Identifying potential tipping points in the benefits derived from the UK's land ecosystems

Ian Bateman, Amy Binner, Brett Day,
Angela Gallego-Sala, Tim Lenton (and team)
University of Exeter

UNIVERSITY OF EXETER

What are ecosystem 'tipping points'?

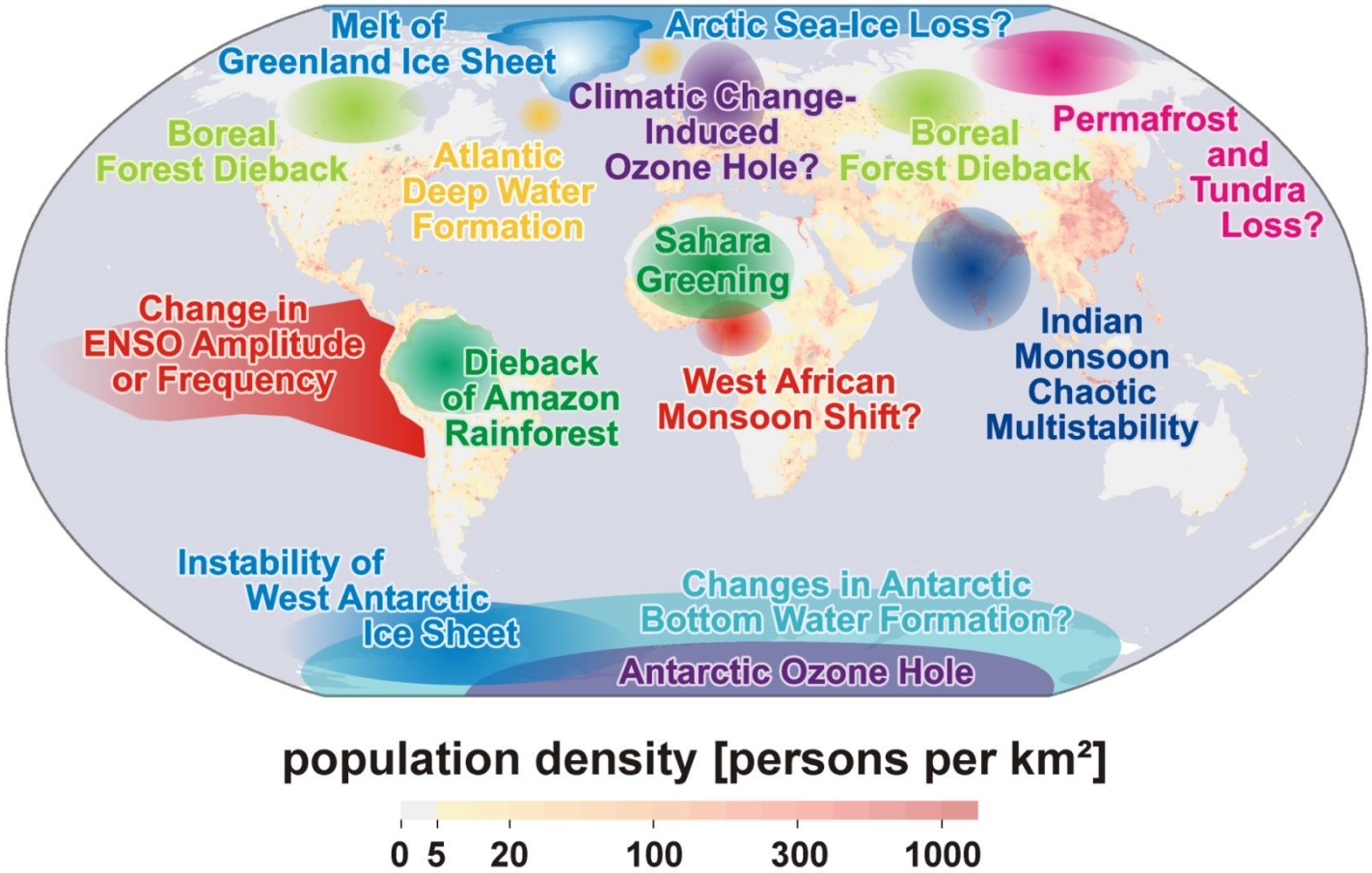
"large, persistent changes in the structure and function of social-ecological systems, with substantive impacts on the suite of ecosystem services provided by these systems" (*http://www.regimeshifts.org*).

Ecosystem tipping points can occur:

i. due to an abrupt change in drivers
ii. due to passing an *ecosystem threshold* of viability for its current state
iii. due to the triggering of self-propelled non-linear dynamics (strong positive feedback) within an ecosystem

UNIVERSITY OF EXETER

Tipping points in the climate system

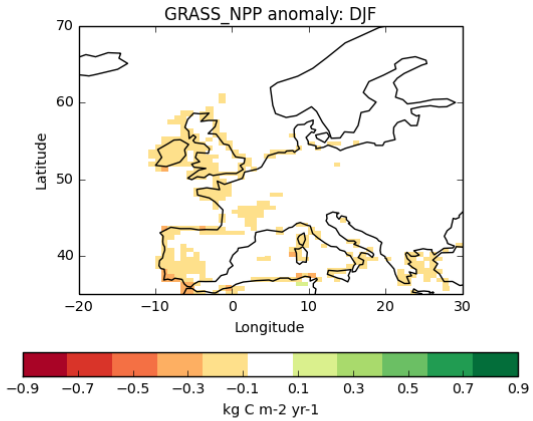


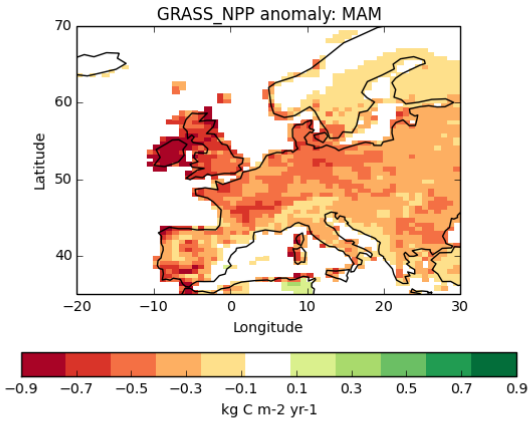
Lenton et al. (2008) *PNAS* 105(6): 1786-1793

Example of abrupt change in drivers:

Collapse of the Atlantic Meridional Overturning Circulation

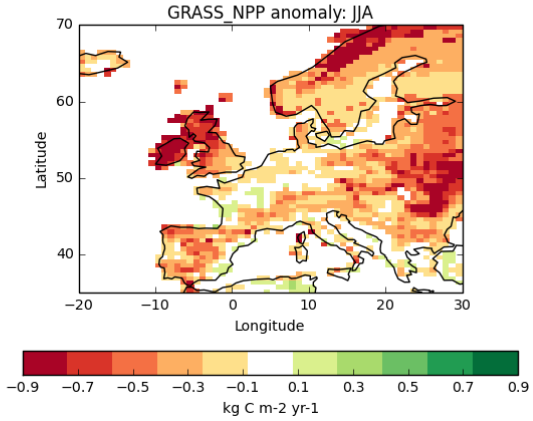
WINTER

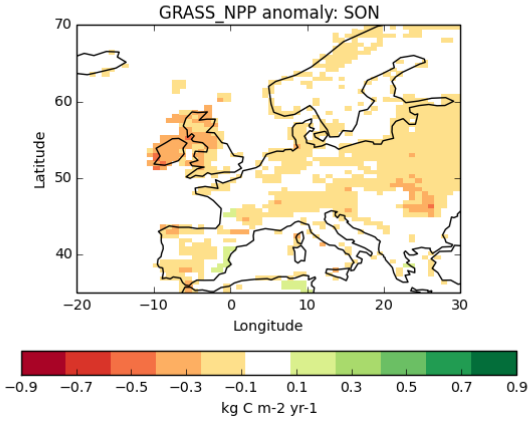




SPRING

SUMMER





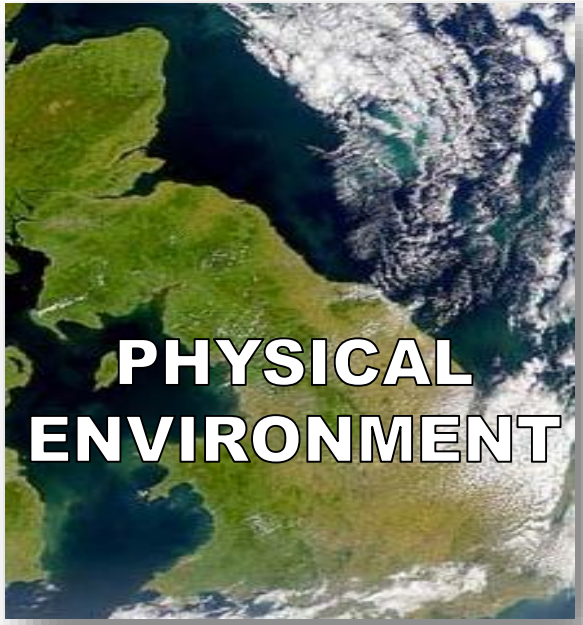
AUTUMN

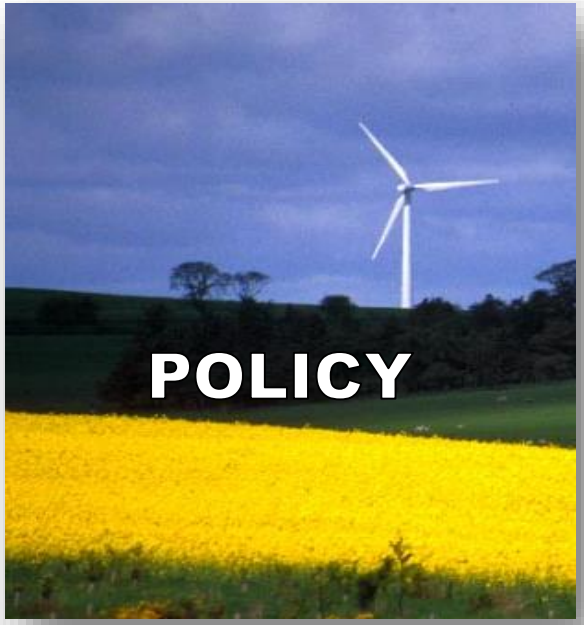
Seasonal anomaly in Net Primary Production of grass

UNIVERSITY OF EXETER

Analysis by Mark Williamson based on simulations by Jackson et al. (2015) Climate Dynamics

Modelling climate change impacts on ecosystem services:
Agricultural land use





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

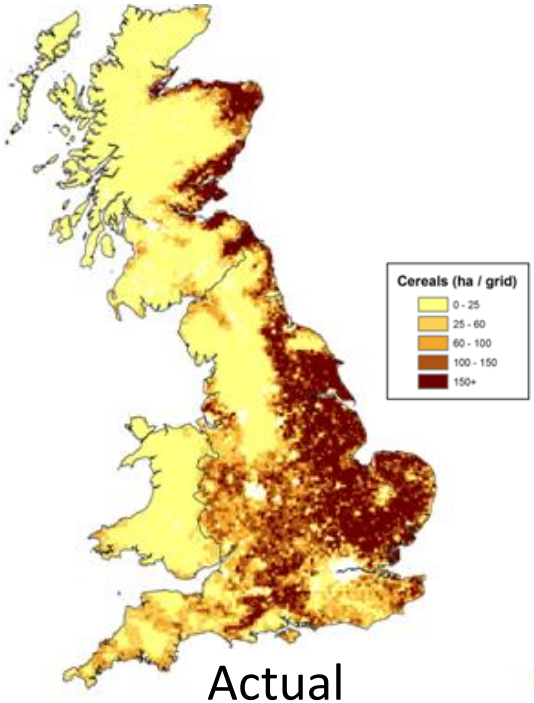
Spatially referenced data for all of GB

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

Model validation

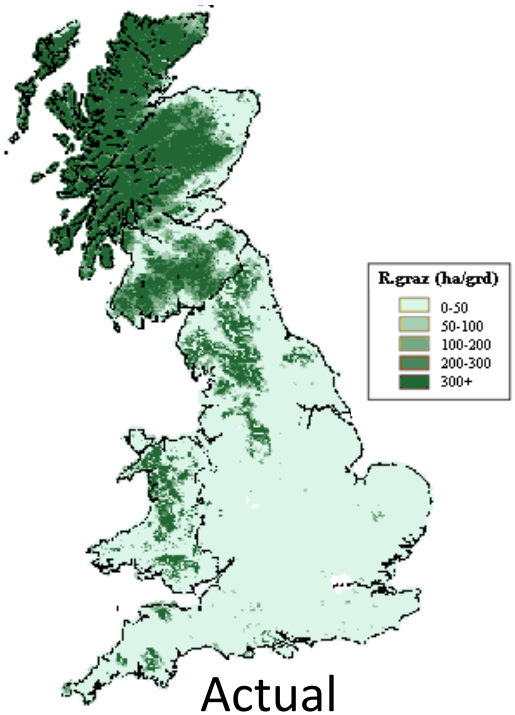
Out-of-sample, actual versus predicted tests

Cereals



Actual

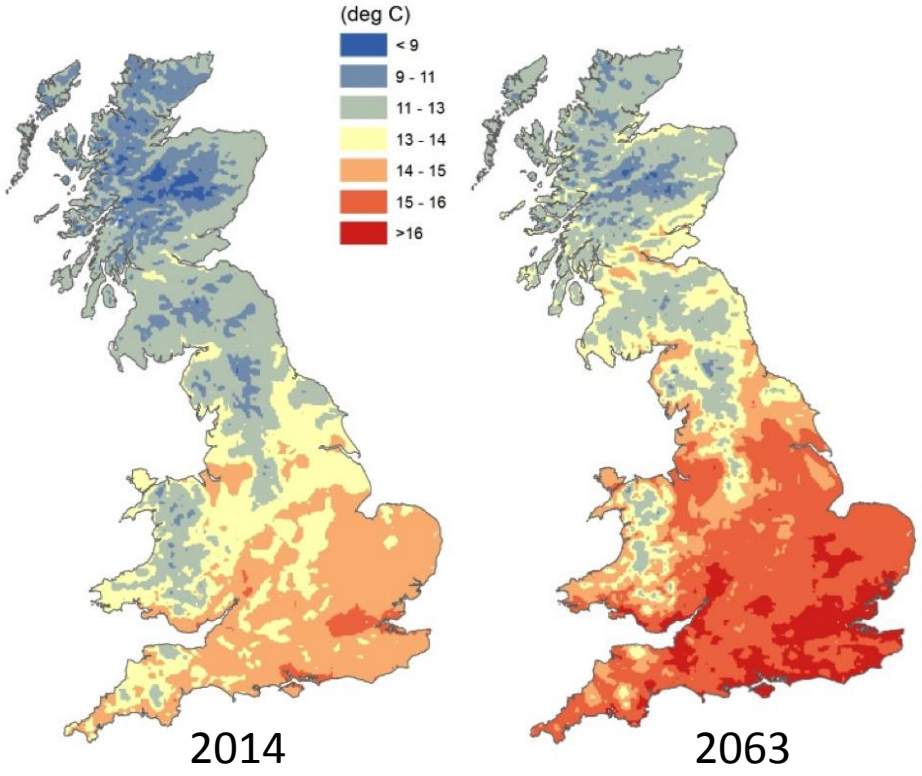
Grasslands



Actual

Model validation
Drivers of land use: Climate change
Out-of-sample, actual versus predicted tests

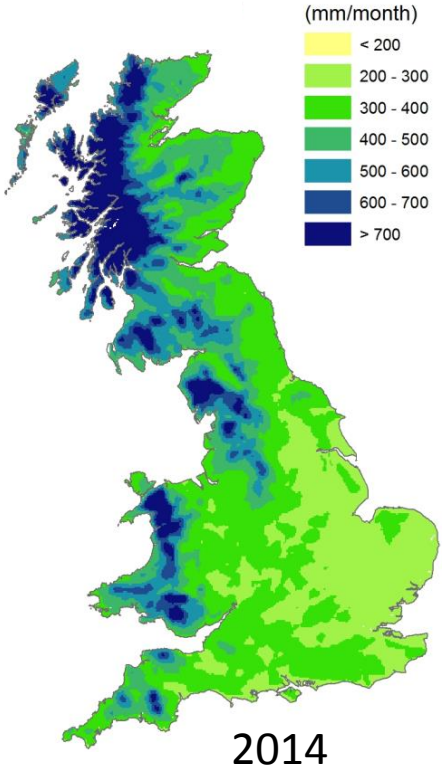
Temperature



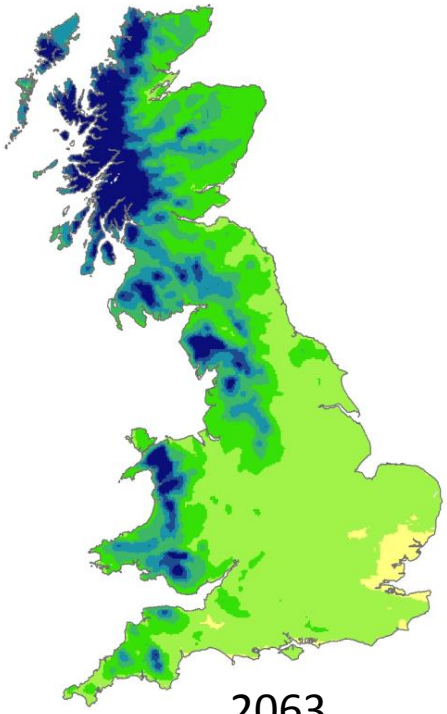
2014

2063

Rainfall



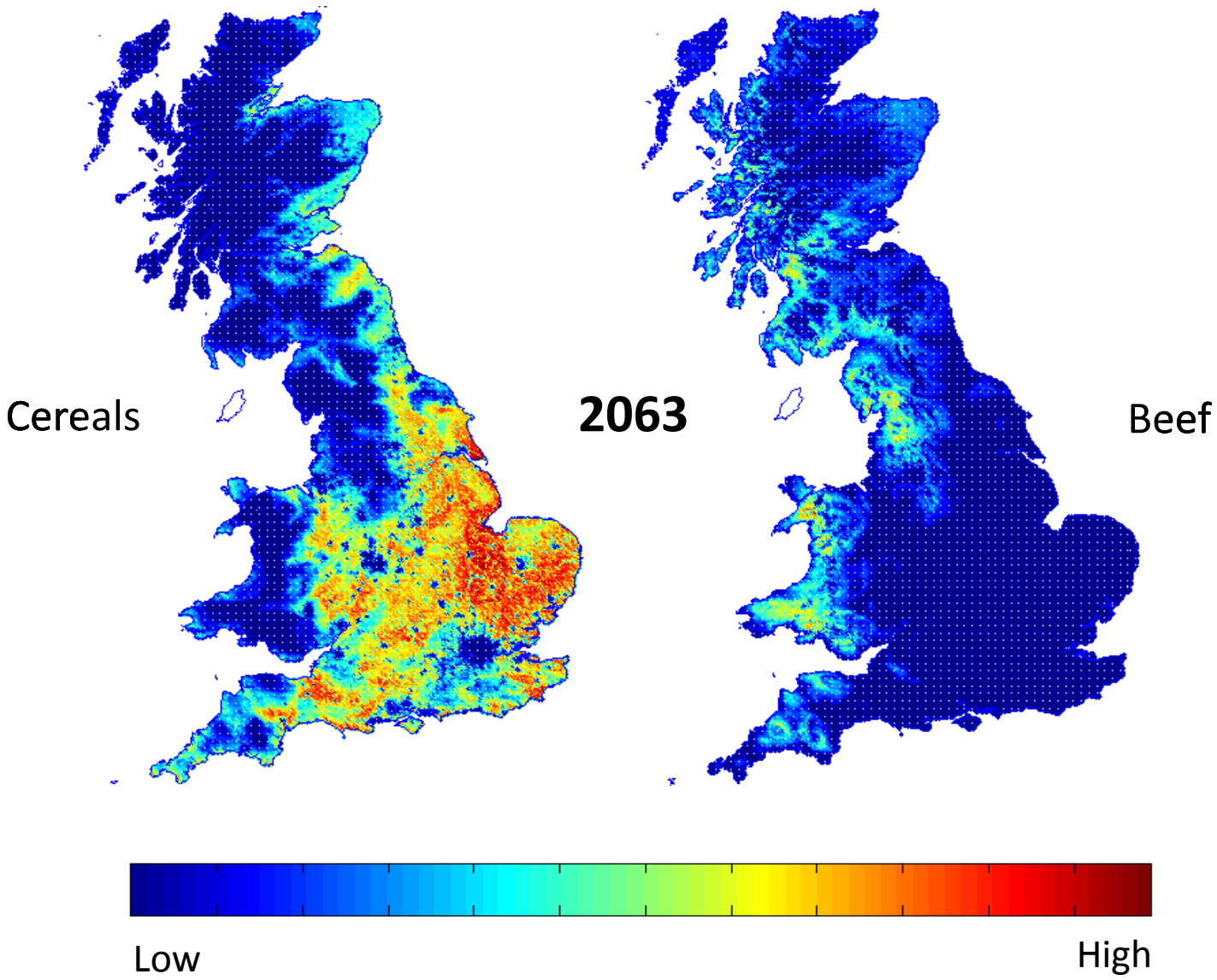
2014



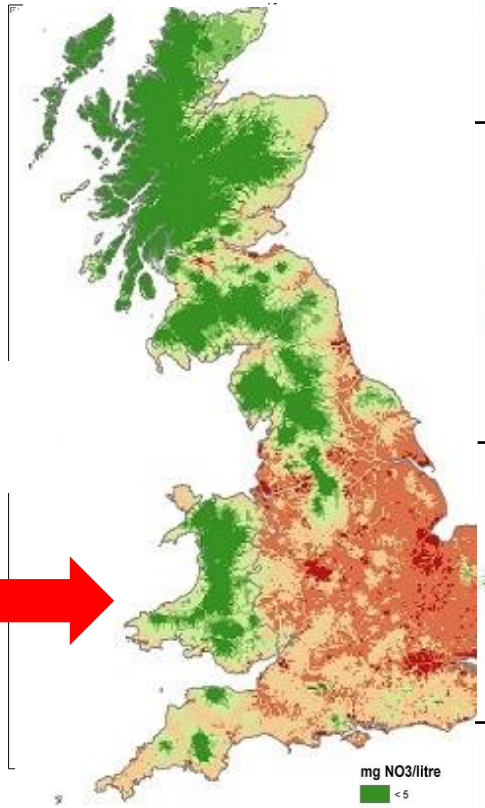
2063

Impacts of climate change on land use 2014-2063:

Assuming no climate tipping points



Land use change impacts on water quality



Nitrates

Low

Market values

e.g. water treatment costs

Non-market values

e.g. recreation values

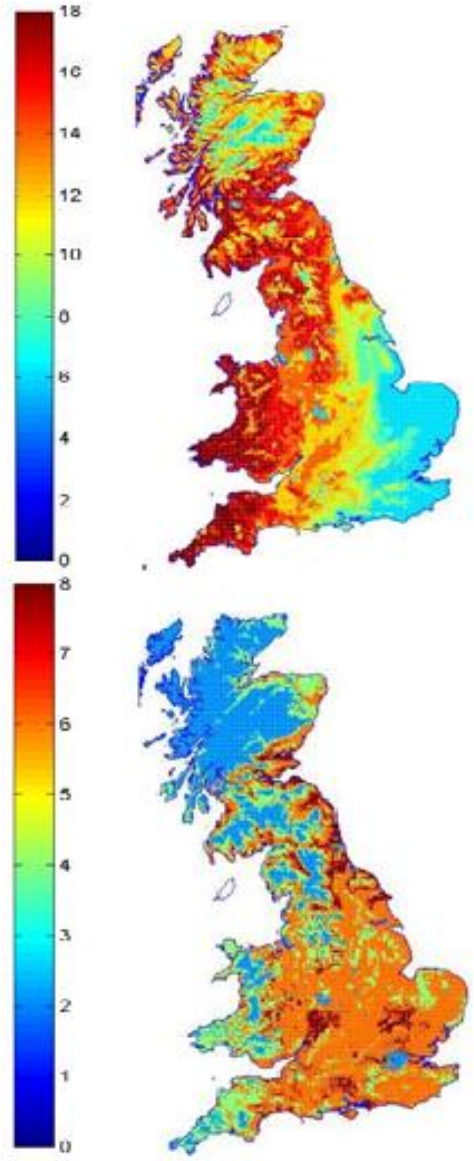
Linking land use to water quality, ecological quality and economic values

Impact of climate change on tree growth and timber value

Sitka Spruce: Likes cool wet conditions – so growth falls as climate changes

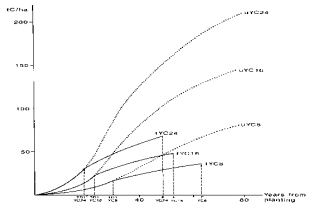
Oak: Responds positively to warmer weather

$m^3/ha/yr$ **2010**

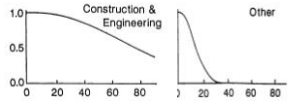


Land use change impacts on GHG emissions & storage

Carbon storage in crops & trees



Carbon release from harvest & felling



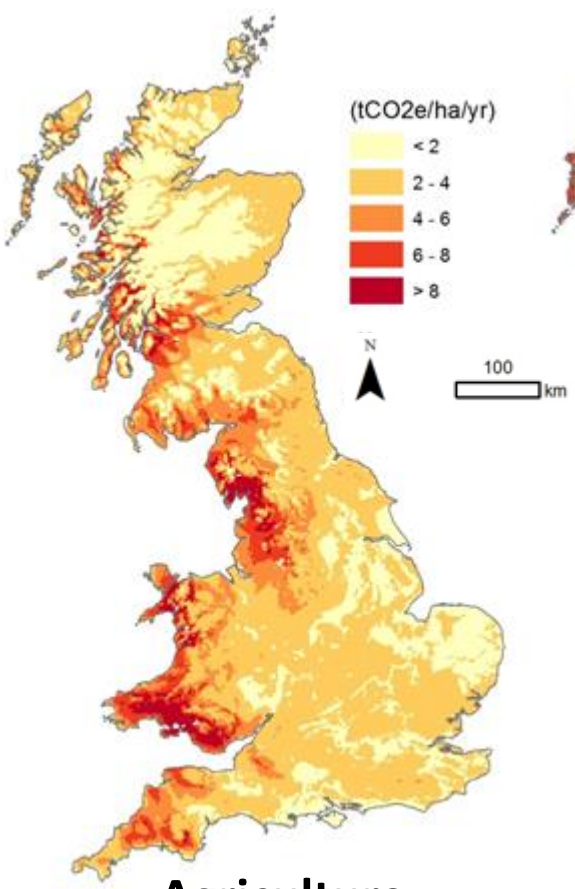
Soil carbon changes

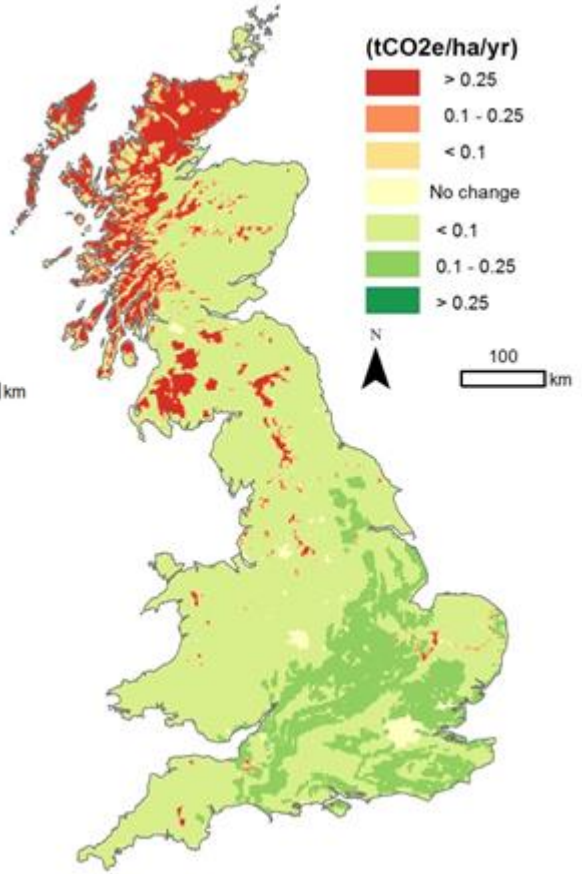
Soil type	Upland sites		
	Under grass	Under trees	Change
Peat	1200	450	(750)
Humic gley	180-400	250-450	50-70
Podzol	200-400	250-450	50
Brown earths	n/a	n/a	n/a
Humic stagno podzol	180-400	250-450	50-70
Stagnogley	170-400	170-450	0-50

Machinery & fertiliser emissions

Livestock emissions

Average annual GHG emissions 2014-63

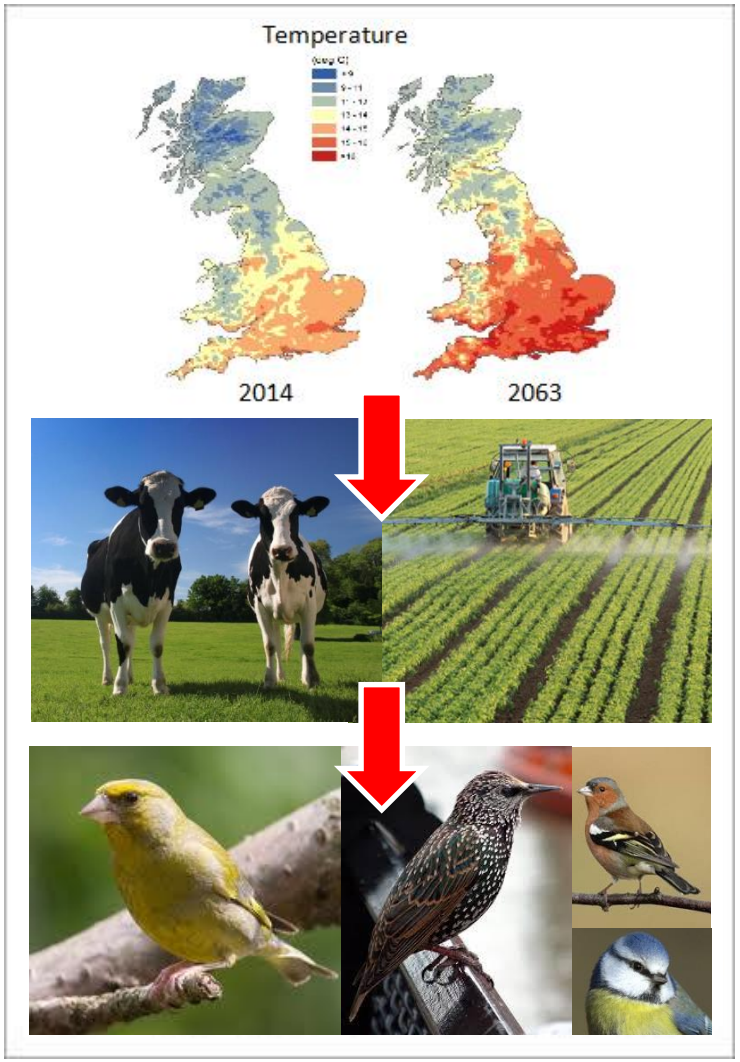


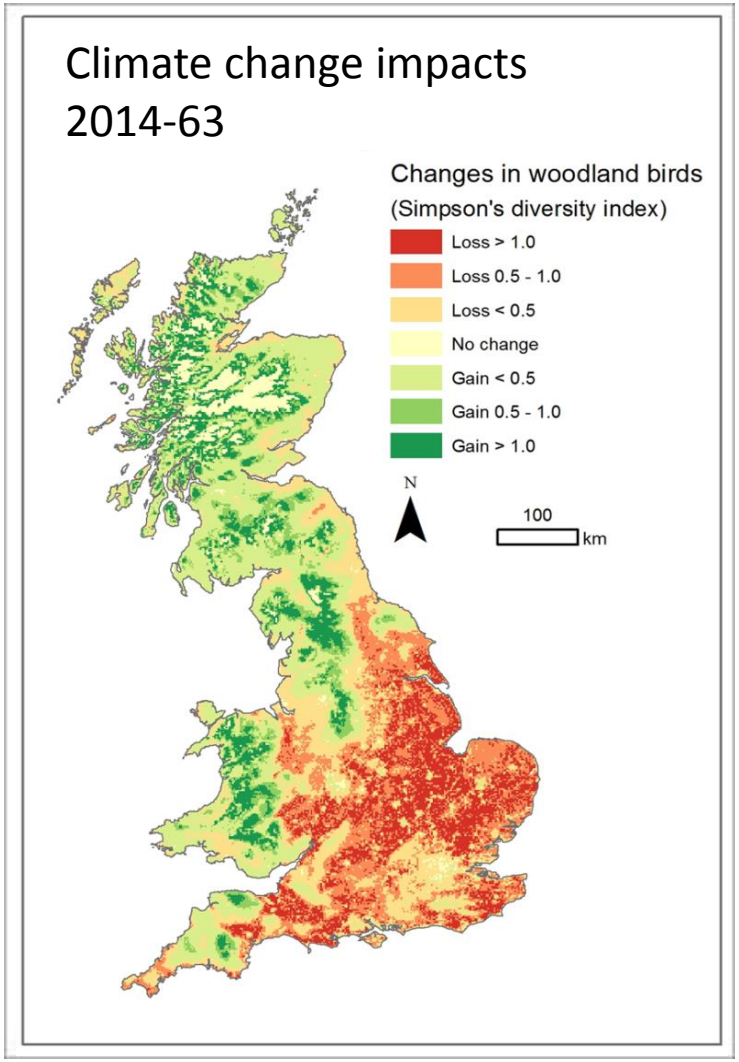


Agriculture

Forestry

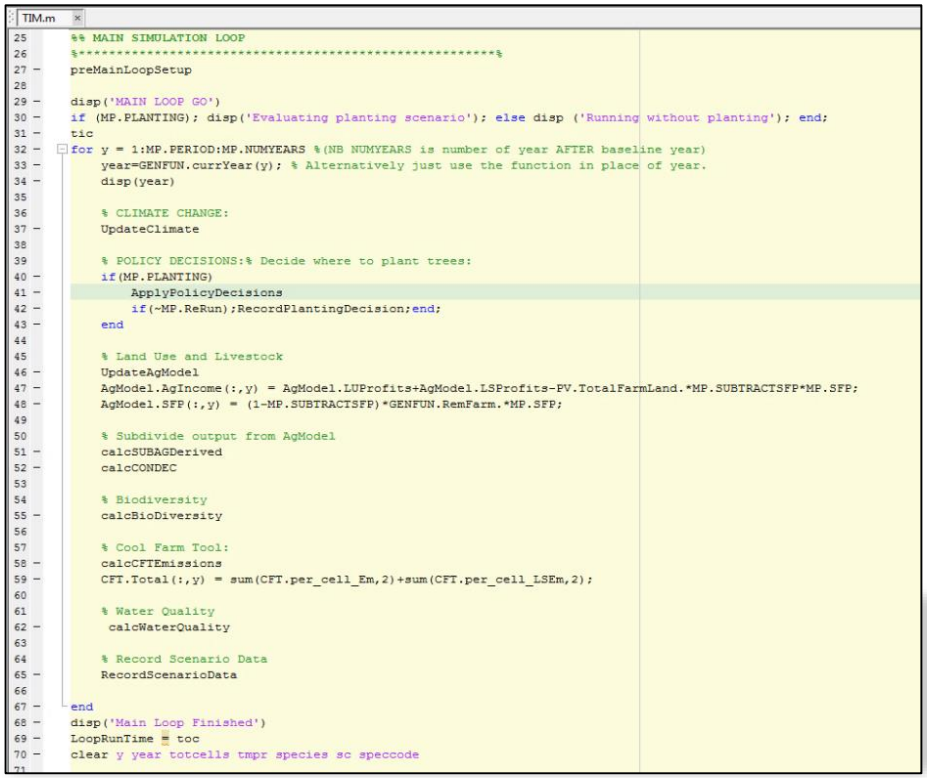
Land use change impacts on Biodiversity





Bringing multiple impacts together:
The Integrated Model

TIM



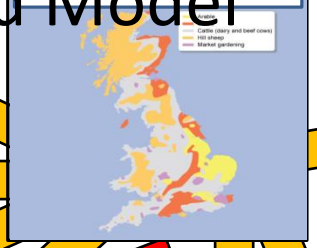
TIM

Bringing multiple impacts together:

The Integrated Model

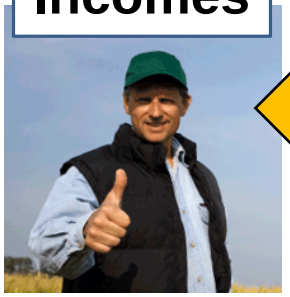
Food

Land use



Timber

Incomes



TIM

Market values

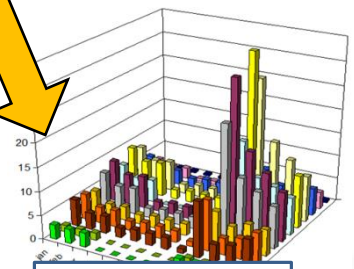
Social Value

Non-market values

Biodiversity

Drivers of change: Policy, Market & Environment

Values



Water

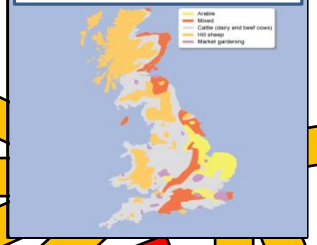
Greenhouse gases

Recreation

TIM

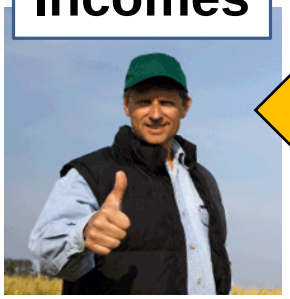
Food

Land use



Timber

Incomes

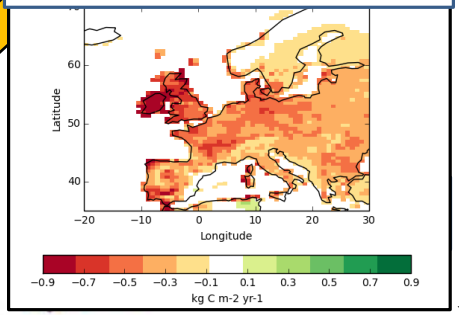


Market values

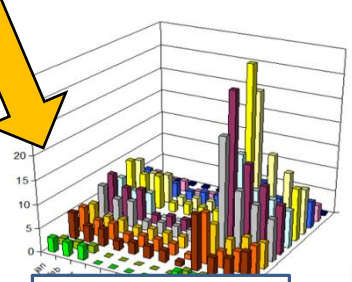
Social Value

Non-market values

Tipping Point



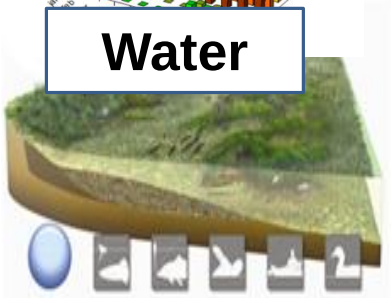
Biodiversity



Greenhouse gases

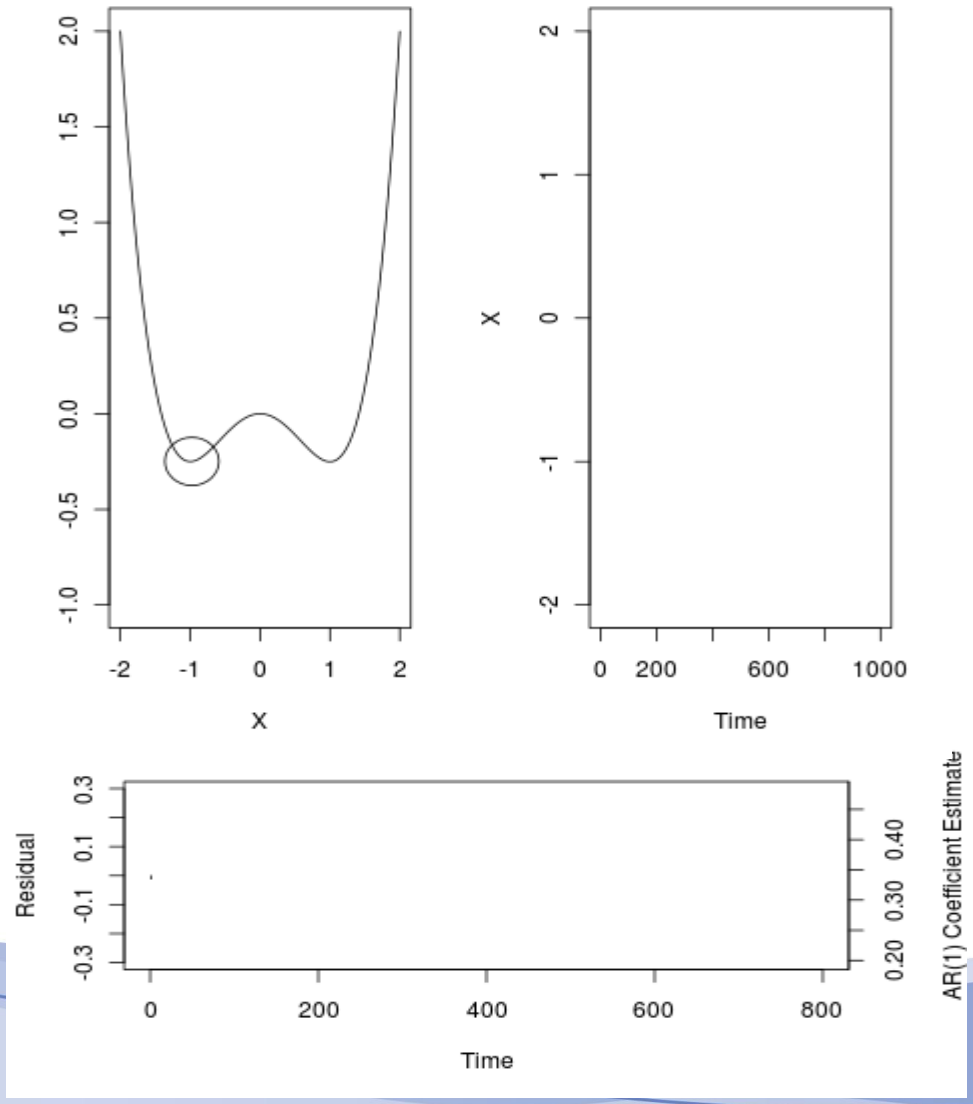
Recreation

Water



Methods of detecting tipping points:

Early warning from increased autocorrelation

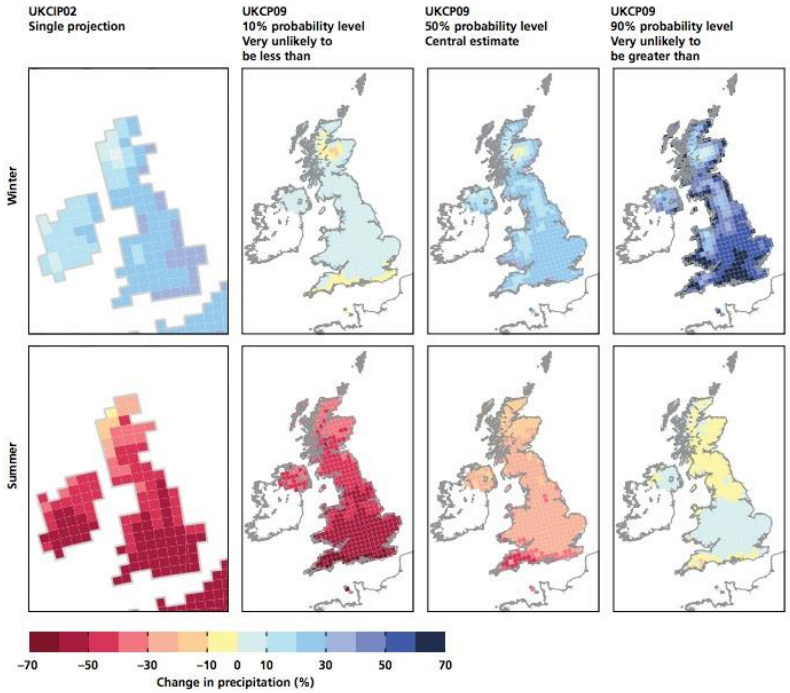


UNIVERSITY OF EXETER

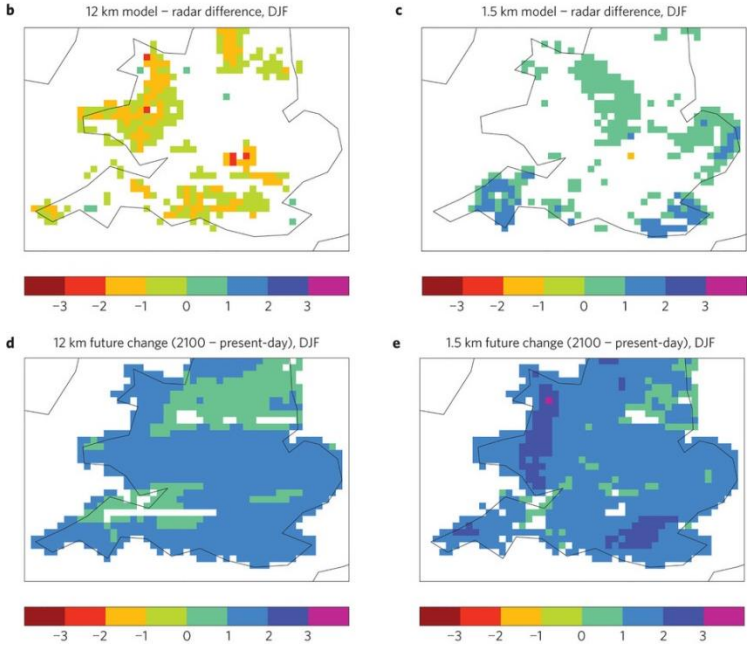
Thanks to Chris Boulton for the animation

Improving the resolution of climate change impact analyses

UKCIP09:
25km resolution

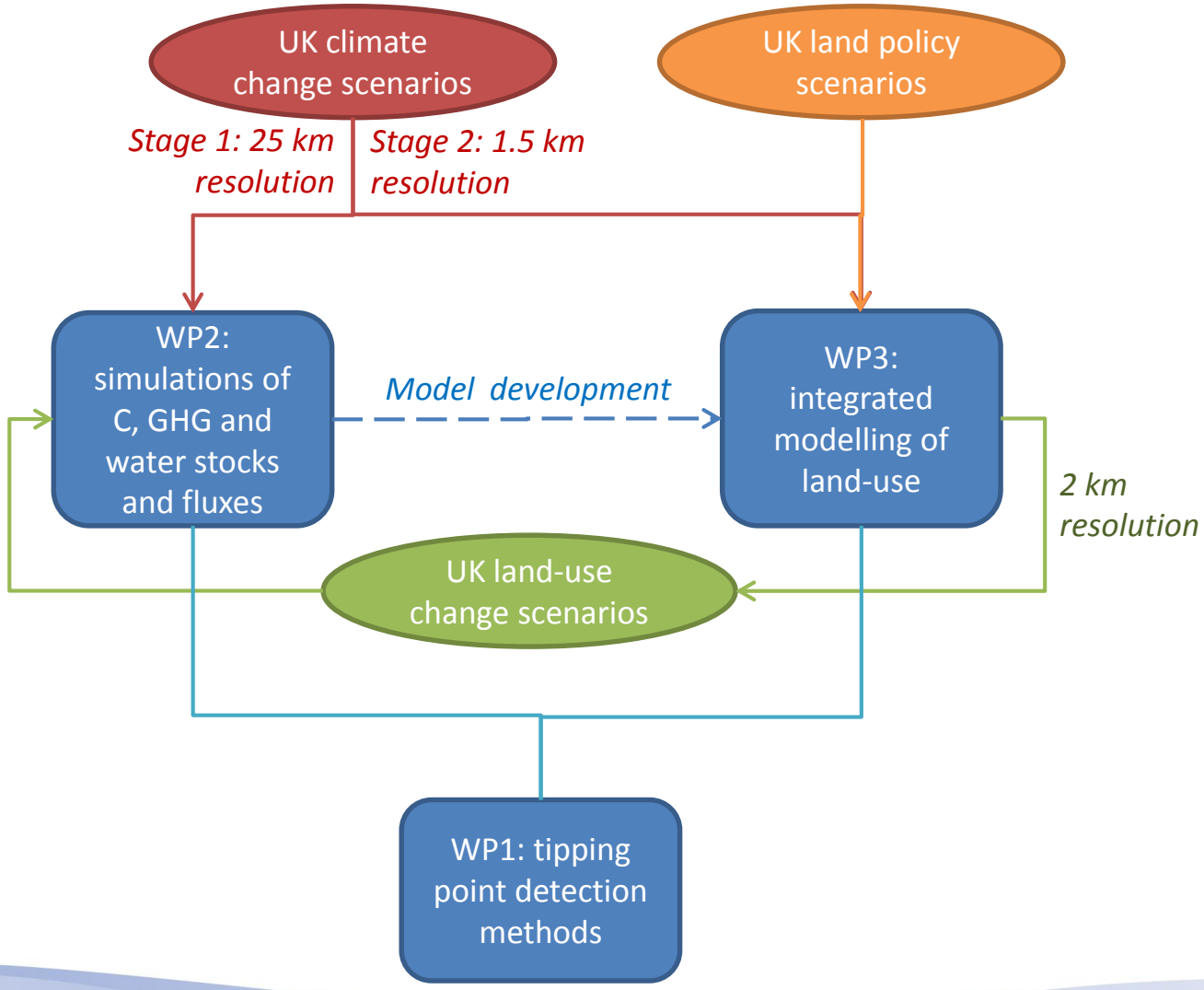


New state of the art:
1.5km resolution



UNIVERSITY OF EXETER

Kendon et al. (2015) Nature Climate Change


UK climate change scenarios
UK land policy scenarios
Stage 1: 25 km resolution
Stage 2: 1.5 km resolution
WP2: simulations of C, GHG and water stocks and fluxes
Model development
WP3: integrated modelling of land-use
2 km resolution
UK land-use change scenarios
WP1: tipping point detection methods