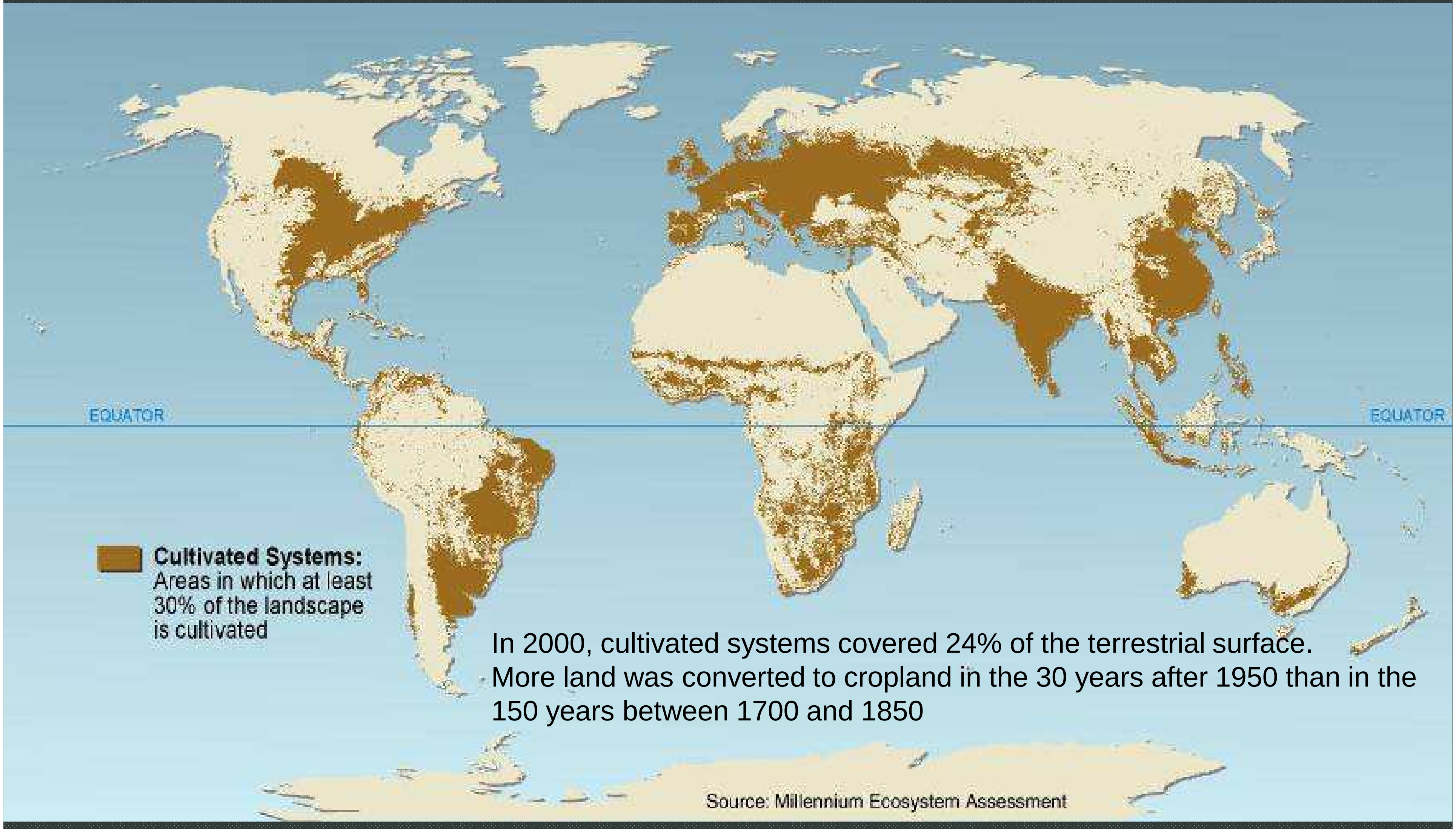
Land use change analysis across scales from global to local

Professor Mark Rounsevell, School of Geosciences

Change in cultivated areas



In 2000, cultivated systems covered 24% of the terrestrial surface.
More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850

Some of Epstein's* reasons to model

- Explain as distinct from predict, e.g. plate tectonics *explains* earthquakes, but cannot *predict* the time and place of their occurrence)
- Guide data collection
- Illuminate core dynamics
- Discover new questions
- Bound (bracket) outcomes to plausible ranges
- Illuminate core uncertainties
- Demonstrate trade-offs / suggest efficiencies
- Challenge the robustness of prevailing theory through perturbations
- Expose prevailing wisdom as incompatible with available data
- Train practitioners
- Discipline the policy dialogue
- Educate the general public

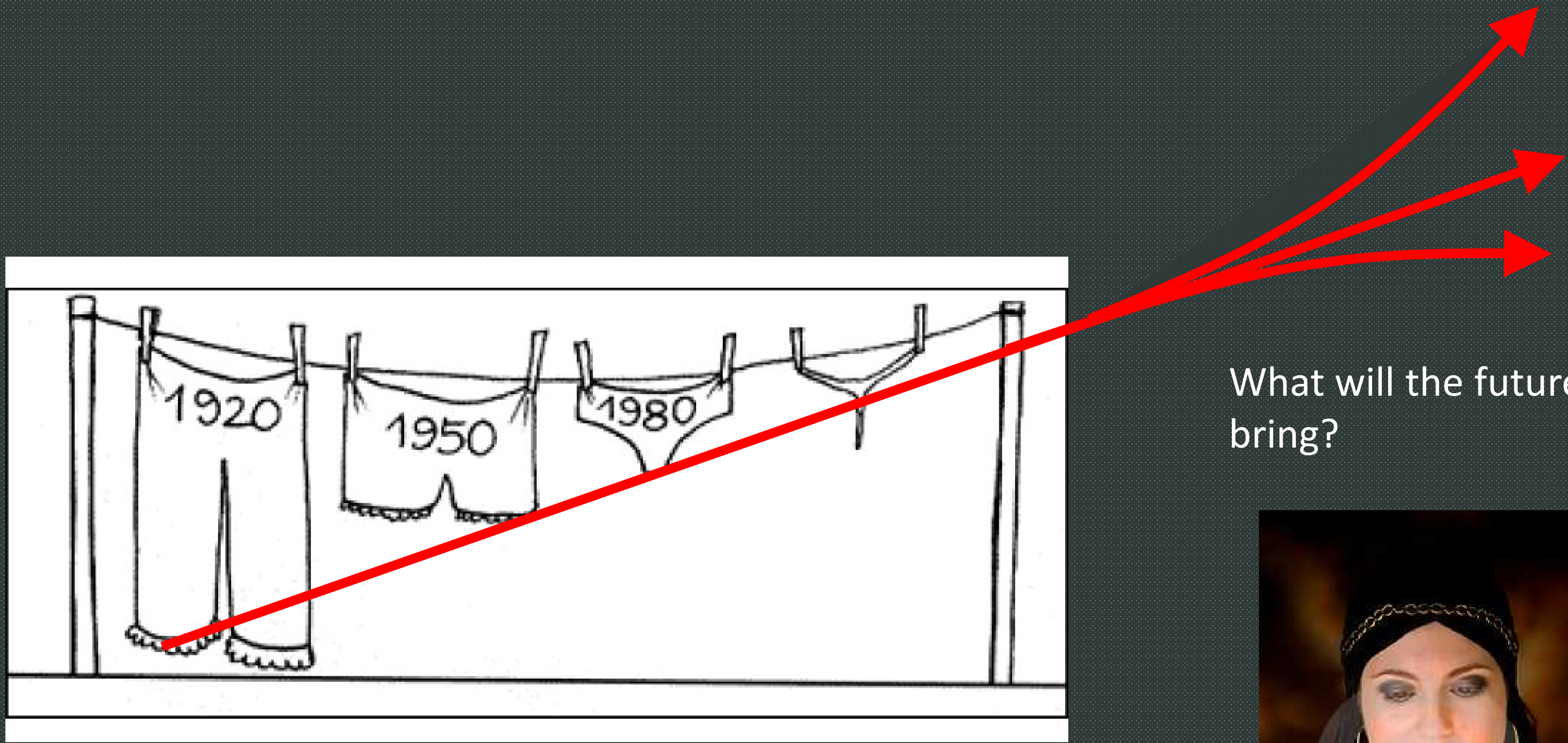
*Epstein, J.M. 2008. 'Why Model?'. Journal of Artificial Societies and Social Simulation 11(4): 12
http://jasss.soc.surrey.ac.uk/11/4/12.html

Models and scenarios

"The future isn't what it used to be …"

Herman Kahn
The 'father' of scenario thinking

What will the future bring?



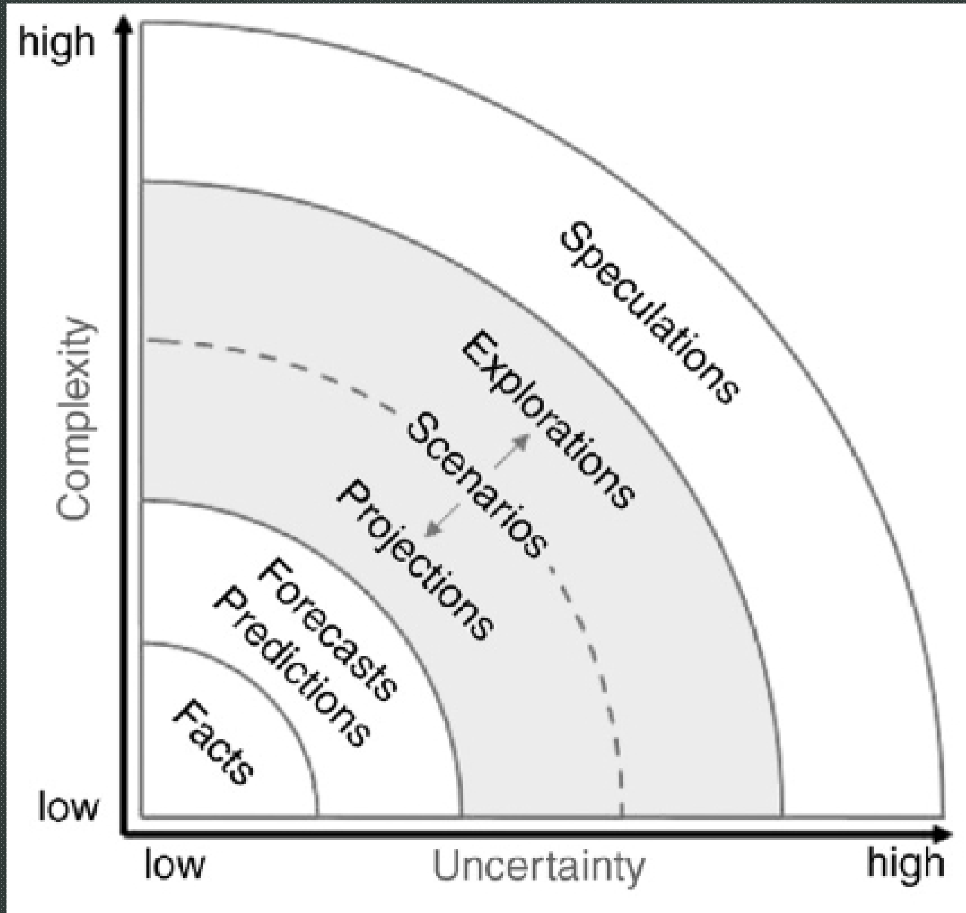
observations

What will the future bring?

The way we address 'futures' in complex systems depends on:

(a) how well we understand a system's *complexity / causalities*;

(b) how *uncertain* we are about future developments of key drivers



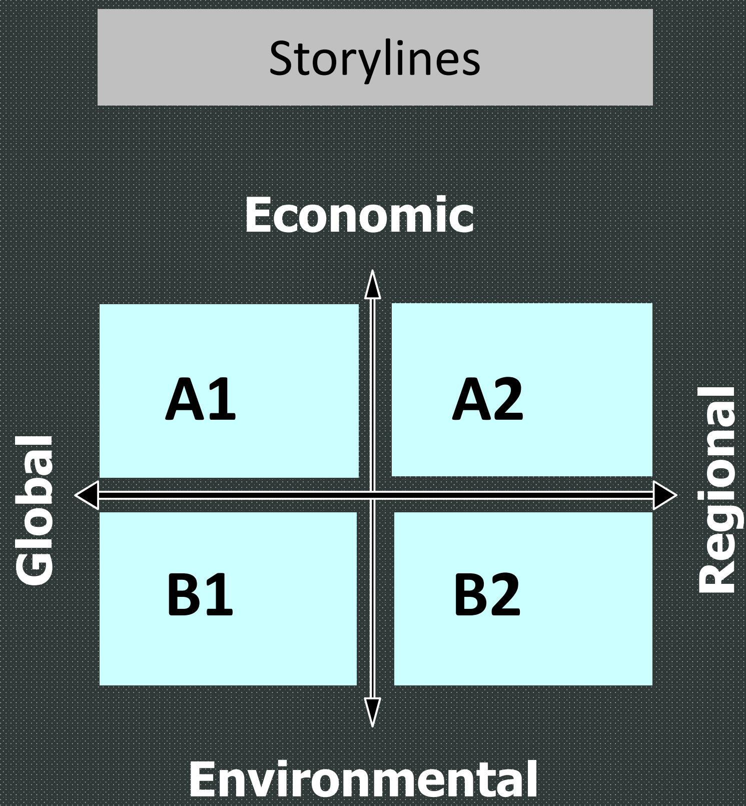
Source: Zurek, M., Henrichs, T., 2007. Linking scenarios across geographical scales in international environmental assessments. Technological Forecasting and Social Change.

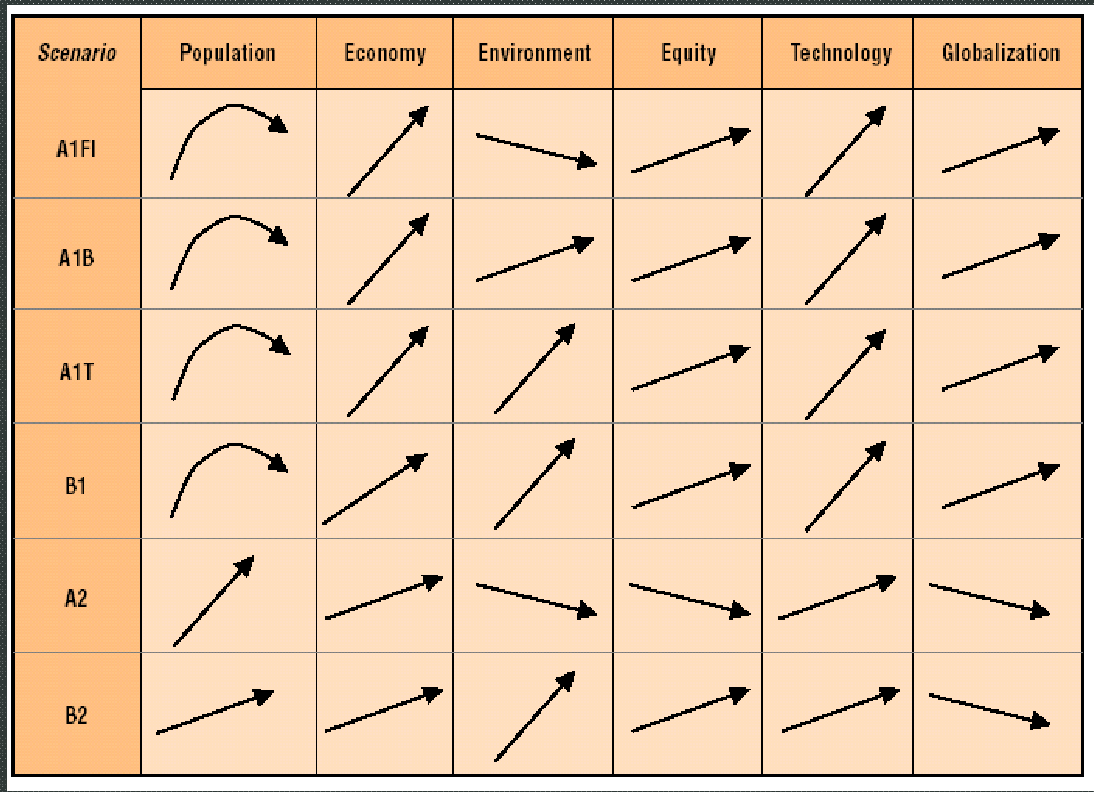
Scenarios as images

My painting is visible images which conceal nothing; they evoke mystery and, indeed, when one sees one of my pictures, one asks oneself this simple question ***'What does that mean'?***

René Magritte, 1947

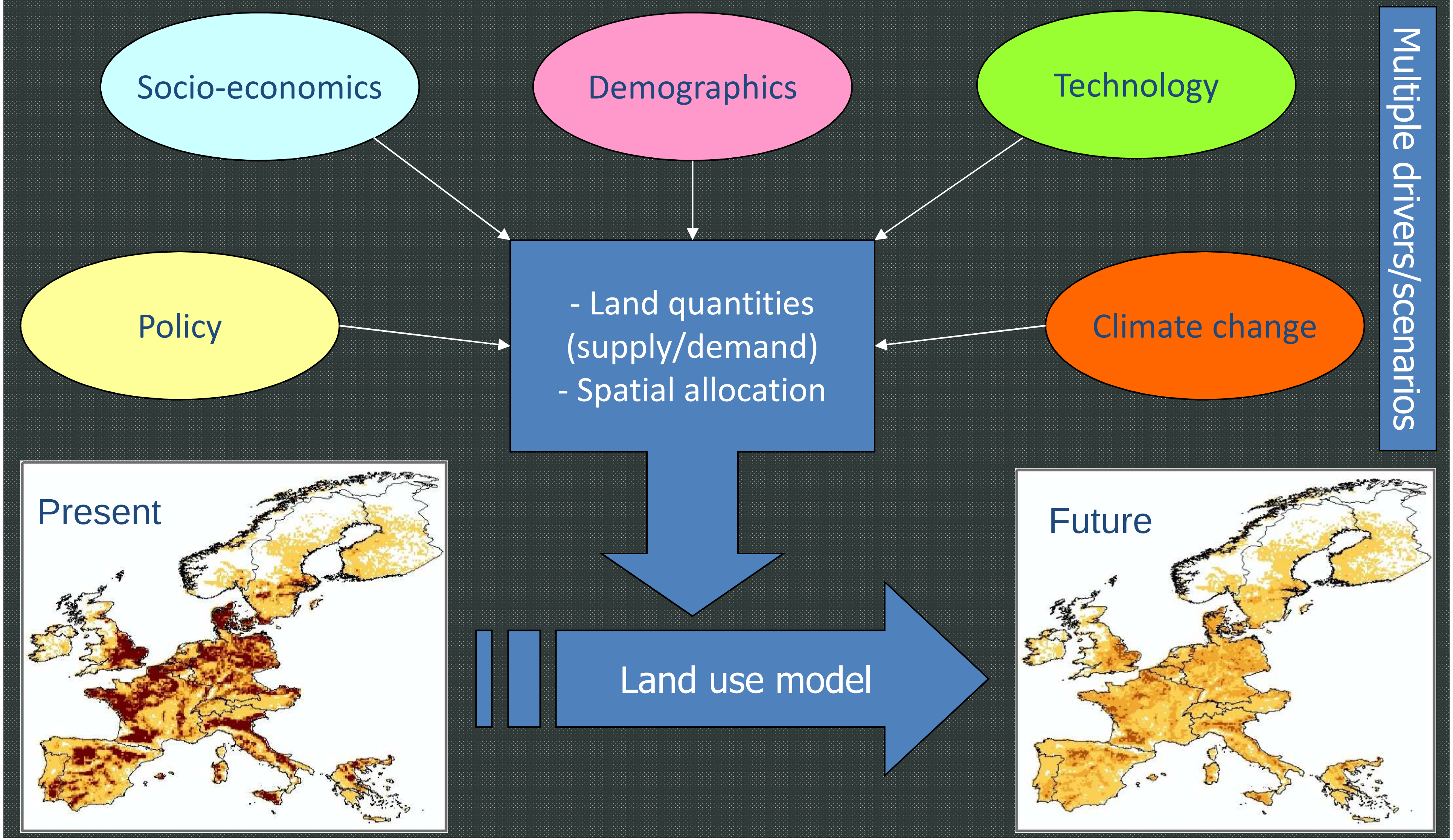
The IPCC SRES* framework





*Special Report on Emissions Scenarios

European land use modelling



European agricultural drivers

Policy	Macro-(socio)economics	
	Demand	Supply
Market intervention (subsidies, quotas)	Population (consumption)	Resource competition (e.g. urban)
Rural development (LFAs)	Consumer preferences (meat, organic)	Climate change (temp, precip, CO_2)
Environmental policy (NVZs, ESAs)	Market liberalisation (WTO)	Technology & management
	EU enlargement	

An agricultural land use (quantity) change model

Based on a simple supply and demand function (Borlaug theory):

$$\frac{L_t}{L_{t_0}} = \frac{D_t}{D_{t_0}} \cdot \frac{P_{t_0}}{P_t} \cdot \frac{O_{r,t}}{O_{r,t_0}}$$

$$L_t = L_{t_0} \cdot \frac{D_t}{D_{t_0}} \cdot \frac{P_{t_0}}{P_t} \cdot \frac{O_{r,t}}{O_{r,t_0}}$$

L …	Agricultural land use *[ha]*
t …	Time
t_0 …	start moment, baseline
D …	Demand for production *[t]*
P …	Productivity *[t/ha]*
O …	Overproduction, relative *[-]*

Unknown Parameters to estimate

After: Rounsevell, M.D.A. Ewert, F. Reginster, I., Leemans, R. and Carter, T.R. (2005). Future scenarios of European agricultural land use. II: projecting changes in cropland and grassland. *Agriculture, Ecosystems and Environment*, **107**, 117-135

Estimated demand changes

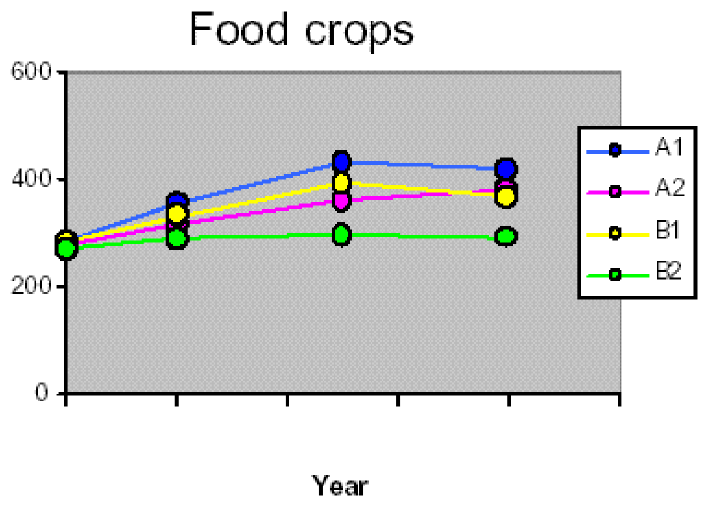
Approach

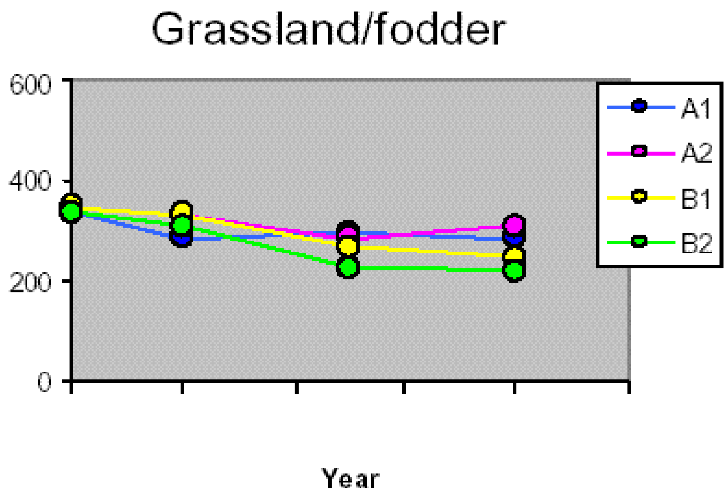
$$\frac{L_t}{L_{t_0}} = \frac{D_t}{D_{t_0}} \cdot \frac{P_{t_0}}{P_t} \cdot \frac{O_{r,t}}{O_{r,t_0}}$$

IMAGE model

Estimated future demand

1 000 000 Gg/yr





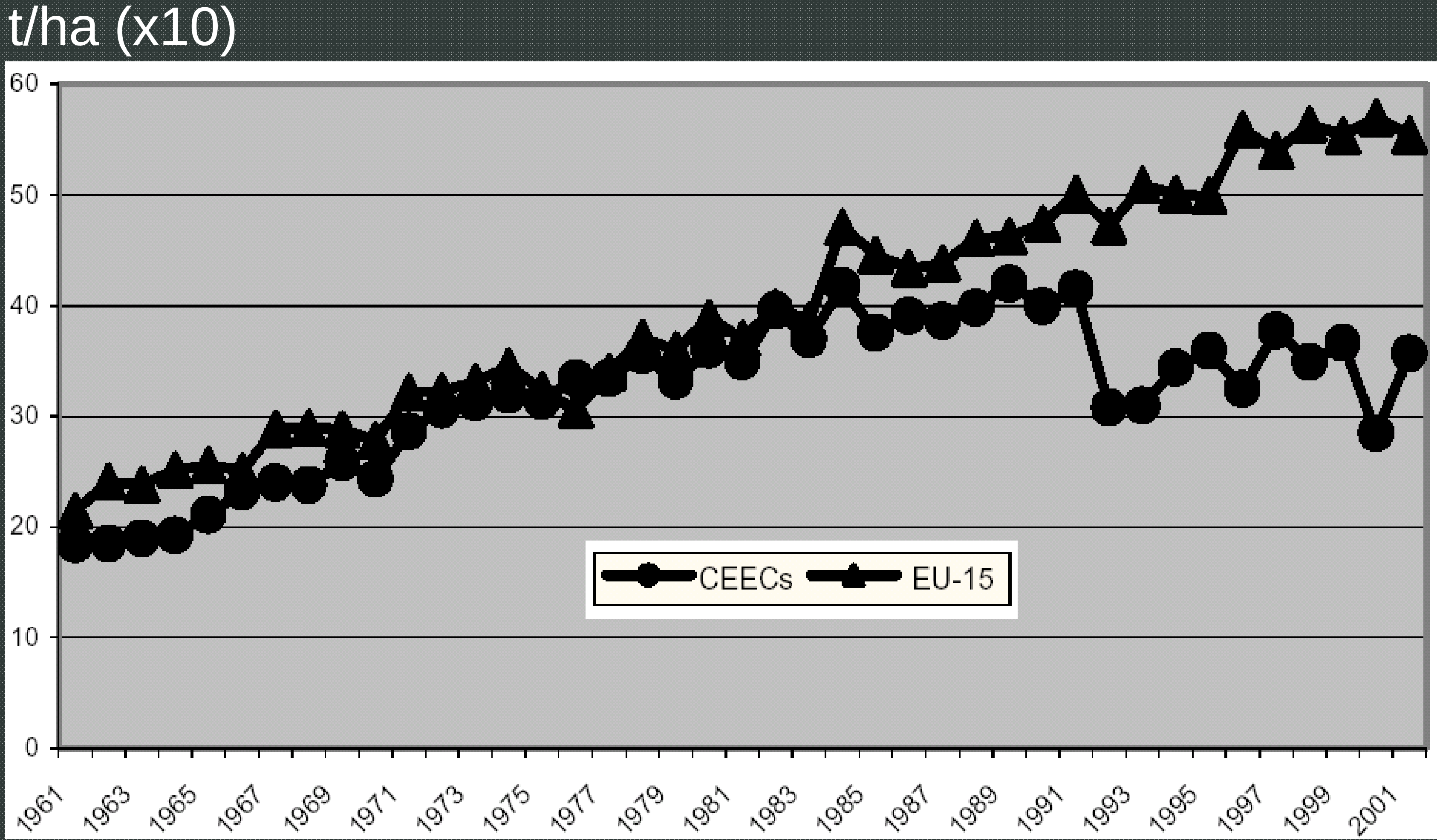
CO_2 effect estimates

- Values for the effect of CO_2 on crop/grass yields estimated from the literature (baseline = 1.00)

Scenario	2020	2050	2080
A1F1	**1.04**	**1.16**	**1.32**
A2	**1.04**	**1.13**	**1.27**
B1	**1.04**	**1.09**	**1.11**
B2	**1.04**	**1.11**	**1.15**

Change in wheat yields

The role of technology

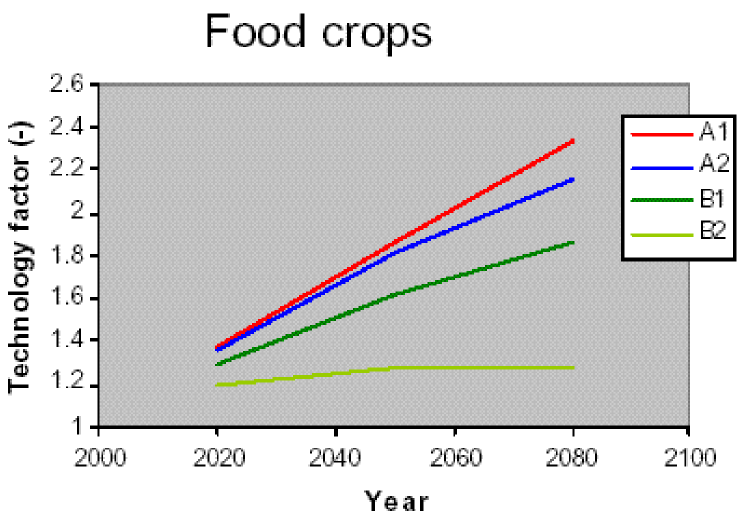


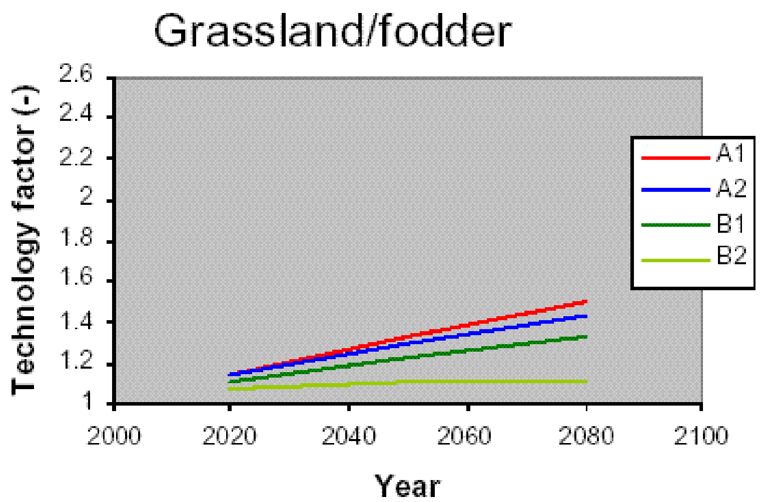
Technology change factors

Approach

$$\frac{P_{t_0}}{P_t} = \frac{1}{1 + ((P_{t,C} / P_{t_0} - 1) + (P_{t,CO_2} / P_{t_0} - 1) + (P_{t,T} / P_{t_0} - 1))}$$

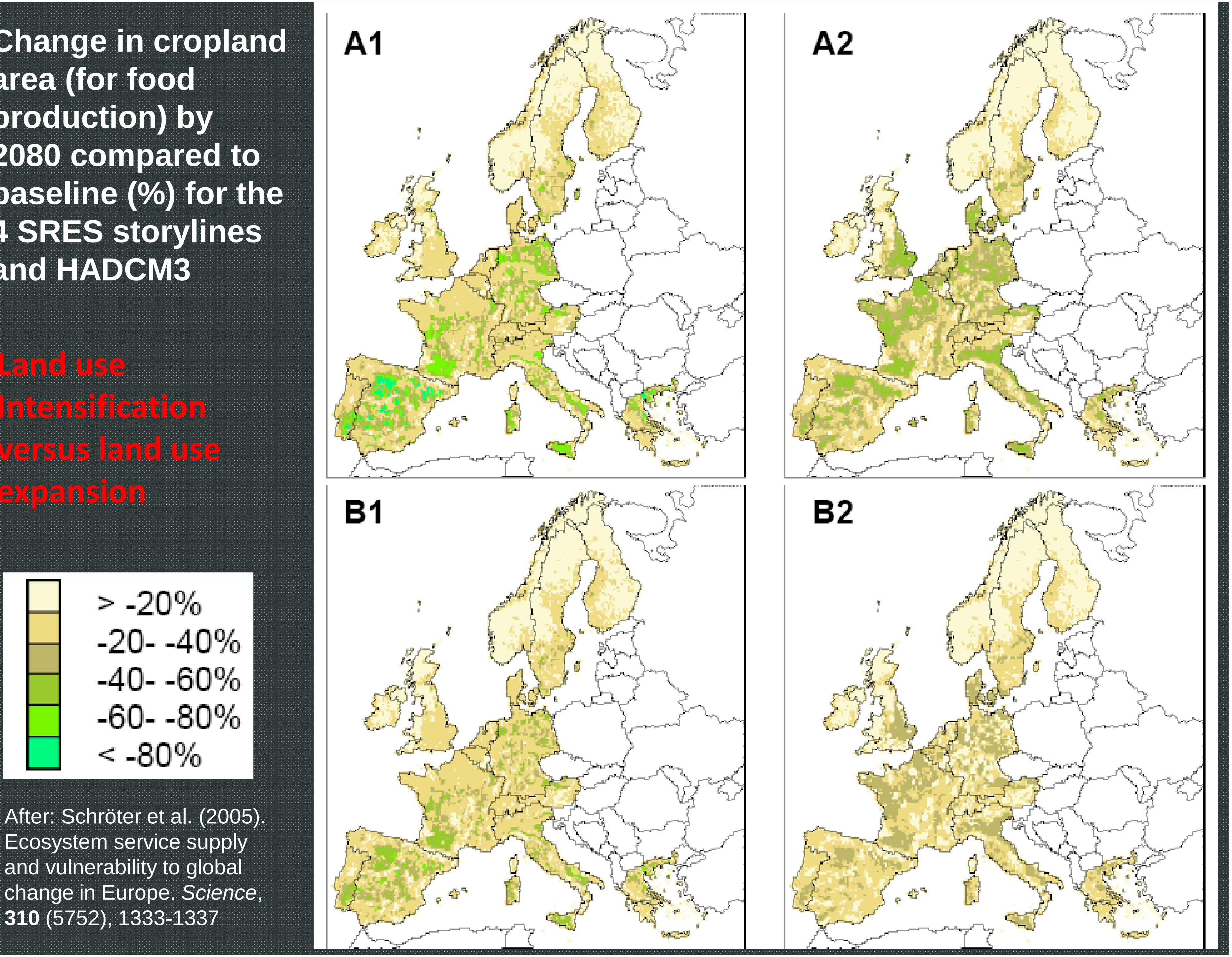
Technology factors





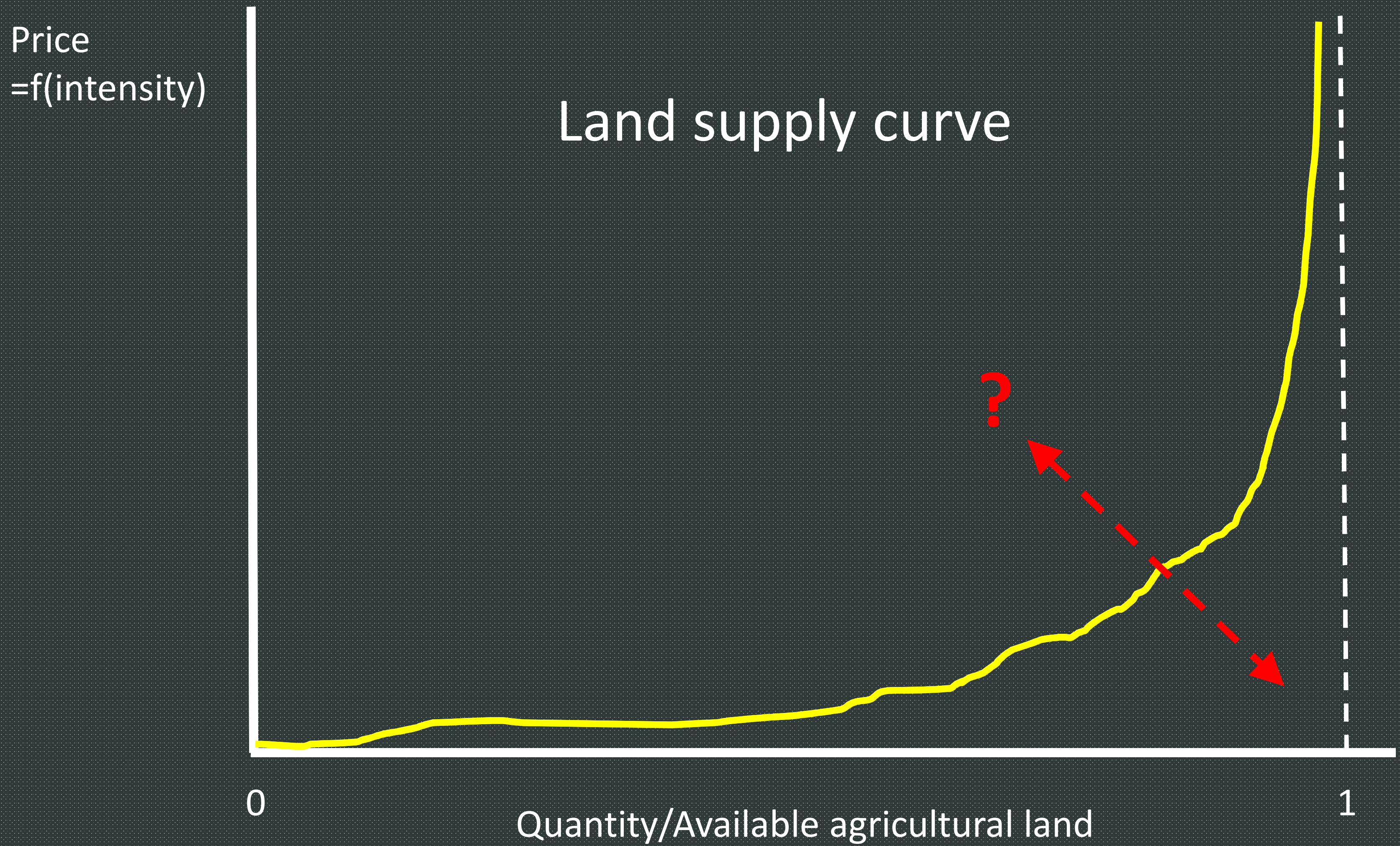
Change in cropland area (for food production) by 2080 compared to baseline (%) for the 4 SRES storylines and HADCM3

Land use Intensification versus land use expansion



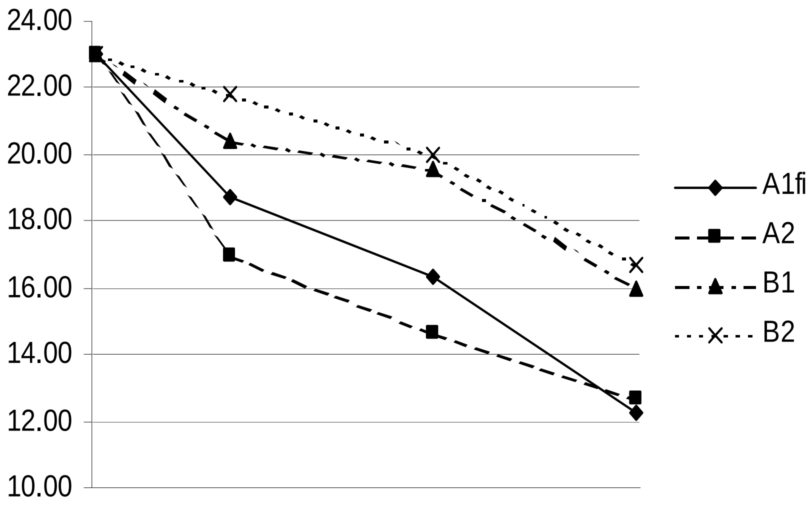
After: Schröter et al. (2005). Ecosystem service supply and vulnerability to global change in Europe. *Science*, **310** (5752), 1333-1337

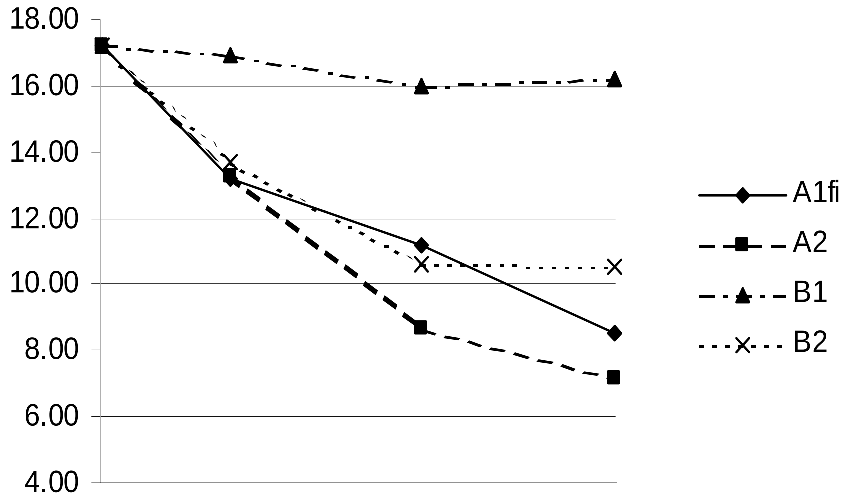
Land use intensification vs expansion



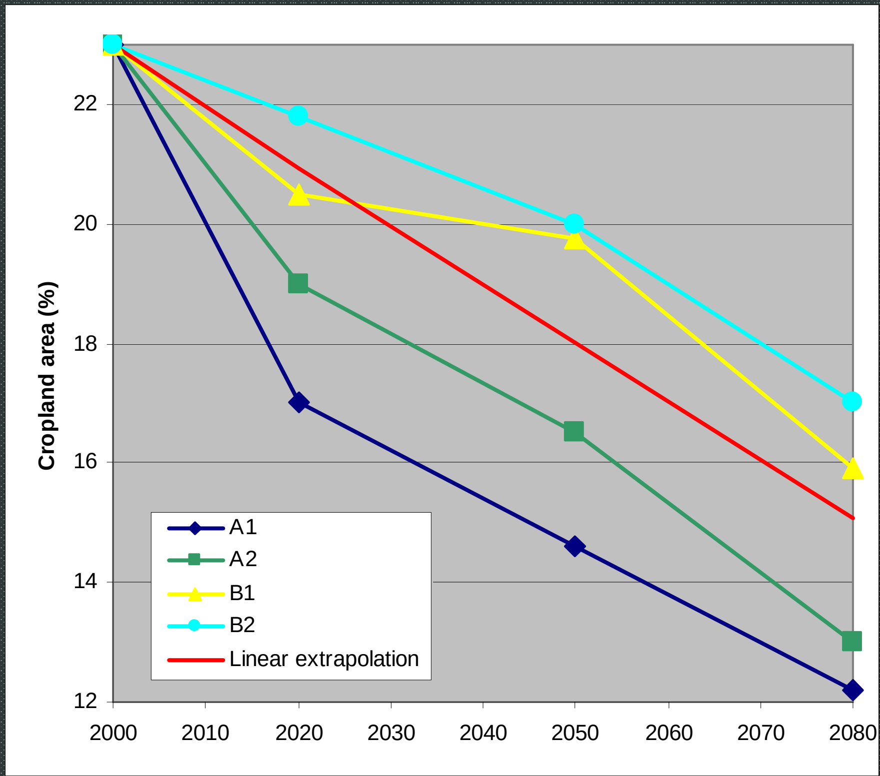
European change quantities

- Ca. 50% declines in agricultural (food) production areas by 2080 (EU15)!

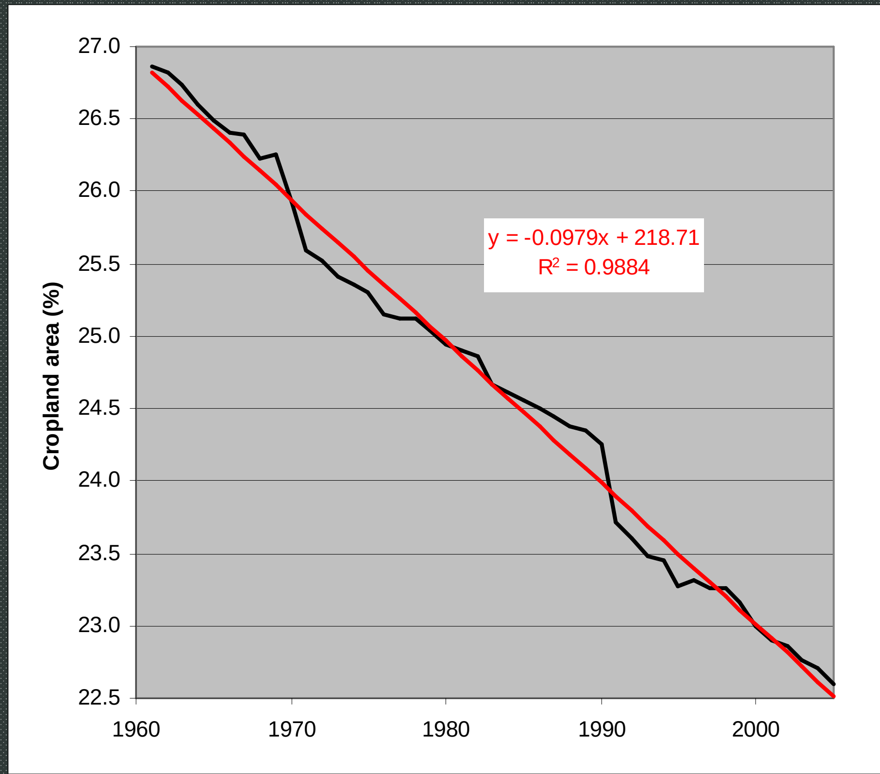




Change in cropland areas within the EU15 (% land surface)

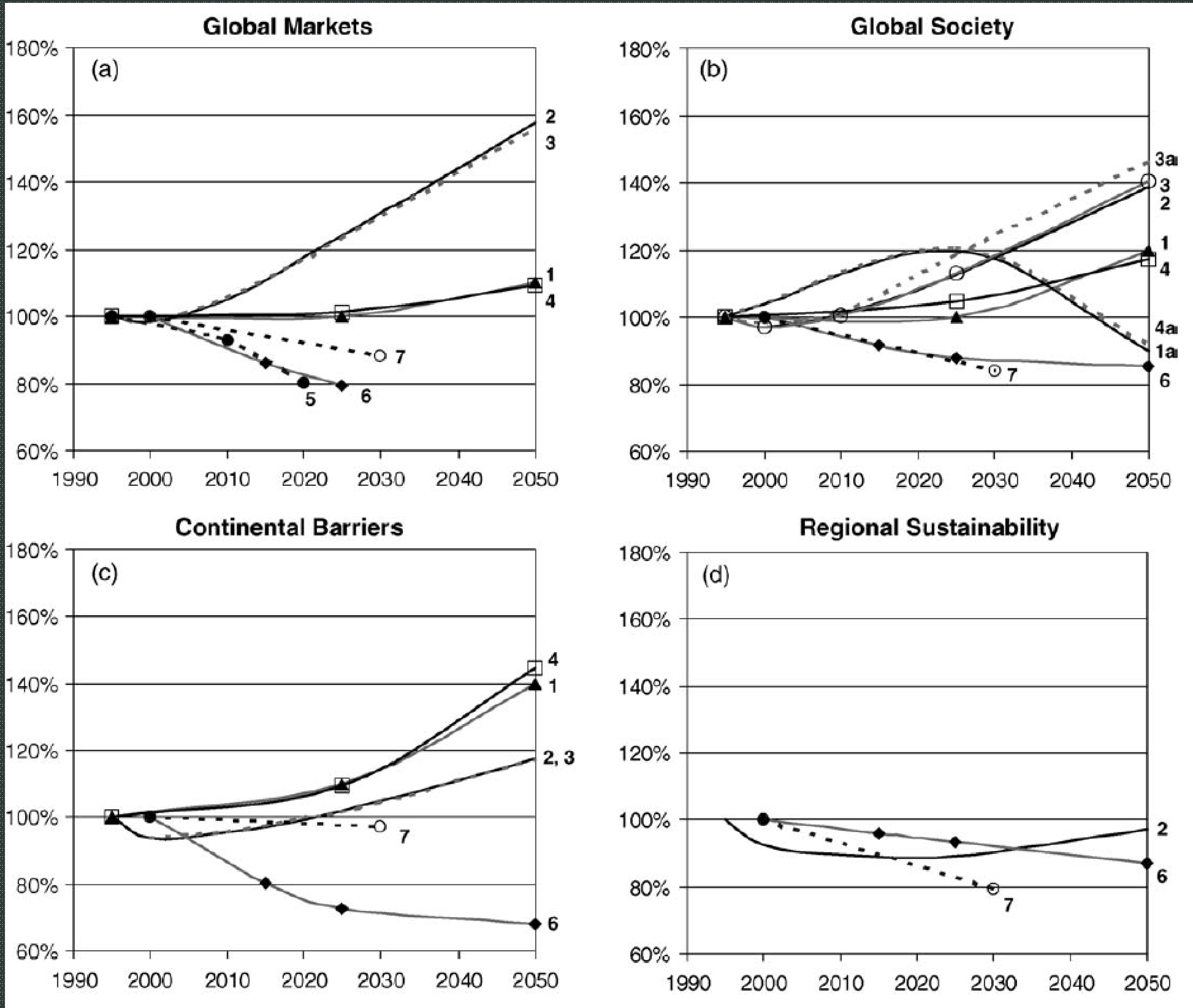


Potential futures (IPCC-SRES)



Past observed (source: FAO)

Change in European cropland areas for a range of scenario studies

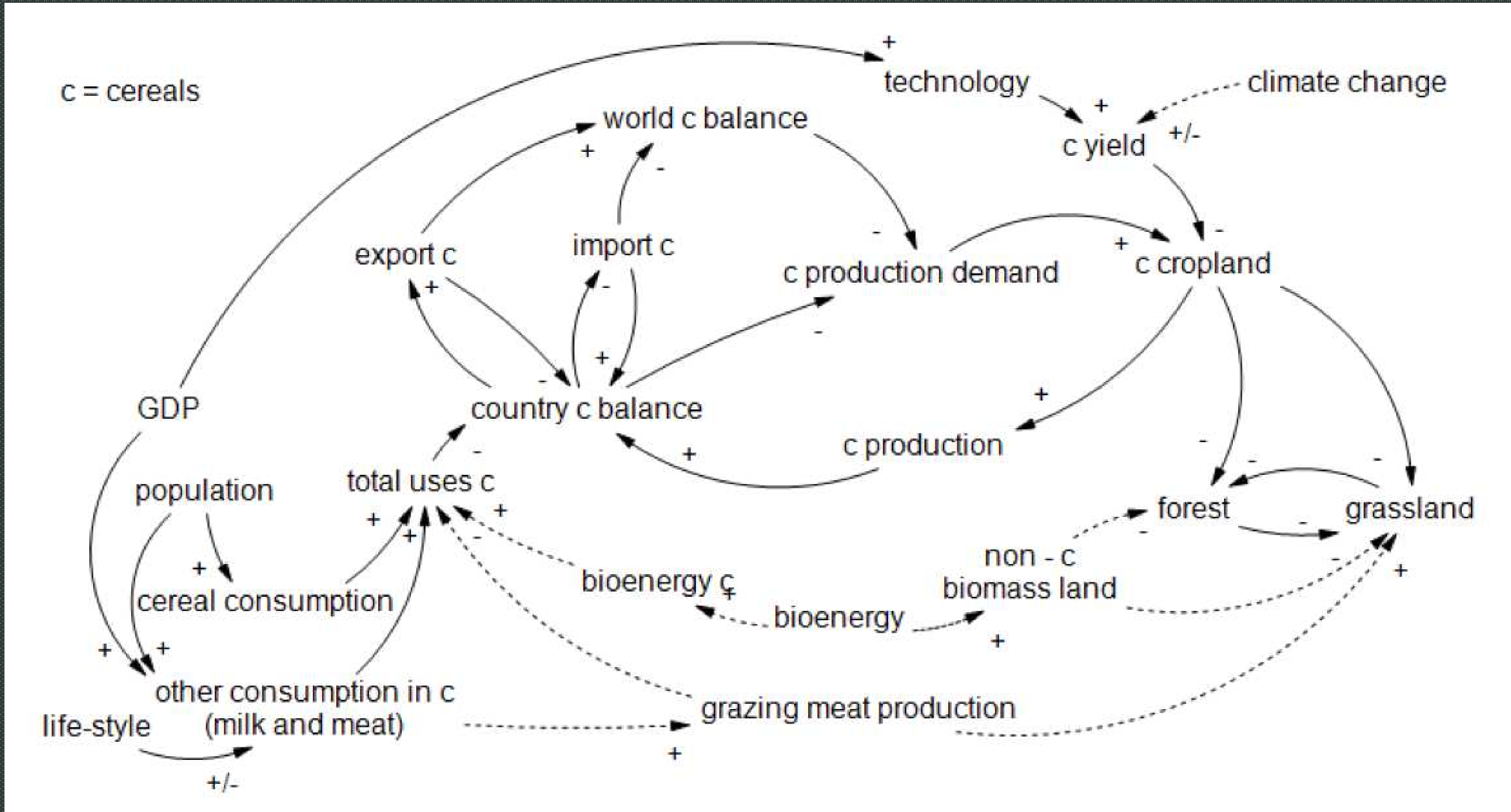


Global studies = 1, 2 (Image), 3, 4, 5

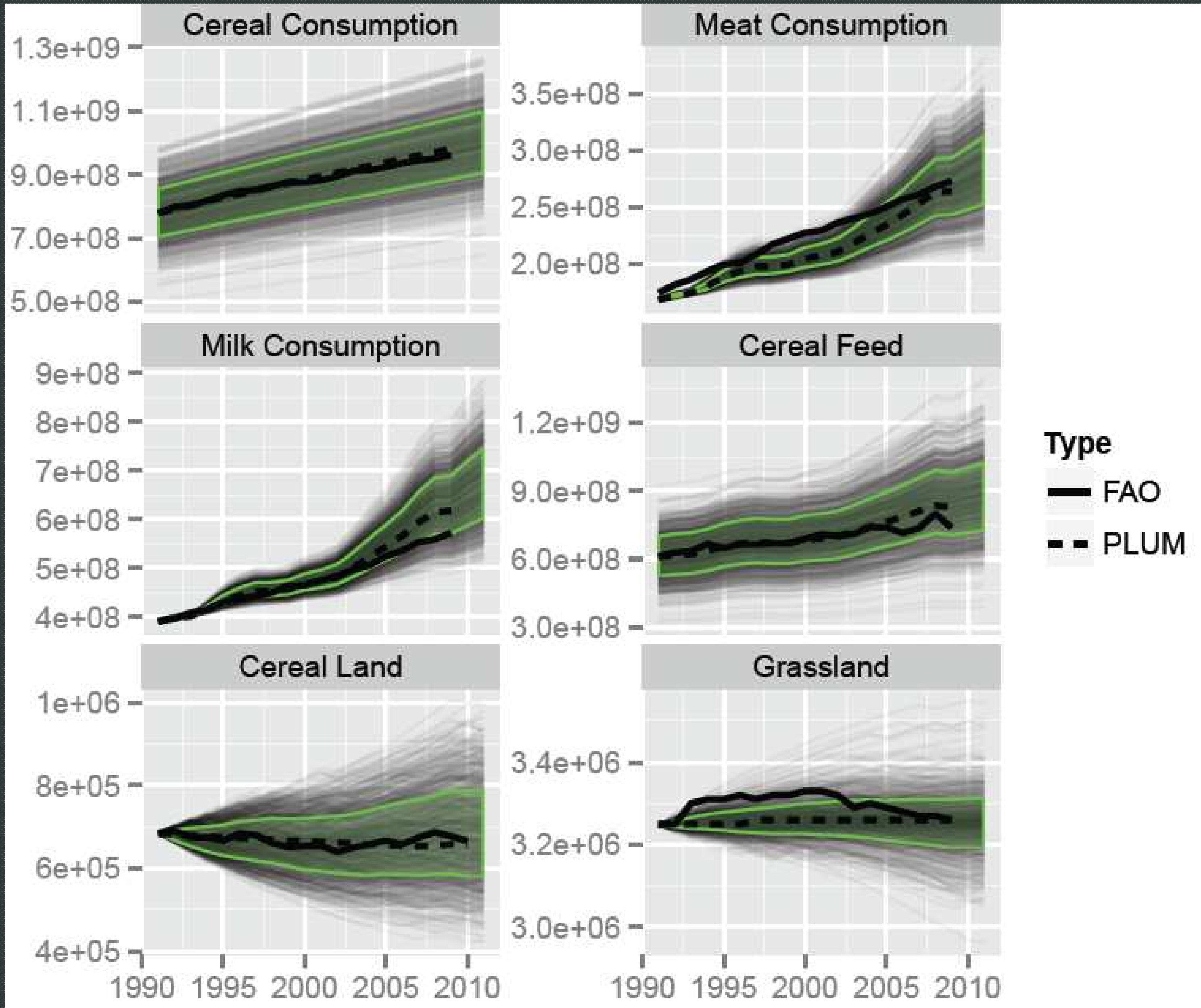
Regional studies = 6 (Ateam), 7 (Eururalis)

Source: Busch, G. (2007). Future European agricultural landscapes - What can we learn from existing quantitative land use scenario studies? *Agriculture, Ecosystems & Environment*

Global land use modelling using PLUM*

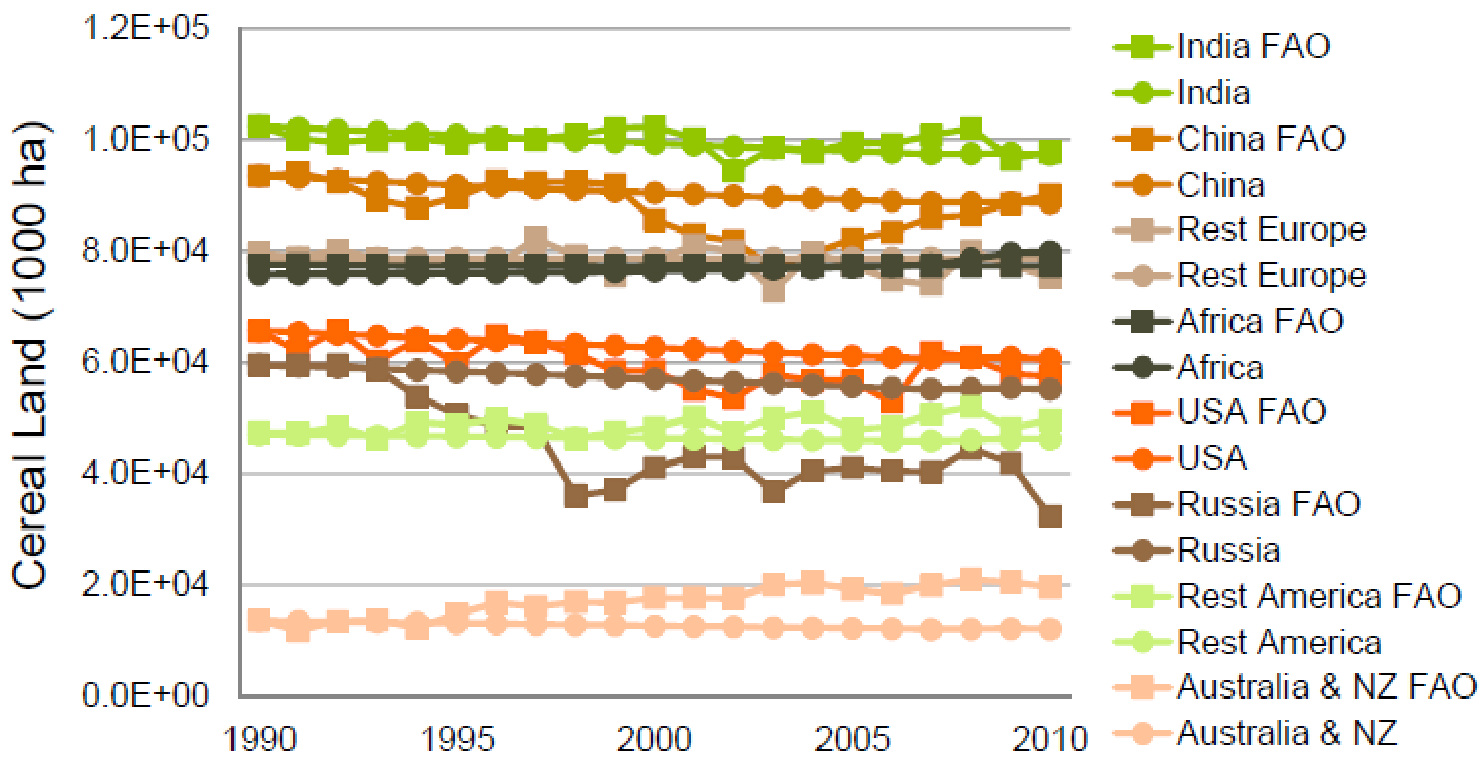


Overview of the concept underpinning *PLUM (Parsimonious Land Use Model) in the form of a causal loop diagram (relationships with dashed lines are not implemented in the current version of PLUM).



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.

Cereal land for regions



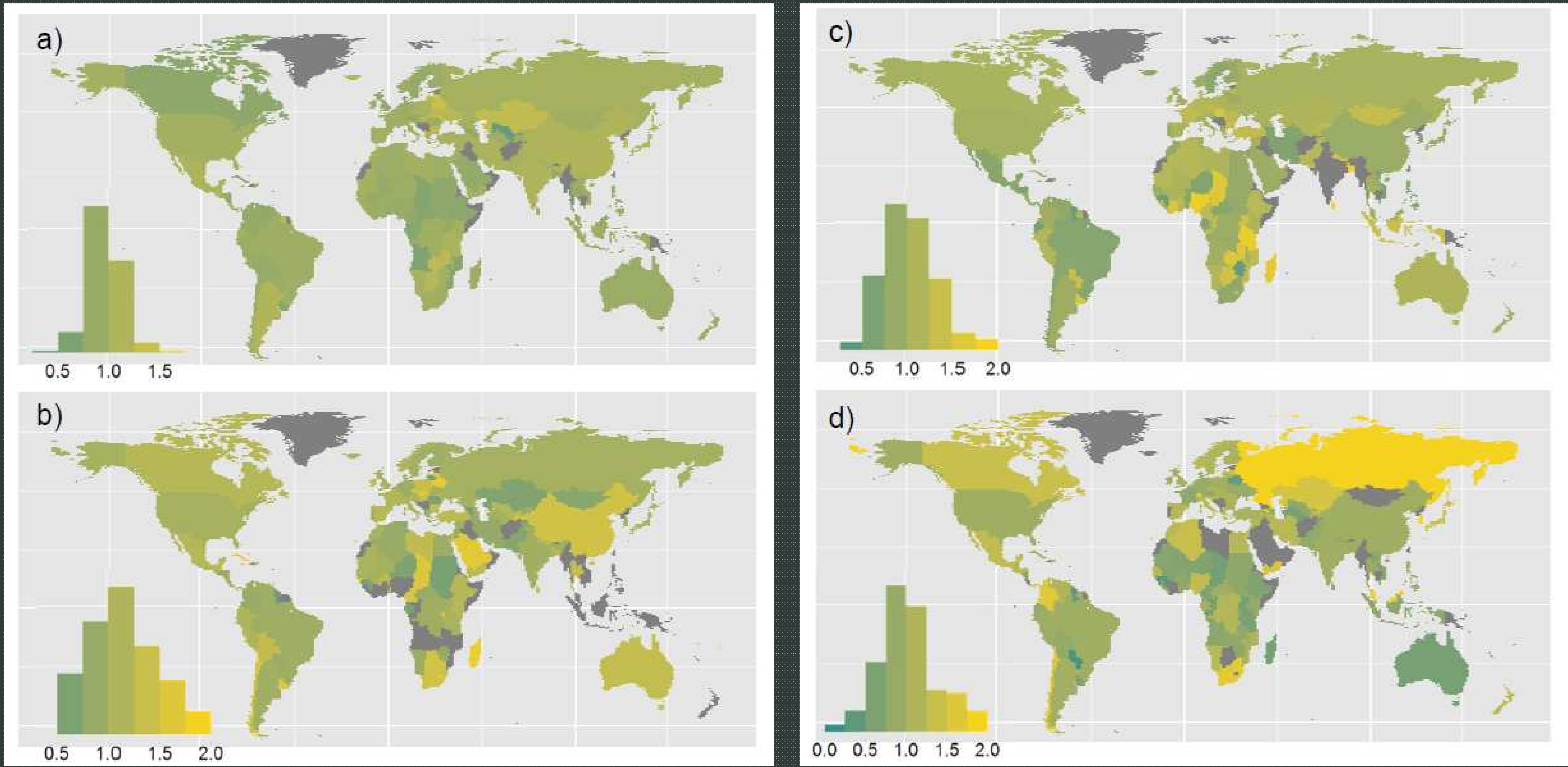
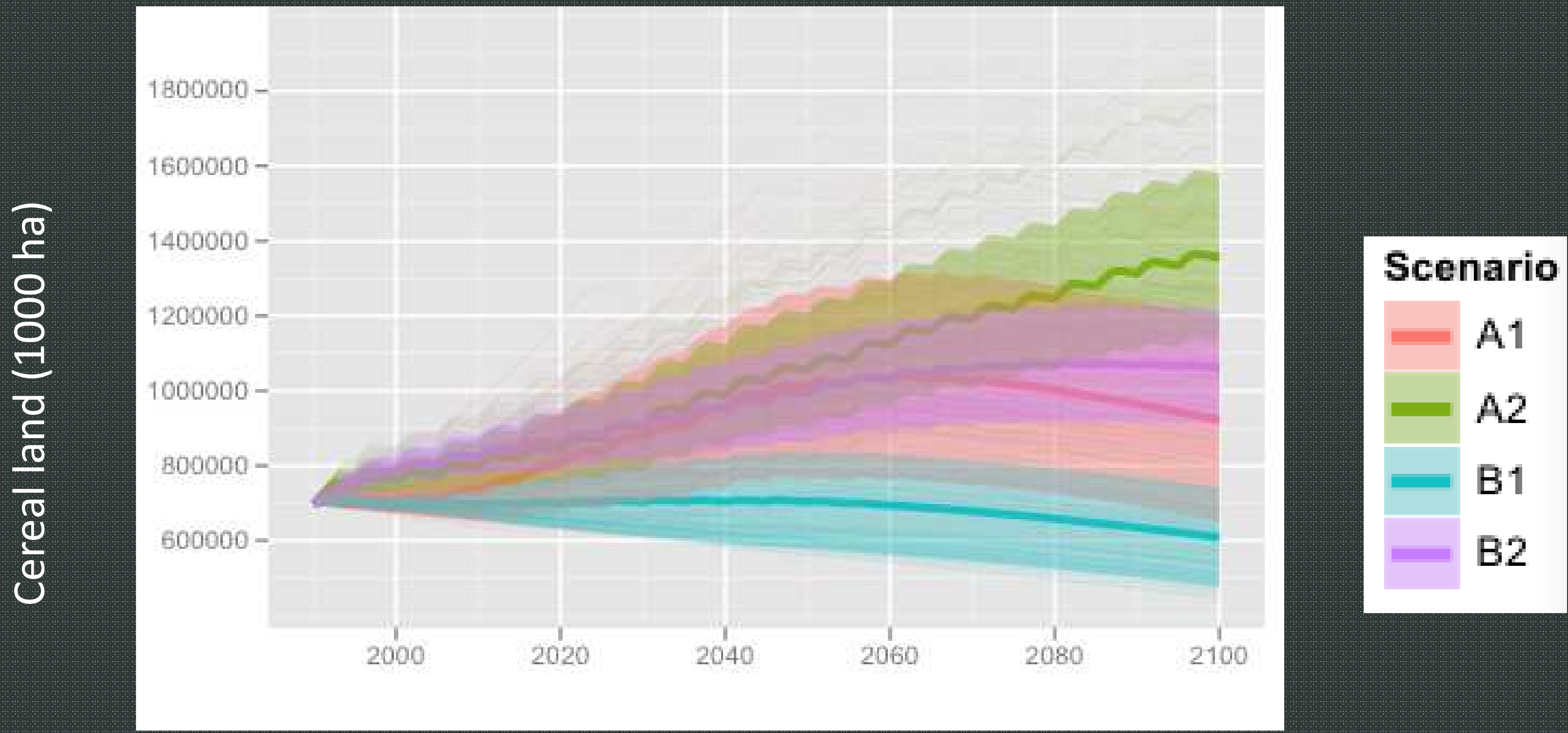
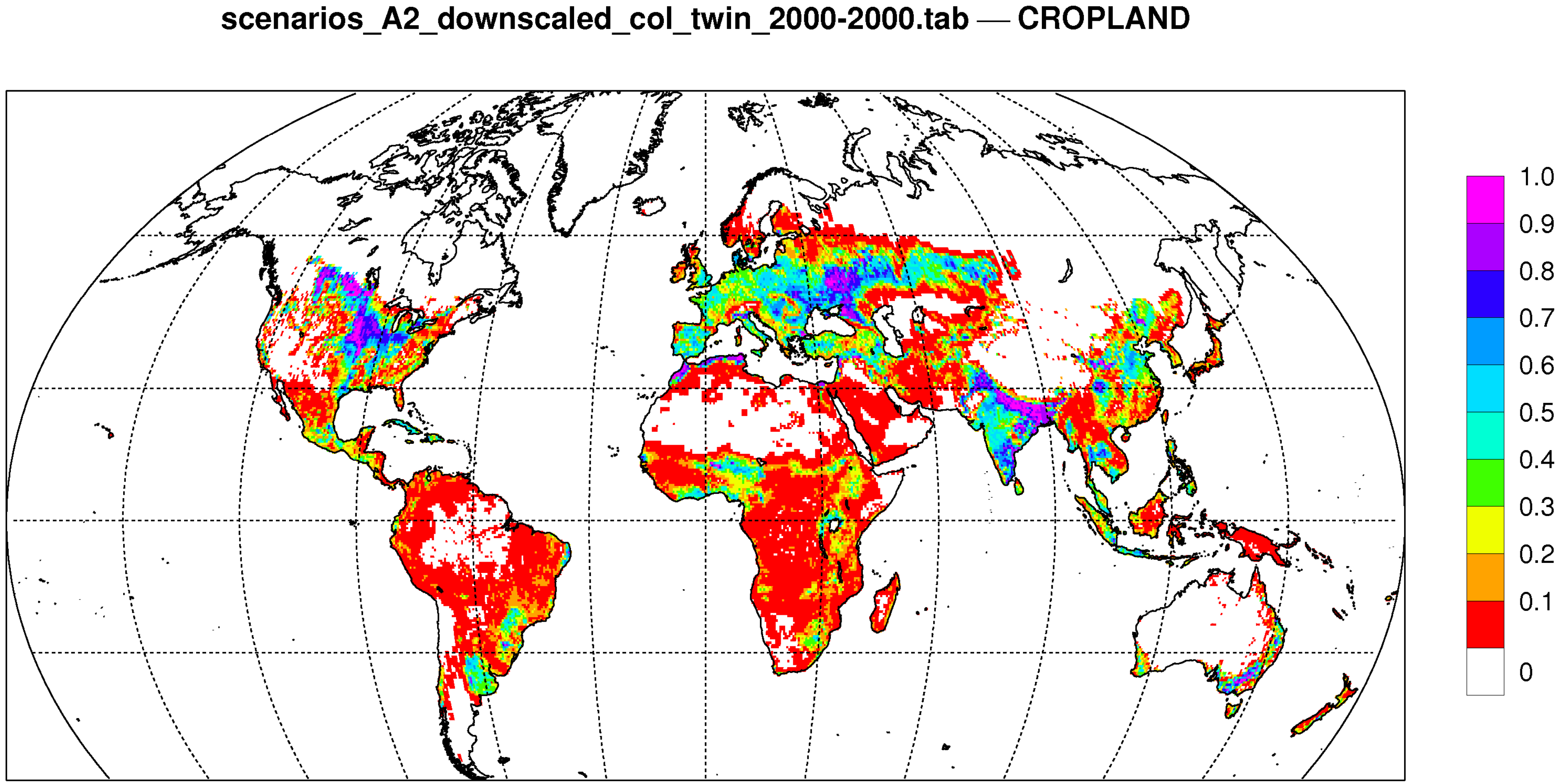


Figure 4: *Rc* for (a) cereal consumption (-), (b) milk consumption (-), (c) meat consumption (-), (d) cereal land (-) in 2009. The colour codes on the maps match the distribution of *Rc* shown in the histogram in the left-hand corner of each panel. Counties for which the model overestimates are more than double the observed and countries that are not included in the model (see Appendix A) are displayed in grey.

Scenario quantifications

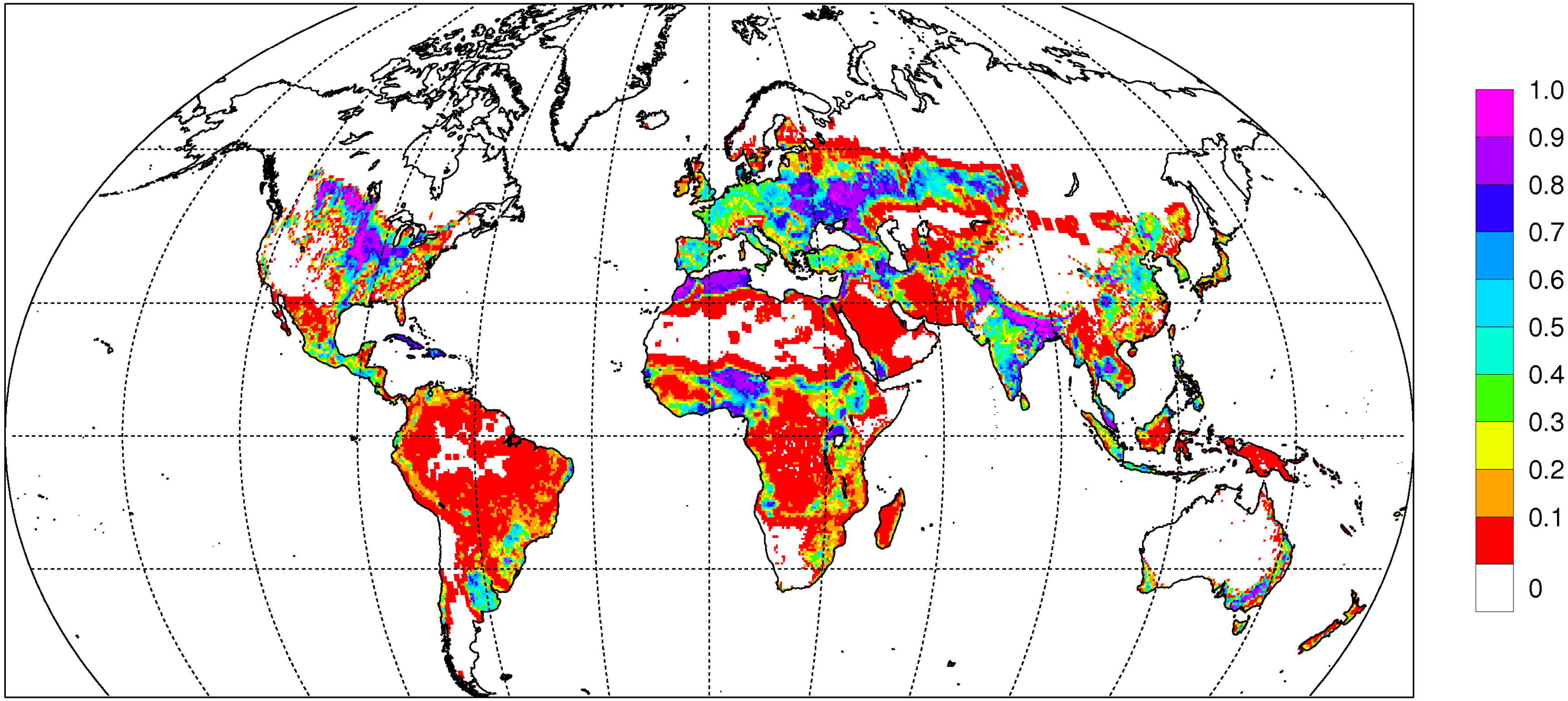


NPP and 8 neighbours

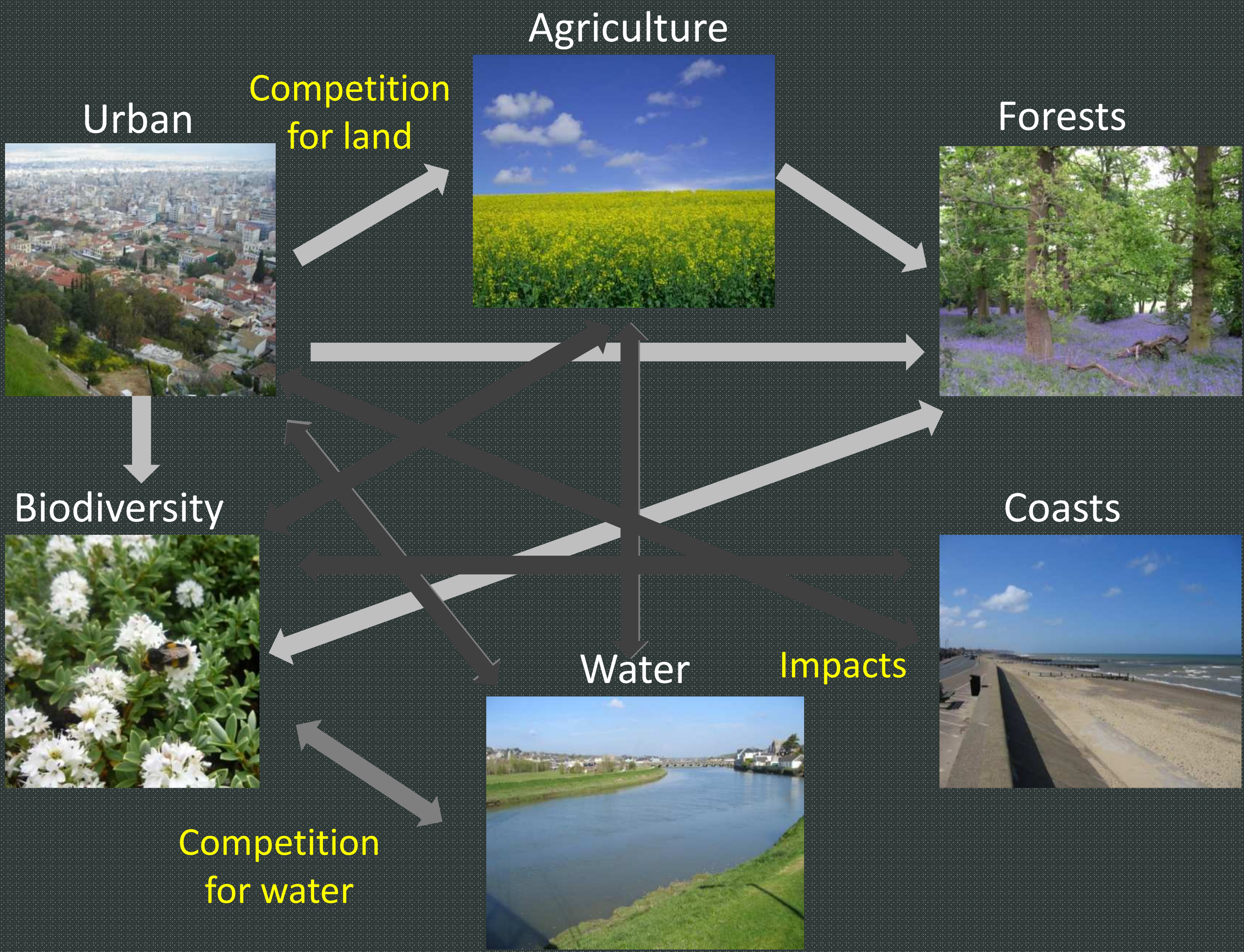


NPP and 8 neighbours

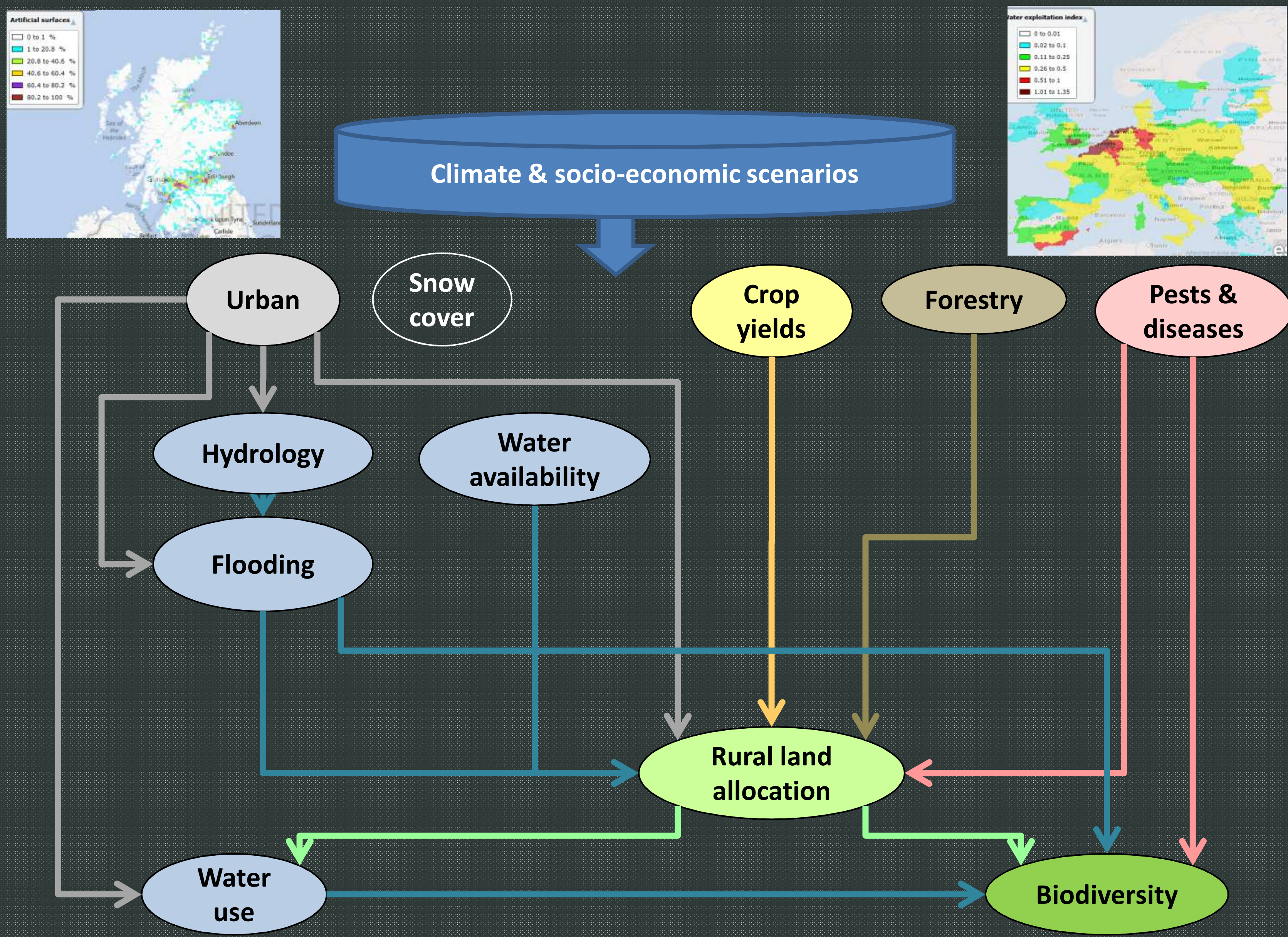
scenarios_A2_downscaled_col_twin_2050-2050.tab — CROPLAND



CLIMSAVE integrated assessment platform



Simplified cross-sectoral linkages



The CLIMSAVE IAP

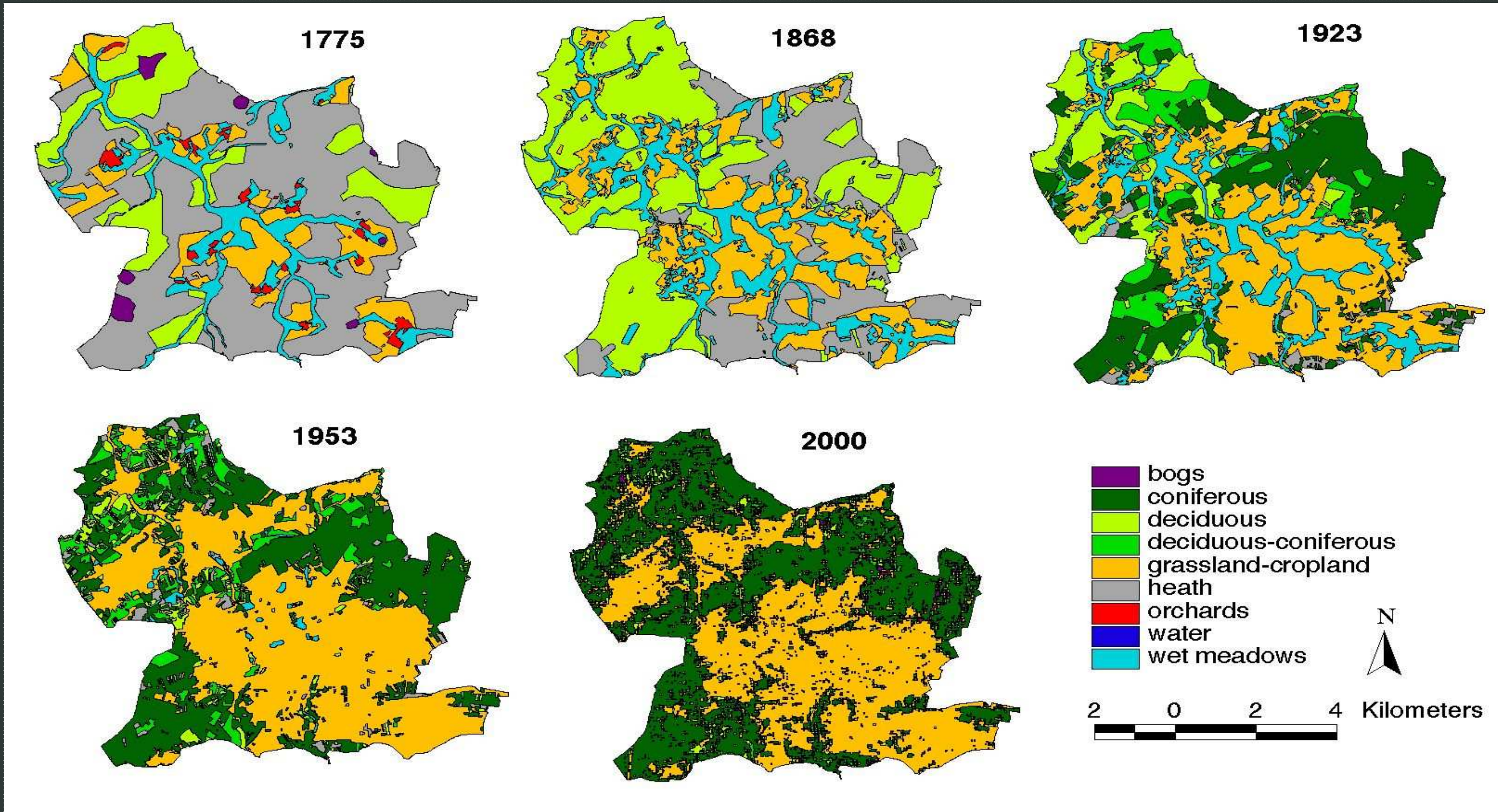
Any questions?

THE UNIVERSITY *of* EDINBURGH
Global Environment & Society Academy

Human Behaviour in Land System Models

Professor Mark Rounsevell, School of Geosciences

Past land cover change (1775-2000) in Lierneux (Belgian Ardennes)

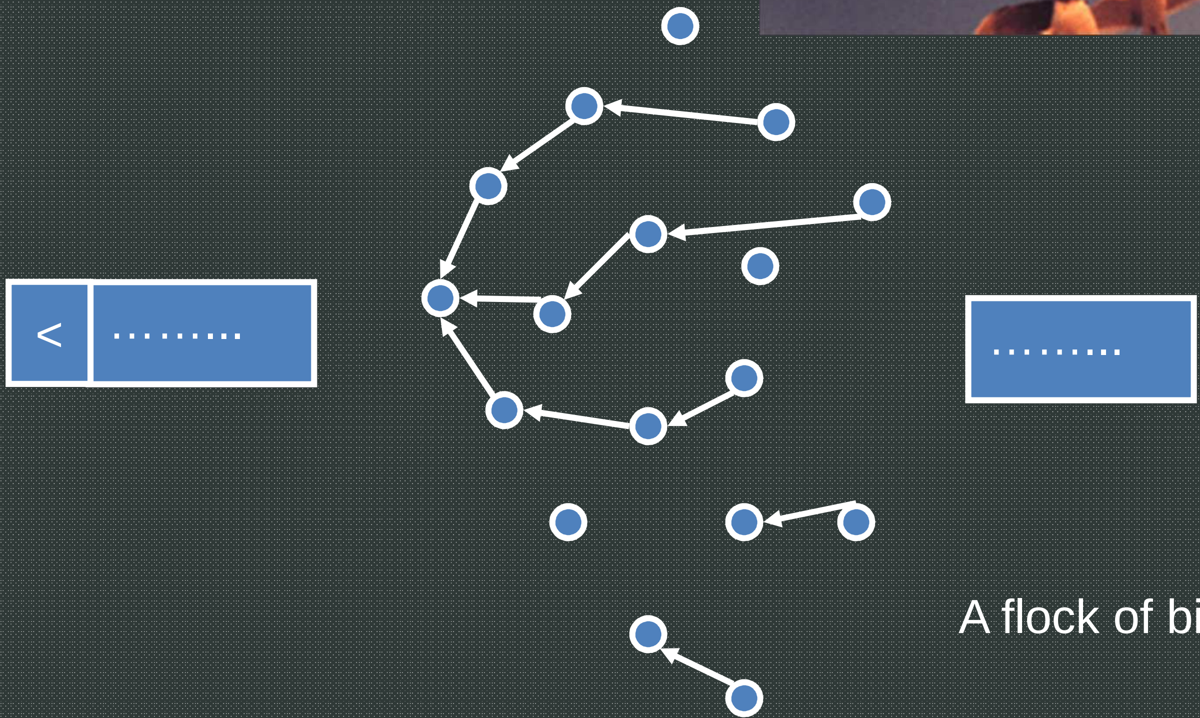


Change drivers: depopulation, accessibility/transport, economics (competition, …)

(Source: Carine Petit, thèse de doctorat, UCL, 2001)

FLOCK OF BIRDS

An example of a *self-organising system*



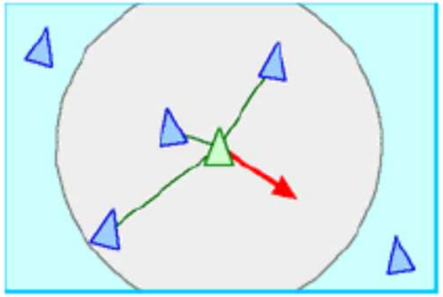
A flock of birds

Flocking

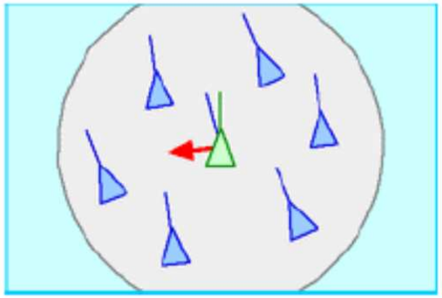
http://vimeo.com/16583119

Boids

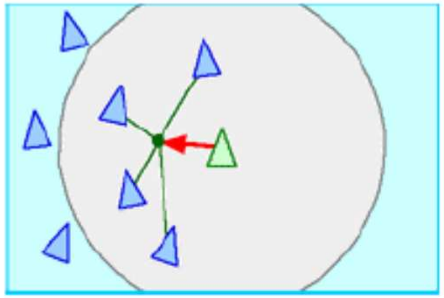
- developed by Craig Reynolds in 1986 (for SIGGRAPH)
- aimed to simulate complex flocking behaviour with simple rules



Don't get too close to others



Folow average heading



Move towards average position

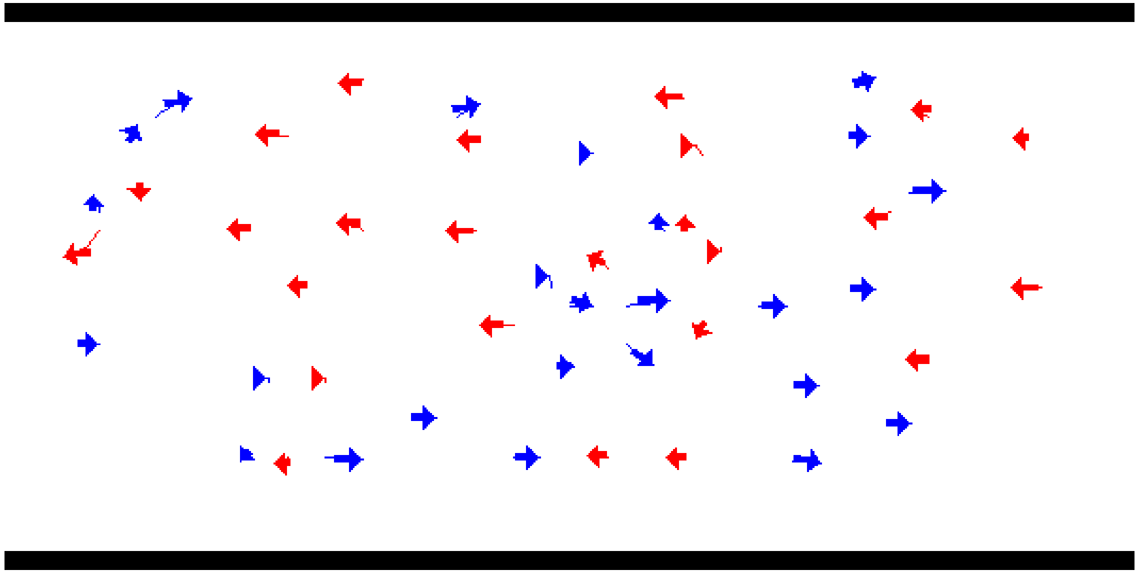
(images from http://www.red3d.com/cwr/boids/index.html, which has many interesting links)

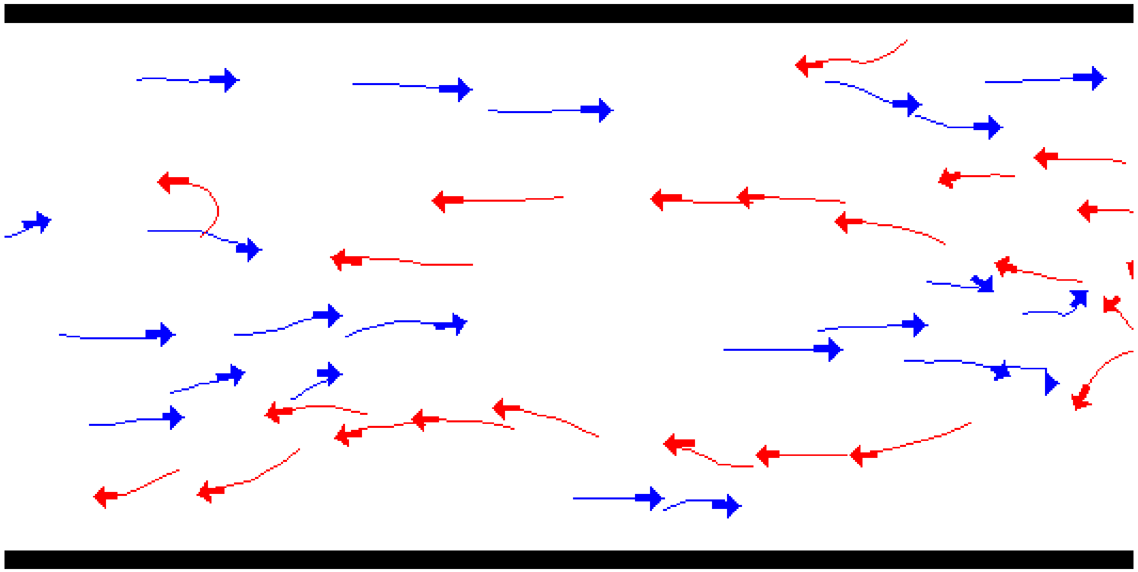
Demo at http://www.theparticle.com/applets/swarm/FlockingSwarmWithControls/index.html

http://www.theparticle.com/applets/swarm/FlockingSwarmWithControls/index.html

Lane Formation in a Street

This applet demonstrates how lanes of uniform walking direction form in a street:





Sheep grazing in Norway

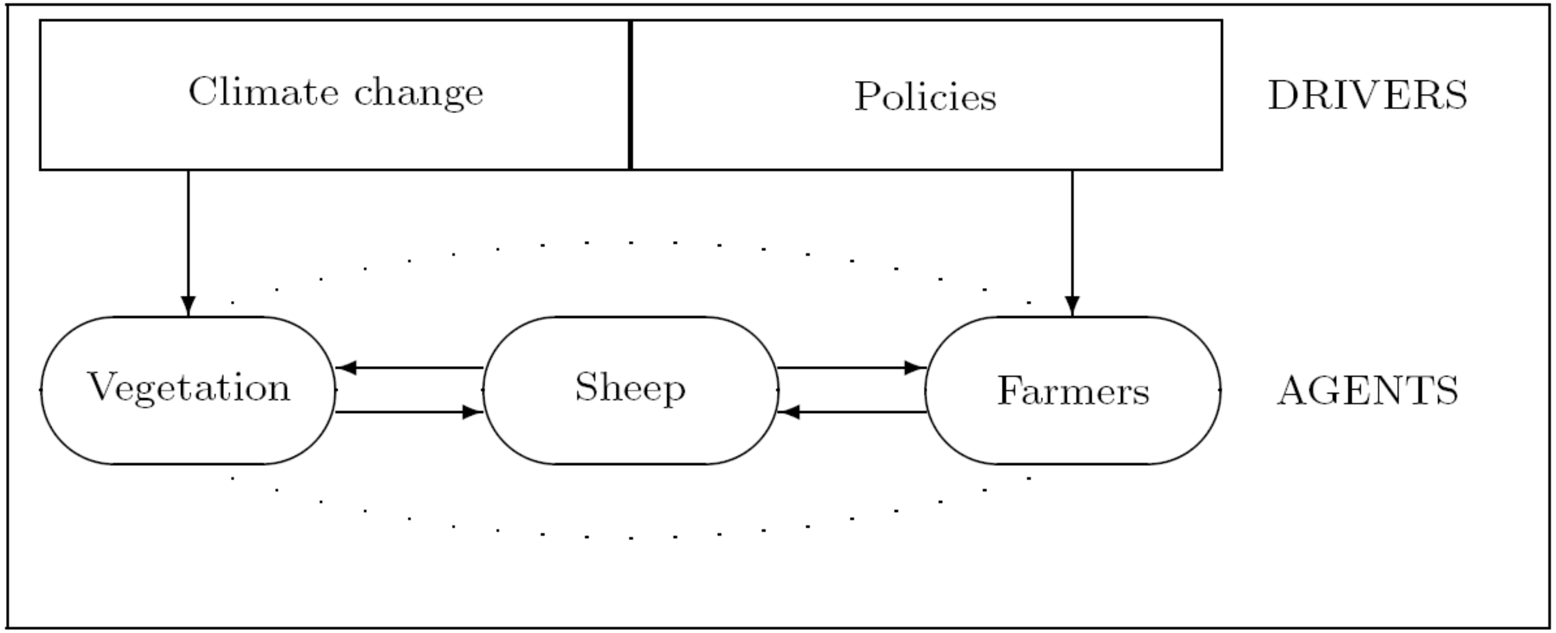
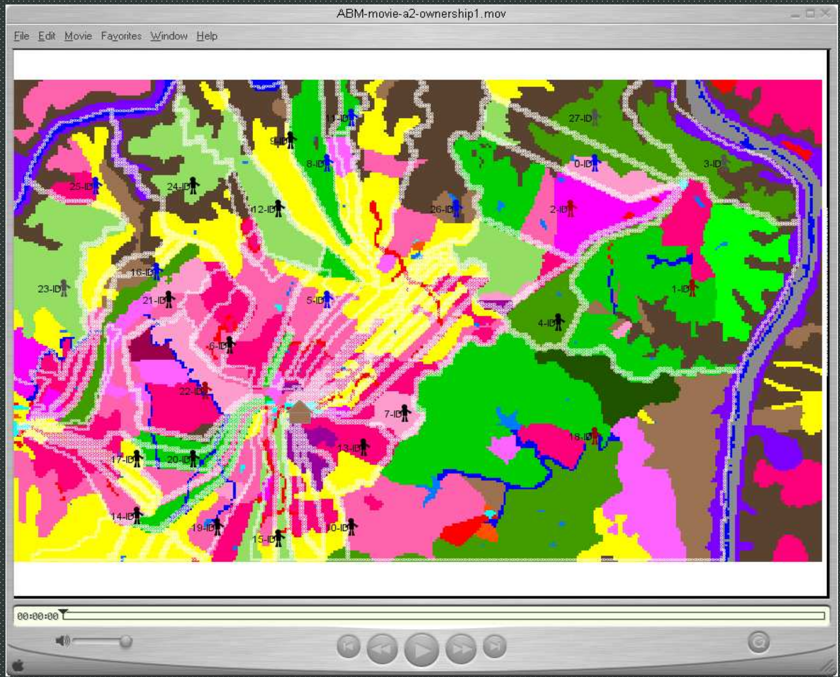
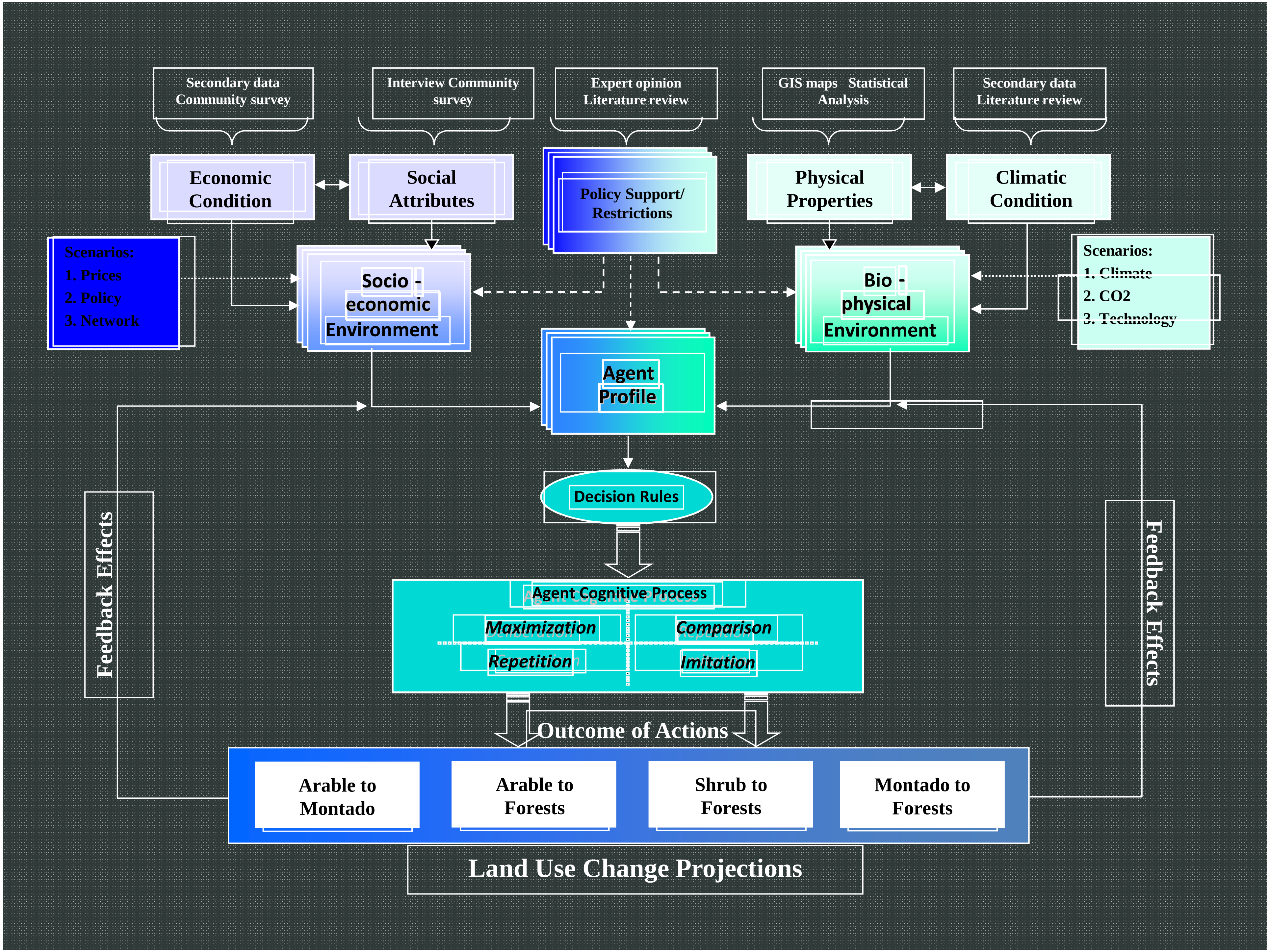


Figure 2: Conceptual framework of the Norway model

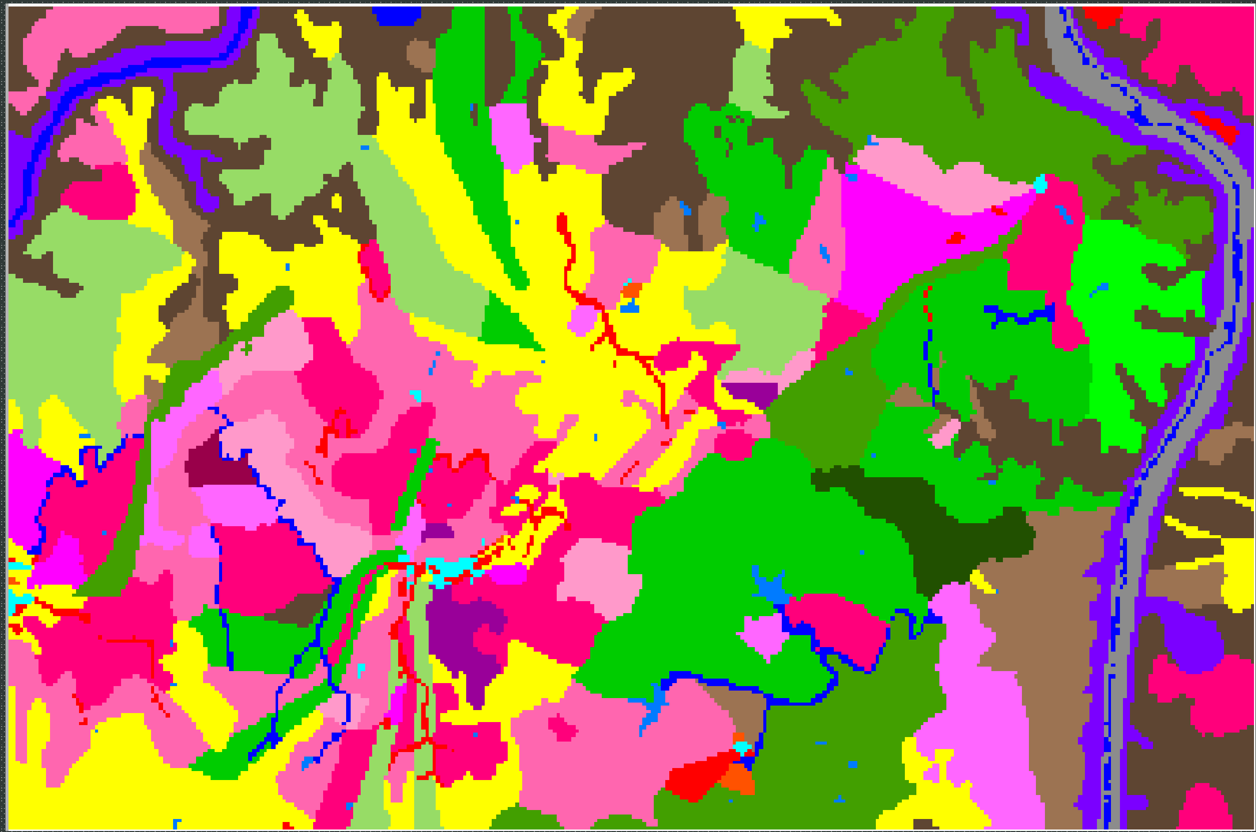
Source: David Dabin. A simple model to demonstrate the principles, which currently lacks the human dimension (work in progress)


ABM-movie-a2-ownership1.mov
File Edit Movie Favorites Window Help
00:00:00


Secondary data Community survey
Interview Community survey
Expert opinion Literature review
GIS maps Statistical Analysis
Secondary data Literature review
Economic Condition
Social Attributes
Policy Support/ Restrictions
Physical Properties
Climatic Condition
Scenarios:
1. Prices
2. Policy
3. Network
Socio - economic Environment
Bio - physical Environment
Scenarios:
1. Climate
2. CO2
3. Technology
Agent Profile
Decision Rules
Feedback Effects
Feedback Effects
Agent Cognitive Process
Maximization
Comparison
Repetition
Imitation
Outcome of Actions
Arable to Montado
Arable to Forests
Shrub to Forests
Montado to Forests
Land Use Change Projections

Agents' environment

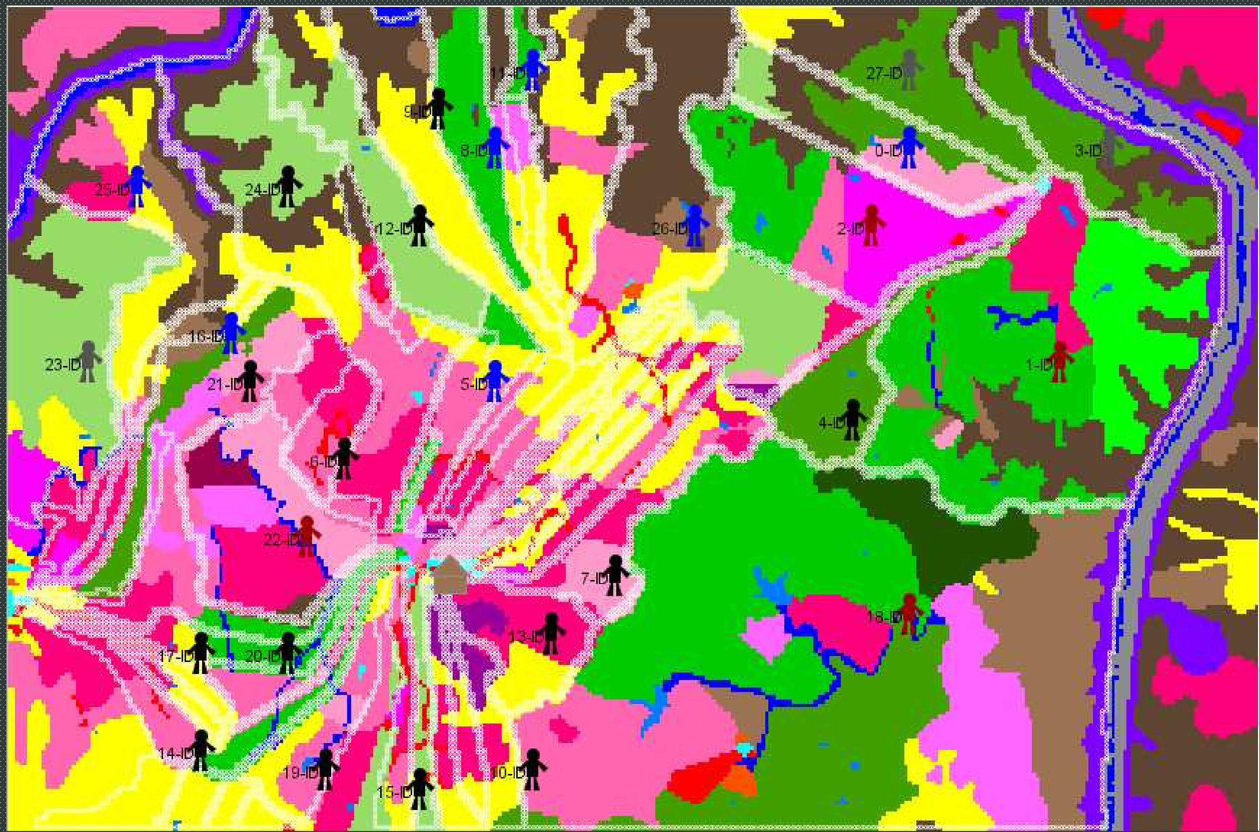
Land use map (2000):



Legend:
agro-sylvo pastoral – magenta
arable or pasture – yellow
forest plantations – green
dense shrubs – dark brown
natural pasture with some
mixed forest – lime
shrubs – brown
olive groove – red
horticulture – orange
waterlines – blue
reservoirs – sky blue
bare rocks – gray
mediterranean shrubs – violet
hamlet and farm buildings – cyan

Agents' profile and cognition

Farmers and Ownership:



Legend:
Innovative – red
Active – blue
Absentee – gray
Retiree – black

Social attributes
1. age
2. residence
3. education
4. profession

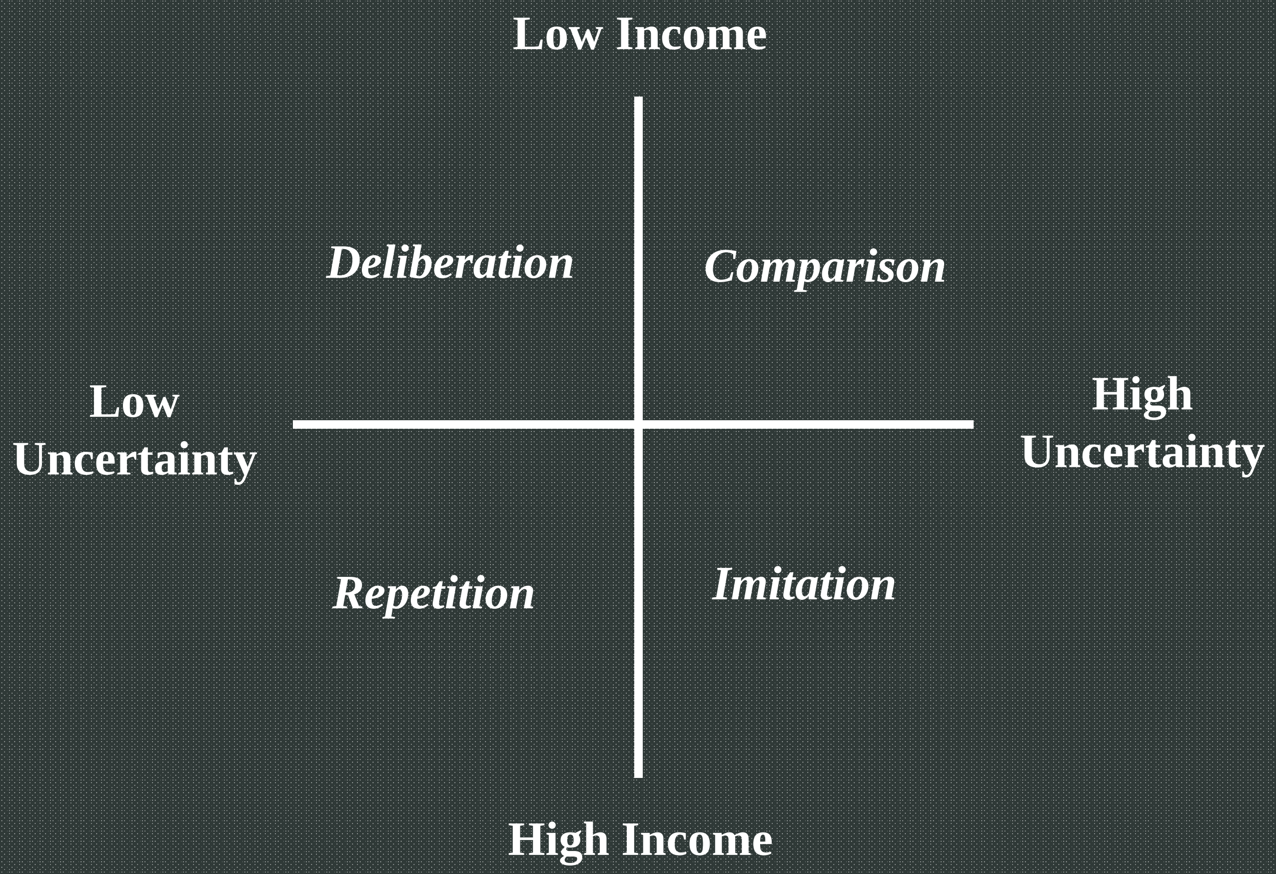
Economic attributes
1. farm size
2. income source
3. number workers
4. available successor

ABM: agents' attributes

Profiles of the reactive agents:

Code	name	hectares	age	gender	educa	prof	residence	time	start	obtain	hect	pers	succ	sell	basis	markt
ADS1	Maria do Carmo Sa	127	4	"M"	1	2	1	"P"	1	"I"	3	"N"	"Y"		"F"	
AdS10	Manuel Guerreiro C	136	4	"M"	1	1	1	"F"	3	"I"	3	"N"	"Y"		"L"	
AdS11	Arsénio Colaço	149	3	"M"	1	1	1	"F"	2	"I"	1	"N"	"N"		"L"	
AdS12	Manuel António Pa	107	2	"M"	4	1	2	"F"	1	"I"	2	"Y"	"N"		"L"	
AdS13	Fernando da Luz F	187	4	"M"	1	1	1	"F"	2	"I"	3	"N"	"N"		"L"	
AdS14	Manuel Colaço	14	3	"M"	1	2	2	"P"	2	"I"	1	"N"	"N"		"L"	
AdS15	Fernando e Xico P	31	2	"M"	1	2	2	"P"	3	"I"	2	"N"	"Y"		"L"	
AdS16	Maria Rosa	42	4	"F"	1	1	1	"F"	3	"I"	1	"N"	"N"		"R"	
AdS17	Claudia Melo	140	2	"F"	4	2	2	"P"	1	"B"	3	"Y"	"Y"		"L"	
AdS18	José Madeira	78	3	"M"	1	2	2	"P"	2	"I"	2	"Y"	"N"		"C/H"	
AdS19	Luis Claudino	159	3	"M"	3	2	3	"F"	2	"B"	3	"N"	"Y"		"F"	
ADS2	Francisco António	73	4	"M"	1	1	1	"F"	3	"I"	2	"Y"	"Y"		"NONE"	
AdS20	Manuel Fabião	780	2	"M"	2	1	2	"F"	2	"B"	4	"Y"	"Y"	N	"H"	O
AdS21	Manuel da Graça	20	4	"M"	1	1	1	"F"	3	"I"	1	"N"	"N"	Y	"R"	I
AdS22	Leonel Belchior	343	3	"M"	3	1	2	"F"	2	"B"	3	"Y"	"N"	N	"F/L/M"	O
AdS23	José Gasparo Mac	167	4	"M"	1	1	3	"P"	2	"I"	3	"Y"	"Y"	N	"F"	N
AdS24	Paula Madeira & A	101	2	"F"	3	2	3	"P"	1	"I"	3	"Y"	"Y"	N	"F"	L
AdS25	Manuel Madeira	144	3	"M"	4	1	2	"F"	2	"I"	3	"Y"	"Y"	N	"F/L"	I
AdS26	Severino Cavaco	43	4	"M"	3	2	3	"P"	2	"I"	1	"N"	"Y"	N	"F"	N
AdS27	Augusto Madeira	75	4	"M"	1	1	1	"F"	3	"I"	2	"N"	"N"	N	"R"	_
AdS28	Ze do Carmo (filho	167	4	"M"	1	1	3	"P"	2	"I"	3	"Y"	"Y"	N	"F"	N
ADS3	Antonio Mauel Ros	25	4	"M"	0	1	1	"P"	2	"I"	1	"N"	"N"		"R"	
ADS4	Francisco Alvito	20	2	"M"	1	1	1	"F"	2	"B"	3	"N"	"N"		"L"	
ADS5	Joaquim Manuel S	117	4	"M"	1	1	3	"P"	2	"I"	3	"N"	"Y"		"L"	
AdS6	Catarina Rodrigues	11	4	"F"	0	1	1	"F"	2	"I"	1	"N"	"Y"		"R"	
ADS7	António Nicolau	13	4	"M"	4	2	1	"F"	2	"I"	1	"N"	"Y"		"R"	
AdS8	Carlos Mateus	144	2	"M"	1	1	1	"F"	2	"I"	3	"Y"	"Y"		"L"	
AdS9	Joaquim Francisco	45	4	"M"	1	1	1	"F"	3	"B"	1	"N"	"N"		"R"	

Cognitive strategies

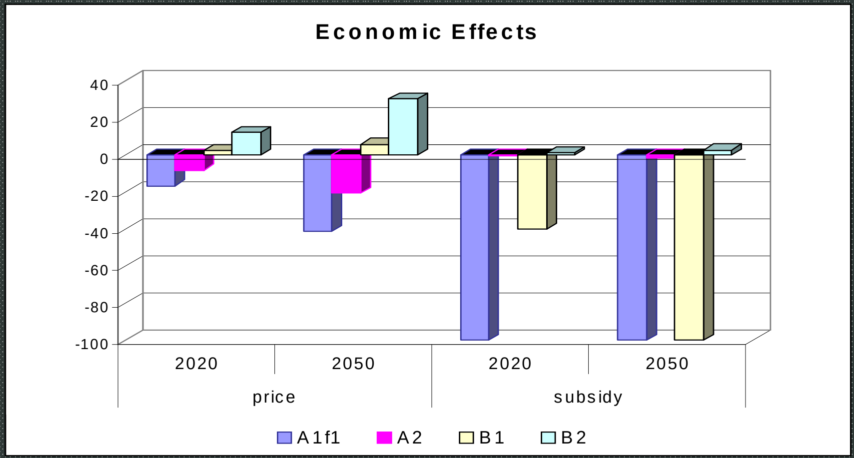


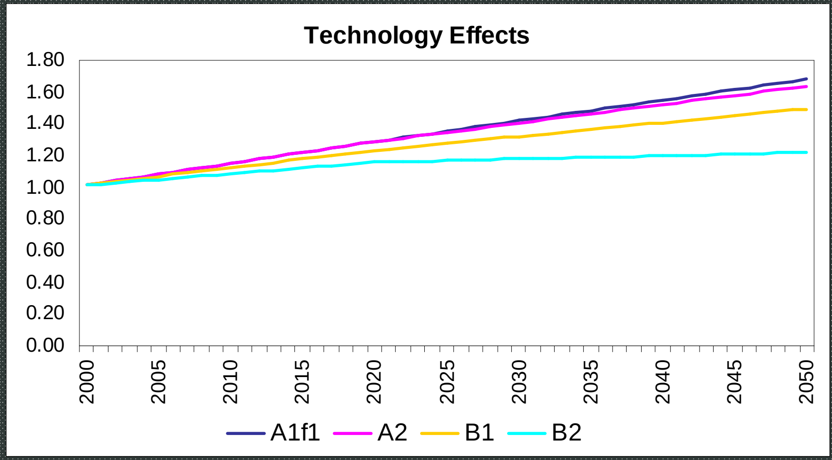
Agent profile and cognition (typology of behaviour)

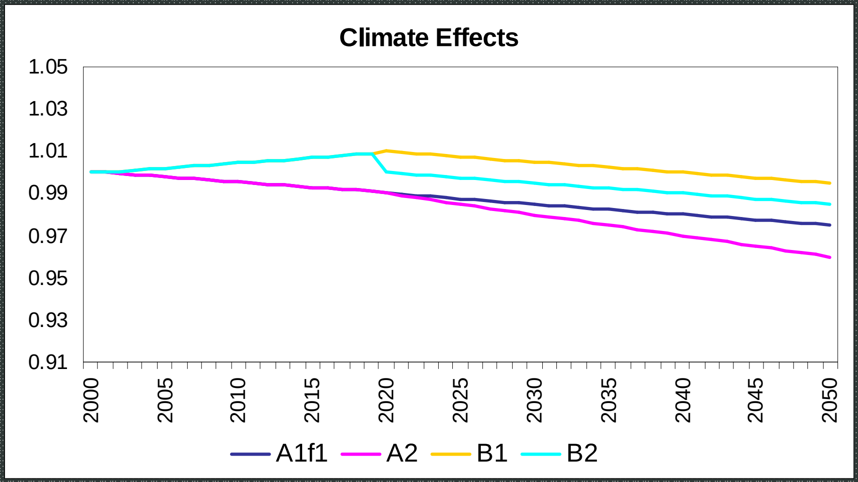
Profile	Characteristics	Strategies
Innovative	Large farm ownership High education Young farmers Diversified source of income	Maximization, repetition
Active	Small to medium farm ownership Moderate to High education Young farmers Traditional source of income	Maximization comparison, repetition
Absentee	Medium to large farm ownership Profession other than farming Young to old farmers Diversified source of income	Imitation, repetition
Retiree	Small farm ownership Low education Old farmers Pension and land rent	Repetition

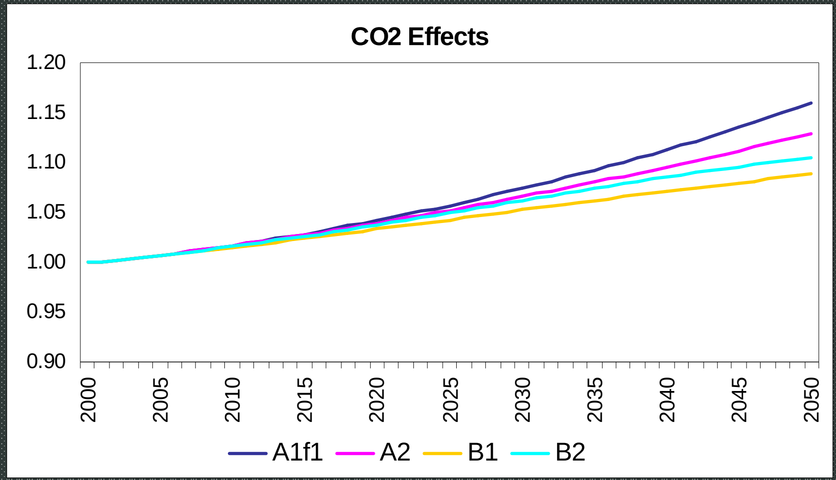
Source: Lilibeth Acosta-Michlik and Anne Van Doorn

Exogenous drivers



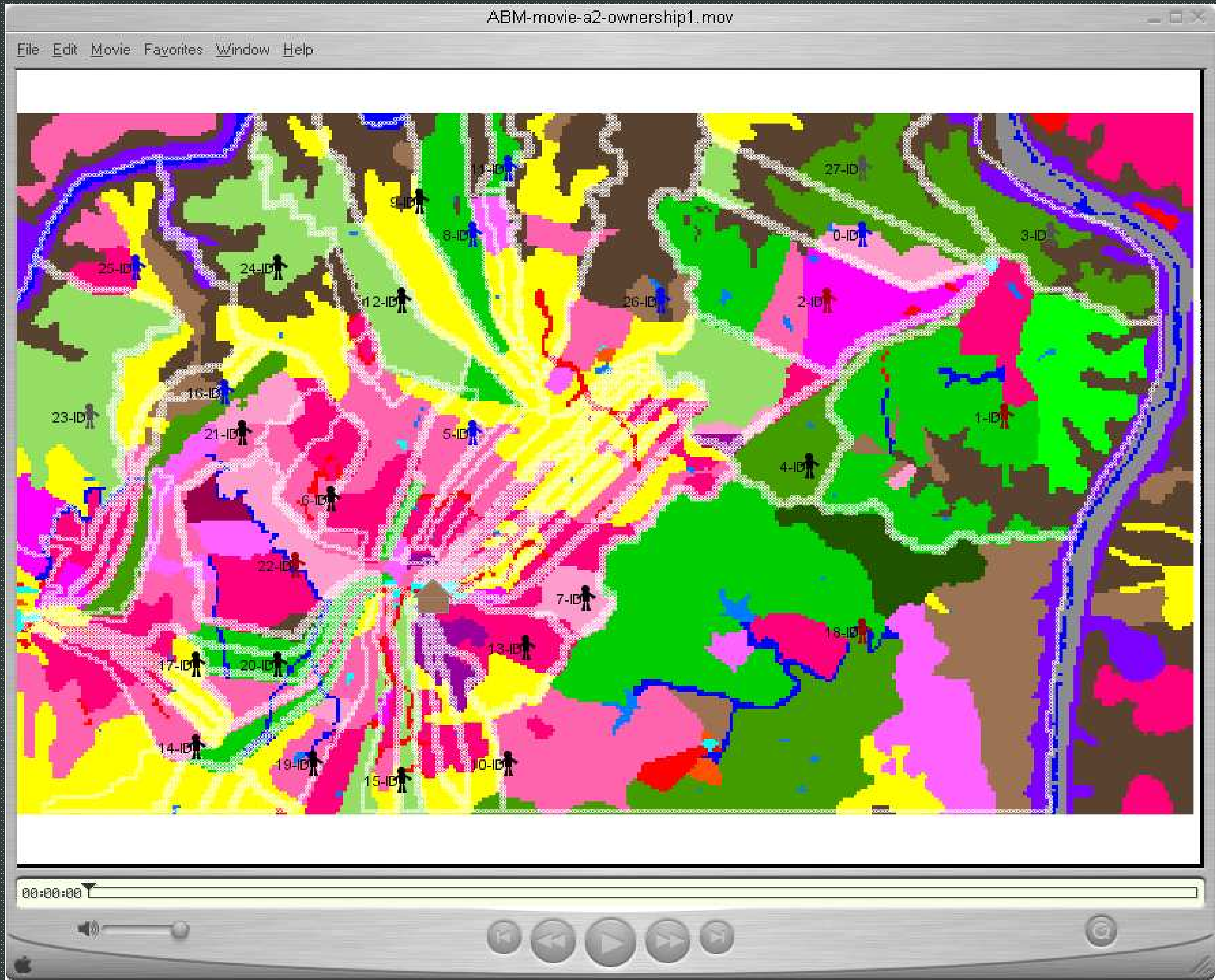






Note: Based on ACCELERATES and ATEAM projects

Model platform and results

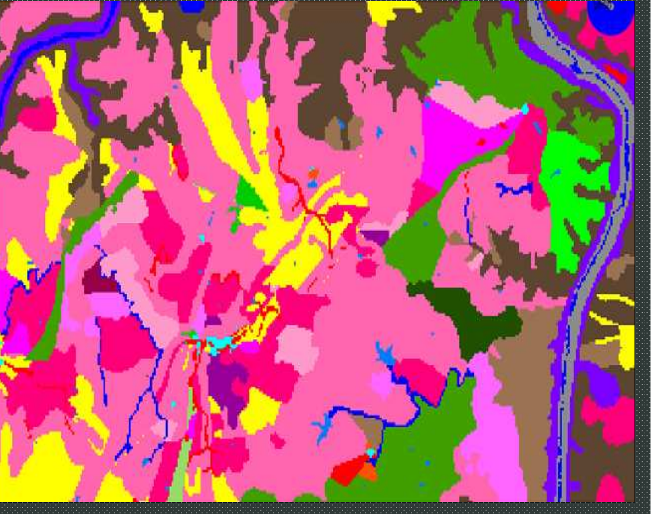


Land use in 2050 in the Alentejo, Portugal

Legend:
Pink – Montado
Green – woodland
Yellow – cropland
Black/brown – abandoned/scrub

A1 Scenario

A2 Scenario



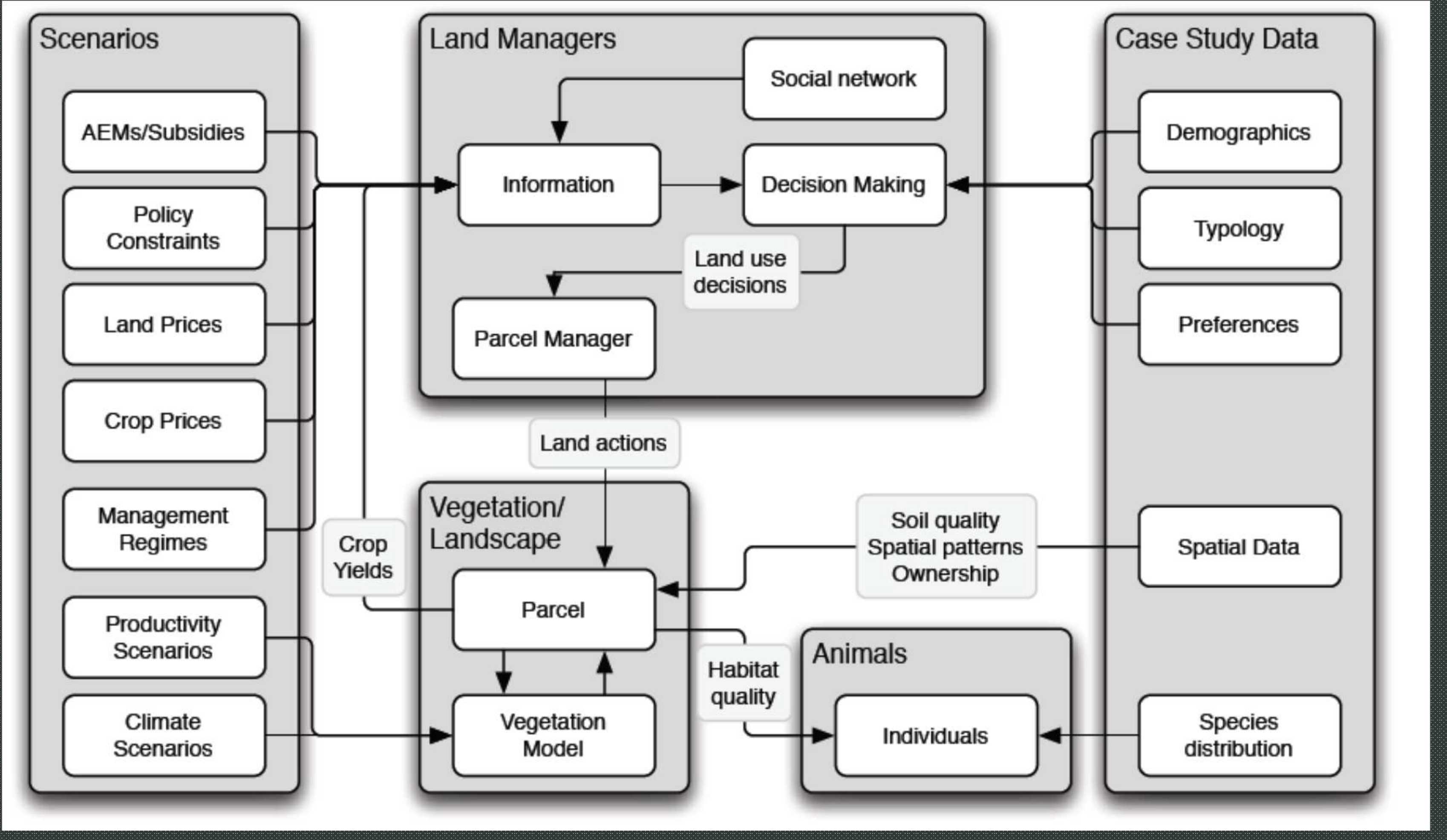
B1 Scenario

B2 Scenario

Social survey to inform ABM

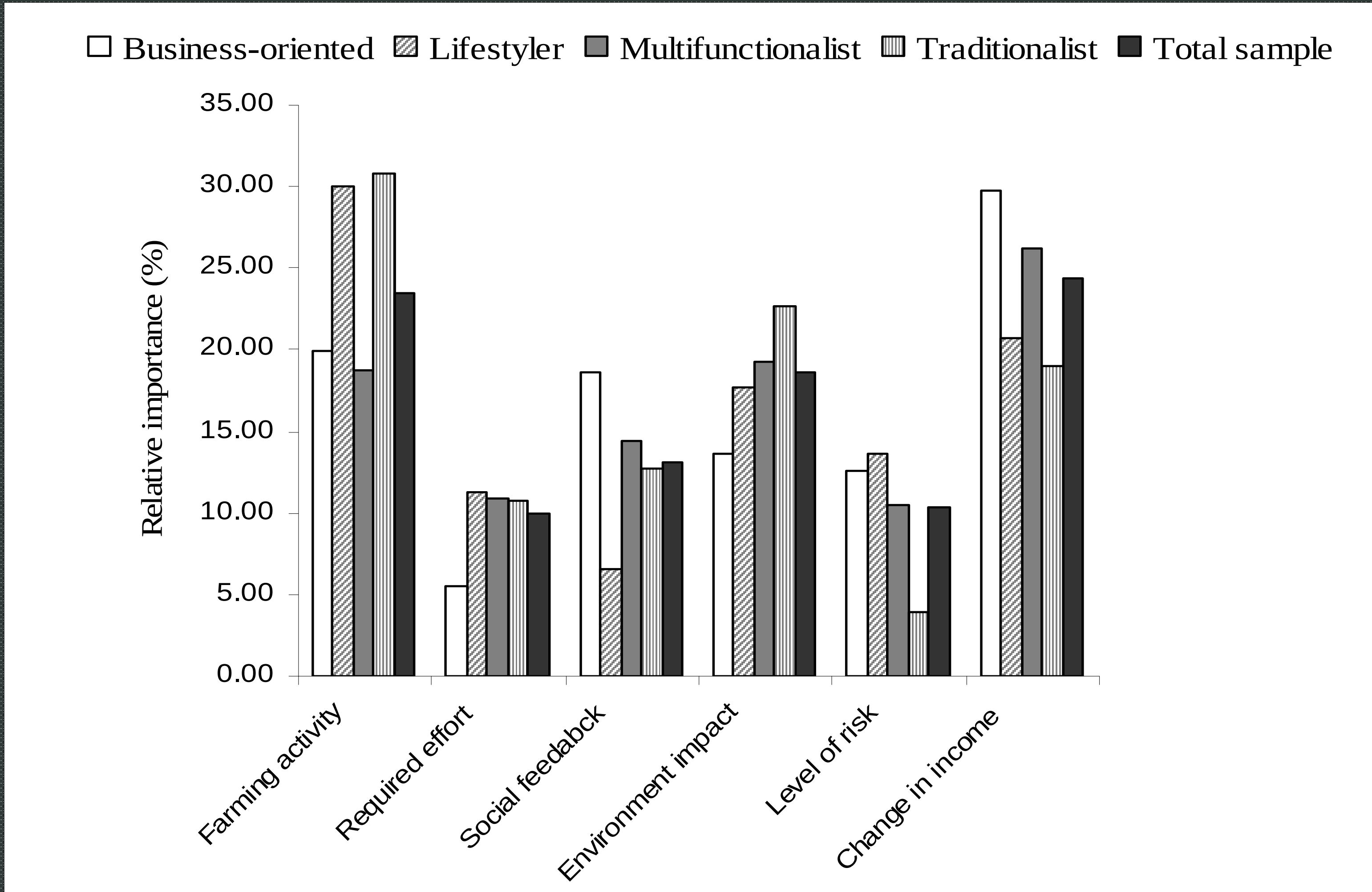
- Brabant-Wallon, Belgium
- Aargau, Switzerland
- Lunan catchment, Scotland

The modelling framework
Agent-Based Modelling (ABM)



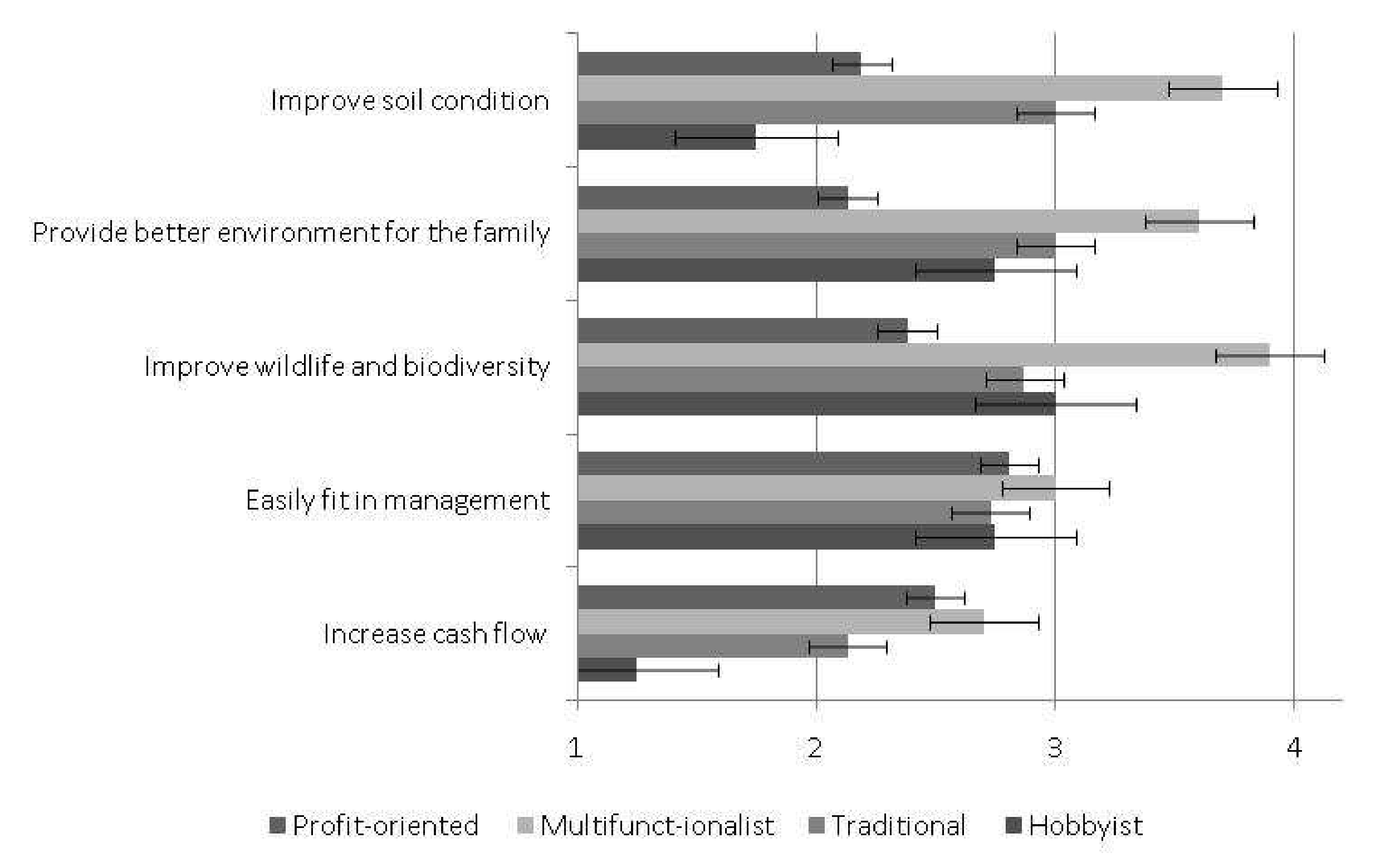
After: Murray-Rust, D., Dendoncker, N., Dawson, T., Acosta-Michlik, L., Karali, E., Guillem, E. and Rounsevell, M.D.A. (2011). Conceptualising the analysis of socio-ecological systems through ecosystem services and agent based modelling. *Journal of Land Use Science*, **6**, 83-99

Agent types and preferences



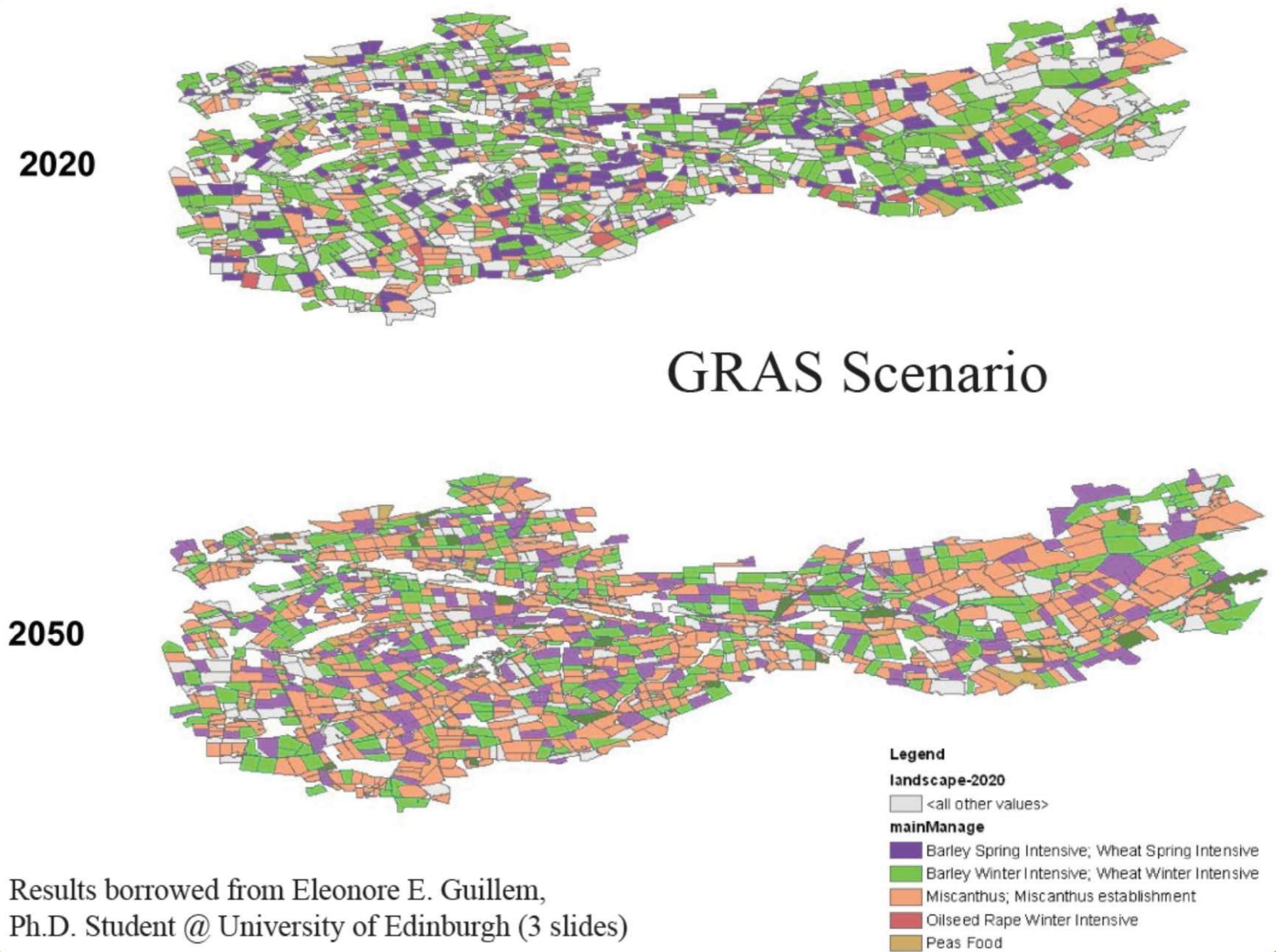
Relative importance of attributes included in the cluster analysis for the Aargau, Switzerland

Response to environmental policy



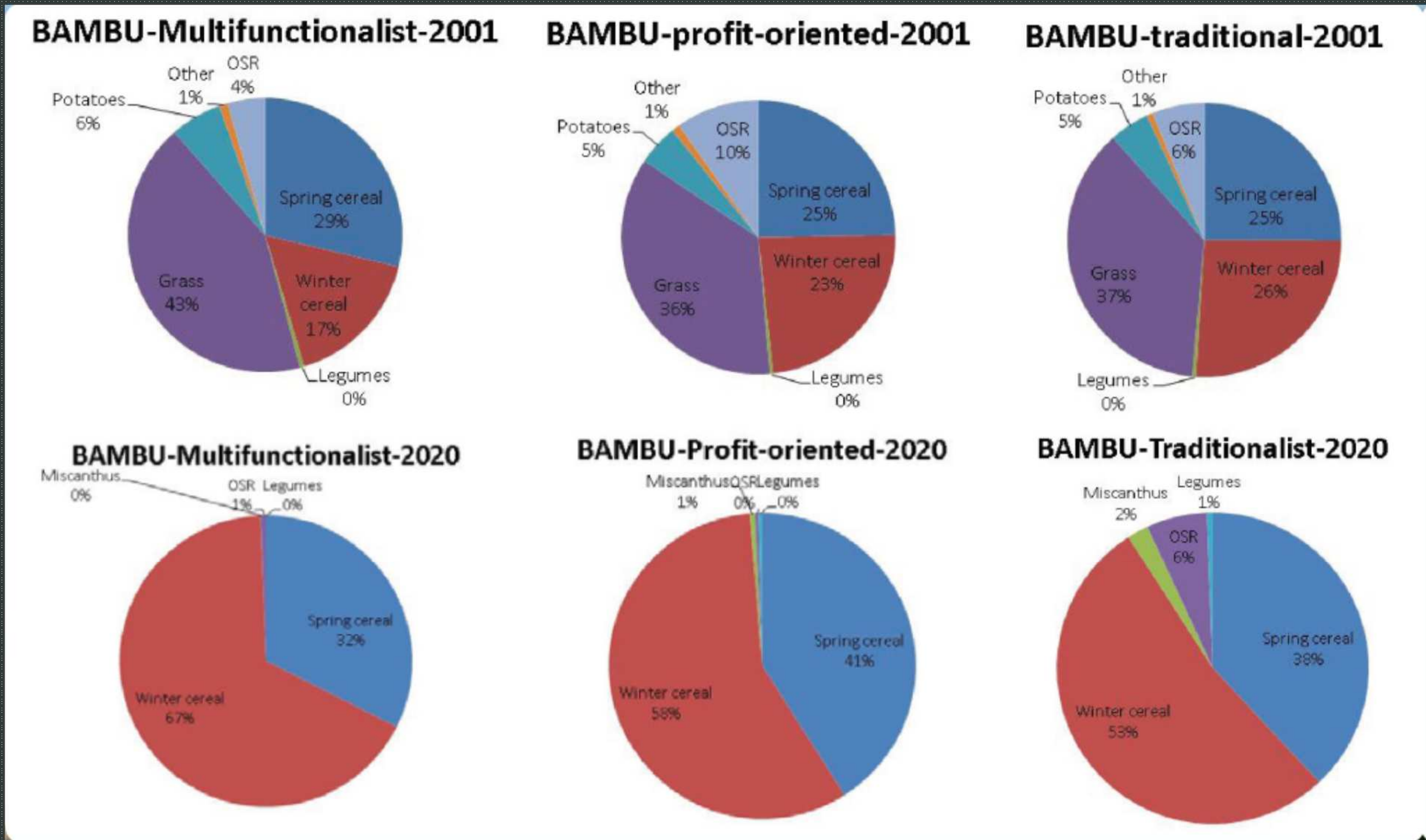
Mean responses for Motivations to agri-environmental scheme participation with standard deviations (1: no influence, 2: slight influence, 3: some influence, 4: big influence) – Lunan catchment, Scotland

Example simulation for Scotland

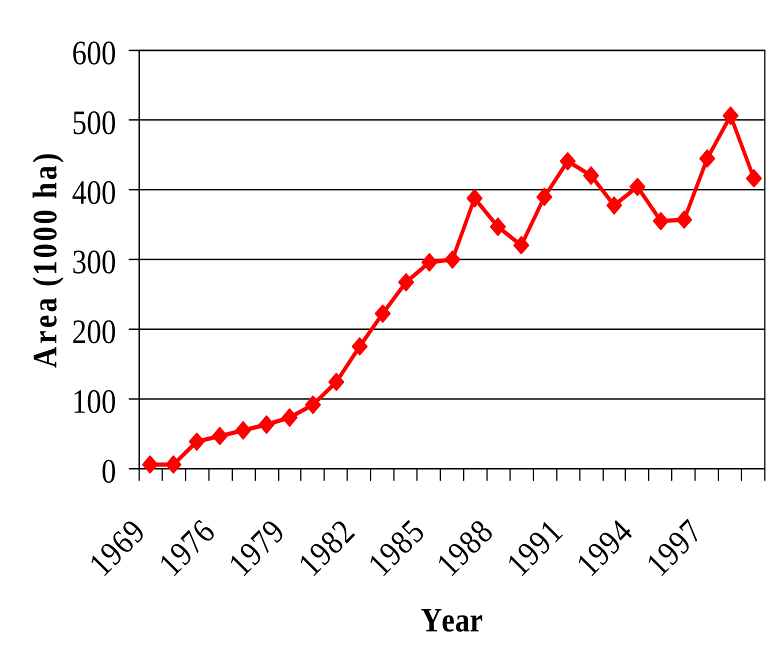


Results borrowed from Eleonore E. Guillem,
Ph.D. Student @ University of Edinburgh (3 slides)

… role of farmer type in scenarios

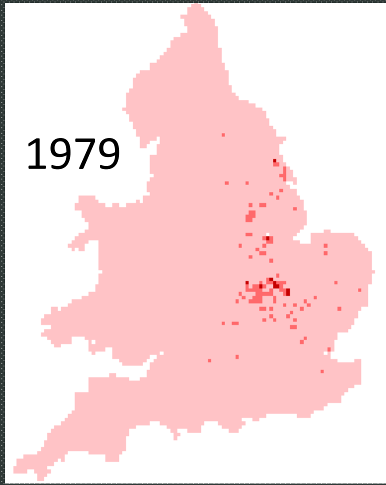


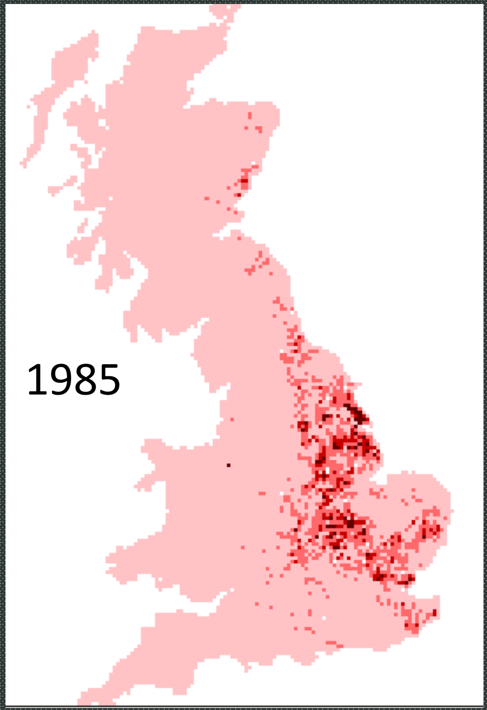
The role of knowledge exchange

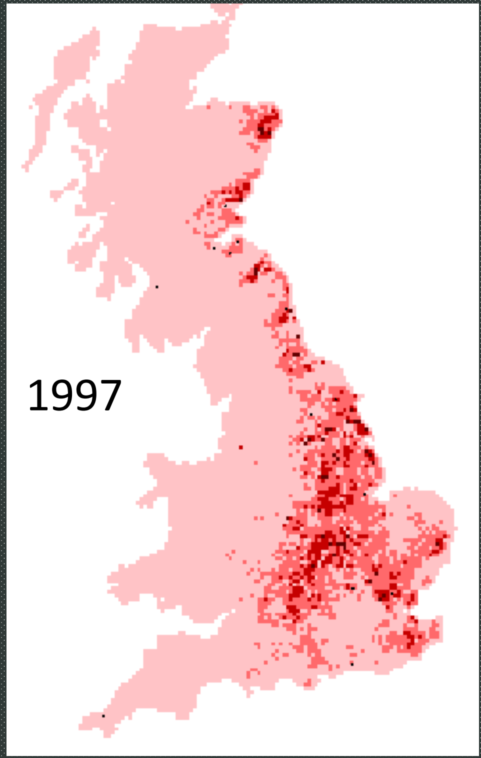


Change in oilseed rape areas in GB (1969-1999)

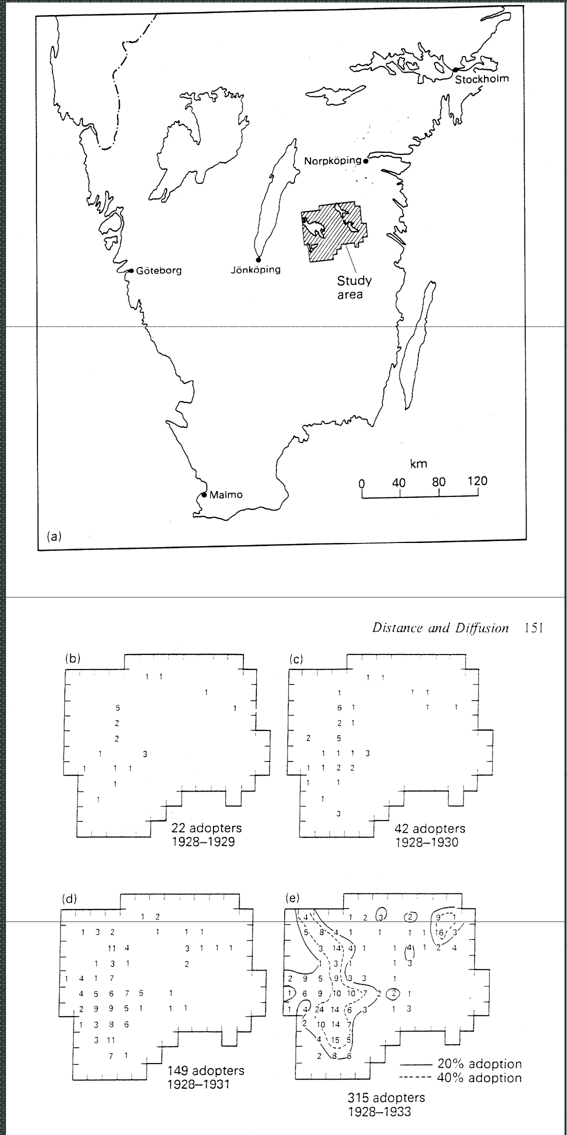
US soyabean shortage leads to European oilseed subsidy in the early 80s; during the 90s OSR is used as a biofuel crop on set-aside land







HÄGERSTRAND - DIFFUSION OF INNOVATION IN A RURAL COMMUNITY



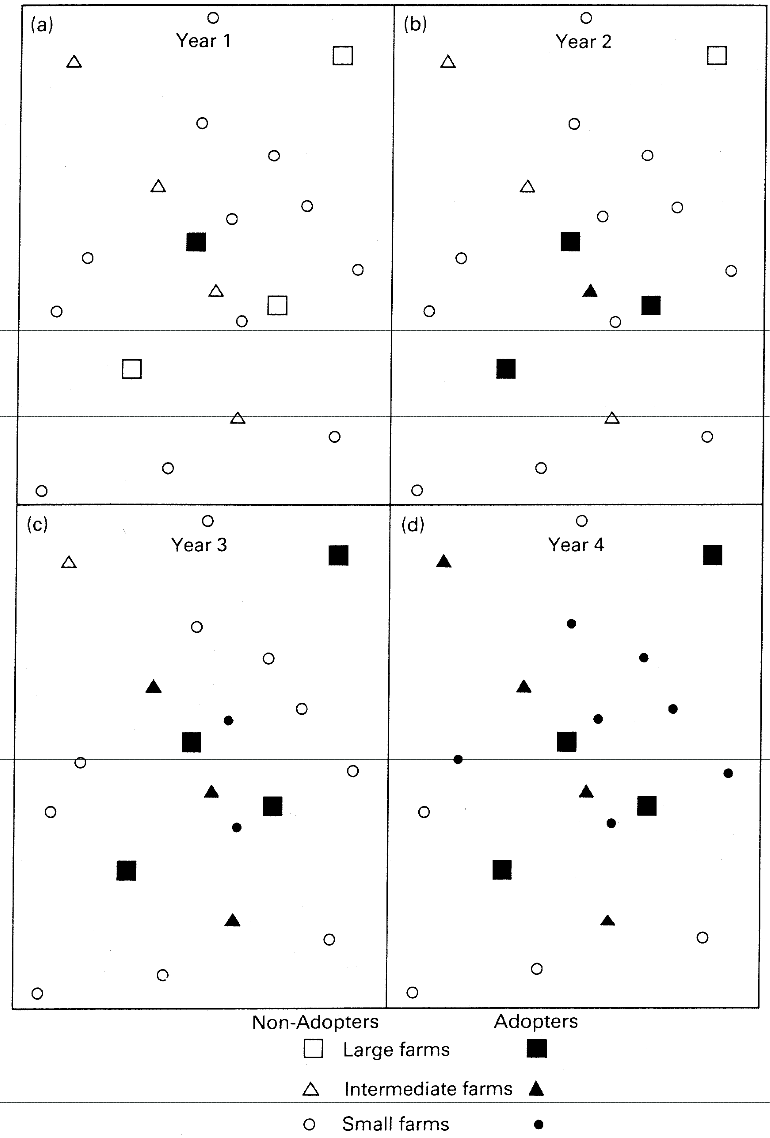


Fig. 7.2 Evolution of a diffusion pattern.

INNOVATION DIFFUSION

- Cellular space
- Diffusion through *contact* between actors
- *Mean information fields* as Neighbourhoods with a distance decay
- Stochastic rules

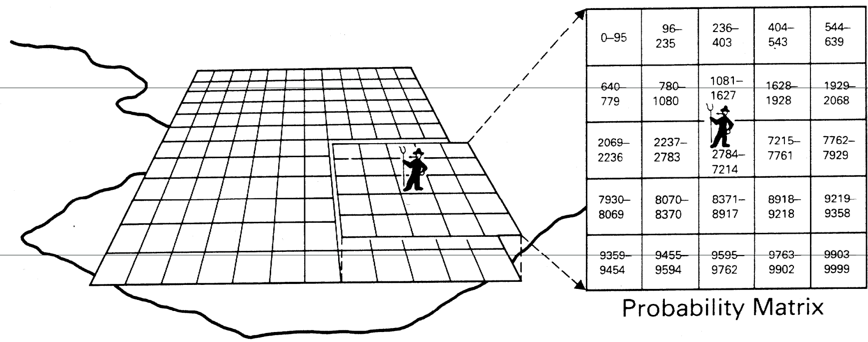


Fig. 7.6 Probability matrix and mean information field (after Hägerstrand (trans. Pred), 1967).

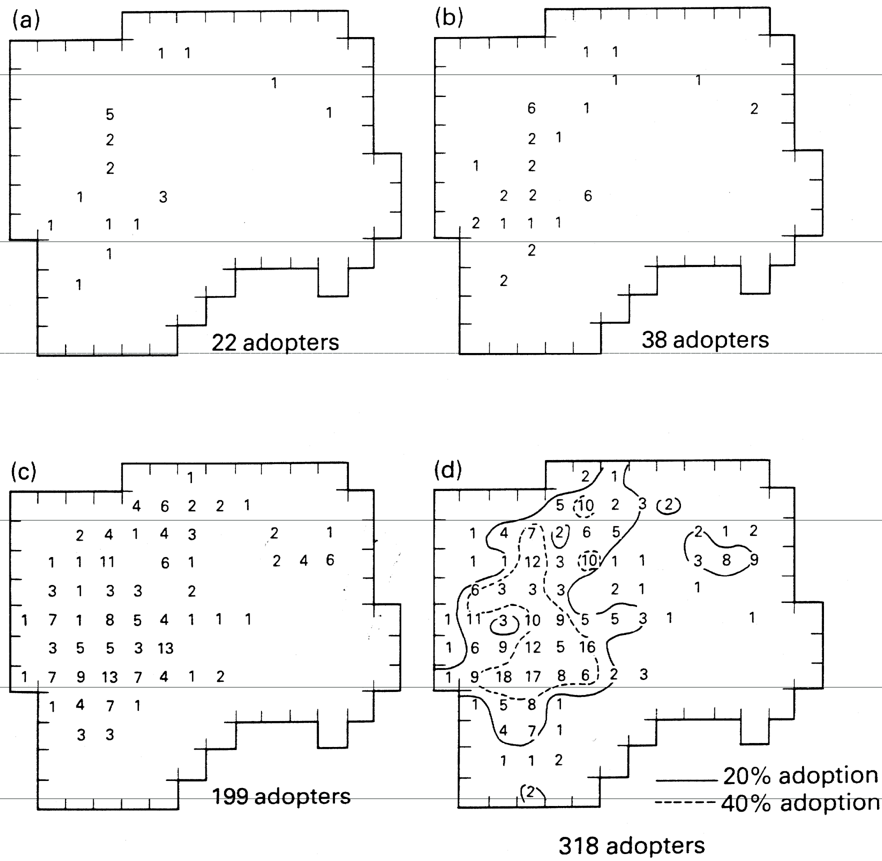
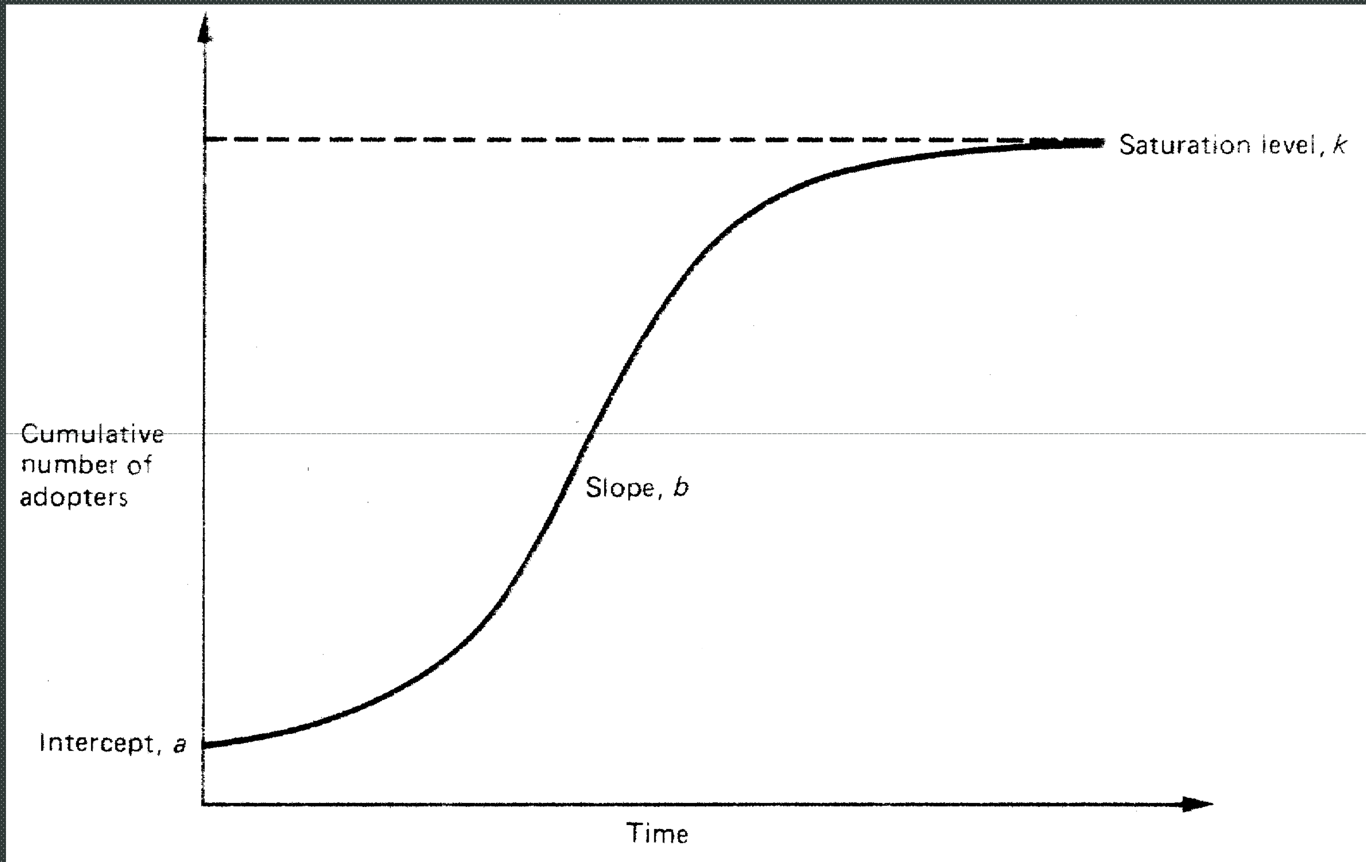


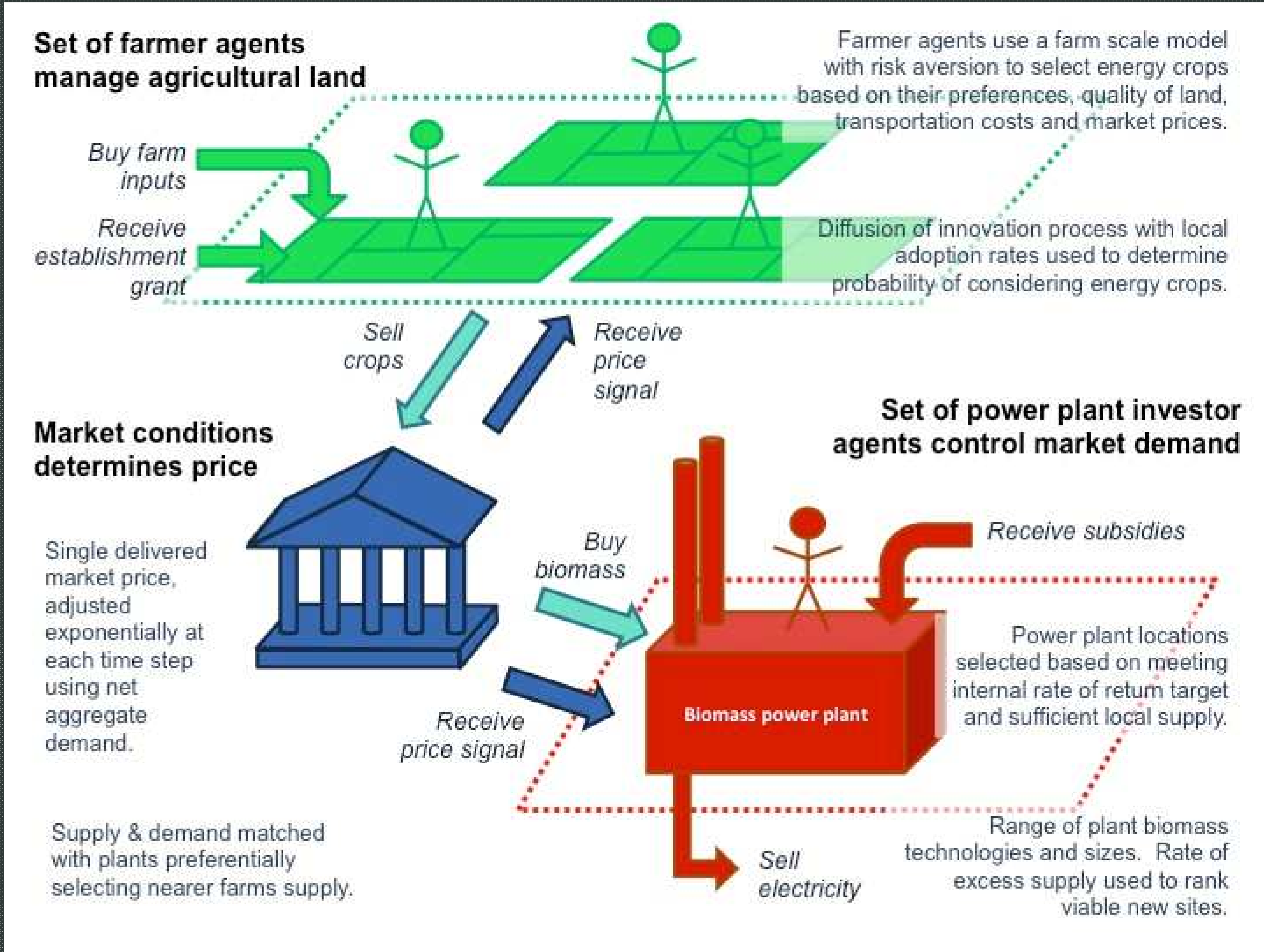
Fig. 7.7 Simulated adoption of pasture improvement in part of southern Östergötland, Sweden: (a) study area; (b) 1928–1929; (c) 1928–1930; (d) 1928–1931; (e) 1928–1933 (after Hägerstrand (trans. Pred), 1967).

Diffusion of innovation/knowledge

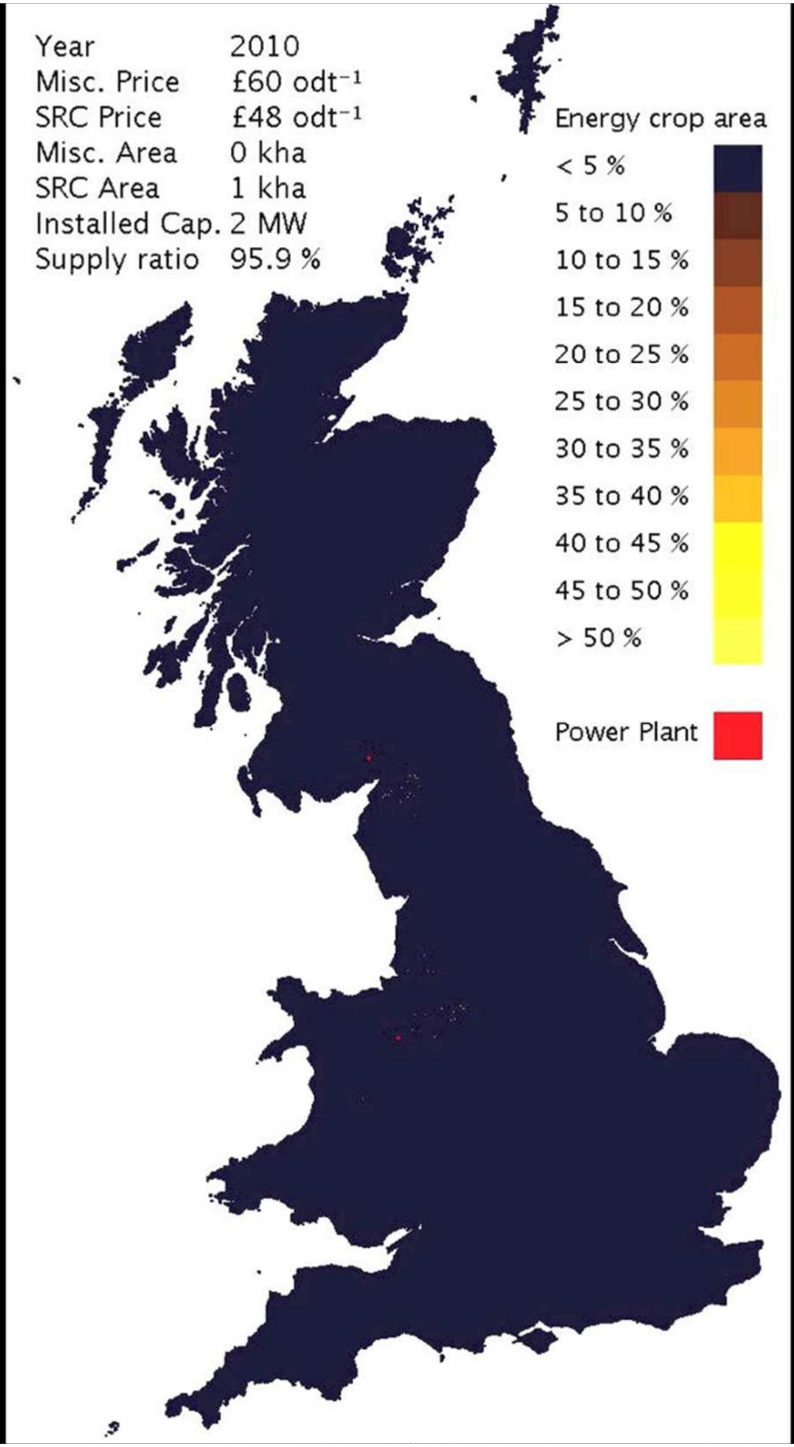


$N = K / (1 + \exp(a + b.d^2 - c.t))$

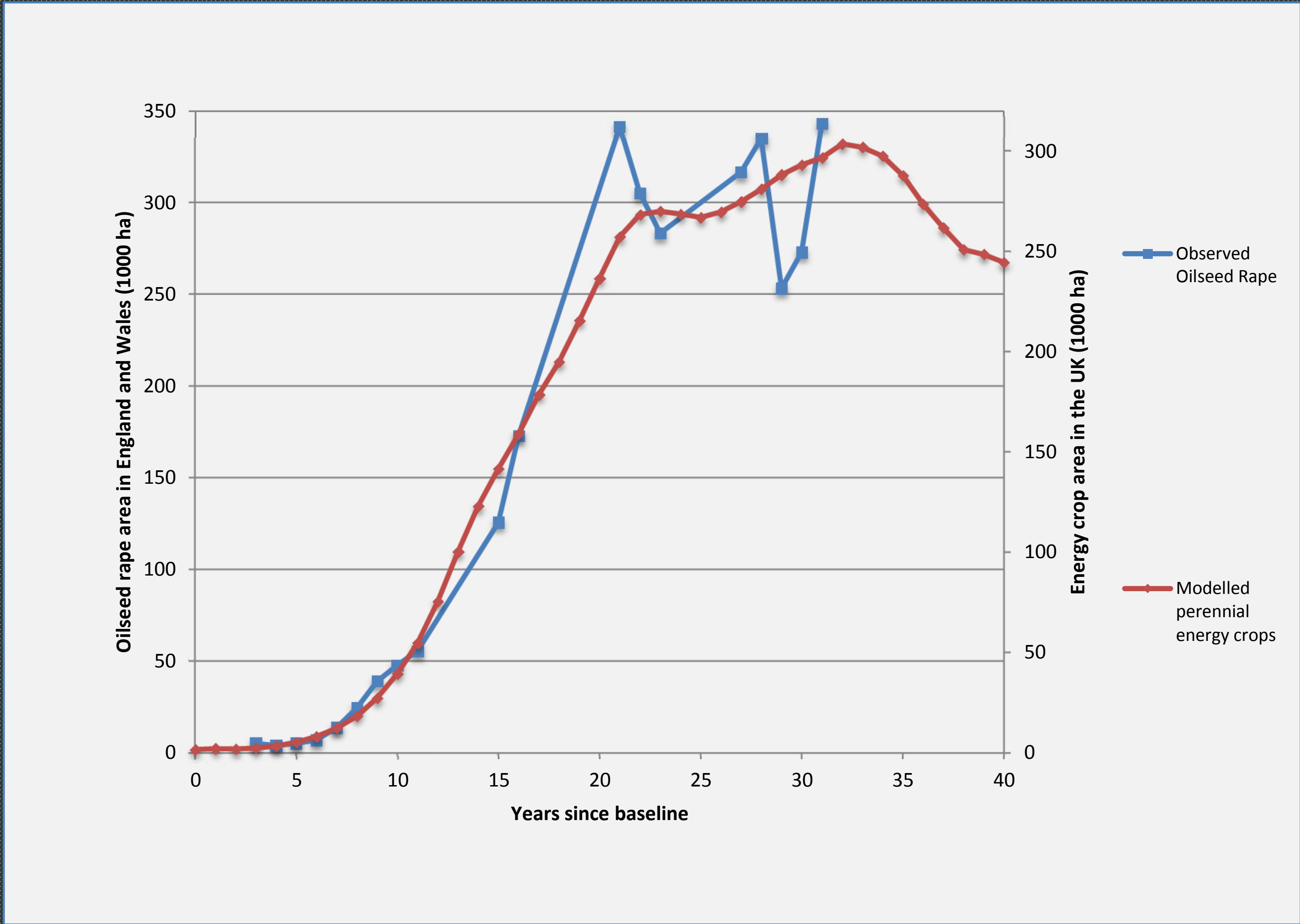
a, b and c are constants, d is distance, and K = 1 (for 0 > N < 1)



Schematic representation of the main agent processes and interactions within the perennial energy crop market model

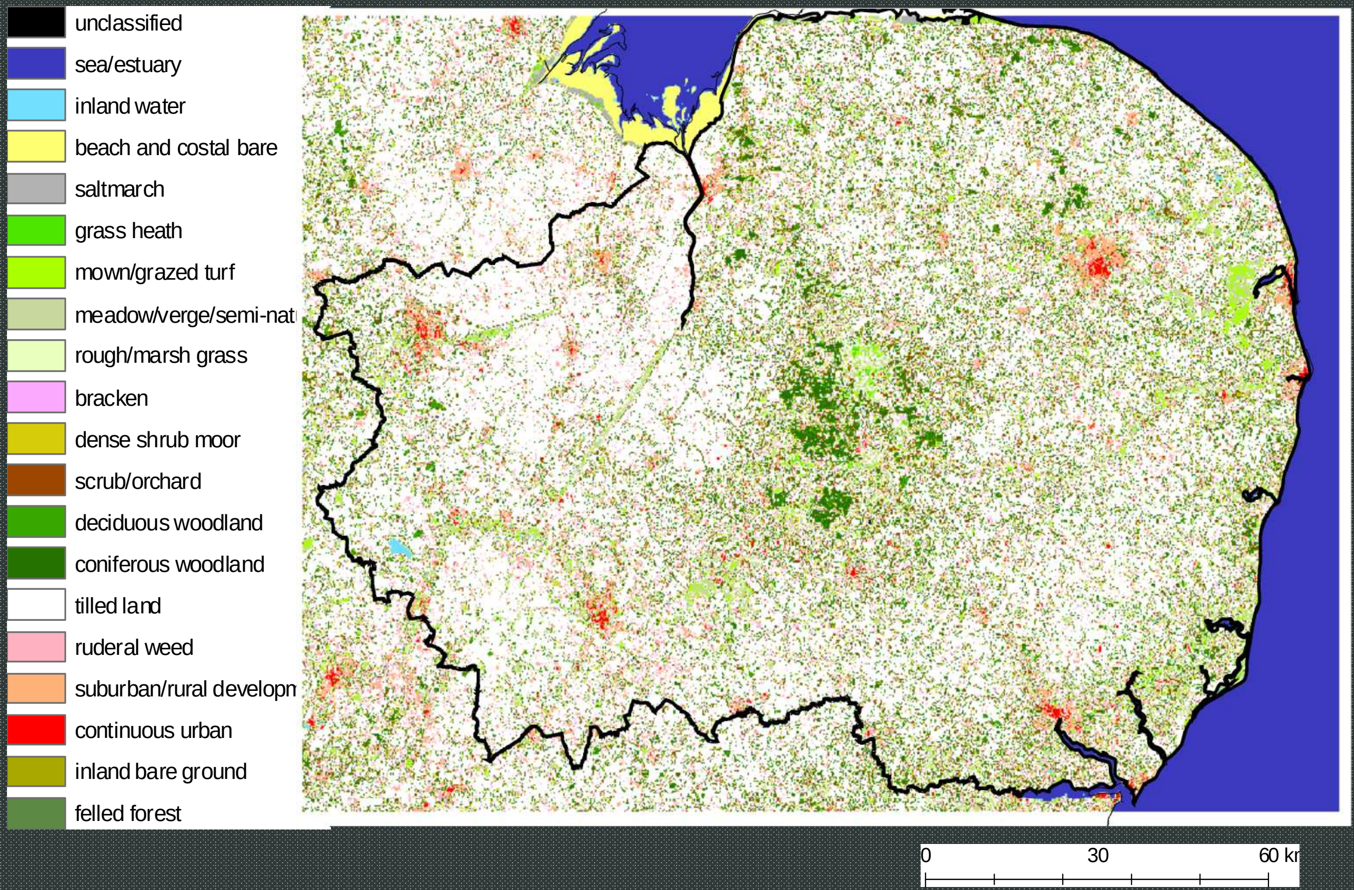


Year 2010
Misc. Price £60 odt^{-1}
SRC Price £48 odt^{-1}
Misc. Area 0 kha
SRC Area 1 kha
Installed Cap. 2 MW
Supply ratio 95.9 %
Energy crop area
< 5 %
5 to 10 %
10 to 15 %
15 to 20 %
20 to 25 %
25 to 30 %
30 to 35 %
35 to 40 %
40 to 45 %
45 to 50 %
> 50 %
Power Plant



Time lags in adaptation - 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 (Source: Peter Alexander, SRUC, Edinburgh)

Residential housing (urban land use) in East Anglia



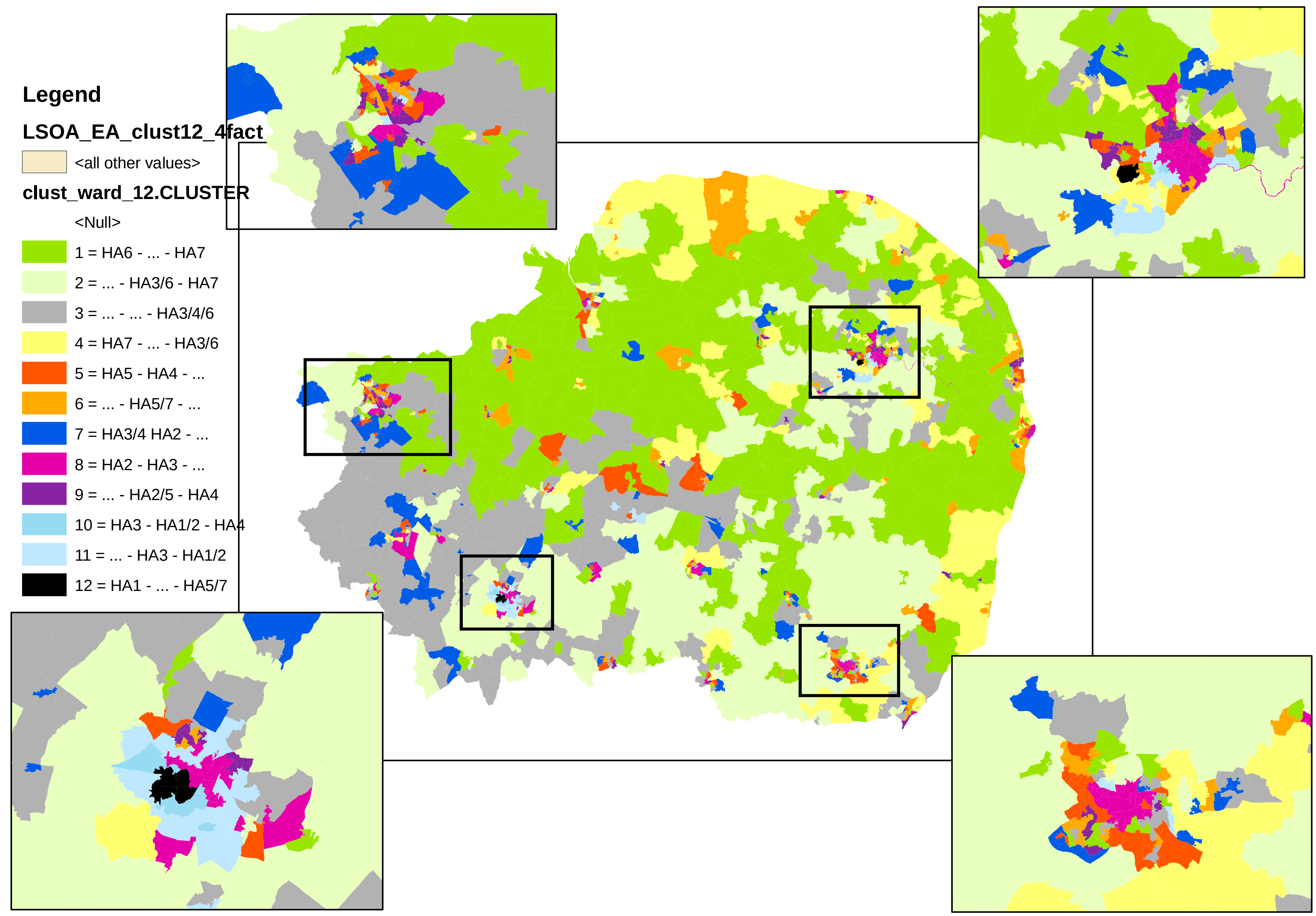
Source: Corentin Fontaine Lilibeth & Acosta-Michlik

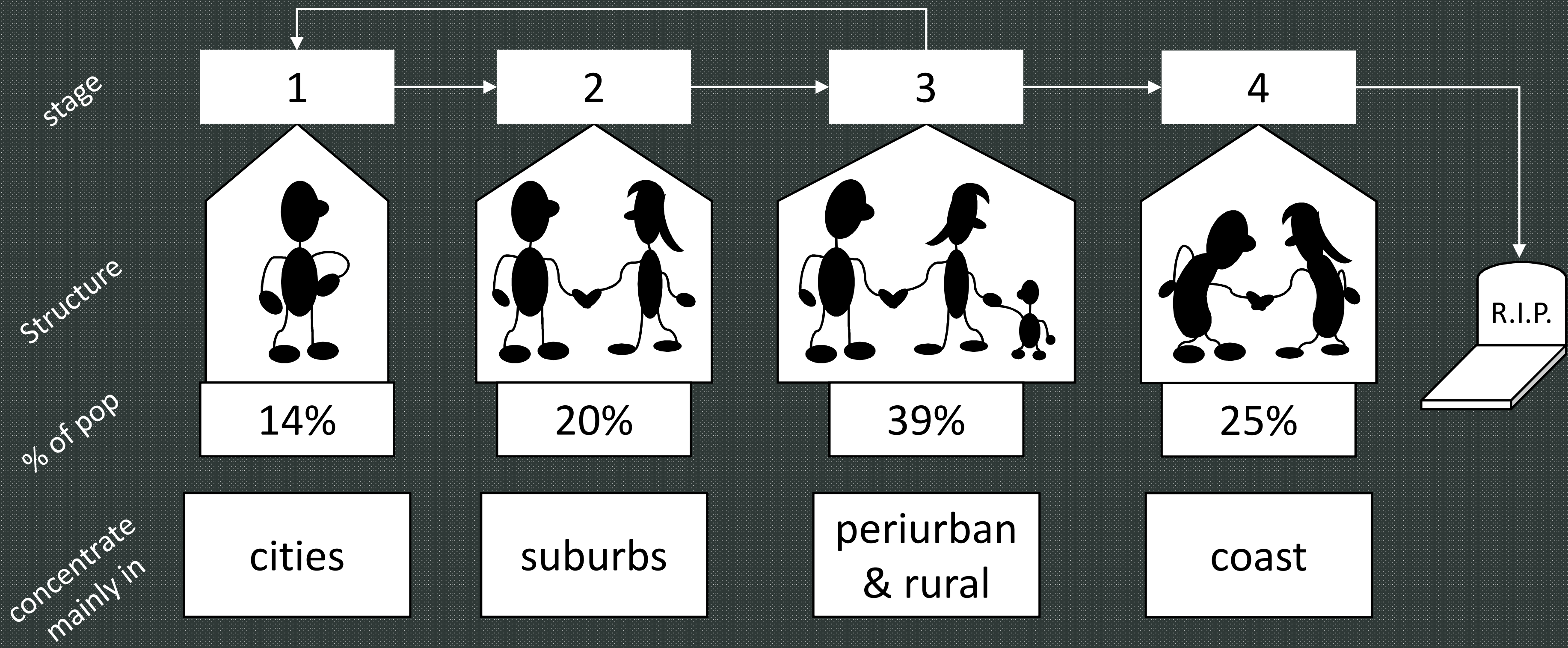
Residential agents

- Socio-economic data analysis
- Agent profiles (household types) & location trends

		CLUSTERS											
		1	2	3	4	5	6	7	8	9	10	11	12
isolated student	HA1										++	+	+++
single person	HA2							+	+++	++	++	+	
couple	HA3		++	+	+			+++	++		+++	++	
couple with dep. children	HA4			+		++		+++		+	+		
single-parent family	HA5					+++	++			++			+
couple with non-dep. children	HA6	+++	++	+	+								
all retired	HA7	+	+		+++		++						+

Household agent location preferences




stage
Structure
% of pop
concentrate mainly in
1
2
3
4
14%
20%
39%
25%
cities
suburbs
periurban & rural
coast
R.I.P.

[Model run]

Where do we see ABM?

Massive

THE UNIVERSITY
of EDINBURGH
Global Environment &
Society Academy

"The voyage of discovery is not in seeking new landscapes, but in having new eyes"

Marcel Proust

Discussion questions

- How can we understand and model the competition between land-based food and energy production in a world with a rapidly increasing population?
- What are the processes that control the trade-off between land use intensification and land use expansion (in area)?
- What is the relative importance of different drivers on future land use change, especially technological development (with high uncertainty)?
- What is the role of institutions and governance structures in future land use change, and how can we model these?





THE UNIVERSITY
of EDINBURGH
Global Environment &
Society Academy

"The voyage of discovery is not in seeking new landscapes, but in having new eyes"

Marcel Proust

Land Use Policy 29 (2012) 899–910

Contents lists available at SciVerse ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Challenges for land system science

Mark D.A. Rounsevell [a,*], Bas Pedroli [b], Karl-Heinz Erb [c], Marc Gramberger [d], Anne Gravsholt Busck [e], Helmut Haberl [c], Søren Kristensen [e], Tobias Kuemmerle [f,j], Sandra Lavorel [g], Marcus Lindner [h], Hermann Lotze-Campen [j], Marc J. Metzger [a], David Murray-Rust [a], Alexander Popp [j], Marta Pérez-Soba [b], Anette Reenberg [e], Angheluta Vadineanu [k], Peter H. Verburg [l], Bernhard Wolfslehner [i]

[a] School of Geosciences, University of Edinburgh, Drummond Street, Edinburgh EH8 9XP, UK
[b] Alterra, Wageningen UR, P.O. Box 47, NL-6700 AA Wageningen, The Netherlands
[c] Institute of Social Ecology Vienna (SEC), Alpen-Adria Universitaet Klagenfurt, Wien, Graz, Schottenfeldgasse 29, 1070 Vienna, Austria
[d] Prospex bvba, Vlugestal 6, B-3140 Keerbergen, Belgium
[e] Department of Geography and Geology, University of Copenhagen, Oster Voldgade 10, 1350 Copenhagen, Denmark
[f] Department of Geography, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany
[g] Laboratoire d'Ecologie Alpine, CNRS UMR 5553, Université Joseph Fourier, BP 53, 38041 Grenoble Cedex 9, France
[h] European Forest Institute, Torikatu 34, 80100 Joensuu, Finland
[i] European Forest Institute, Regional Office for Central Eastern Europe, c/o University of Natural Resources and Life Sciences, Vienna, 1180 Vienna, Austria
[j] Potsdam Institute for Climate Impact Research (PIK), PO Box 601203, 14412 Potsdam, Germany
[k] Department of Systems Ecology and Sustainability, University of Bucharest, Spl. Independentei 91-95, Bucharest, Romania
[l] Institute for Environmental Sciences, VU University Amsterdam. De Boelelaan 1087, 1081HV Amsterdam, The Netherlands

Key questions

1. Which innovative 'visions' can be formulated for future sustainable resource management and land use policy development under a range of environmental and management conditions?
2. What are the socio-economic and ecological 'processes' that shape land use transitions?
3. How can bottom-up and top-down modelling tools be improved and used in a comprehensive 'assessment' of critical thresholds for resource management with reference to land use change and ecosystem services?

Conceptual framework

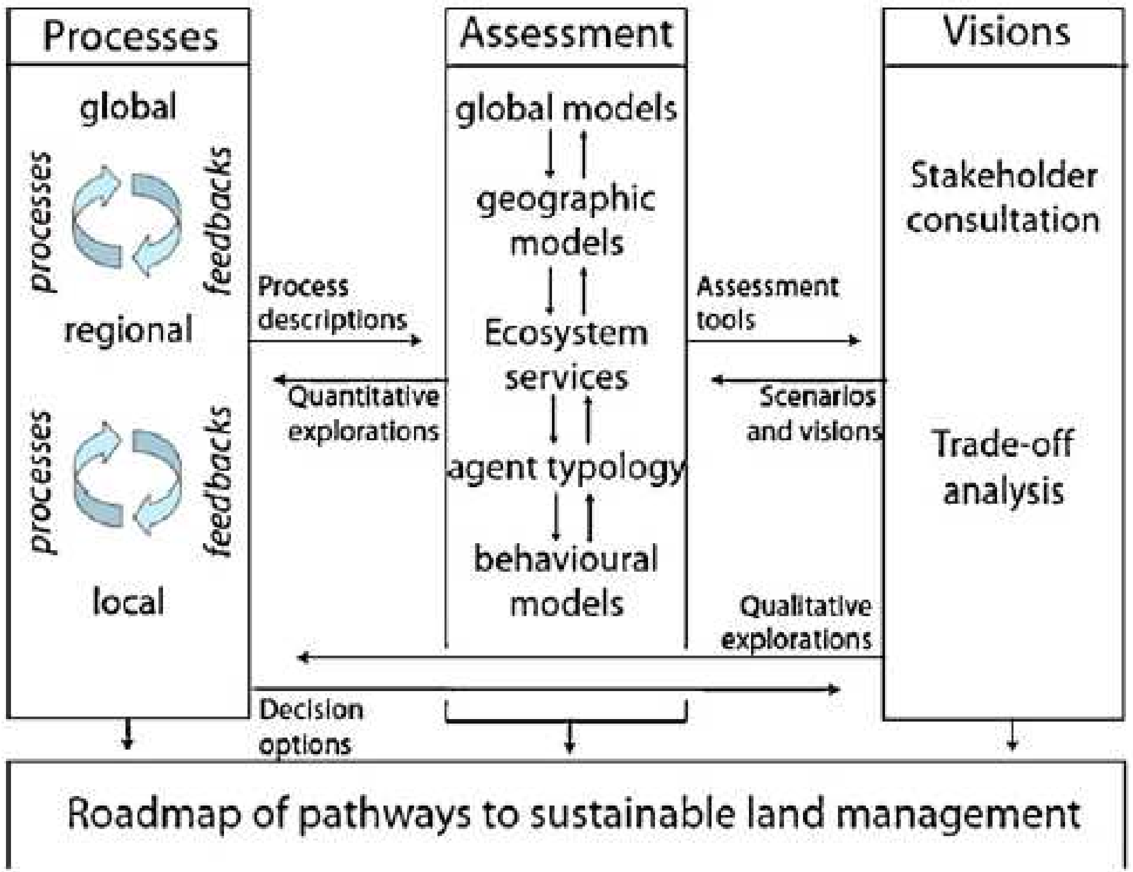


Fig. 2. An integrated methodological framework to assess land systems in the past, present and future.

Challenges for processes

- Contemporary landscapes are contingent outcomes of past and present patterns, processes and decisions
- Empirical analysis of past and present land-use change to provide insights into the socio-economic and ecological processes that shape land use transitions
- Gradual vs rapid land system dynamics and understanding changes in land use intensity
- Combining empirical analysis with multi-scale modelling to gain new insights into land system change processes

Challenges for modelling

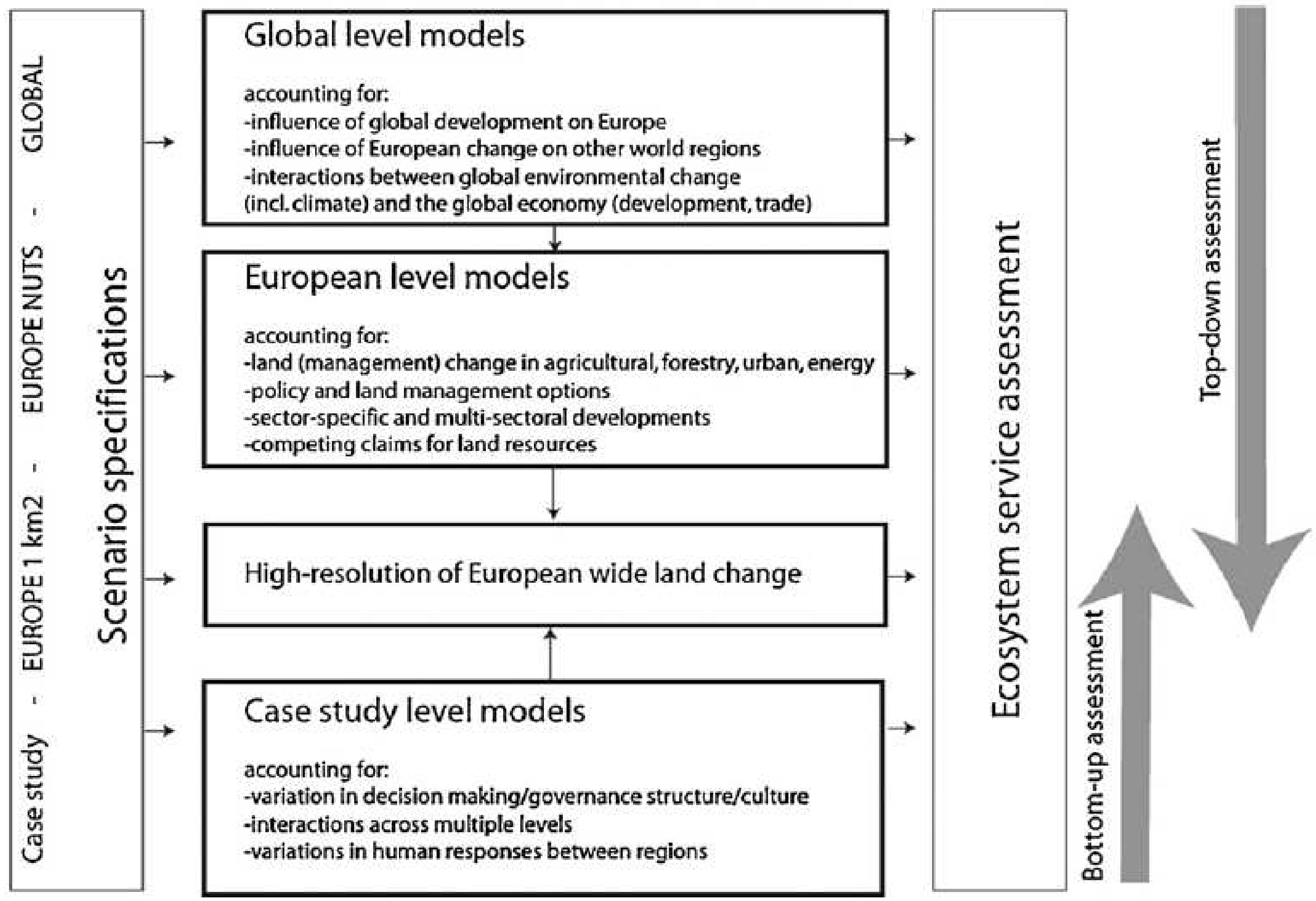


Fig. 4. Overview of an integrated modelling framework.

Land system models have an important role in supporting future land use policy, but model outputs require scientific interpretation rather than being presented as predictions

Challenges for land use futures

- Integrating explorative scenarios that reflect possible outcomes with normative visions that identify desired outcomes
- Road-mapping and envisioning techniques to guide future land use transitions derived from societal choices about future landscapes
- The broad and in-depth involvement of stakeholders in order to link scientific findings to political and societal decision-making culminating in a set of key choices and consequences
- Defining the bandwidth of both potential and desirable pathways of future land use change

Key themes in land system science

- Uncertainty (in observation, experiments, models and futures)
- Integration (across methods, disciplines, spatial and temporal scales, land use types, science and practice)
- Tele-connections (through time and space of people, goods, services, knowledge, …)
- Stakeholders (involved in visions, trade-off analysis, values, institutional analysis, …)
- A changing paradigm in land system science from pattern to process …

Selected questions

- How can we understand and model the competition between land-based food and energy production in a world with a rapidly increasing population?
- What are the processes that control the trade-off between land use intensification and land use expansion (in area)?
- What is the relative importance of different drivers on future land use change, especially technological development (with high uncertainty)?
- What is the role of institutions and governance structures in future land use change, and how can we model these?

Conclusions

- Providing insight into human–environment interactions is possible through integrated analysis of empirical and historical land system datasets, if empirical analysis and model simulation are used in combination to explore the drivers of land system change at a range of spatial and temporal scales.
- Integrated modelling based on the ecosystem service concept is expected to contribute substantially to the testing of hypotheses about land system functioning and decision making, assuming that iteration is undertaken between stakeholders, model applications and model outputs.
- The choices that society has about future landscapes can be informed in an innovative way through road-mapping and envisioning techniques that can guide future land use transitions.
- This will allow for the better definition of the bandwidth of both potential and desirable pathways of future land use change.
- There is growing awareness that the effectiveness of science in advising policy making can only be achieved through closer integration.
- This is especially true for land system research which aims to support policy making in the sustainable management of land resources because land plays a central and integrative role in many environmental decision processes from global to local scales.
- Sustainable land use strategies would benefit from being underpinned by a sound process understanding of how policies affect land use and ecosystem services and vice versa, and how the trade-offs and synergies between them work in practice.
- Embedding policy makers and relevant stakeholders in the research process through a carefully planned strategy of knowledge exchange, has the potential to support the formulation of sound, evidence-based policies.
- This paradigm shift in land system science requires a commitment to capacity building (mainly interdisciplinary and intra-disciplinary) that brings together the scientific and decision making communities.