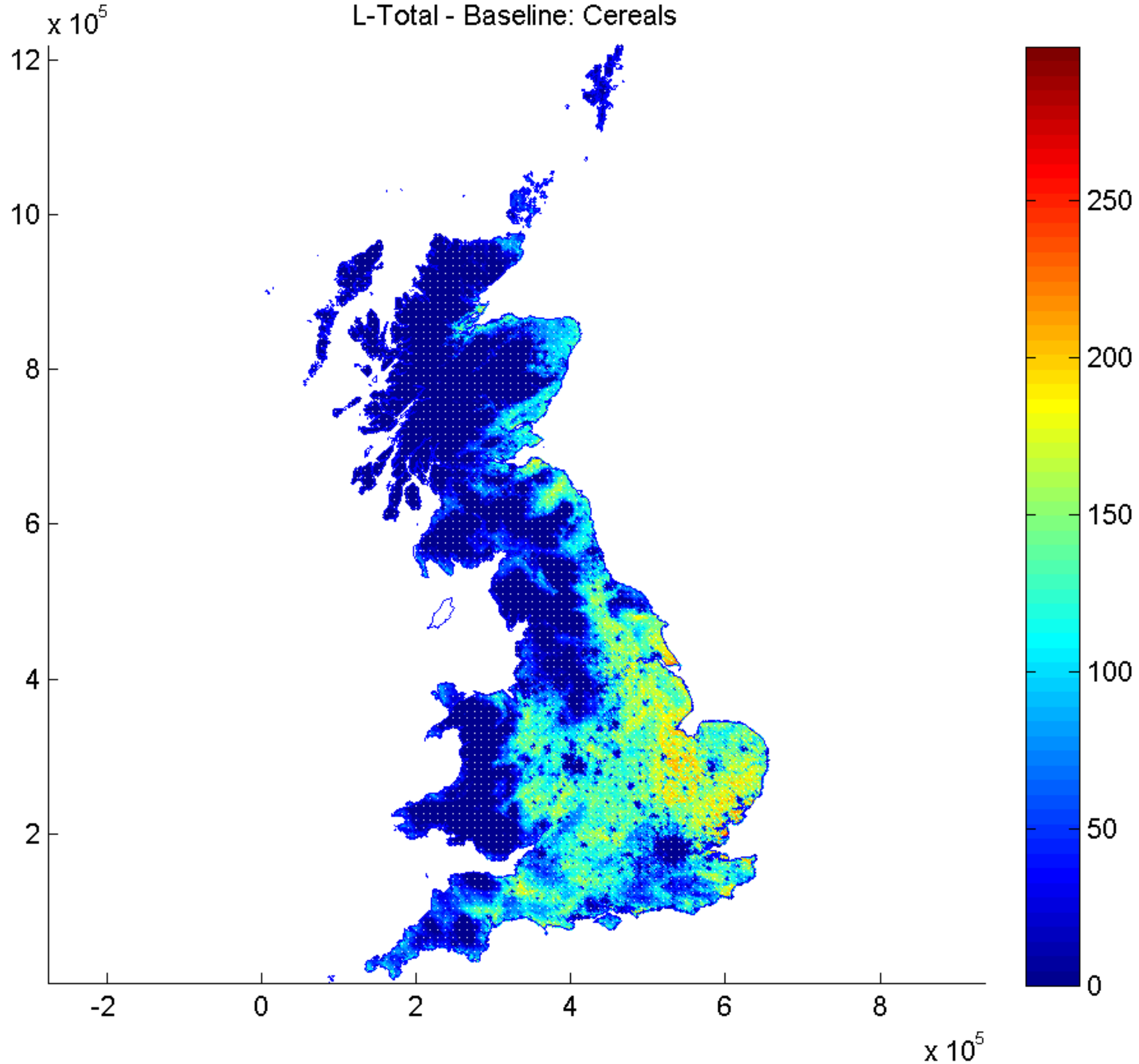
Temperature



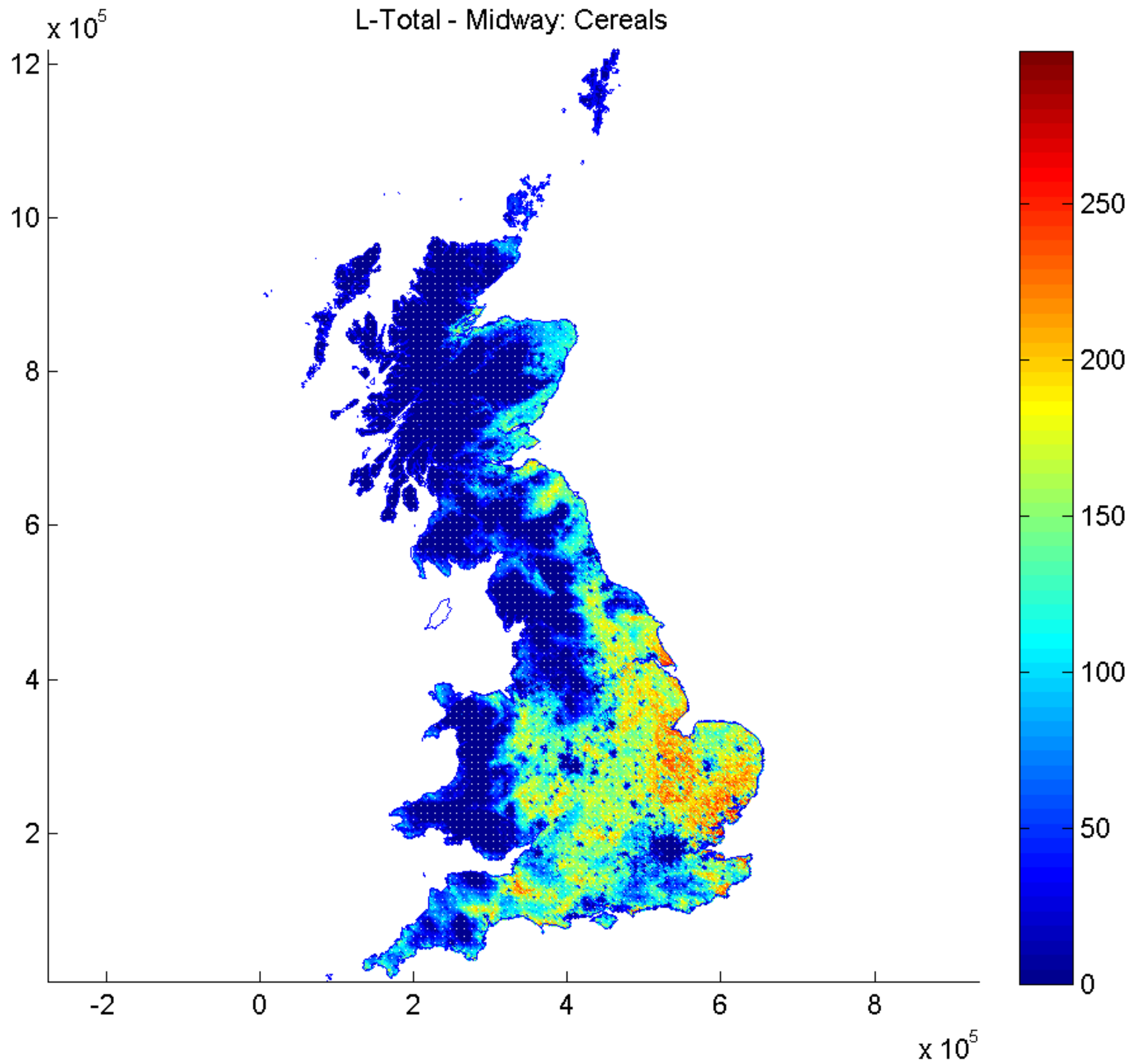
Rainfall



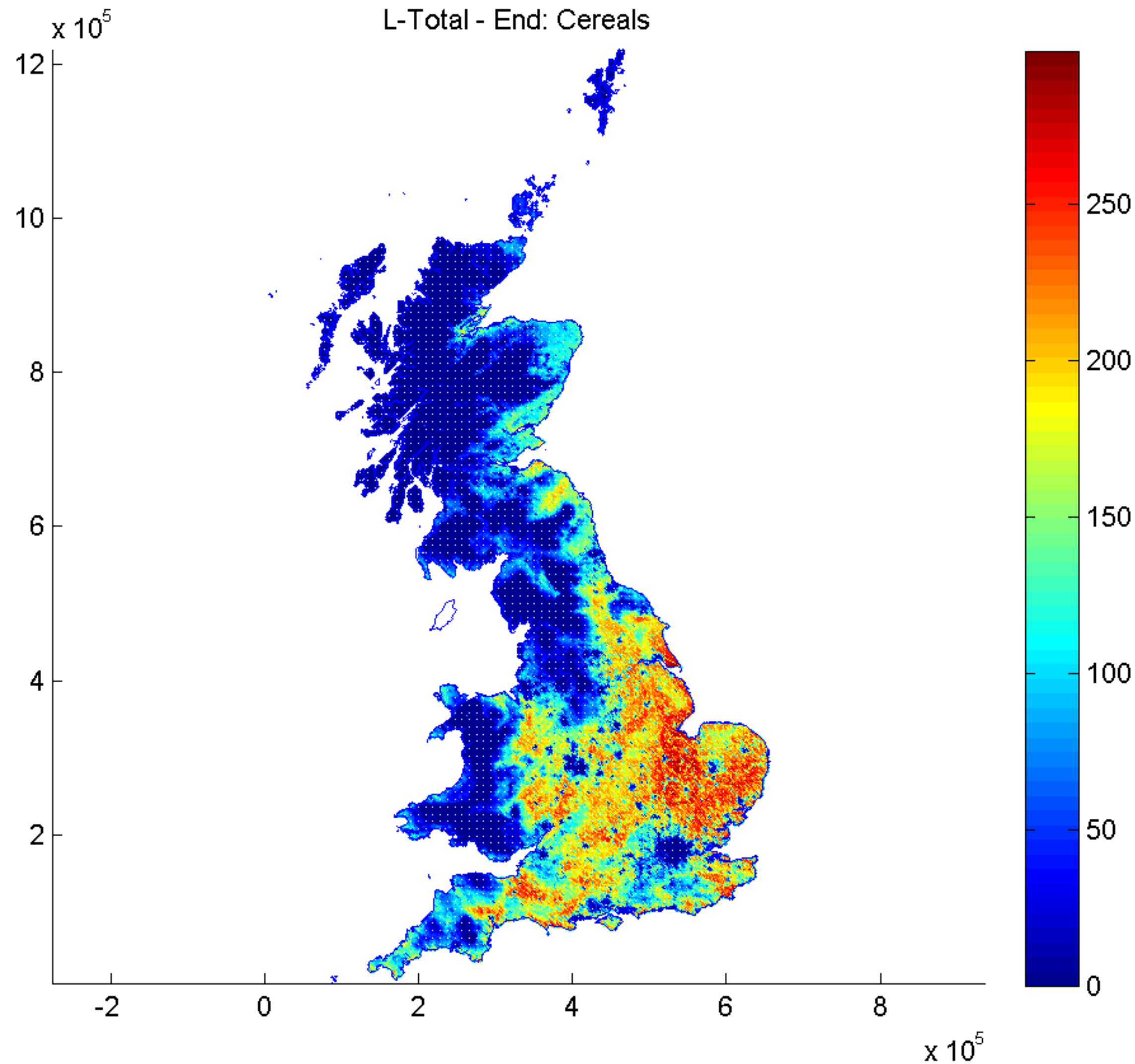
Climate change impacts: Cereals 2014



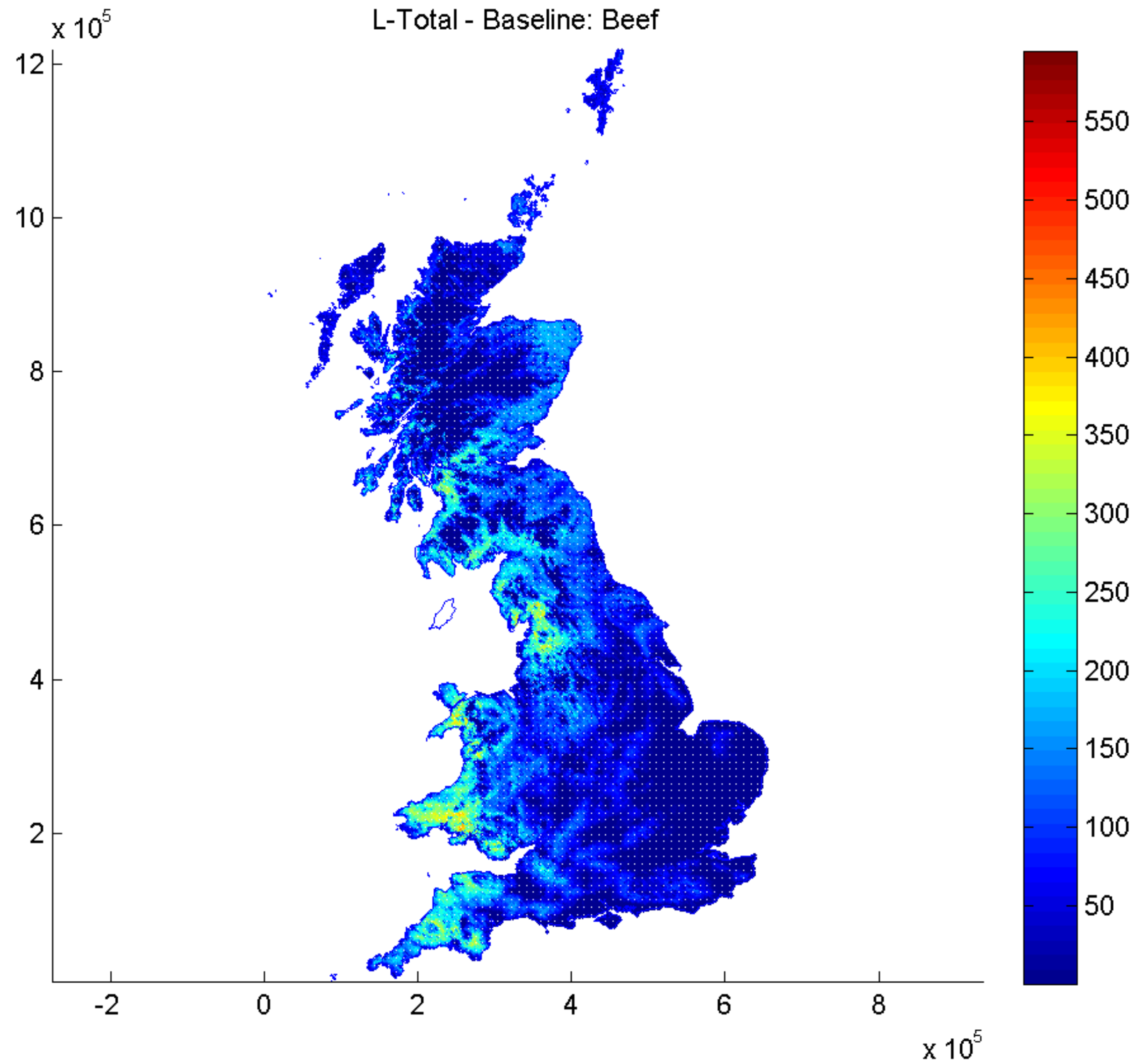
Climate change impacts: Cereals 2039



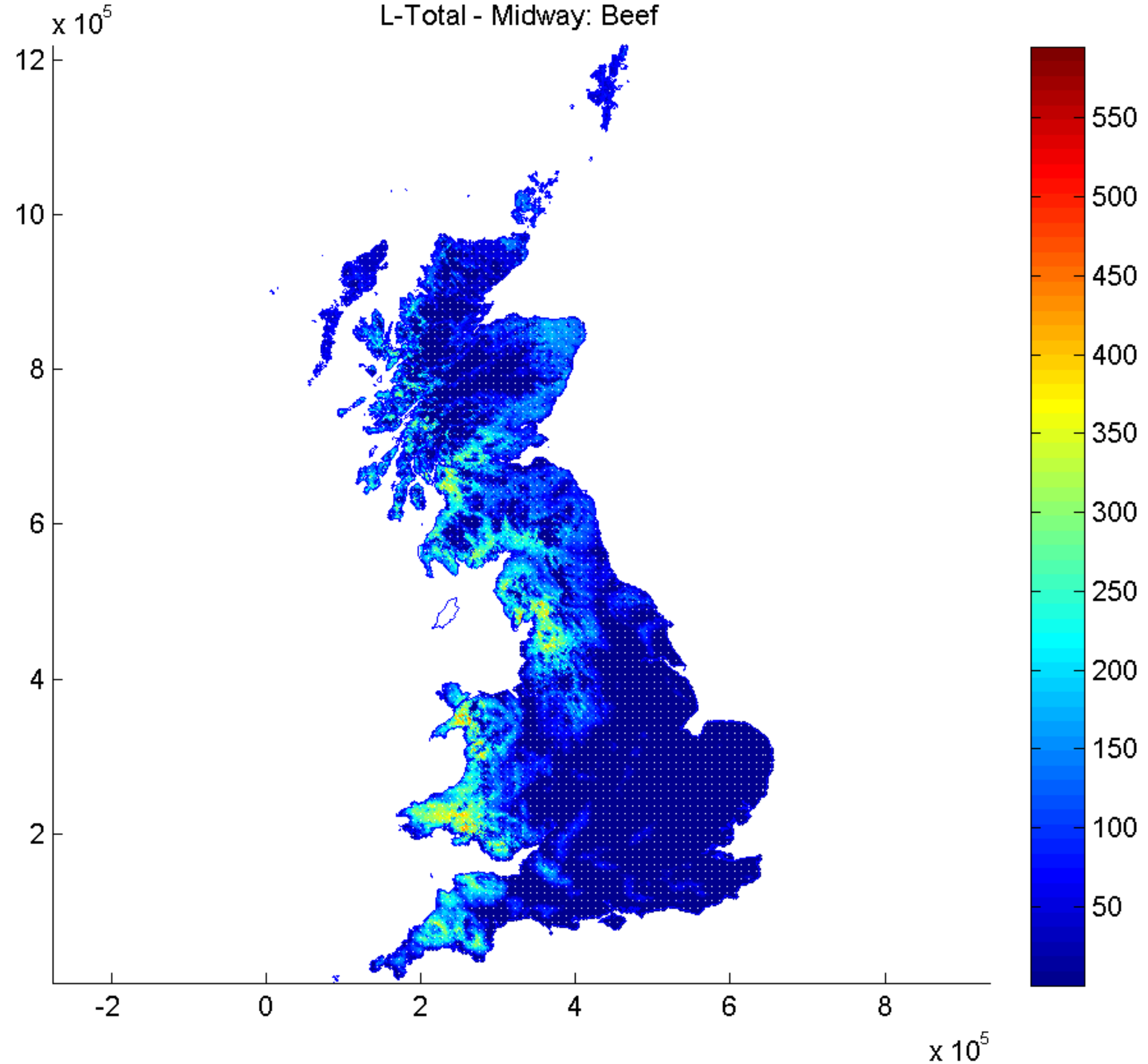
Climate change impacts: Cereals 2063



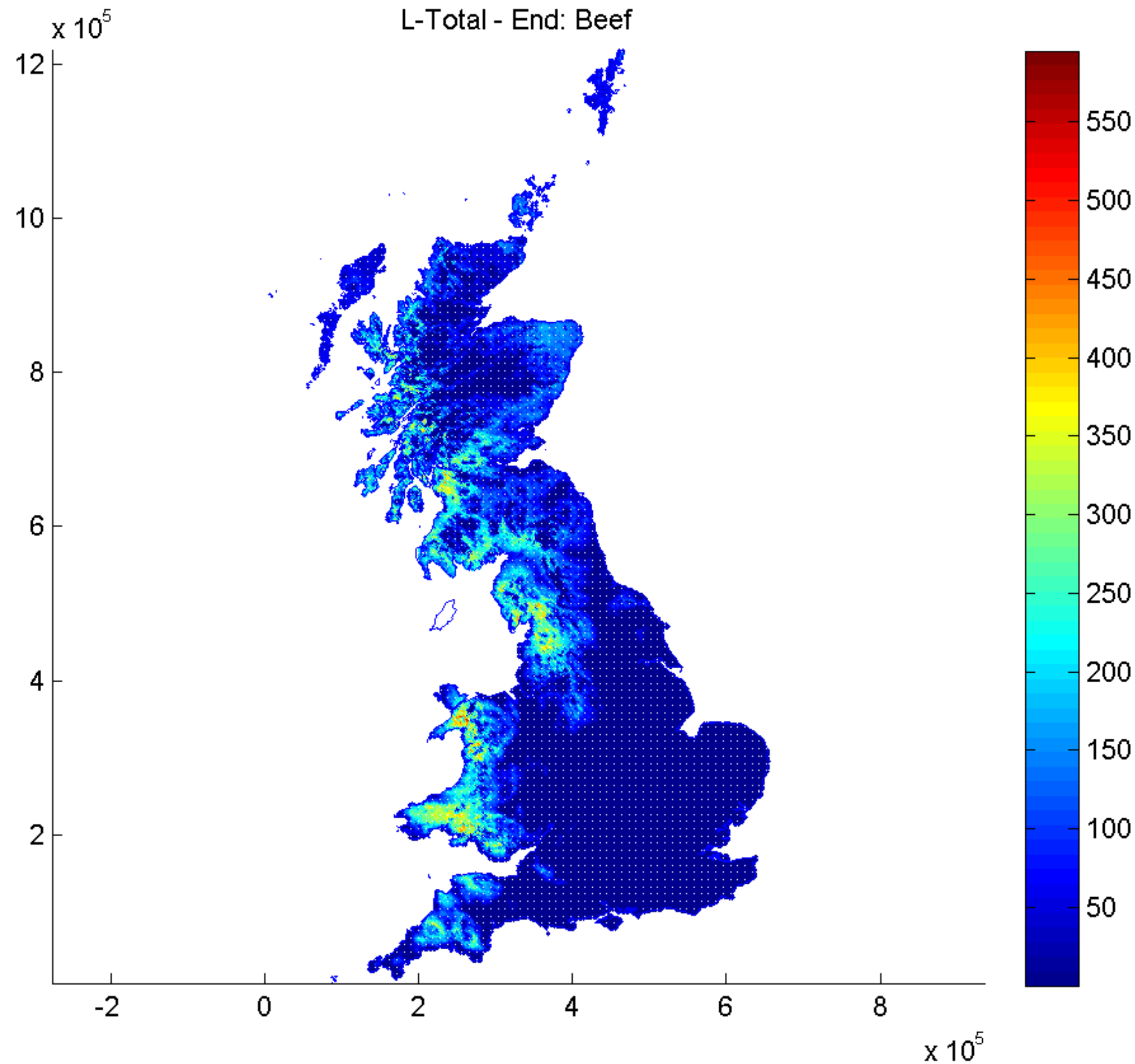
Climate change impacts: Beef 2014



Climate change impacts: Beef 2039



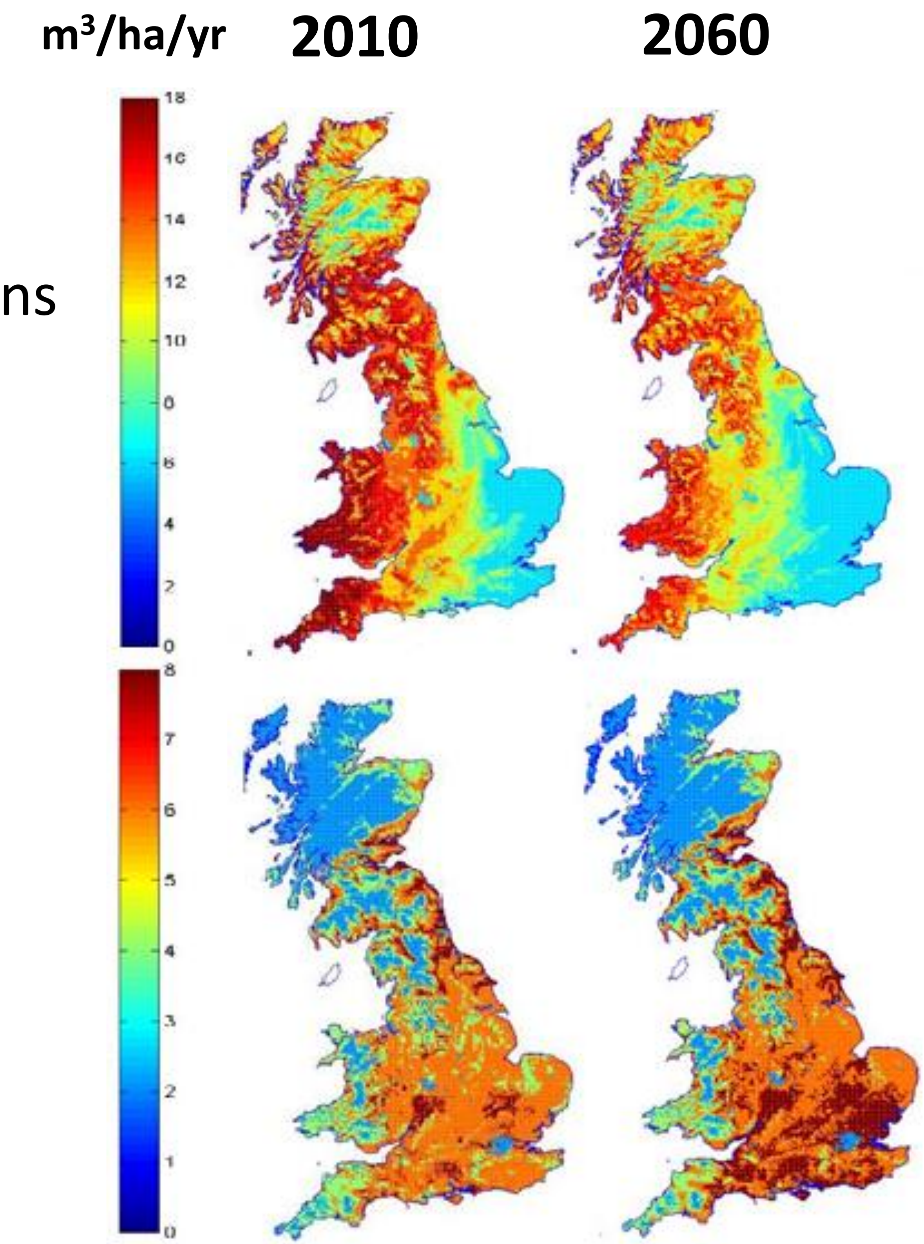
Climate change impacts: Beef 2063



Forestry Commission

Impact of climate change on tree growth

CSERGE

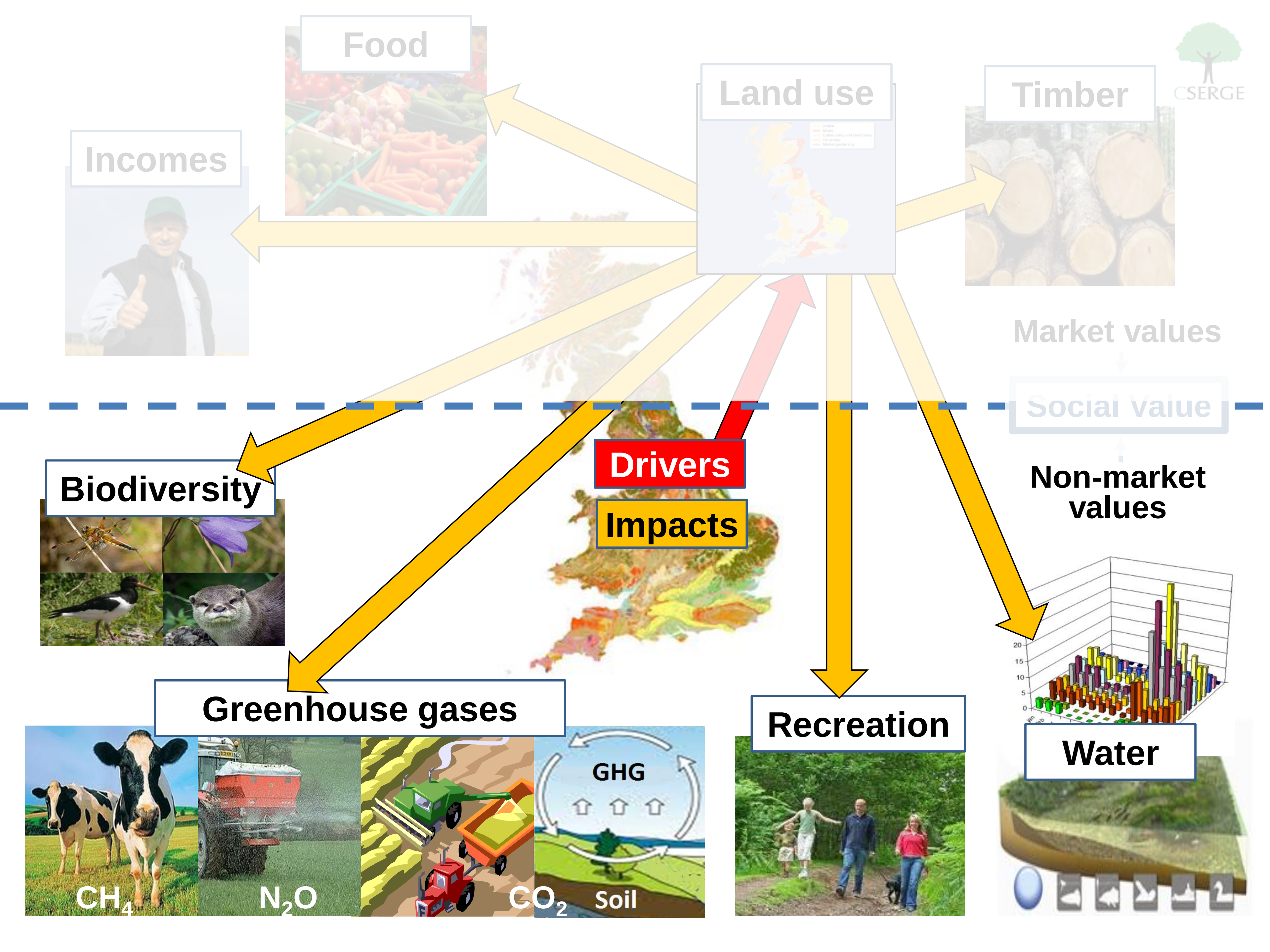


Sitka Spruce

Likes cool wet conditions – so growth falls as climate changes

Oak

Responds positively to warmer weather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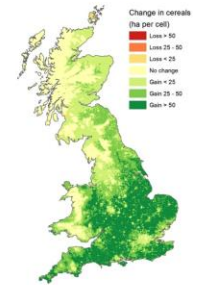
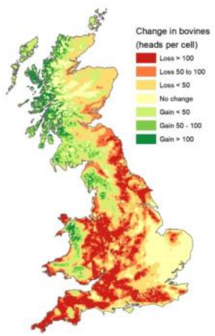
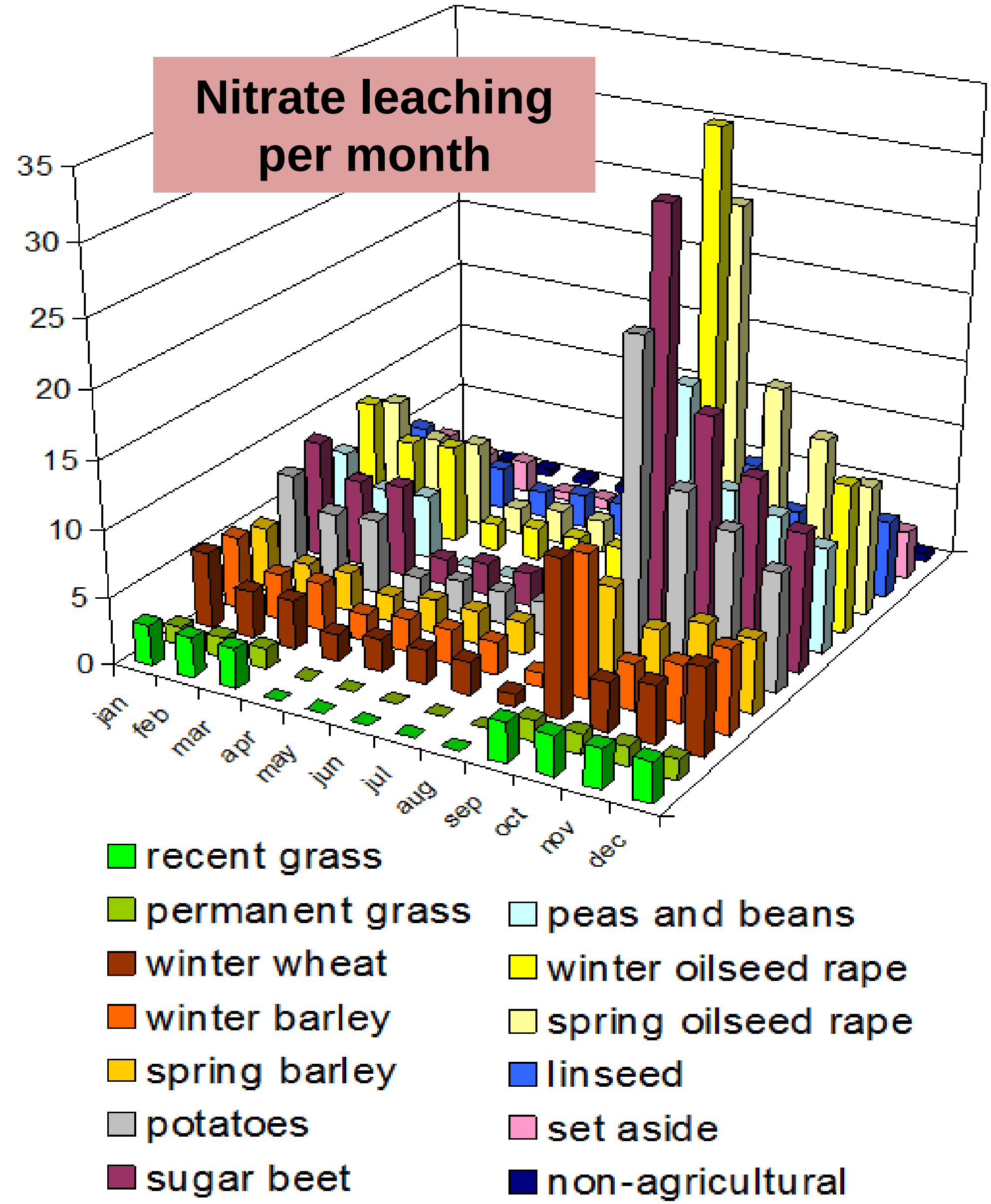
Soil

Land use change & water quality

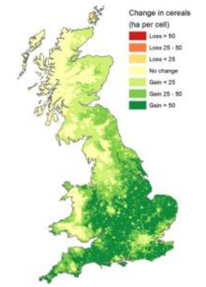


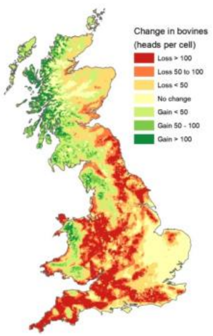


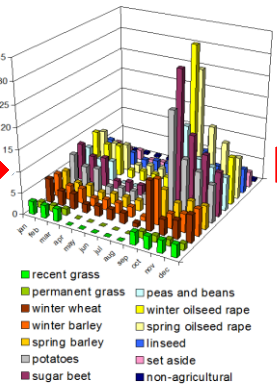


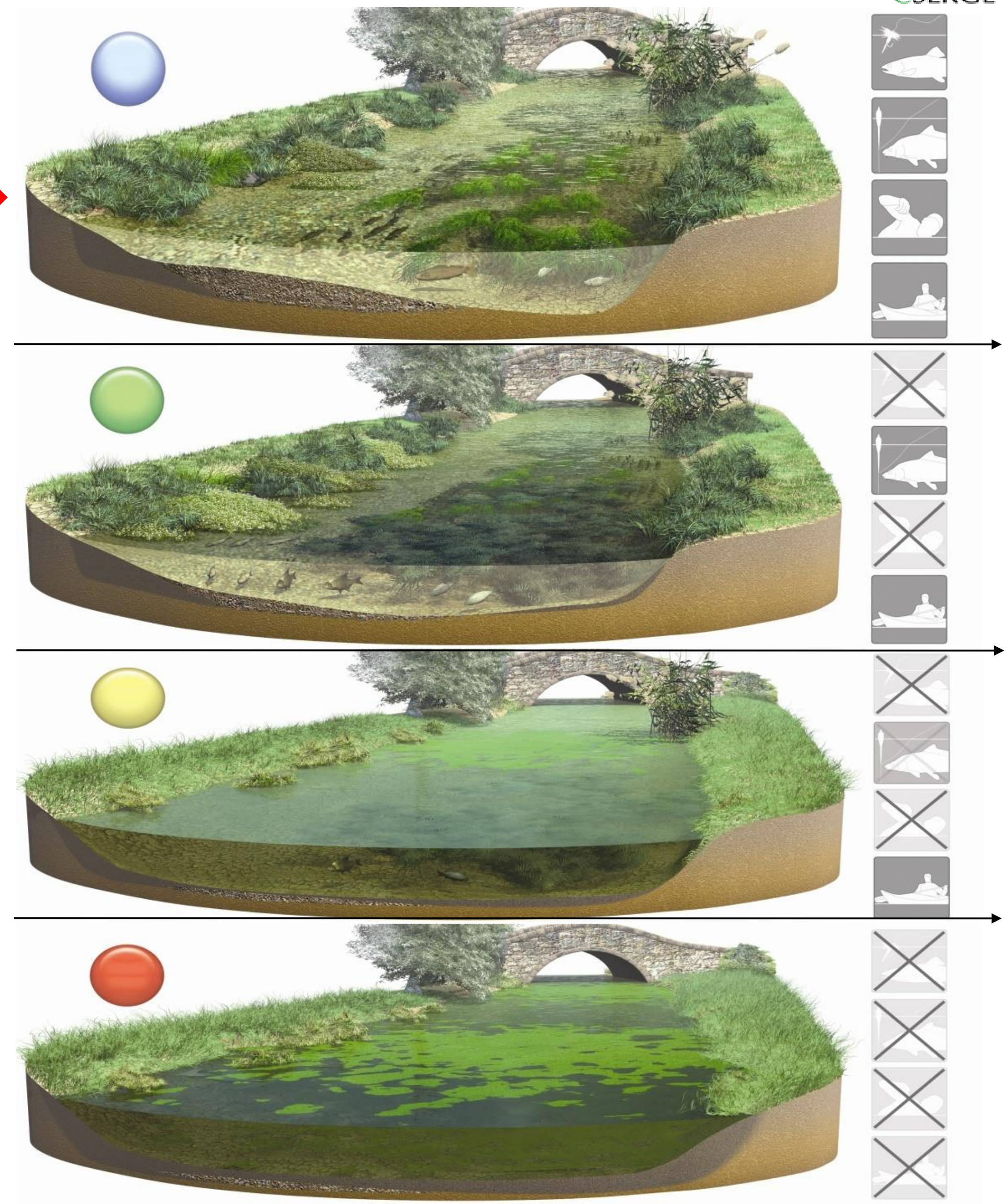
Linking land use with water quantity & quality

Land use change & water quality









Impacts of land use change on river water quality and ecosystems services

Linkage to the value of outdoor recreation

- Household survey data:
  - Home location
  - Location of visited sites
  - Visit frequency
  - Calculate visit travel time & costs
- Obtain data on water quality at sites
- Random utility model

$$u_{ij} = \alpha_j + \boldsymbol{x}_j \boldsymbol{\beta} + \gamma\left(I_{i,t} - tc_{ij}\right) + \varepsilon_{ij} \qquad (j = 0, 1, \ldots, J \text{ and } \forall i)$$

Utility of visit to site j by person i

observed

unobserved

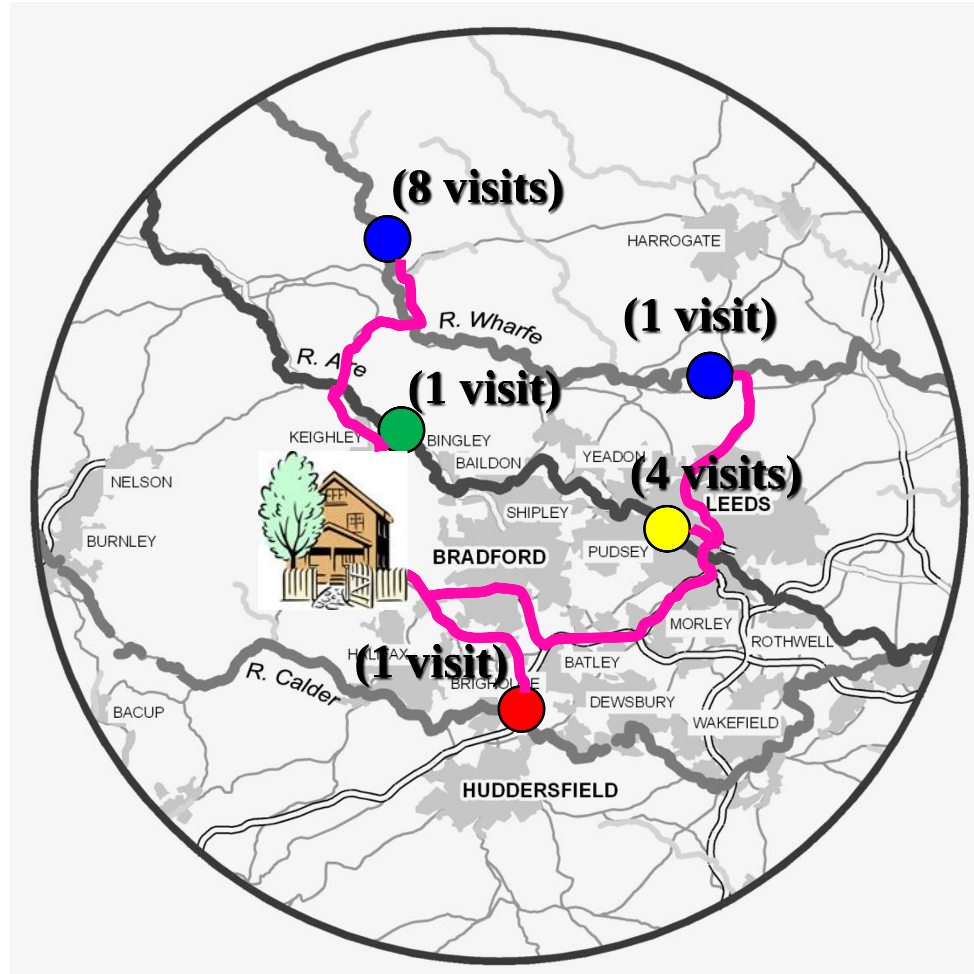
Attributes of site j

Income of person i

Travel cost to site j

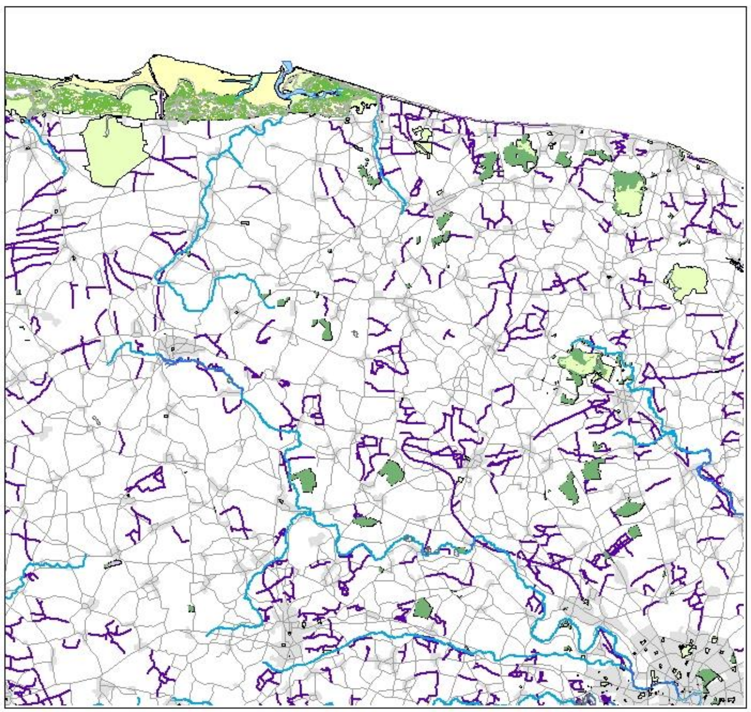
econometric error

- Observed site choices reveal trade-off between site quality and visit costs:
  - As costs increase so visits fall
  - As quality increases so visits rise
  - Reveals value for improved sites

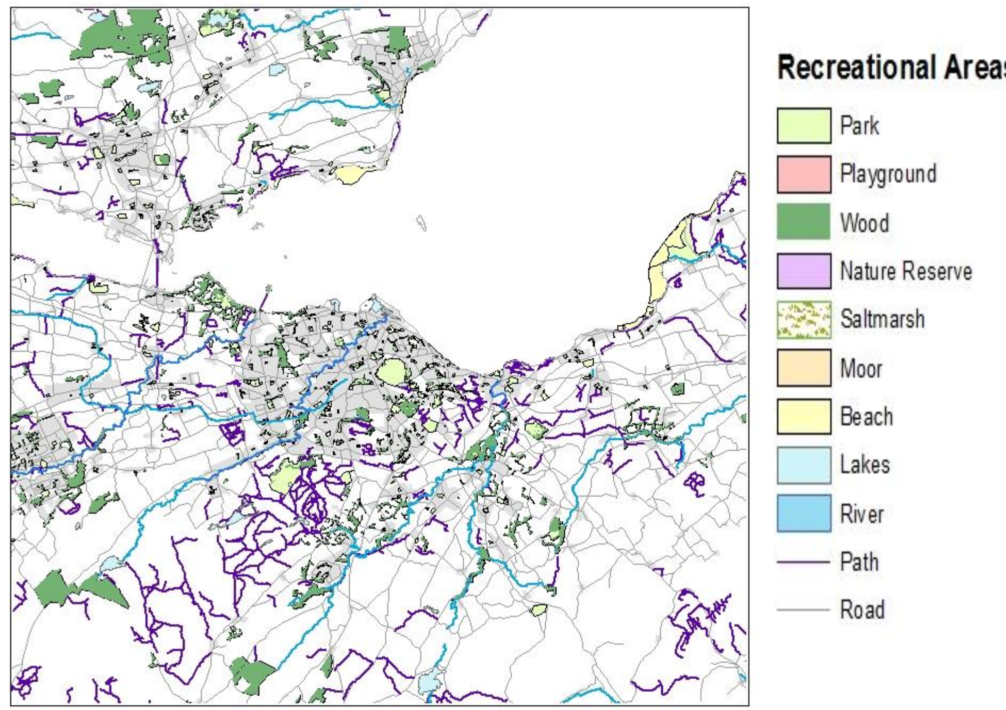


Extending the data set
Substitute availability

Compiling a comprehensive, GIS based dataset of recreational sites across Great Britain



Norfolk

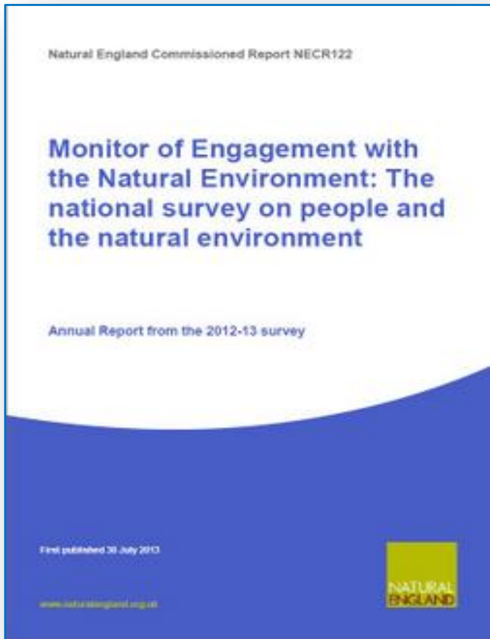


Edinburgh

Extending the data set

Larger sample, all types of outdoor recreation

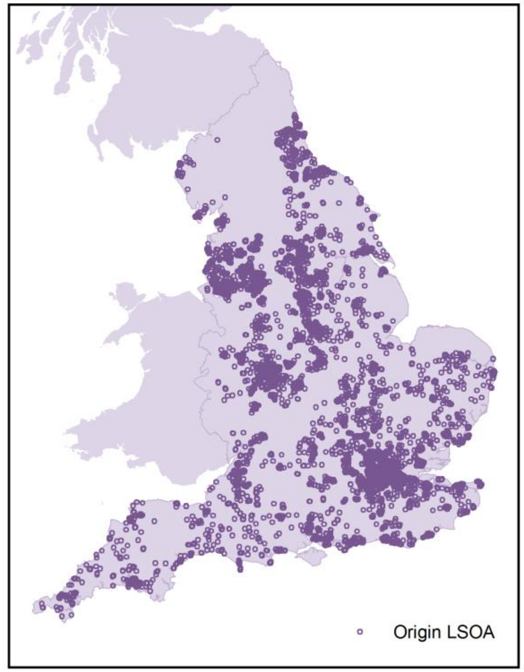
Monitor of Engagement with Natural Environment (MENE) survey

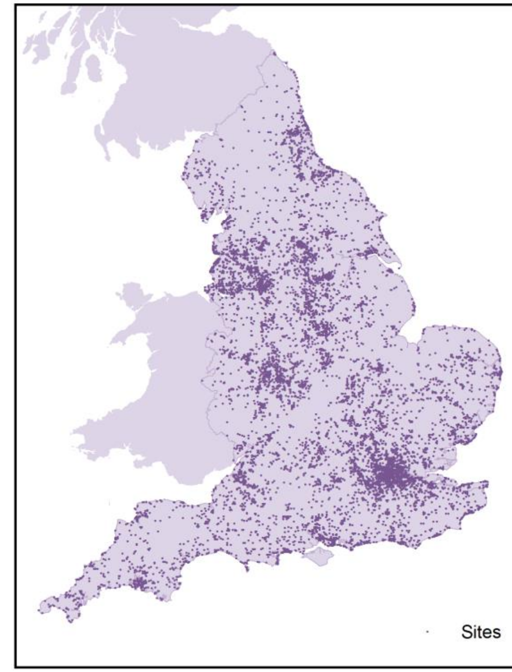

Natural England Commissioned Report NECR122

Monitor of Engagement with the Natural Environment: The national survey on people and the natural environment

Annual Report from the 2012-13 survey

NATURAL ENGLAND



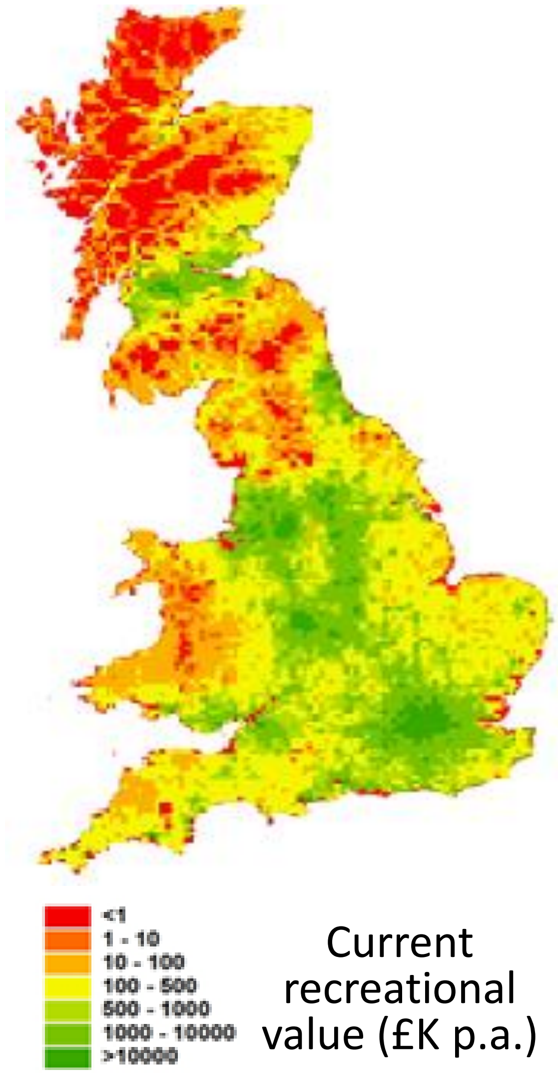


Final dataset contains 15 million respondent-site choice options

Outputs

- Recreation valuation model
- Recreation values for current and future land use

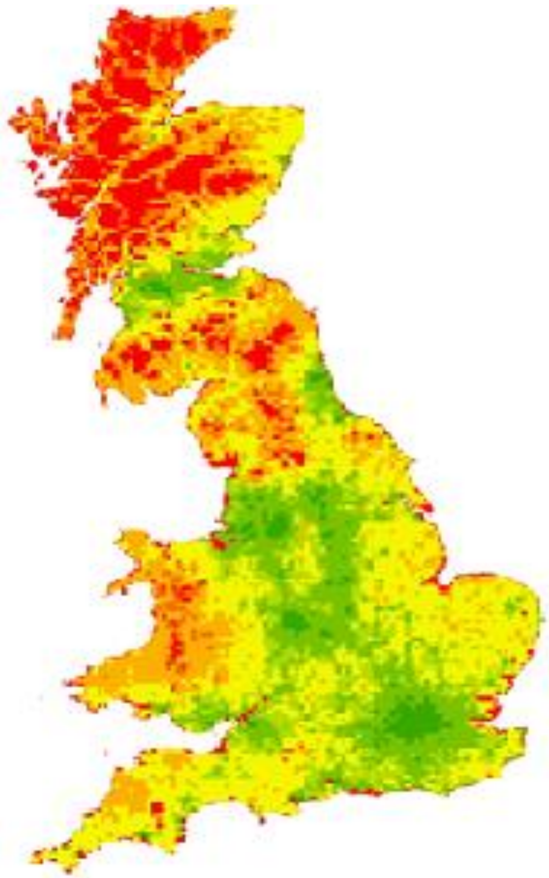
Recreation values: Status quo spatial distribution



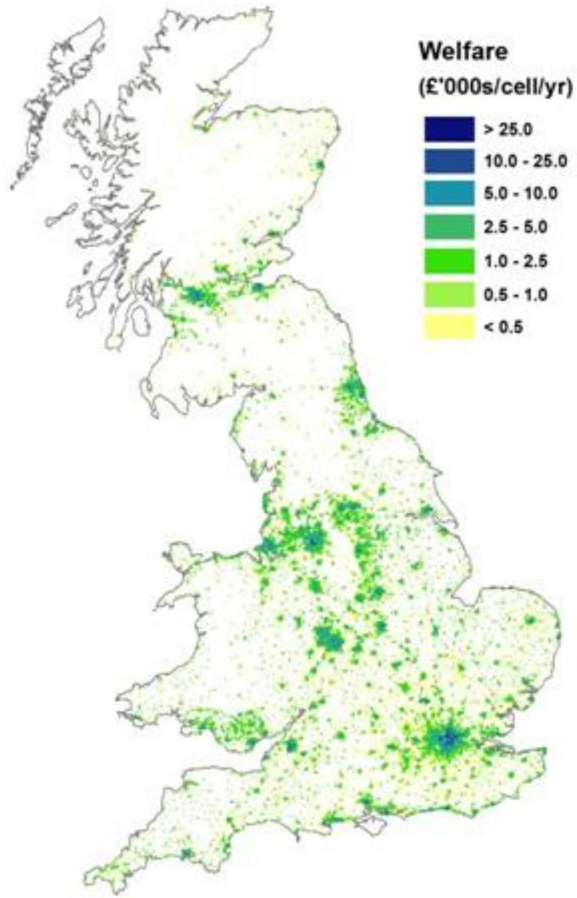
Current recreational value (£K p.a.)

Population centres

Welfare gains from creating new recreational sites at different distances from population (e.g. woodland sites)

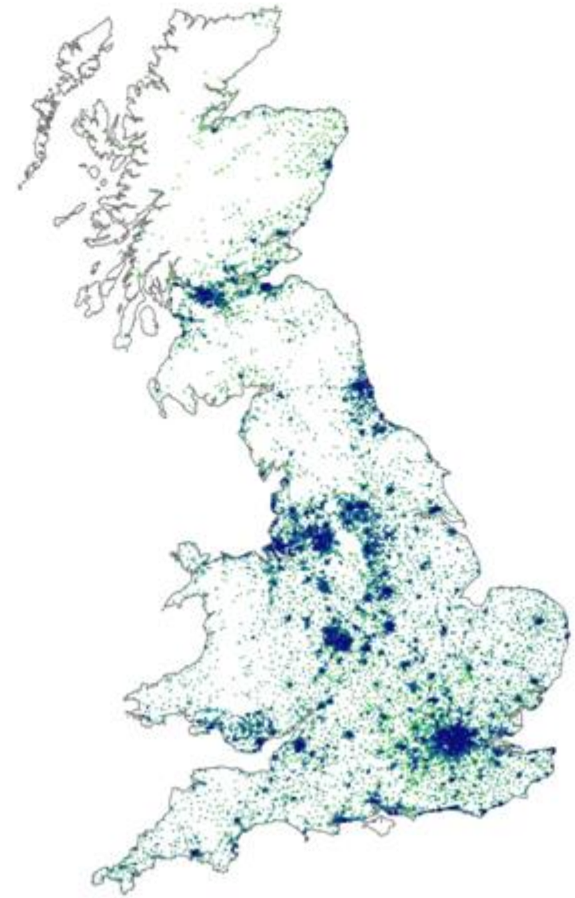


Current recreational value (£K p.a.)



Sites located 20 minutes away

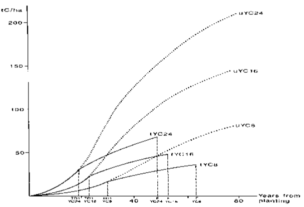
Population centres



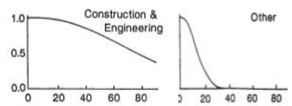
Sites located 10 minutes away

Land use change: GHG values (CO_2, N_2O, CH_4)

Carbon storage in crops & trees



Carbon release from harvest & felling

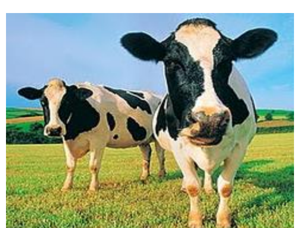


Soil carbon changes

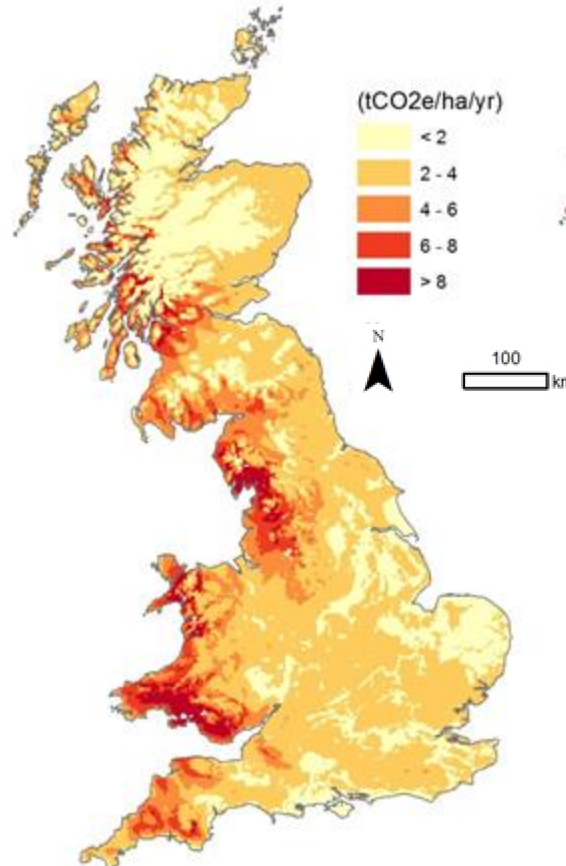
Soil type	Upland sites		
	Under grass	Under trees	Change
Peat	1200	450	(750)
Humic gley	180-400	250-450	50-70
Podzol	200-400	250-450	50
Brown earths	n/a	n/a	n/a
Humic stagno podzol	180-400	250-450	50-70
Stagnogley	170-400	170-450	0-50

Machinery & fertiliser emissions

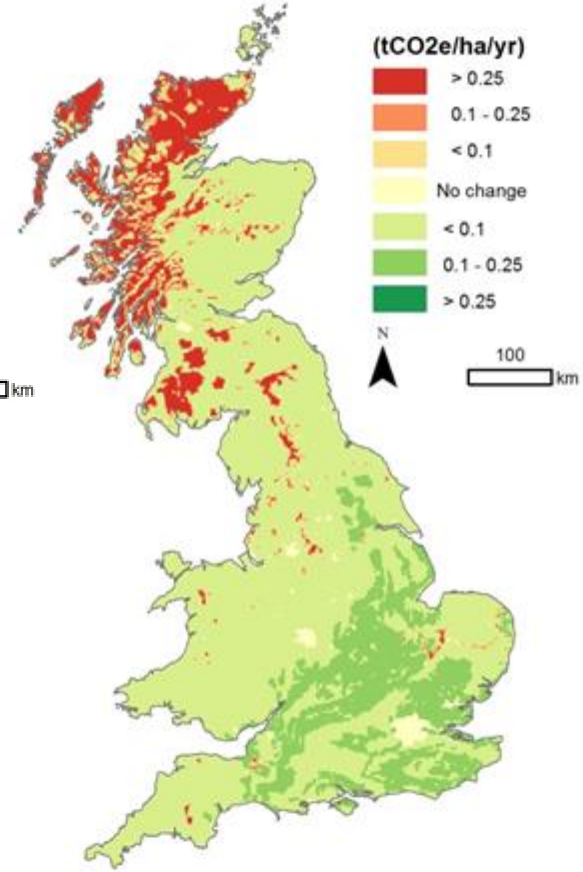
Livestock emissions



Average annual GHG emissions 2014-63



Agriculture



Forestry

Land use impacts on Biodiversity

Data:
- Grid referenced
- GB coverage
- Time series

BBS

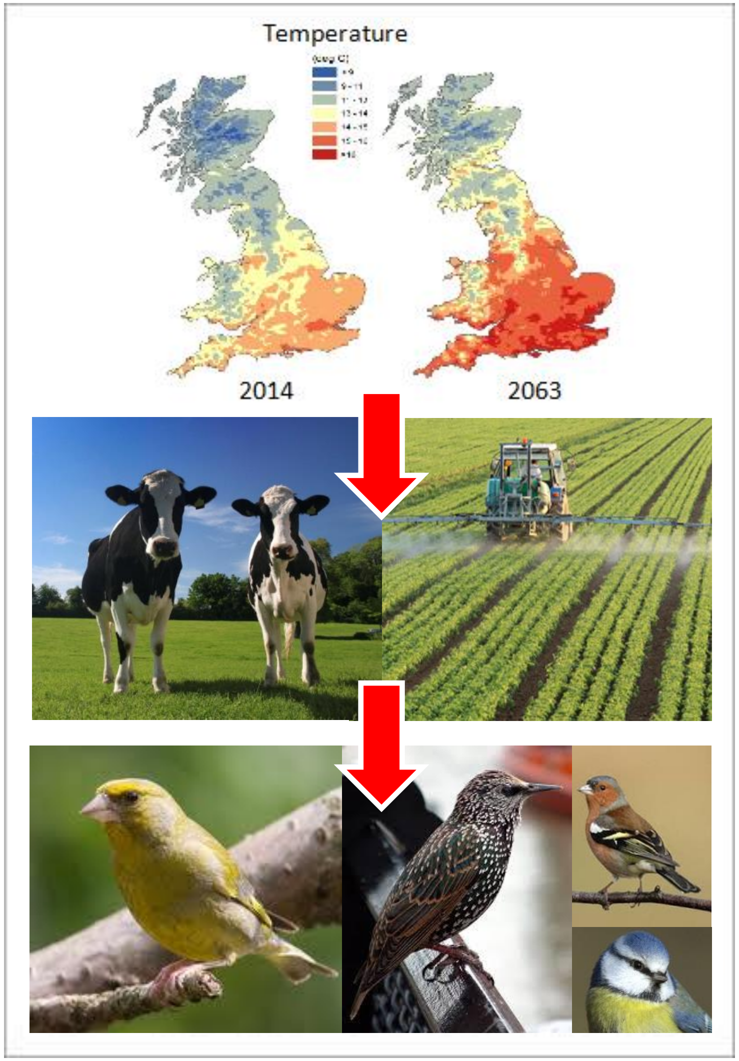
Breeding Birds Survey:
Bird diversity indices

Land use impacts on Biodiversity

Data:
- Grid referenced
- GB coverage
- Time series

Modelled linkages:

Climate change
↓
Land use
↓
Biodiversity



Land use impacts on Biodiversity

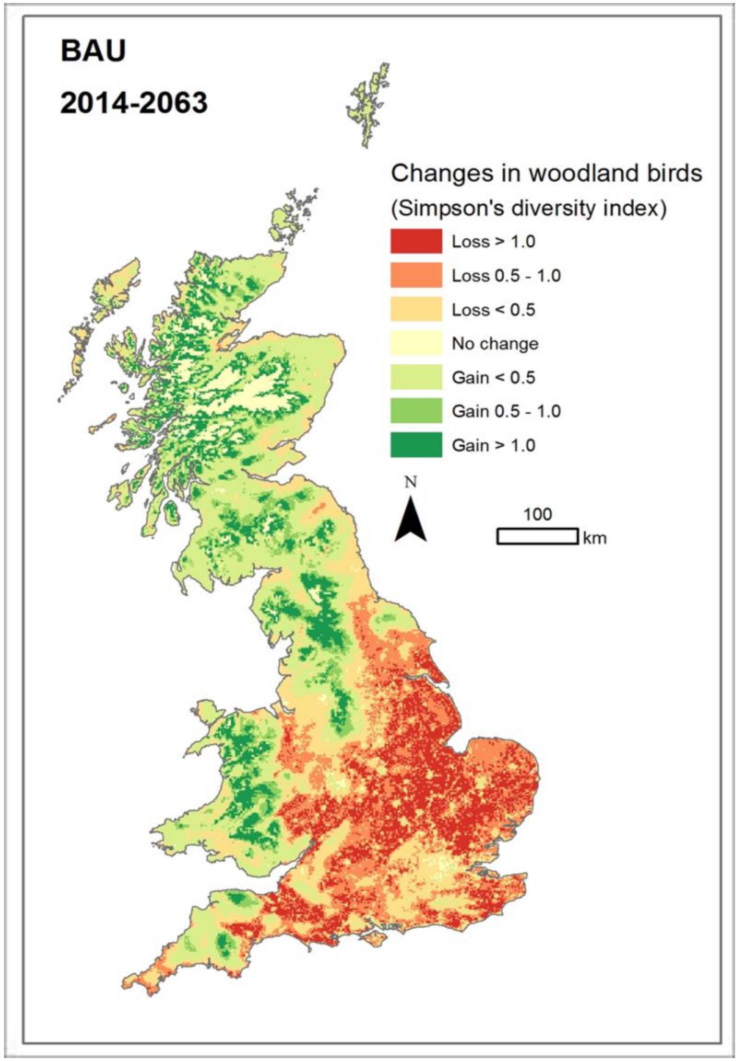
Lack of robust values means that biodiversity impacts were not monetised but rather are used as a constraint (see later)

Data:
- Grid referenced
- GB coverage
- Time series

Modelled linkages:

Impact of climate change induced changes in land use 2014-63:
- Some increases in upland biodiversity
- Offset by losses in lowland areas due to greater extent and intensity of arable production.

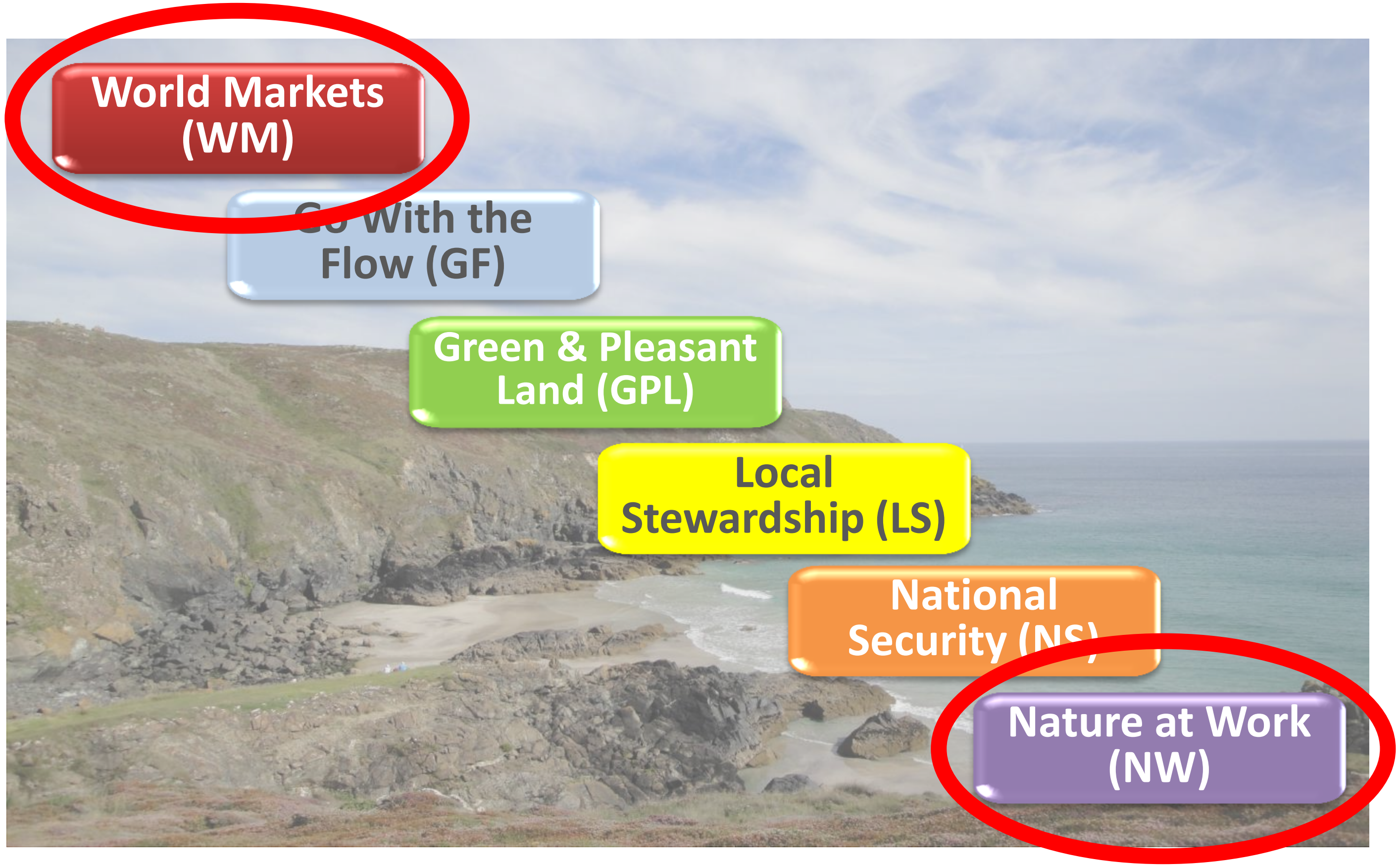
Measure of biodiversity change	Mean*	S.E. Mean
All Birds	-0.248	0.006
Woodland Birds	-0.034	0.004
Farm Birds	-0.032	0.004
Red/Amber Birds	-0.092	0.002



Climate change and policy change

Policy scenarios

**Further intensification,
baseline environmental conservation**



**Increased environmental conservation
with no increase in intensification**

Why valuing ecosystem services matters

CSERGE

Best option

World Markets Scenario
Increased intensification of natural resource use to maximise market values

Market value <u>gain</u>
+ £420 million per annum relative to the current baseline

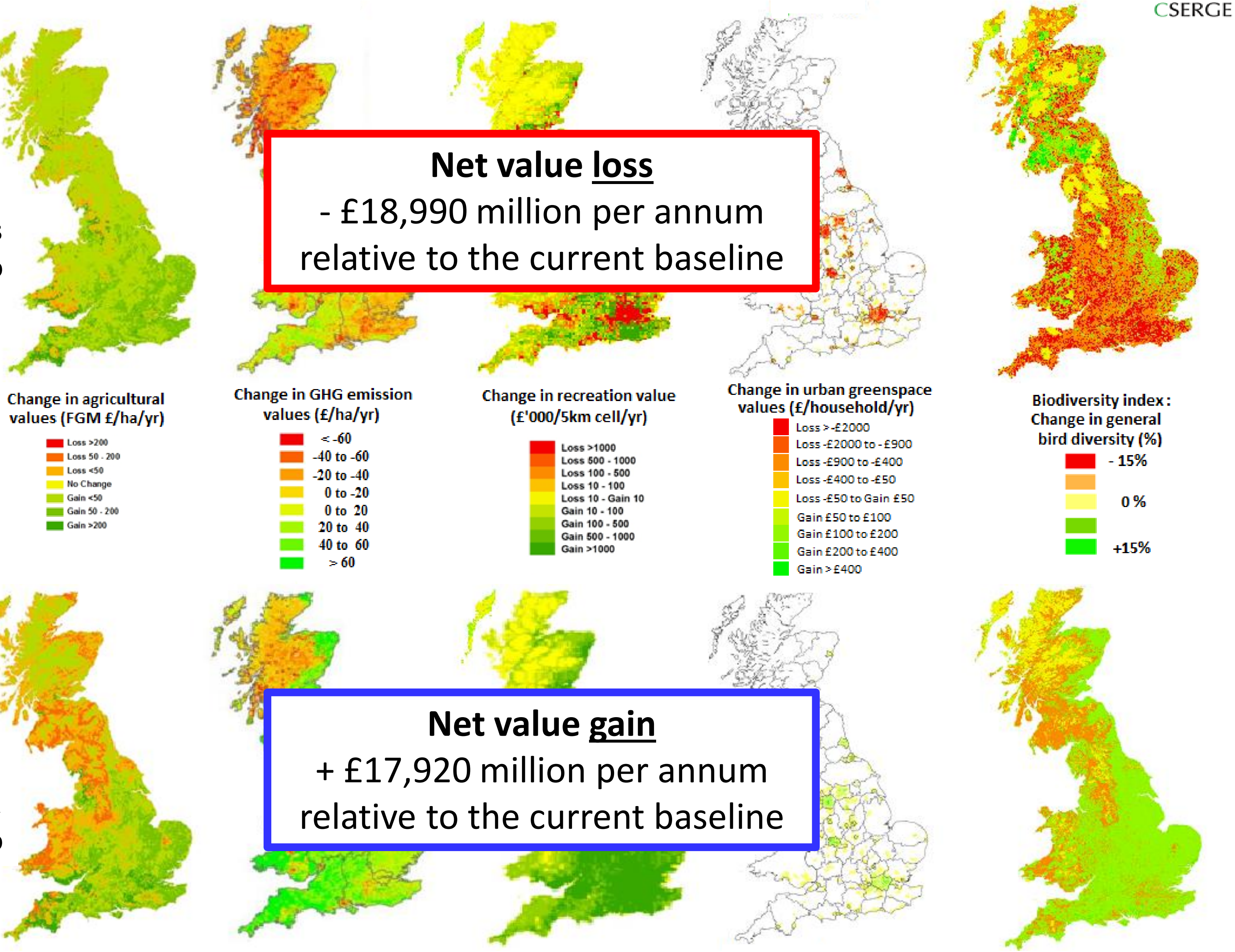
Nature at Work Scenario
Sustainable use of natural resources to maximise net ecosystem service values

Market value <u>loss</u>
- £510 million per annum relative to the current baseline

Why valuing ecosystem services matters

World Markets Scenario

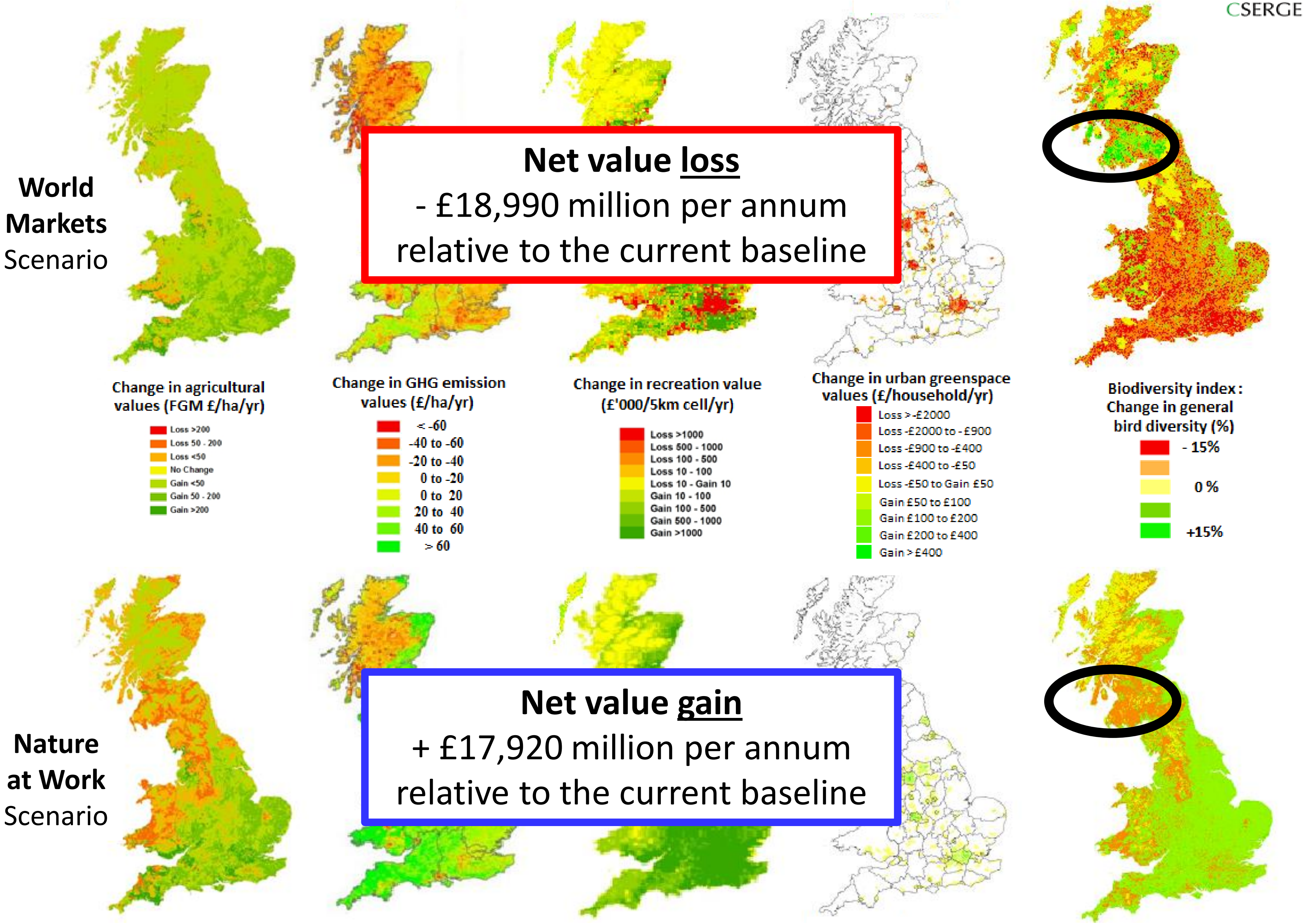
Net value loss
- £18,990 million per annum relative to the current baseline



Nature at Work Scenario

Net value gain
+ £17,920 million per annum relative to the current baseline

Not optimal

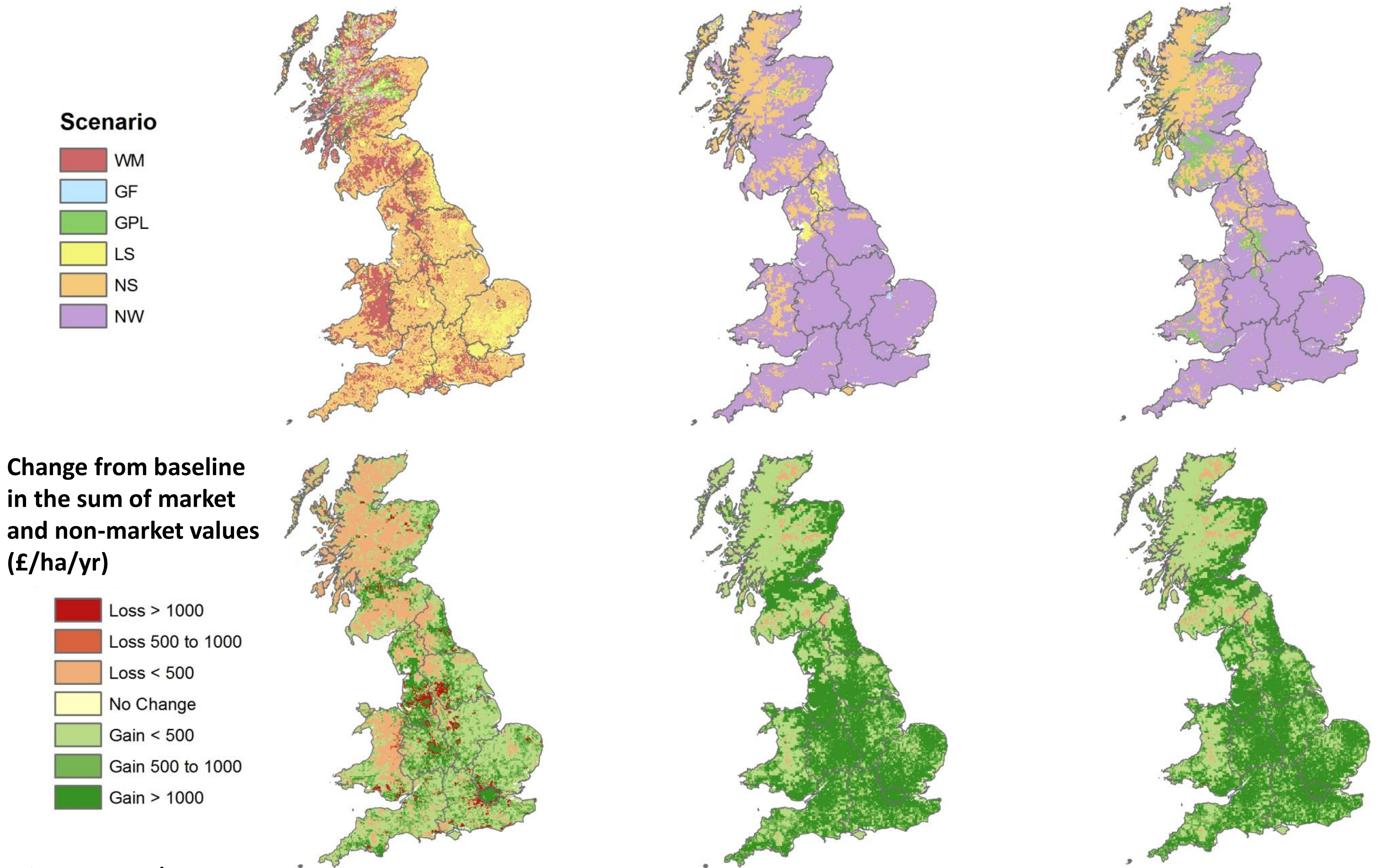


World Markets Scenario
Net value loss
- £18,990 million per annum relative to the current baseline
Change in agricultural values (FGM £/ha/yr)
Loss >200
Loss 50 - 200
Loss <50
No Change
Gain <50
Gain 50 - 200
Gain >200
Change in GHG emission values (£/ha/yr)
< -60
-40 to -60
-20 to -40
0 to -20
0 to 20
20 to 40
40 to 60
> 60
Change in recreation value (£'000/5km cell/yr)
Loss >1000
Loss 500 - 1000
Loss 100 - 500
Loss 10 - 100
Loss 10 - Gain 10
Gain 10 - 100
Gain 100 - 500
Gain 500 - 1000
Gain >1000
Change in urban greenspace values (£/household/yr)
Loss > -£2000
Loss -£2000 to -£900
Loss -£900 to -£400
Loss -£400 to -£50
Loss -£50 to Gain £50
Gain £50 to £100
Gain £100 to £200
Gain £200 to £400
Gain > £400
Biodiversity index : Change in general bird diversity (%)
- 15%
0 %
+15%
Nature at Work Scenario
Net value gain
+ £17,920 million per annum relative to the current baseline

Policy targeting

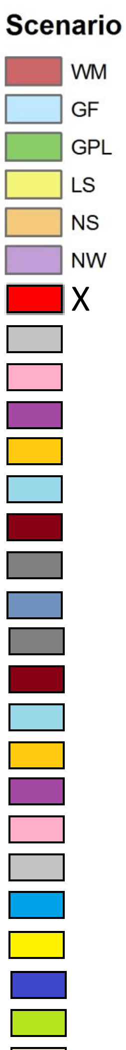
Policy targeting

Maximise market (farm) values	Maximise market & non-market values	Maximise market & non-market values with biodiversity constraints



Cumulative UK values (market & non-market)	£892m	£19,606m	£18,092m

Ongoing work: Optimal land use



Scenarios are typically determined by policy makers:

- No guarantee that the chosen scenarios include the best use of land
- Ideally we want to optimise across all feasible land use options

Requires economic models which incorporate:

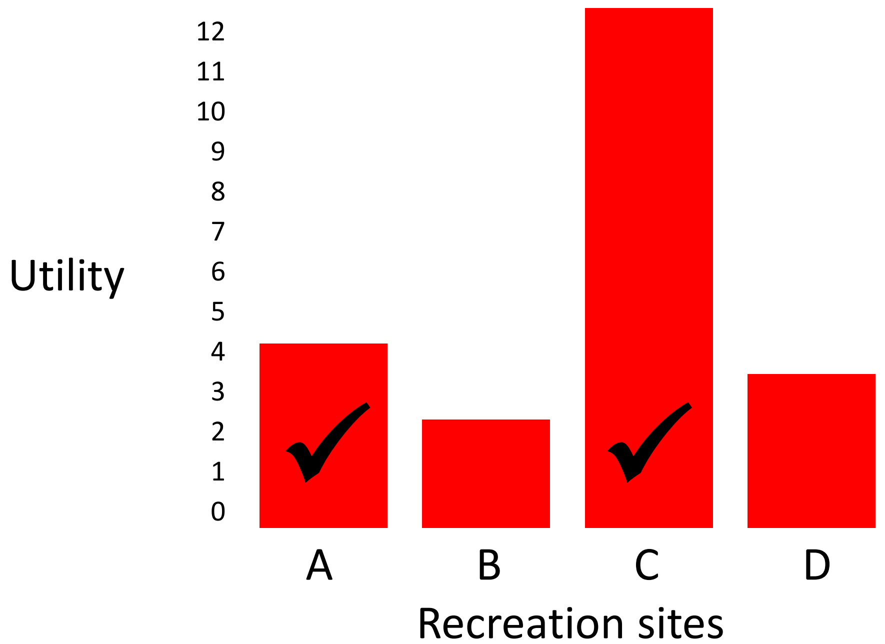
- Economic and natural science data.
- Allows for spatial dependencies (e.g. substitution effects in recreation)
- Allows dynamic optimisation (e.g. selects the set of land use changes which maximise values over multiple years rather than just opting for the one which yields the highest immediate independent value).

- Case study under review (see authors for details)

Stylised optimisation problem

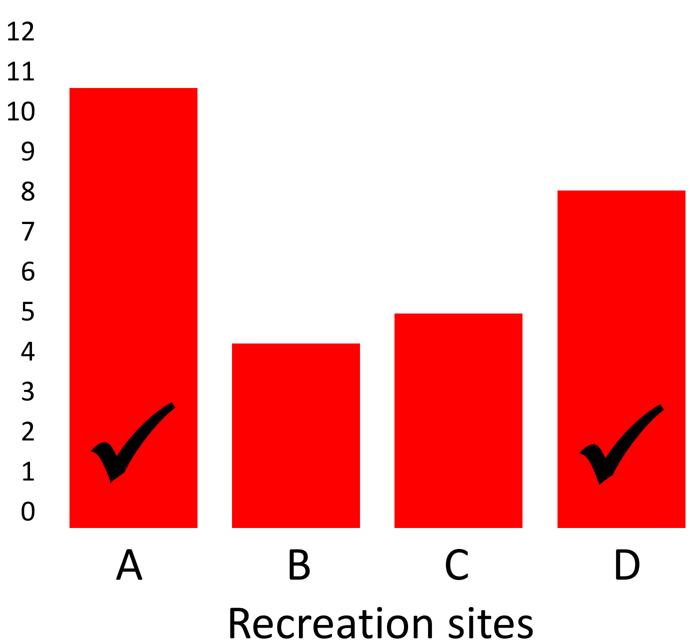
Suppose we want to create two new recreational sites

First-best optimisation



$\Sigma = 16$

Combinatorial optimisation



$\Sigma = 18$

Actual optimisation problem: Identifying the optimal 750,000ha out of the 20,933,100ha that make up Great Britain ensuring (for policy purposes) an equal division across the three countries of England, Scotland and Wales, planted evenly over a 50 year time horizon.
To solve this we used the IBM ILOG CPLEX solver

Future Research

- Uncertainty analysis (e.g. Monte-Carlo)
- Integrated analysis of threshold effects (e.g. biodiversity), resilience & shocks (e.g. extreme weather)
- Sustainable intensification and food security
- Offsetting (for biodiversity or wider natural capital): efficiency versus ‘equity’
- Development of decision tools

Bringing ecosystem services into economic analyses of land use

Presentation to:

Fondazione Eni Enrico Mattei (FEEM)

Isola di San Giorgio Maggiore, Venice, Italy

Thursday, 8th May 2014

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UK National Ecosystem Assessment

VALUING NATURE NETWORK

Bridging disciplines and building relevance