Towards decision-based global land use models for improved understanding of the Earth system

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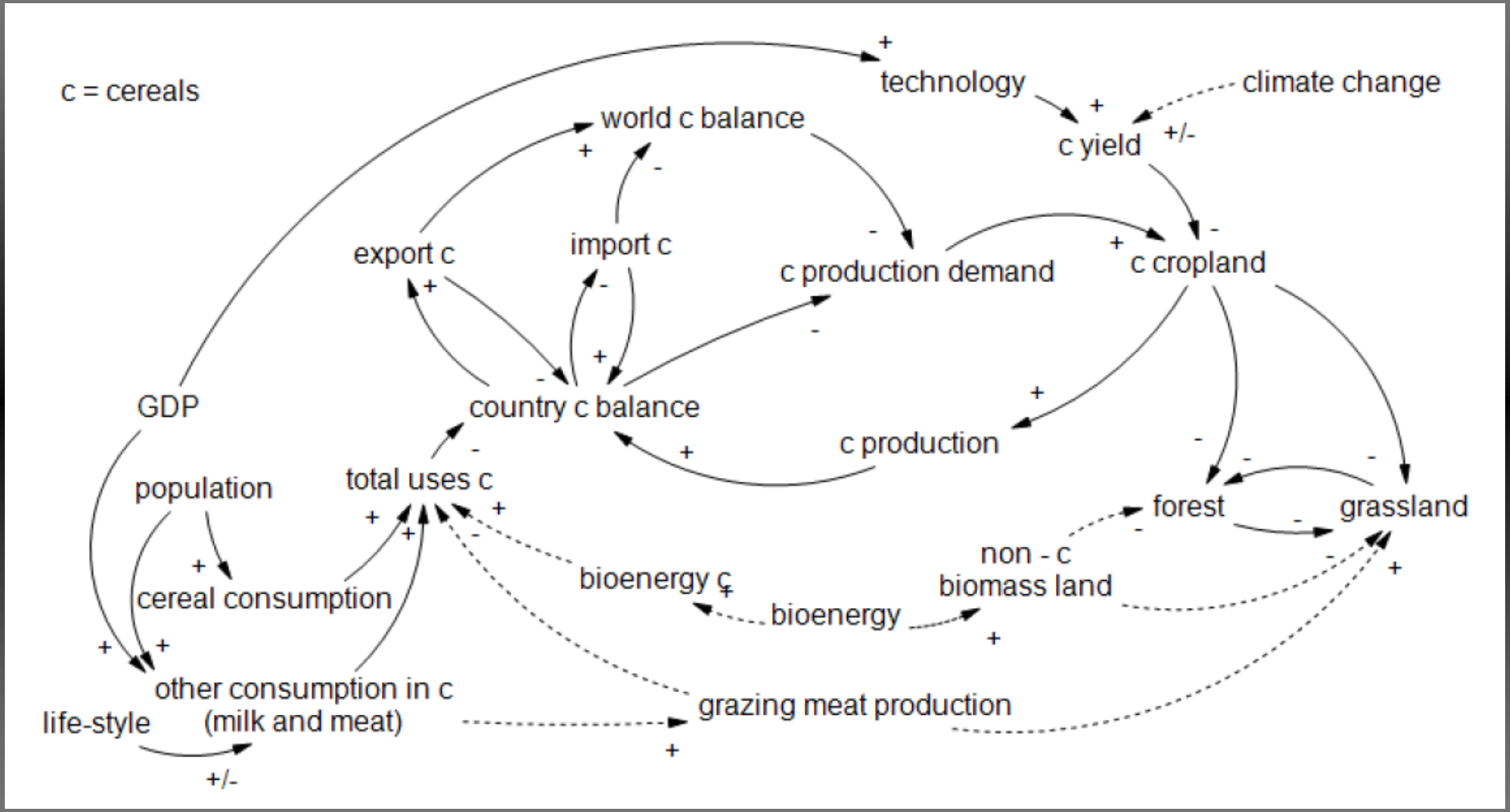
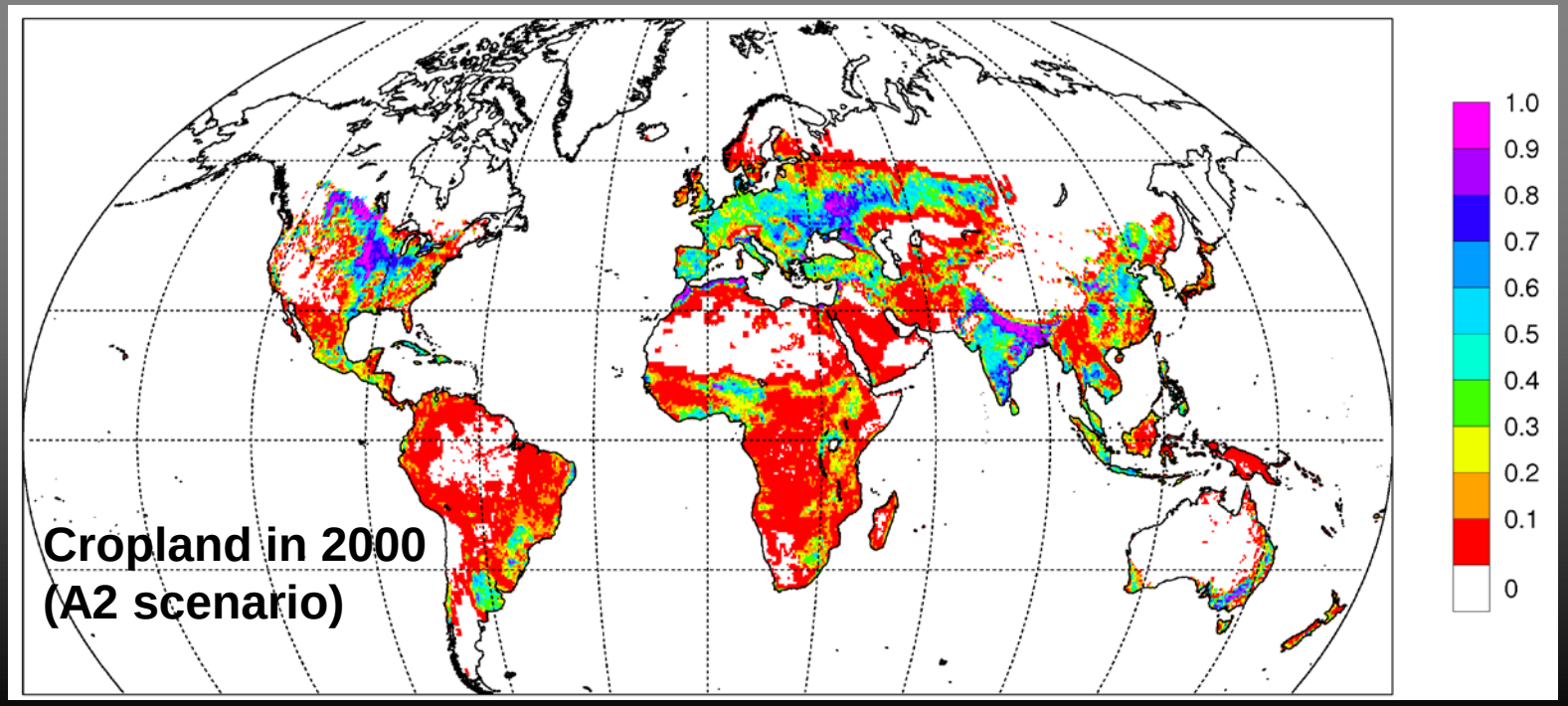
Global LULCC models

- Integrated Assessment Models (IAMs), often linked to Computable General Equilibrium models (CGEs)
- A few dedicated land use models (e.g. ClueMondo, PLUM), but often rely on global boundary conditions from IAMs/CGEs
- Empirical-statistical models based on historic land use trajectories (e.g. GLM)
- All models are ‘top-down’, defining aggregate land use change quantities (for regions or sectors) with a disaggregation (down-scaling) procedure to a spatial grid
- Is there a need for greater diversity in global scales models?

Global agricultural land use modelling using PLUM*



***Overview of the concept underpinning PLUM (Parsimonious Land Use Model) in the form of a causal loop diagram**


Cropland in 2000
(A2 scenario)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
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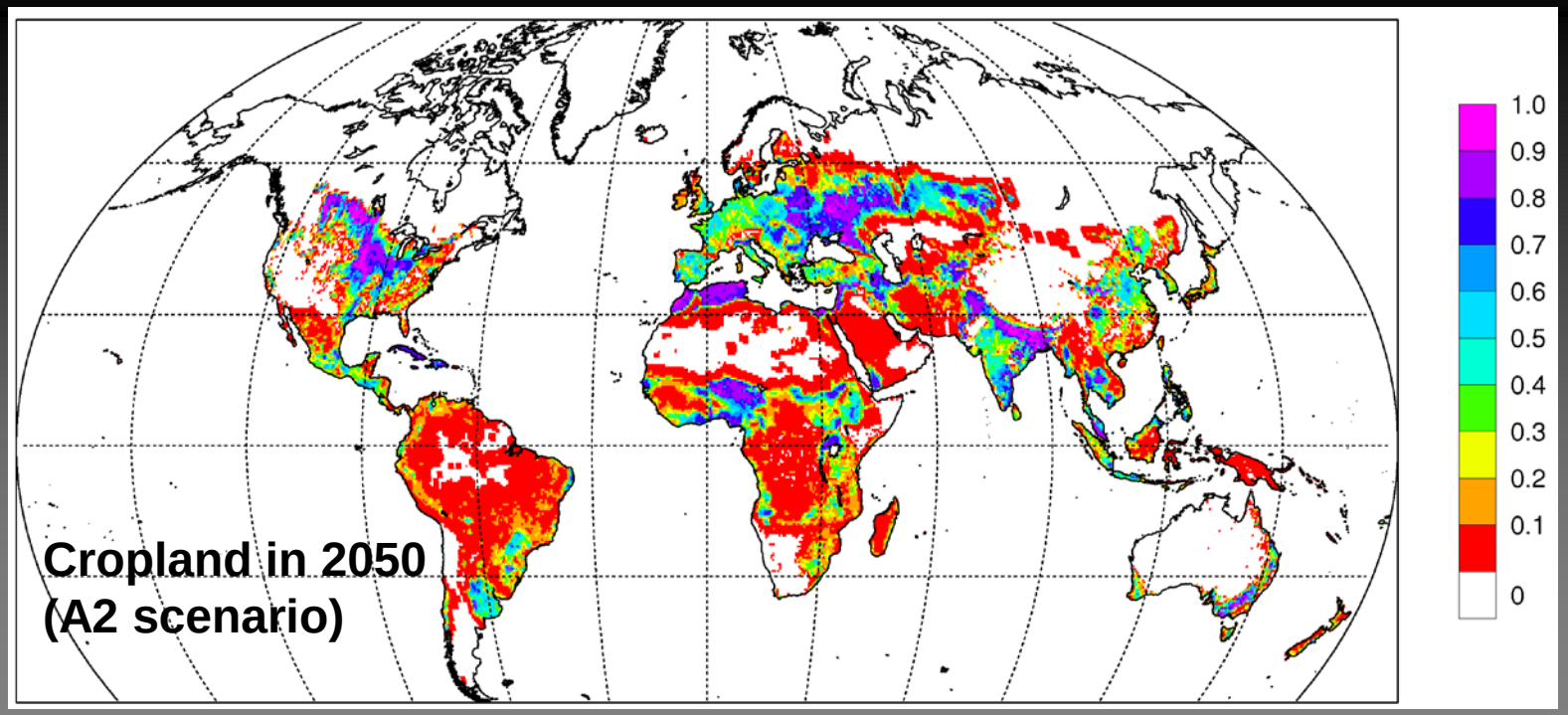
0.1
0


Cropland in 2050
(A2 scenario)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
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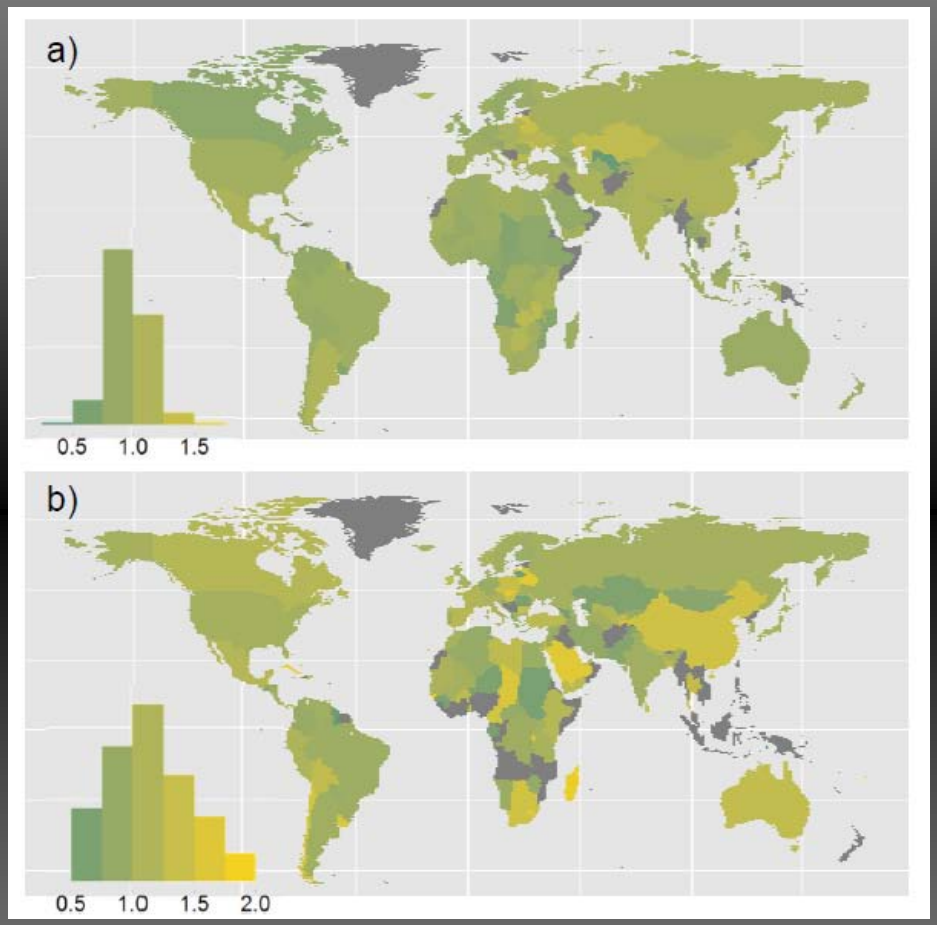
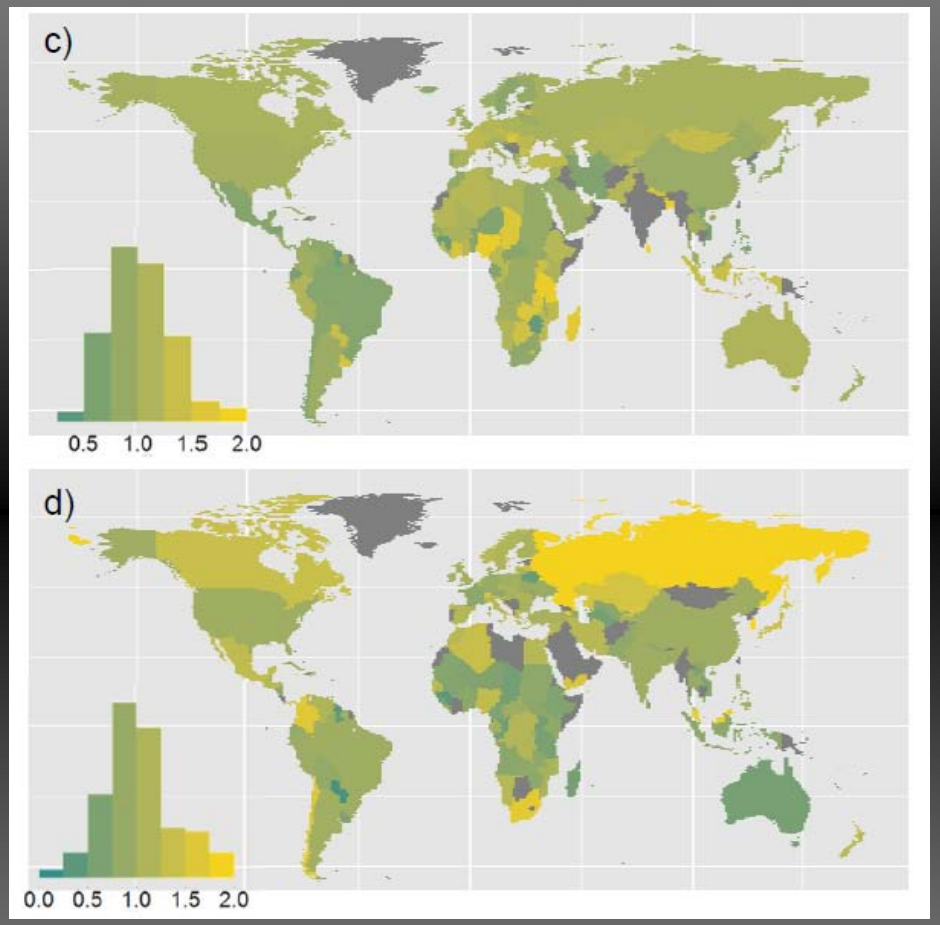
0

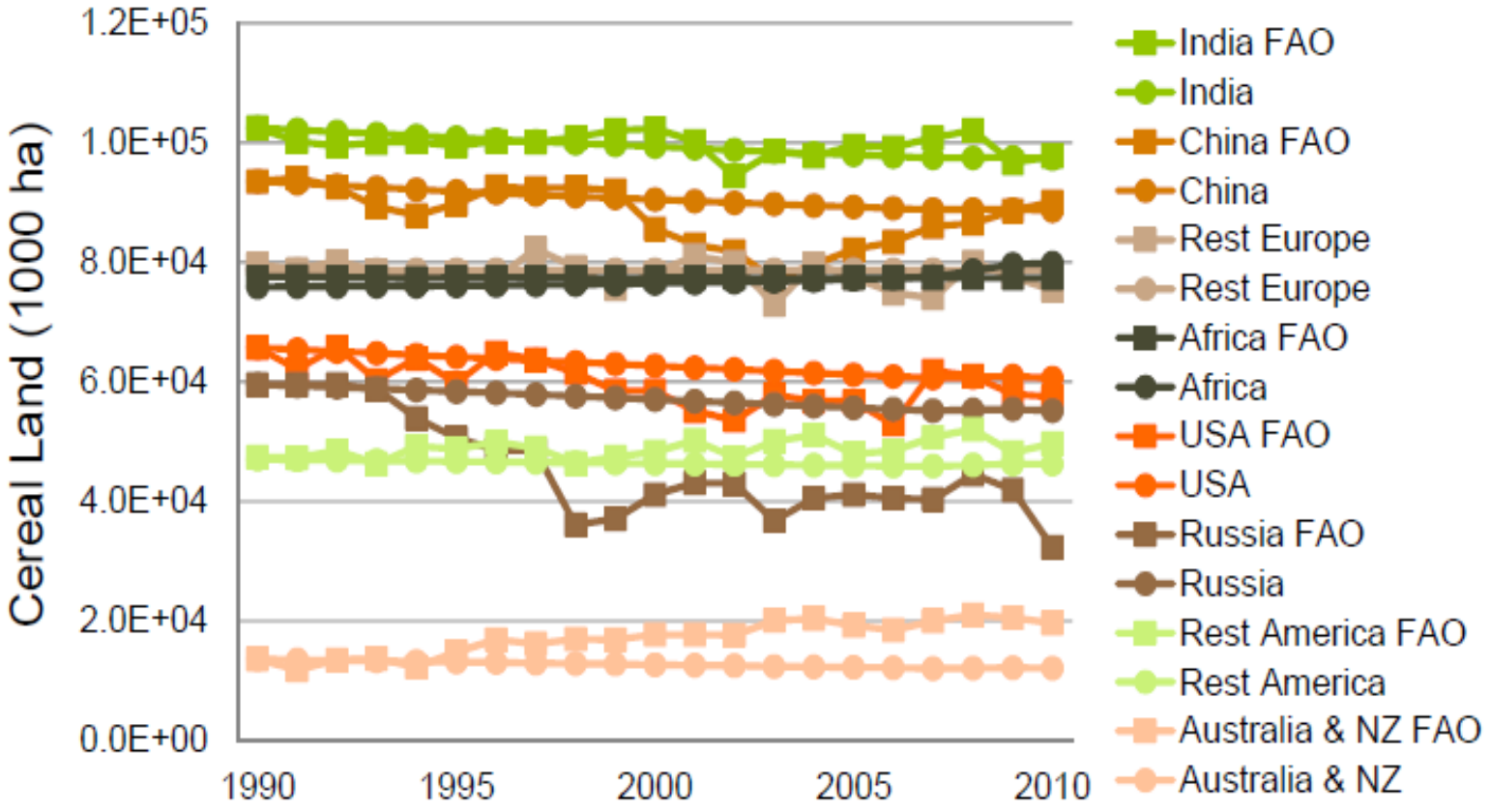
Model validation against past observational data

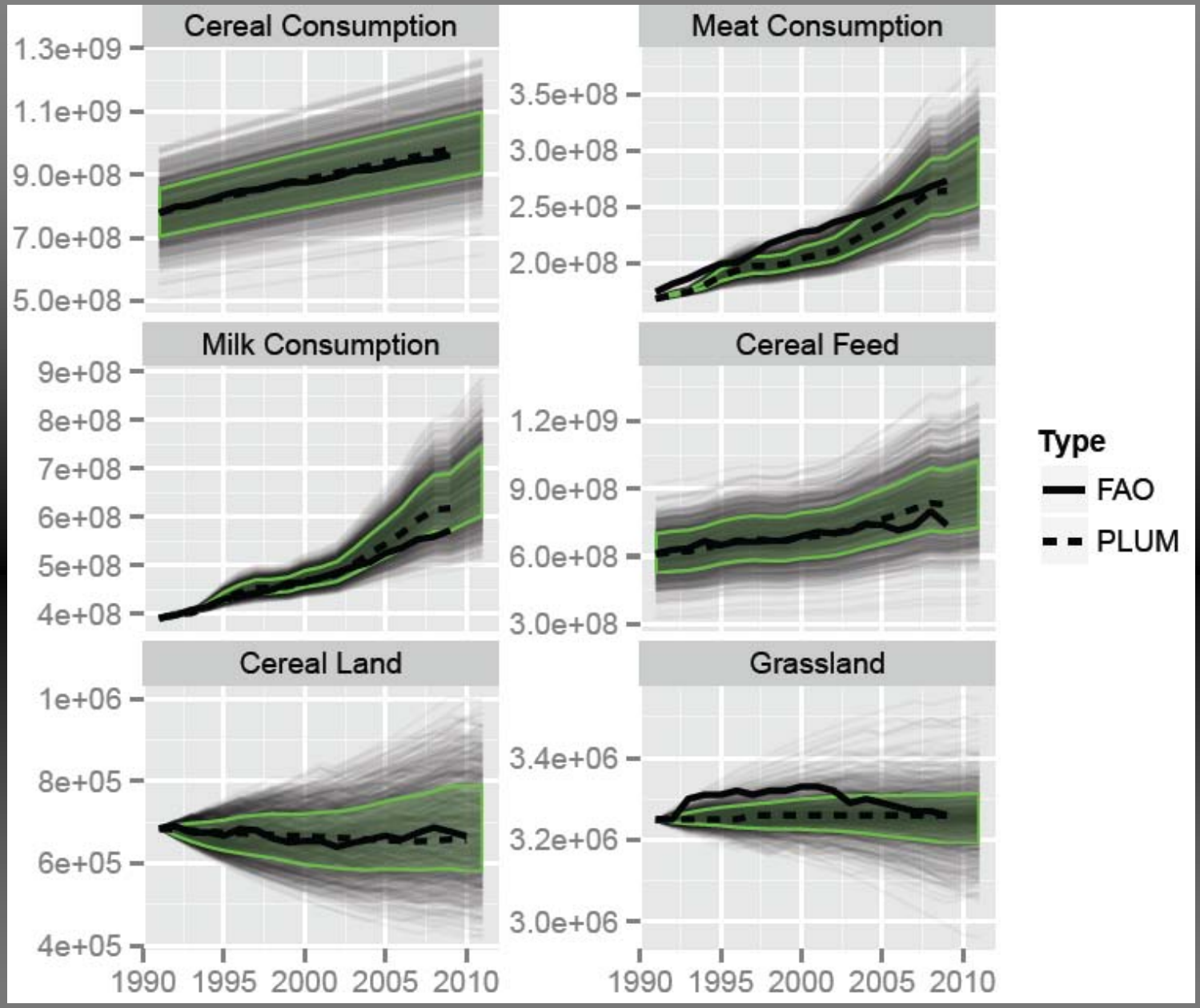




(a) cereal consumption, (b) milk consumption, (c) meat consumption, (d) cereal land in 2009. The colour codes on the maps match the distribution of the relative difference between the model and data shown in the histogram in the left-hand corner of each panel. Grey = missing data or not modelled.

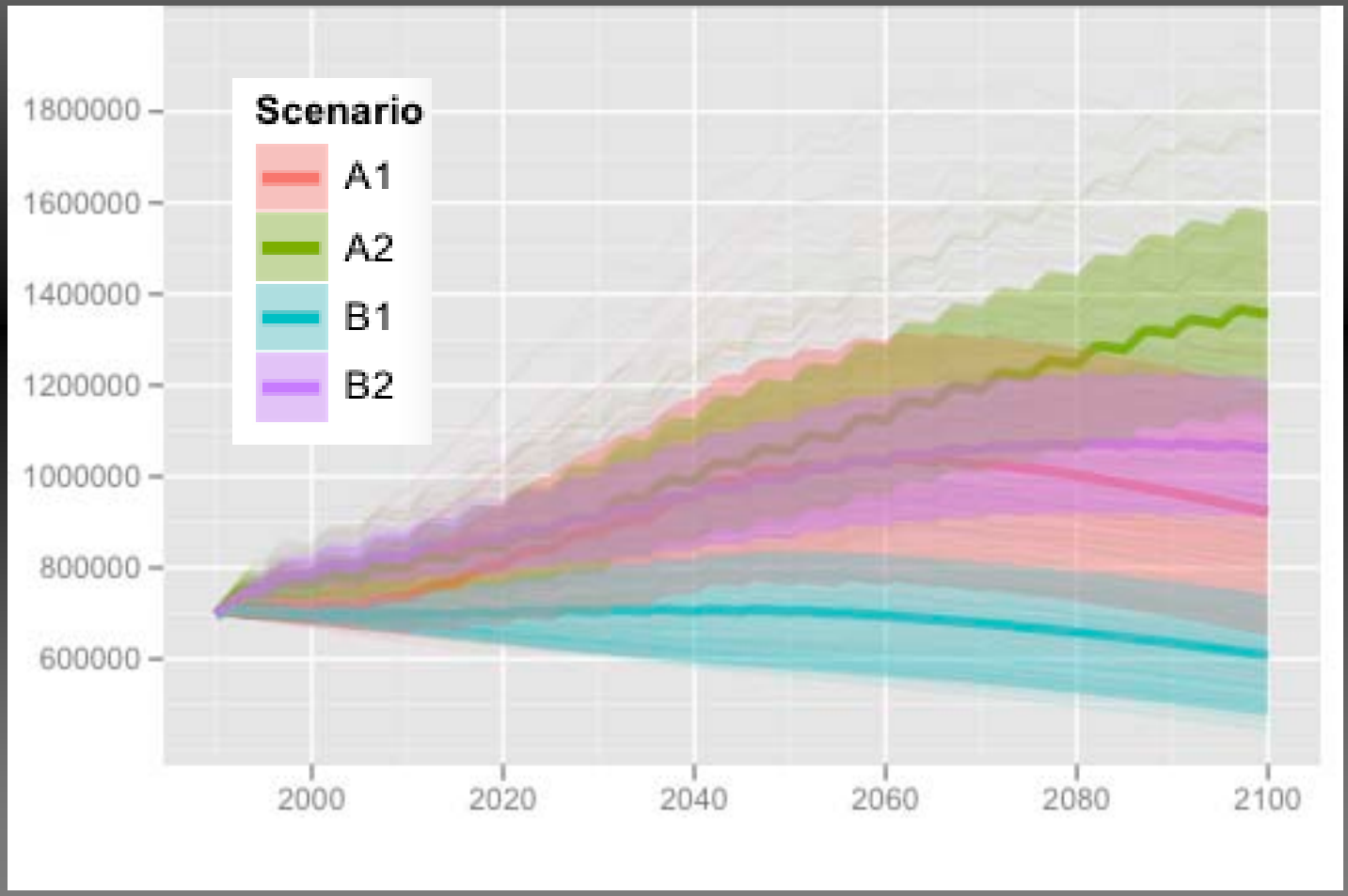
Cereal land for regions





Global observed (FAO, black line) and modelled (PLUM, dashed black line) cereal consumption (tons), meat consumption (t), milk consumption (t), cereal feed (t), cereal land (1000 ha) and grassland (1000 ha). The faint grey lines are single model runs and the grey shaded area indicates the standard deviation of the output for the model runs.

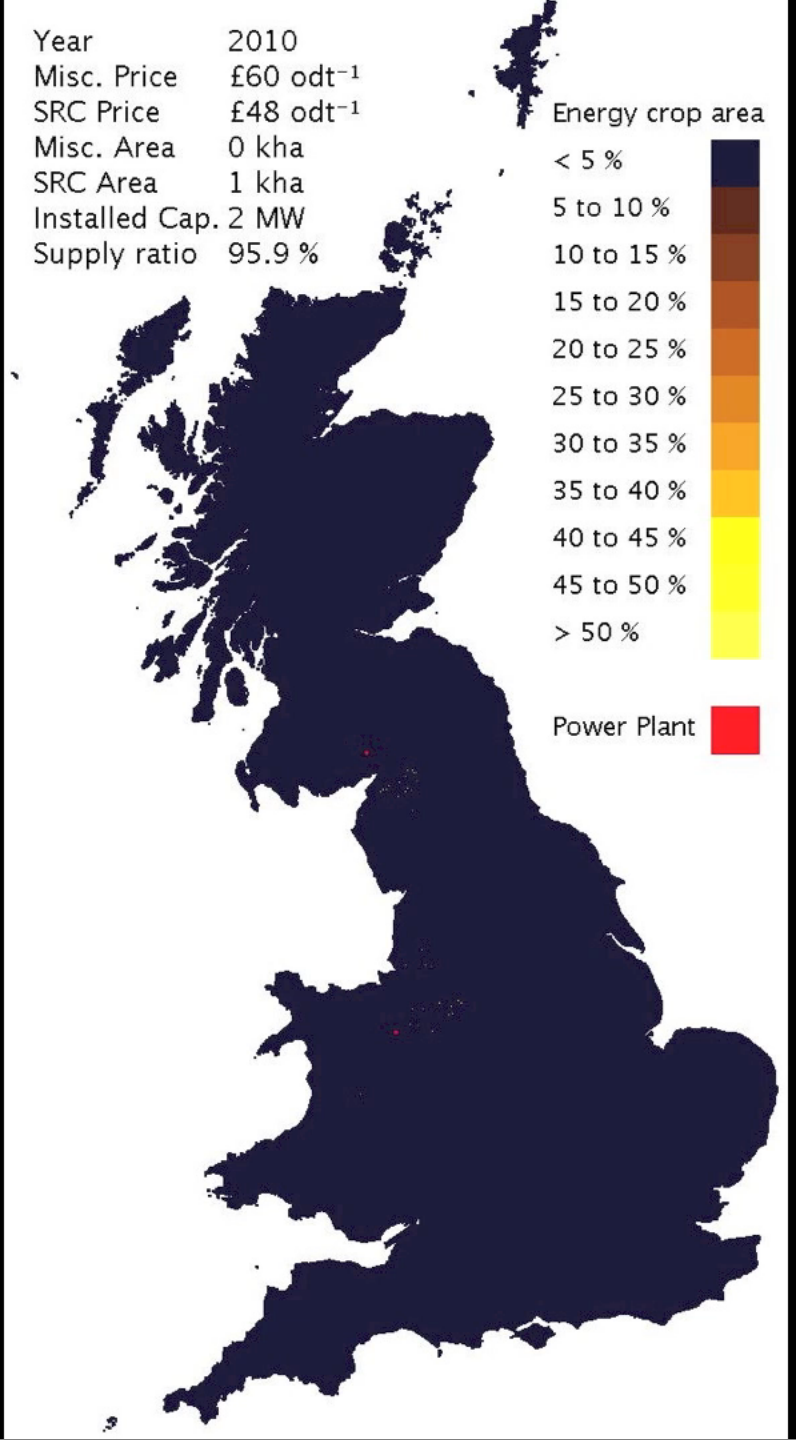
Probabilistic scenario quantifications



So, what are the limitations of current global scale LULCC models?

- Limited heterogeneity of decision-making land users – most are profit/utility maximisers
- Limited (if any!) validation of land use modelling approaches
- Some attempt to reflect uncertainty of input assumptions about the future (conditional probabilities), e.g. PLUM
- Some attempt to explore mosaic landscapes (e.g. ClueMondo)
- Some (but limited attempt) to model land use intensification versus land use expansion
- No (or little) recognition of the diversity of human mediated processes, e.g. culture, behaviour, communication, interaction, knowledge exchange, learning, teleconnections, institutions, …
- In contrast to regional/landscape scale models …

Agent-Based Modelling to simulate time-lags in the uptake of energy crops (miscanthus and Short Rotation Coppicing)



Alexander, P., Moran, D., Rounsevell, M.D.A. & Smith, P. (2013). Modelling the perennial energy crop market: the role of spatial diffusion. *Journal of the Royal Society Interface*, 10, 20130656 doi: 10.1098/rsif.2013.0656

Simulating changes in the distribution of bioenergy crops: Miscanthus and short rotation coppicing

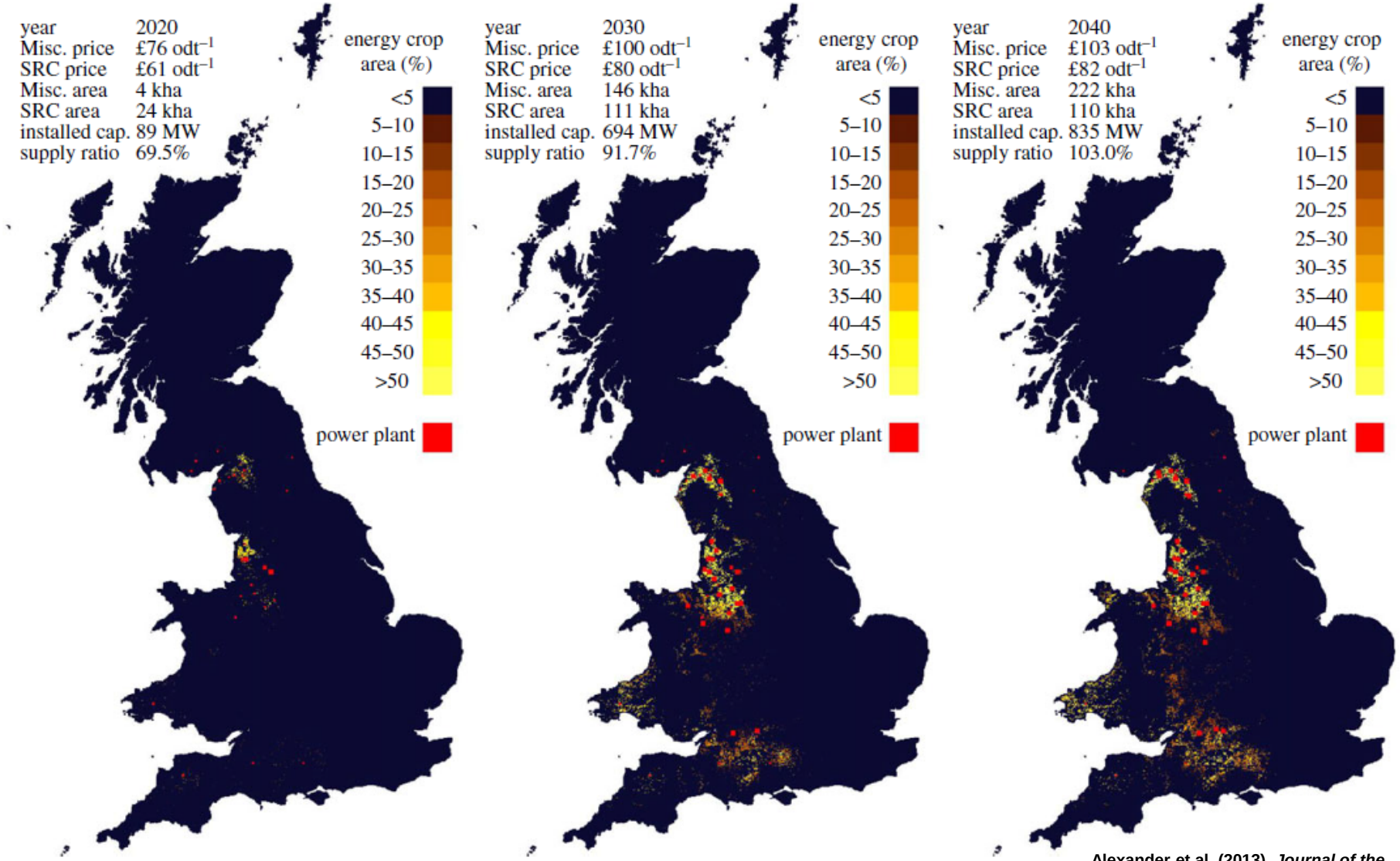
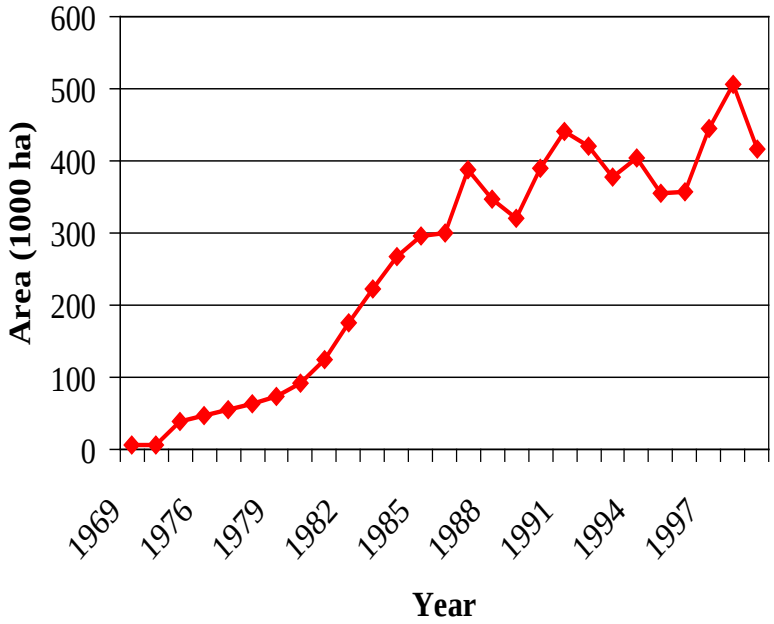


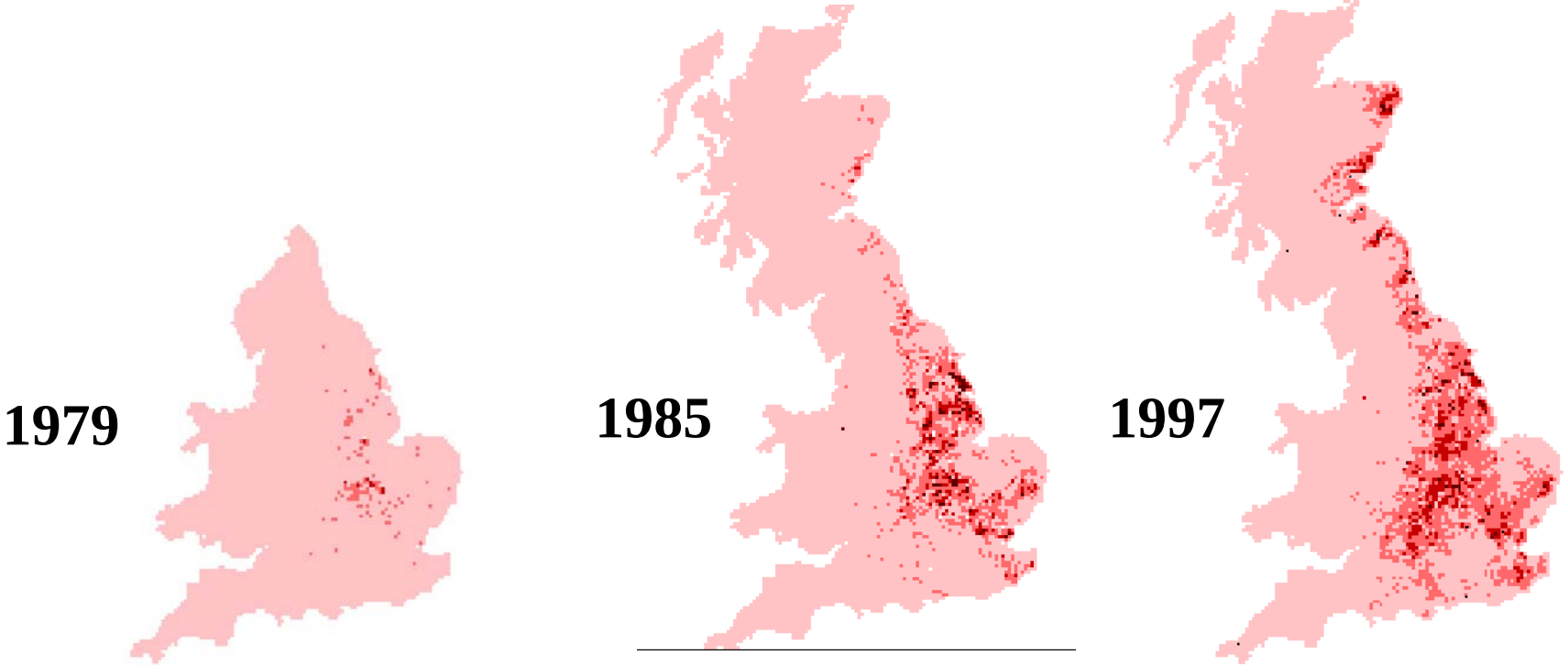
Figure 5. Sample output maps of energy crop selection and power plant locations in 2020, 2030 and 2040.

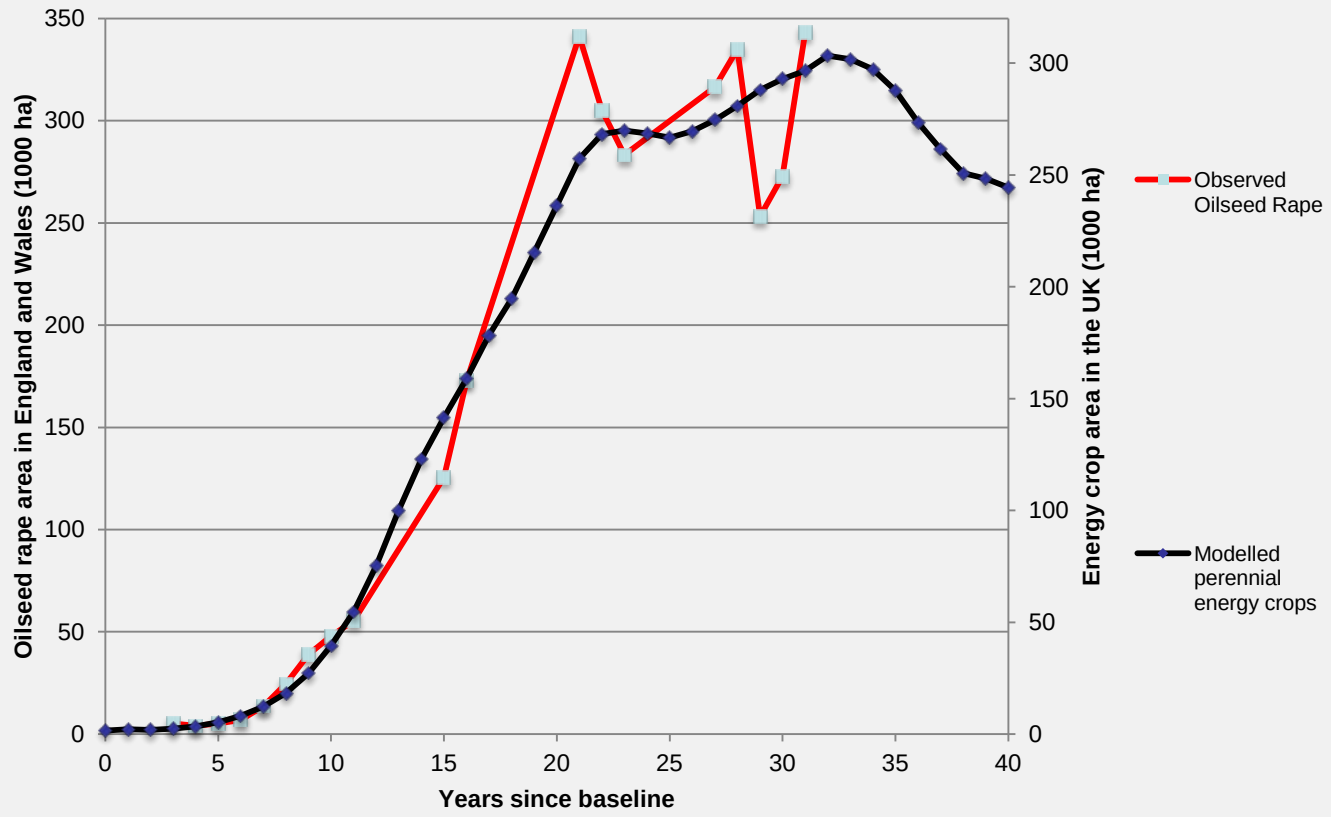
Alexander et al. (2013). ***Journal of the Royal Society Interface***, **10, 20130656**
doi: 10.1098/rsif.2013.0656

Change in oilseed rape areas in GB (1969-1999)

US soyabean shortage leads to European oilseed subsidy in the early 80s; during the 90s OSR is used as a biofuel crop on set-aside land







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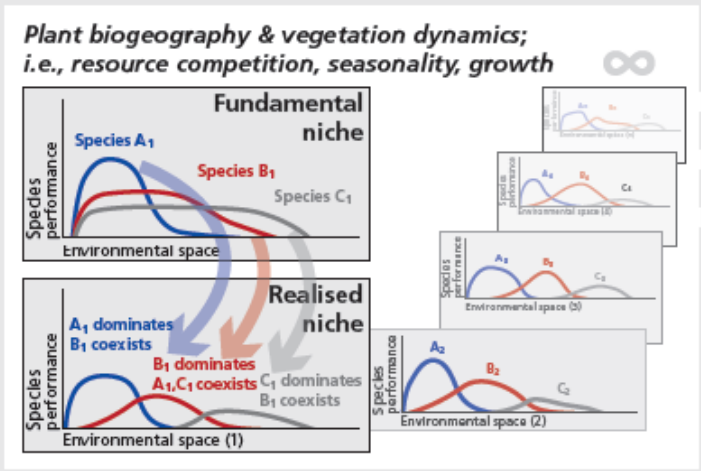
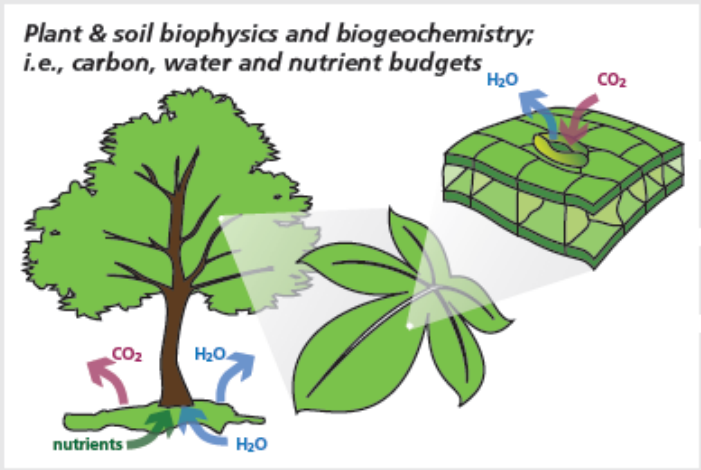
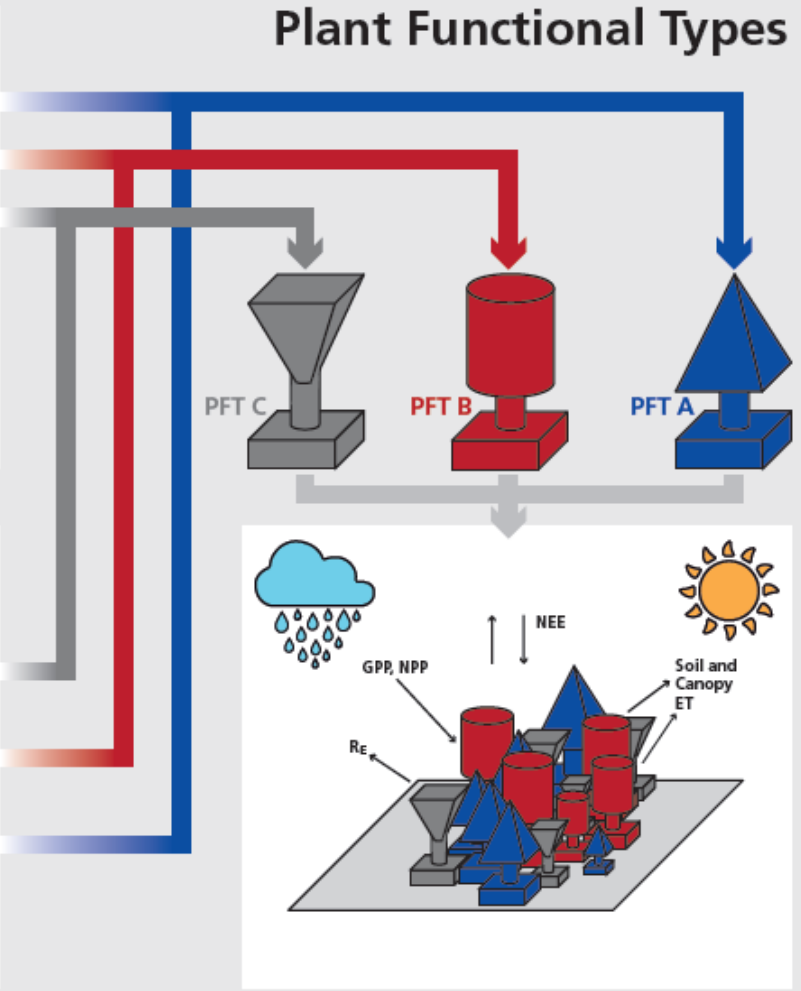
Time lags in land use change - historic oilseed rape data for England and Wales, against a baseline year of 1966, and mean modelled perennial energy crop areas, using a baseline year of 2010

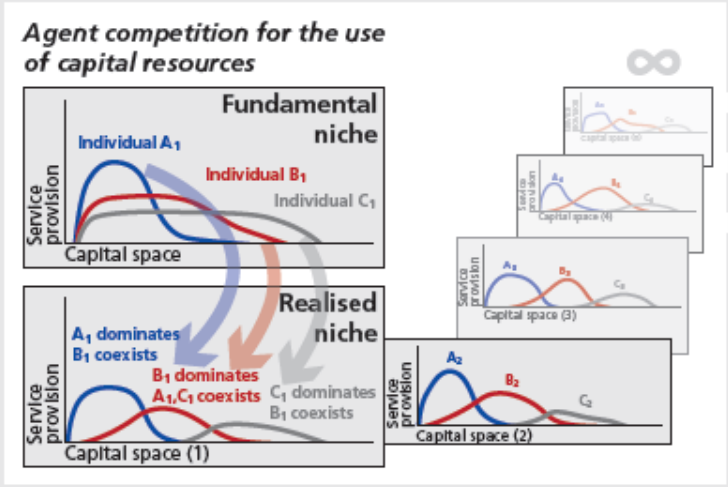
Upscaling agent-based models using the Plant Functional Type analogy

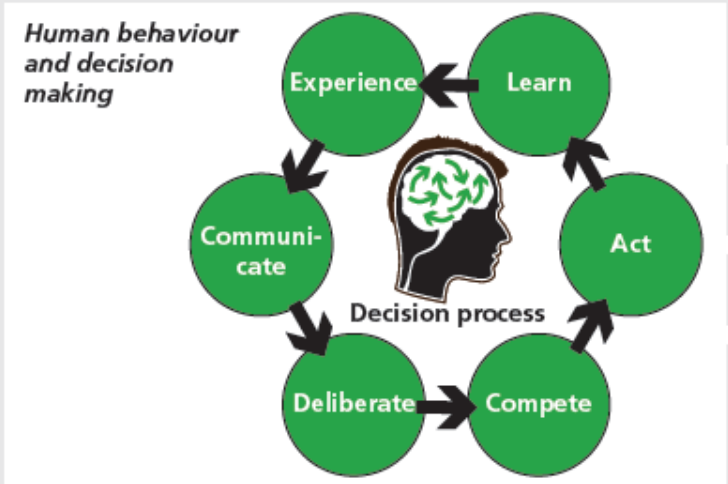


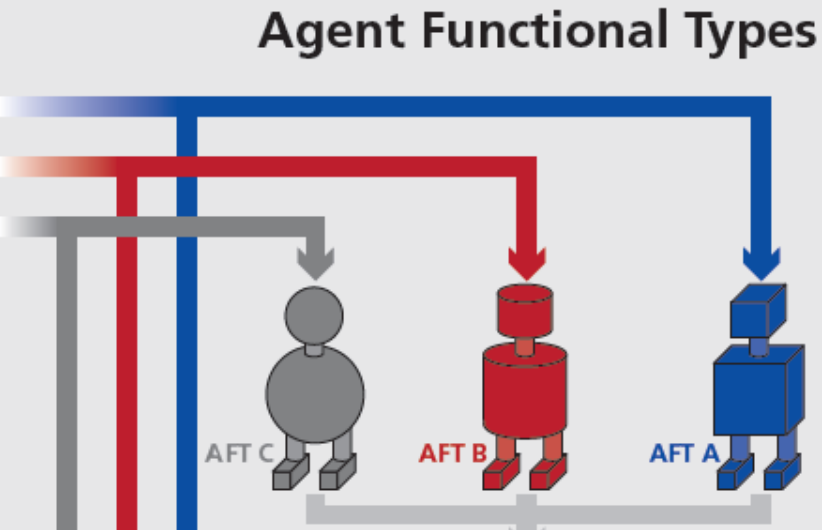


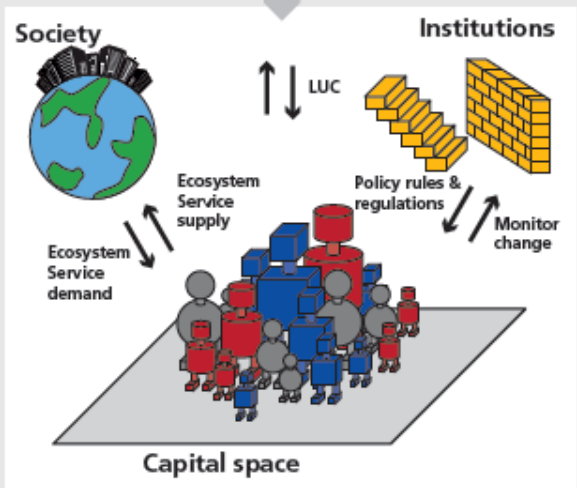


Interacting agents compete for capital resources and interact with society and Institutions

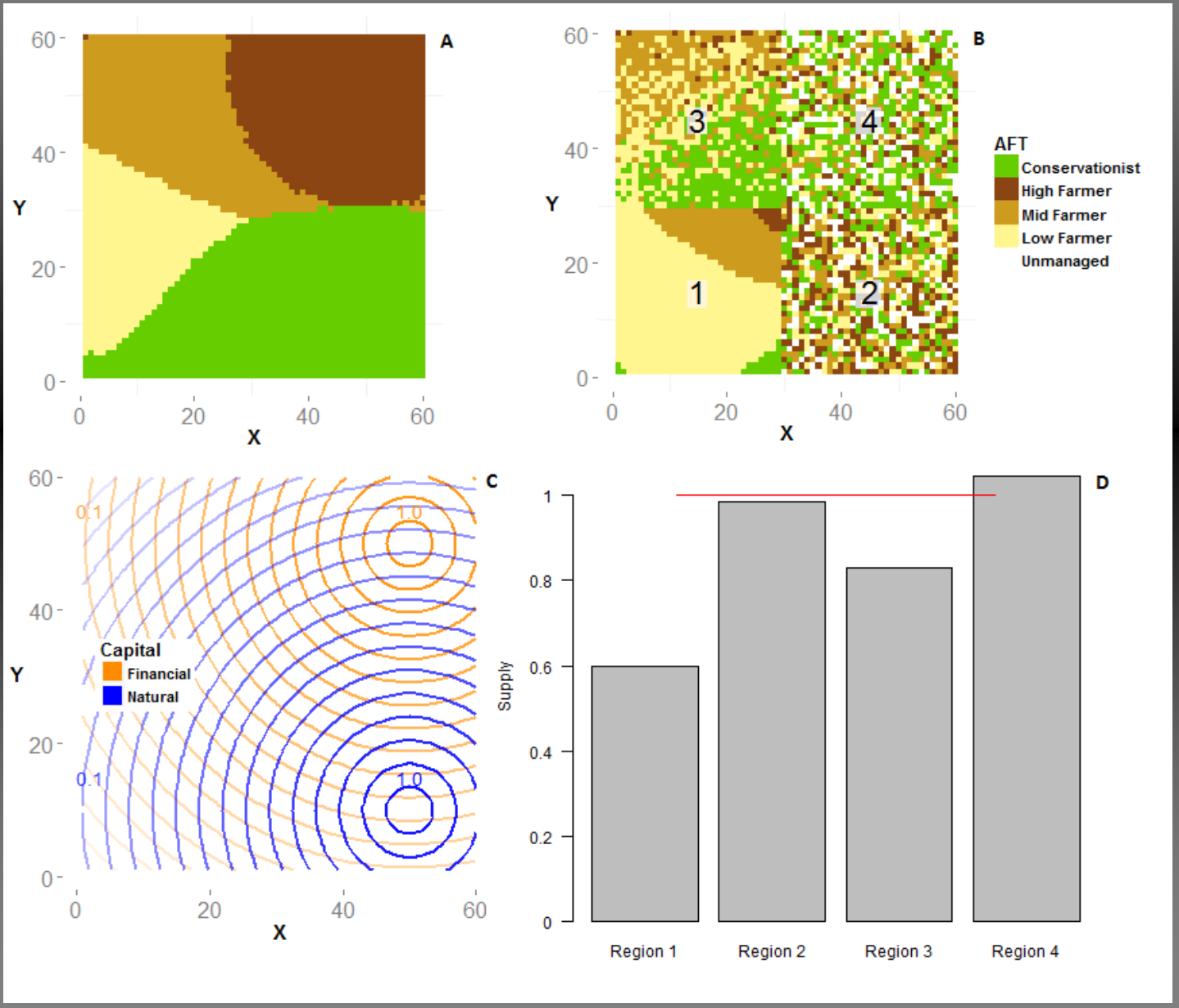








Land use change in a hypothetical region with global and regionalised demand

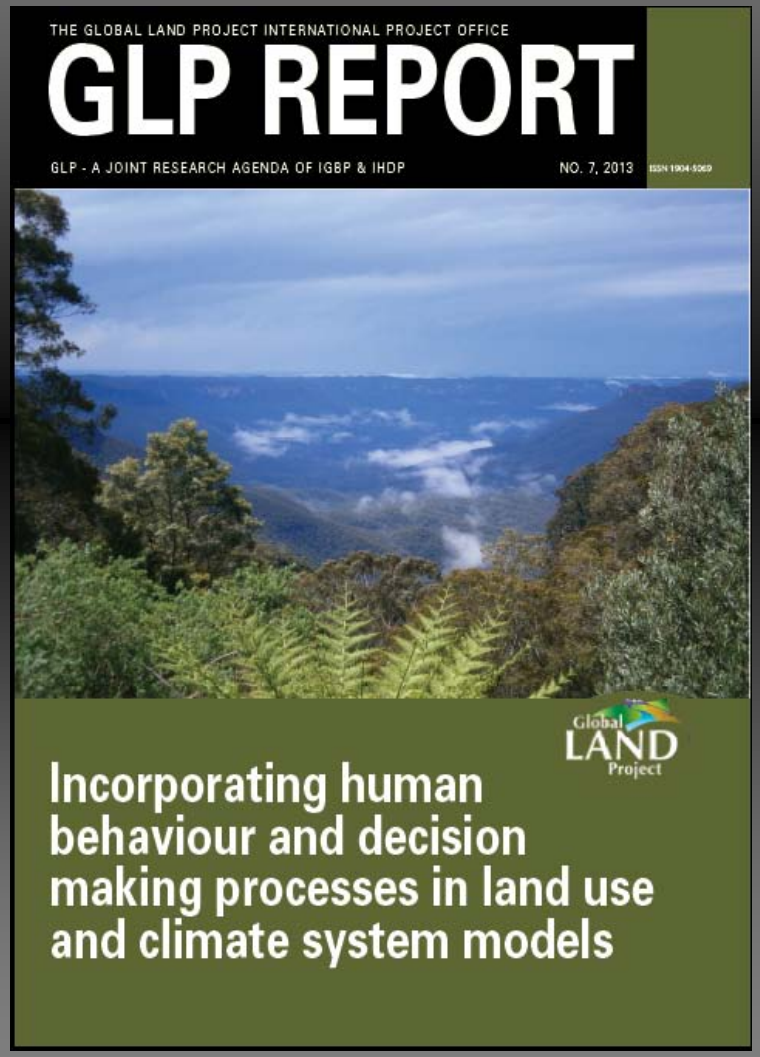


Concluding remarks 1

- All global models are top-down, with limited representation of human behavioural and decision processes
- Most global models are used to make projections rather than to understand processes
- This usually involves some form of supply-demand calculation at an aggregate level (world region or country) followed by statistical downscaling
- There is limited model validation of the LULCC component
- Validation is mostly done on past LULCC data (e.g. FAO), but what does this say about the validity of future LULCC projections in very different worlds?

Concluding remarks 2

- ‘Bottom-up’ models are better able to model a range of human-mediated processes in addition to economics
- But, upscaling such models to global scale levels is a significant challenge
- Hence there are no global scale agent-based models at the global scale that can be compared with existing global modelling paradigms
- A few agent-based models are being developed at country/continental scales (e.g. for Europe)
- The LUC4C project (see next talk) will do a comparison across LULCC models (and scales) to understand differences in outputs and process representation



Rounsevell, M.D.A., Arneth, A., Alexander, P., Brown, D.G., de Noblet-Ducoudré, N., Ellis, E., Finnigan, J., Galvin, K., Grigg, N., Harman, I., Lennox, J., Magliocca, N., Parker, D.C., O'Neill, B.C., Verburg, P.H. and Young, O. (2014). Towards decision-based global land use models for improved understanding of the Earth system. *Earth System Dynamics*, **5**, 1-21, doi:10.5194/esd-5-1-2014