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Extending ABM approaches to national and continental scales

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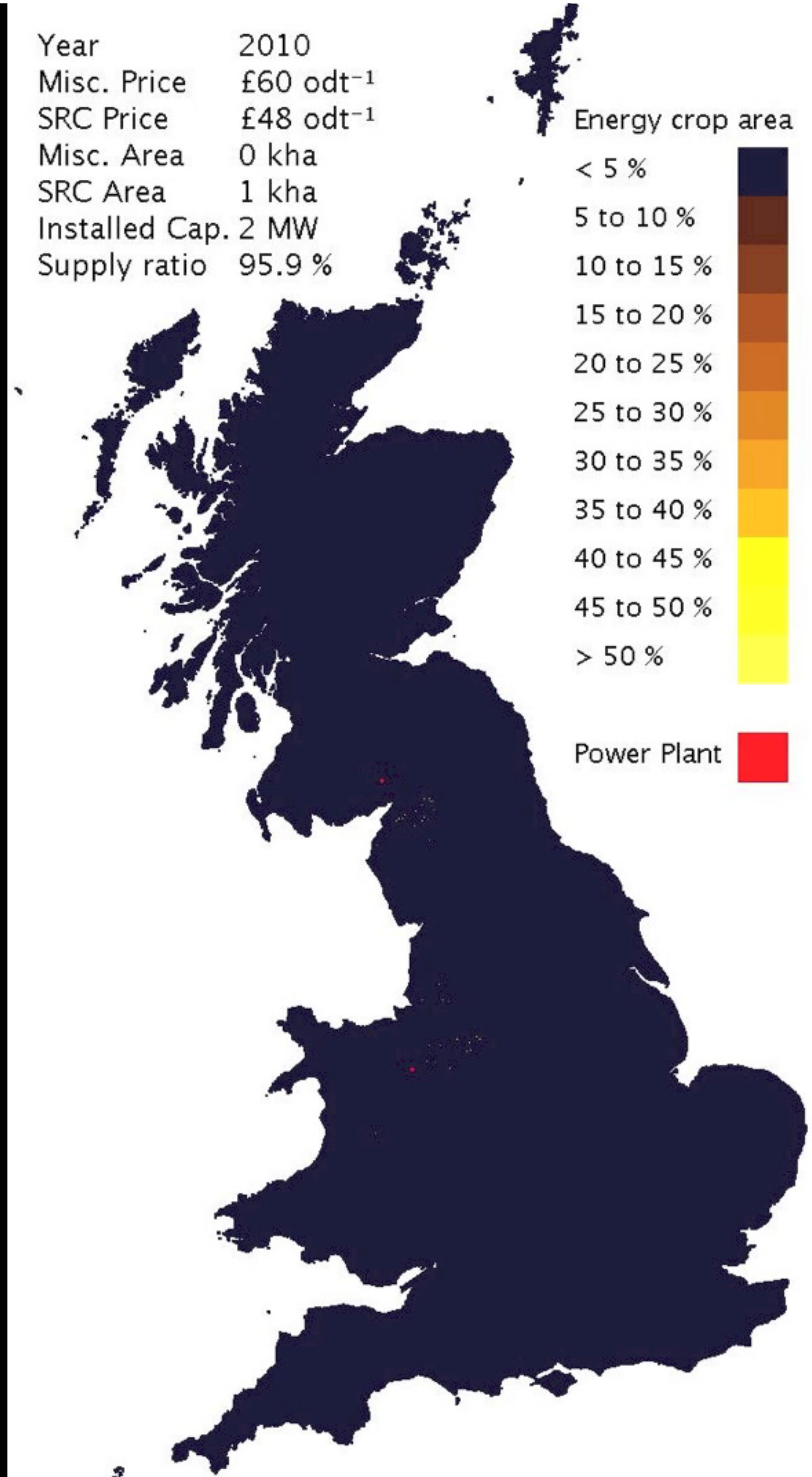
National scale modelling: Agent-Based Models (ABM)



How quickly are climate mitigation policies adopted?

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

Simulation of the uptake of the bioenergy crops miscanthus and short rotation coppicing

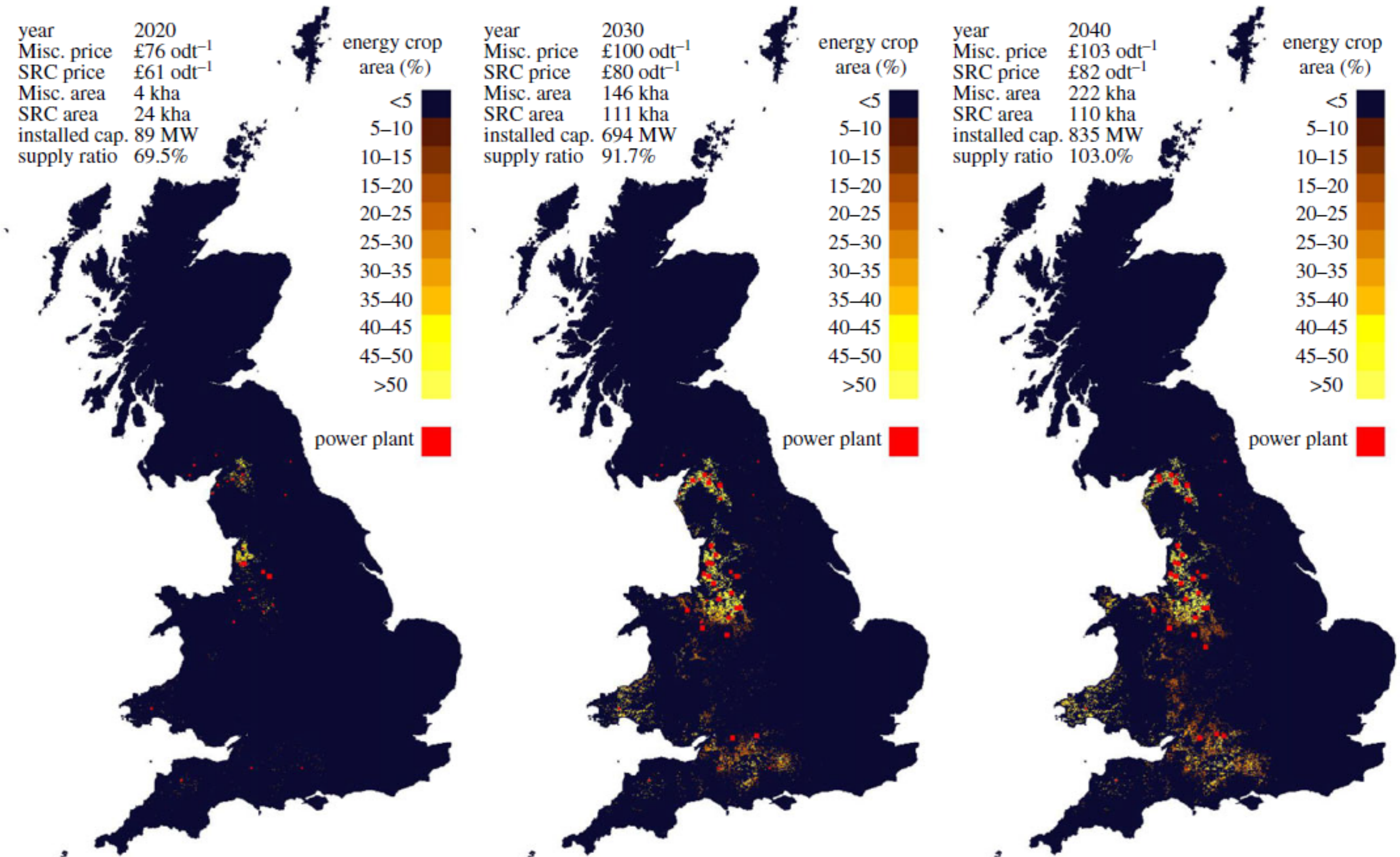
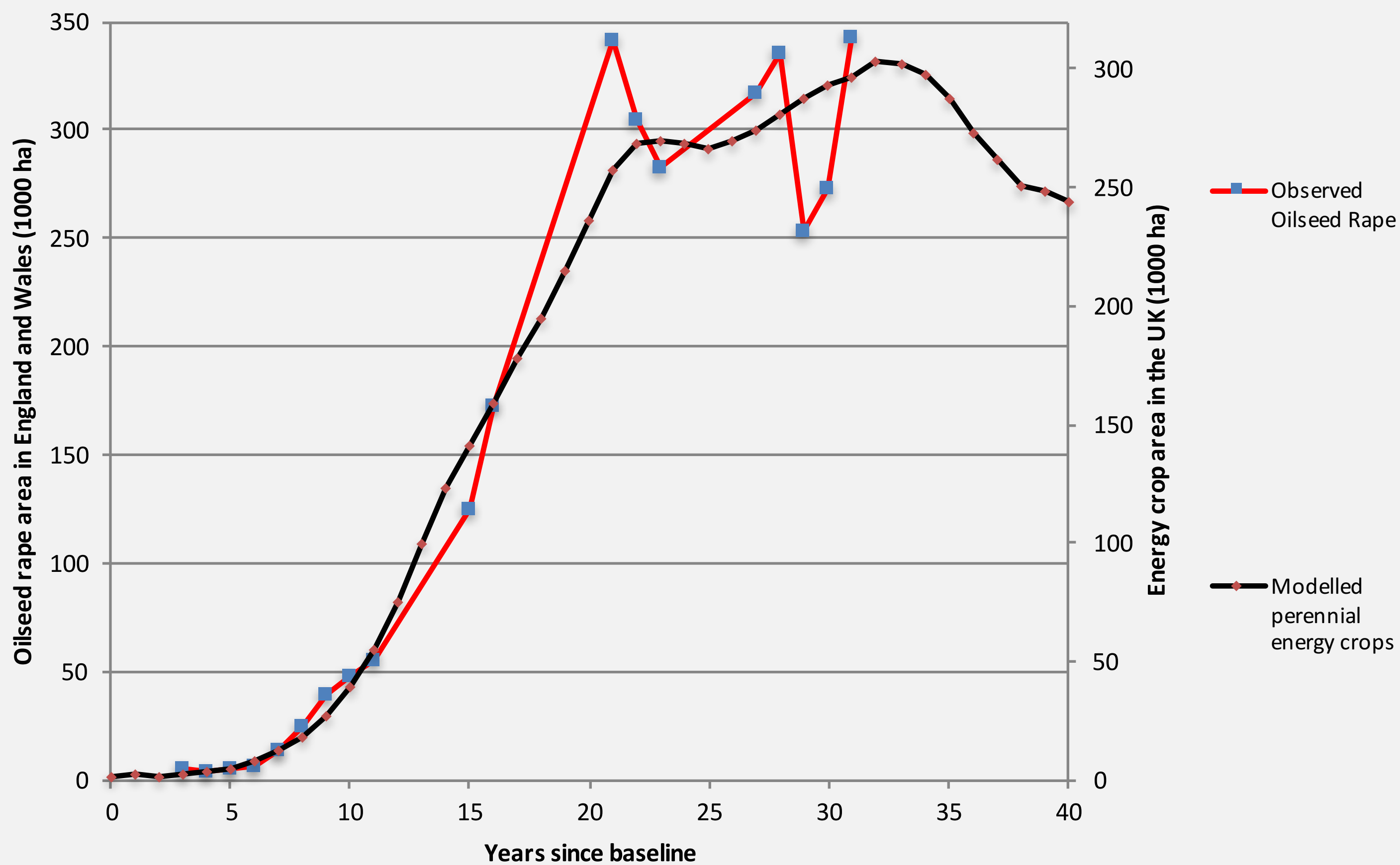


Figure 5. Sample output maps of energy crop selection and power plant locations in 2020, 2030 and 2040.

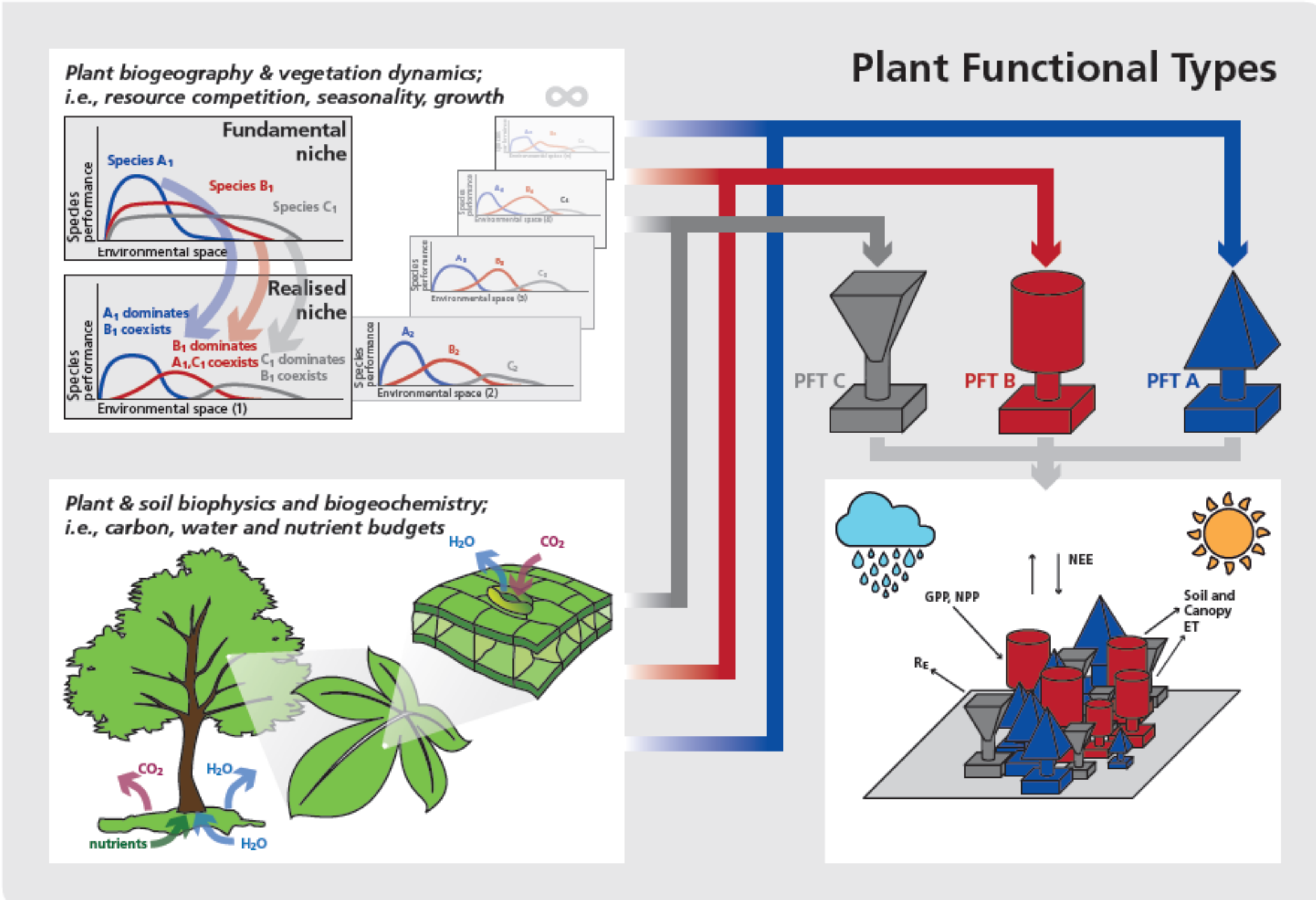
Alexander et al. (2013). *Journal of the Royal Society Interface*, **10**, 20130656



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

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

Plant Functional Types



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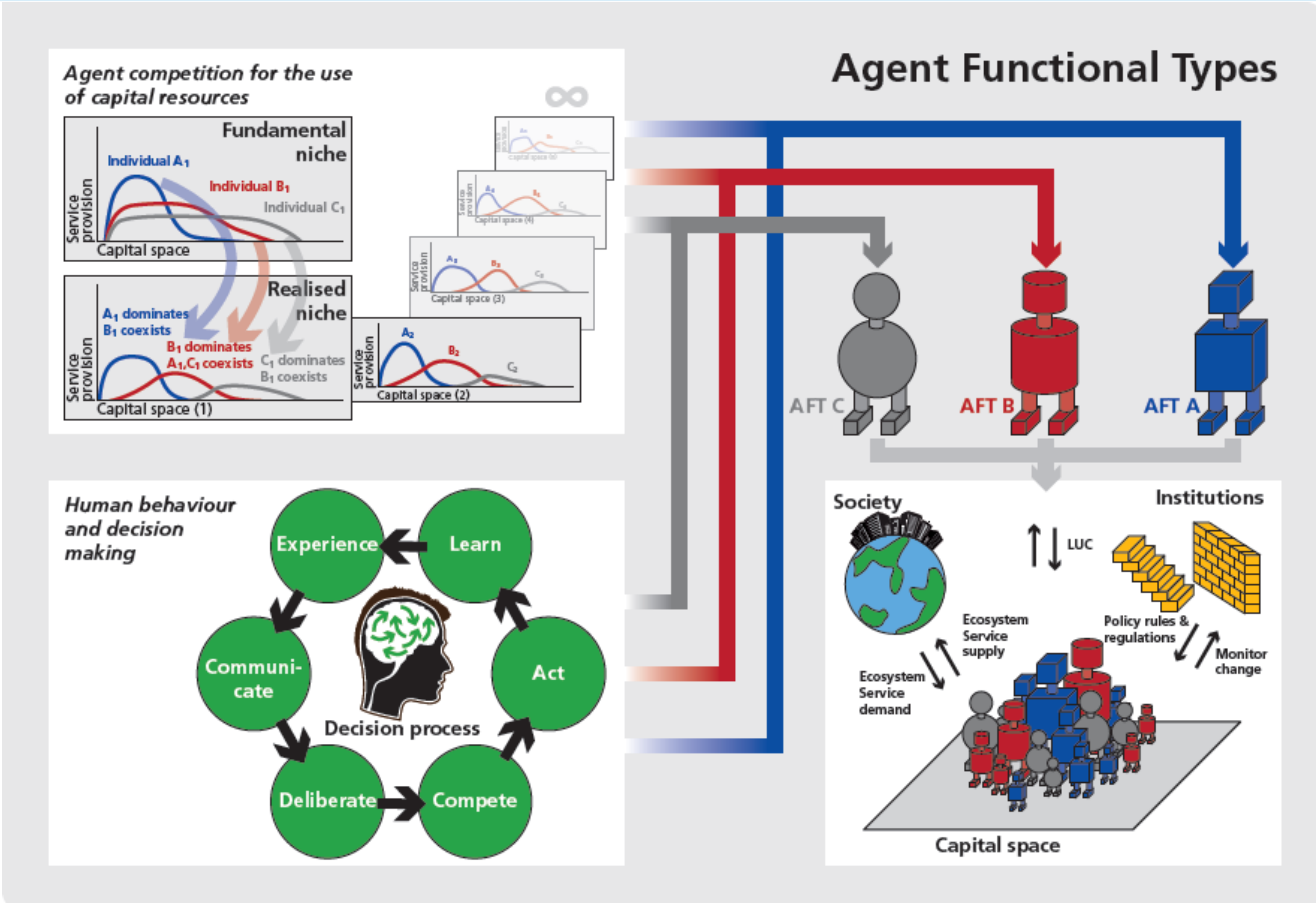
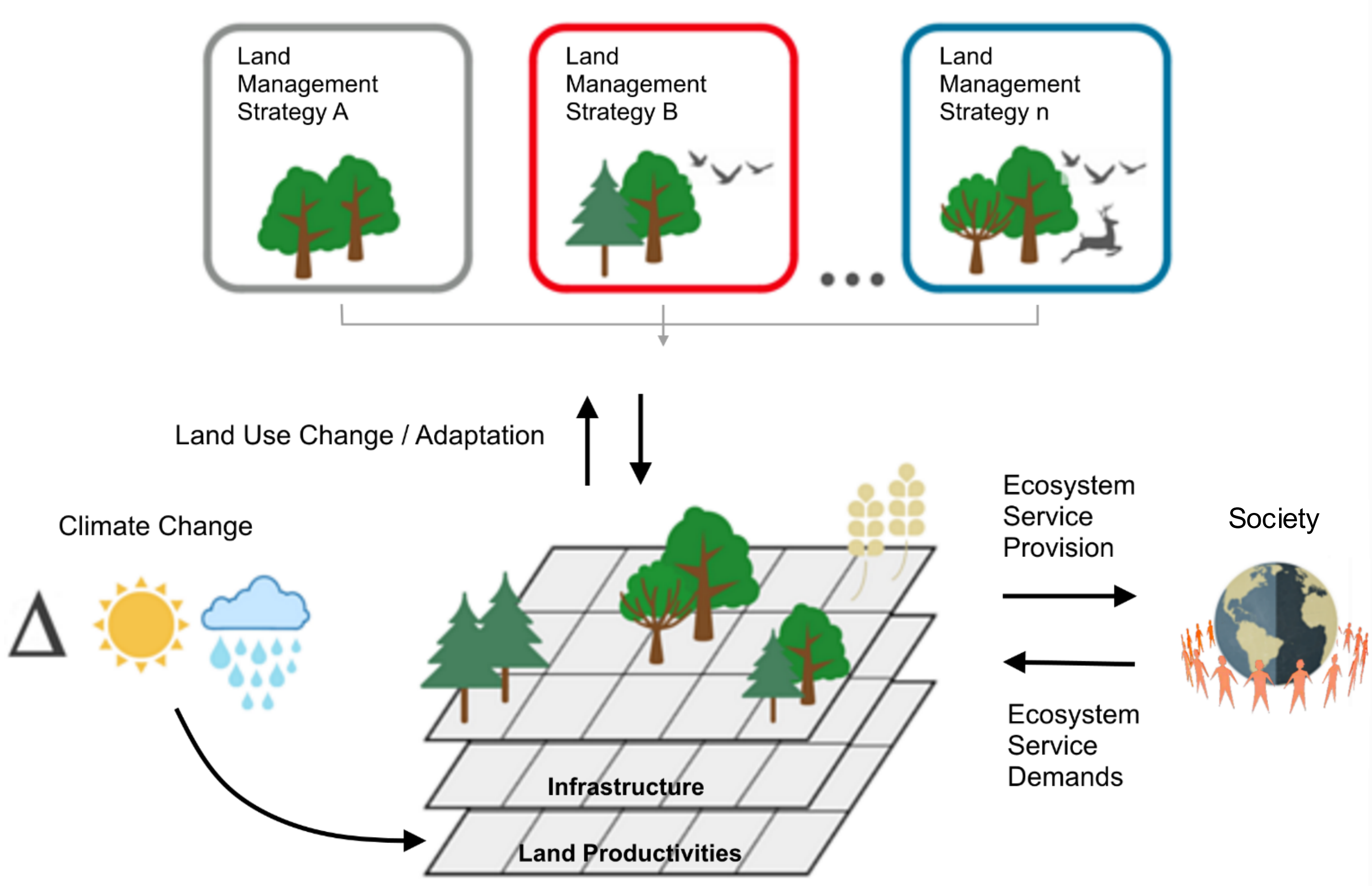


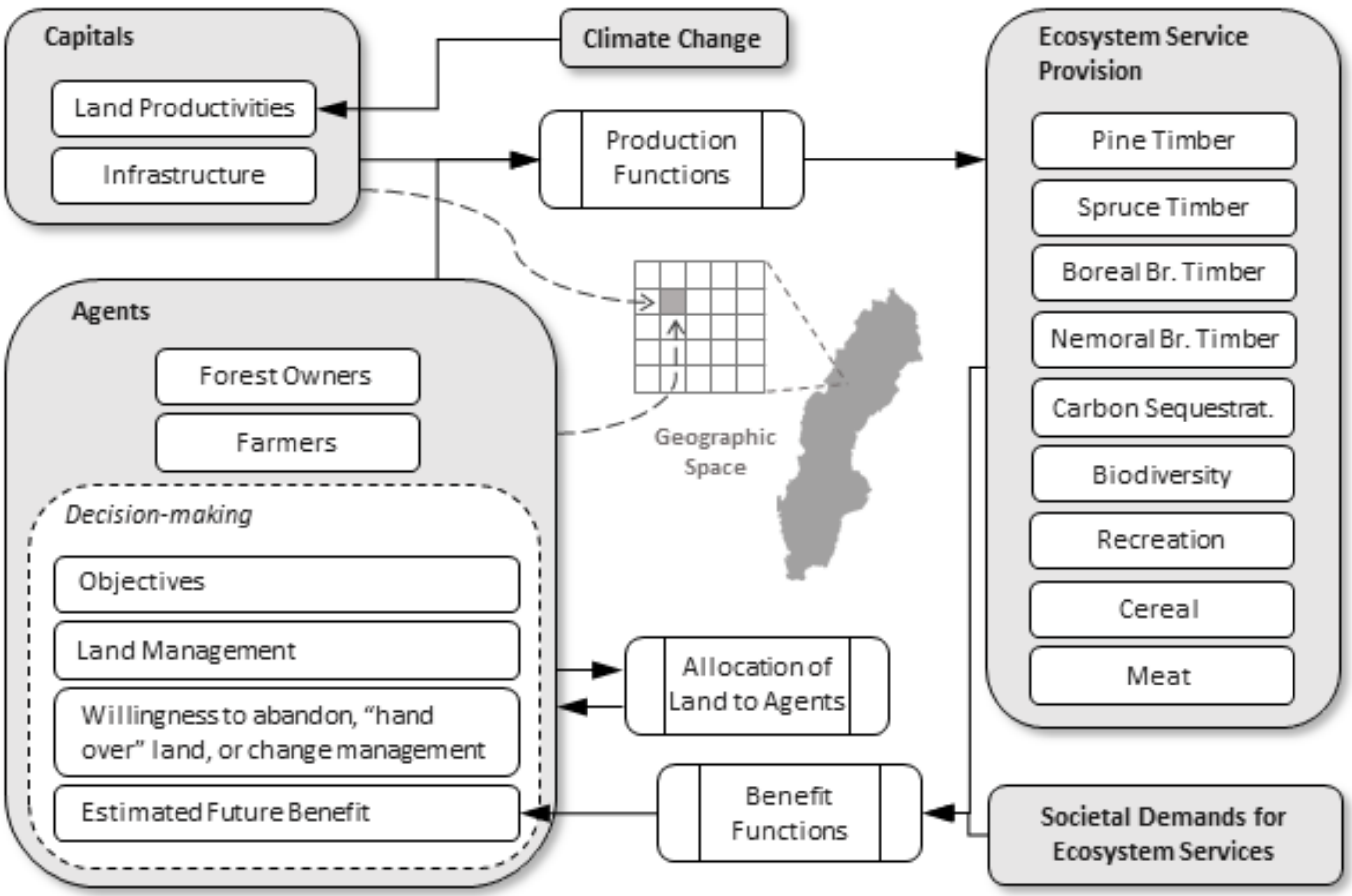
Arneth, A., Rounsevell, M.D.A. & Brown, C. (2014). Global models of human decision-making for land-based mitigation and adaptation assessment. *Nature Climate Change*, **4**, 550–557

Modelling Adaptation to Global Change in the Swedish forestry sector



CRAFTY-Sweden Model

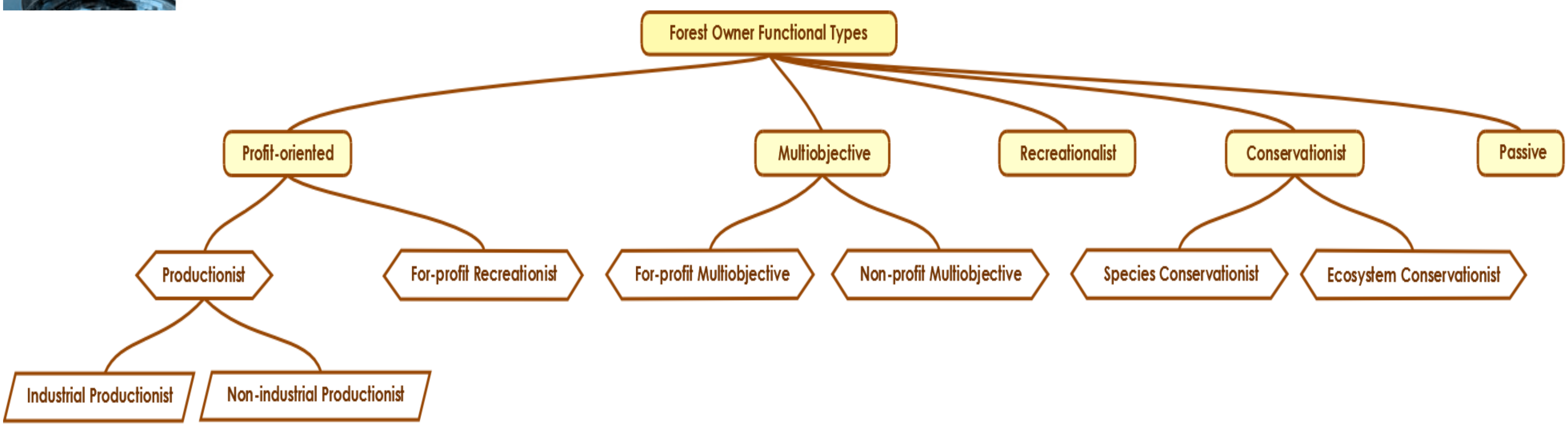
Modelling Adaptation to Global Change in the Swedish forestry sector



1 km² resolution

CRAFTY-Sweden Model

Forest Owner Functional Types



(Blanco et al. 2015)

Mapping and modelling Land Owner Types

Land Use

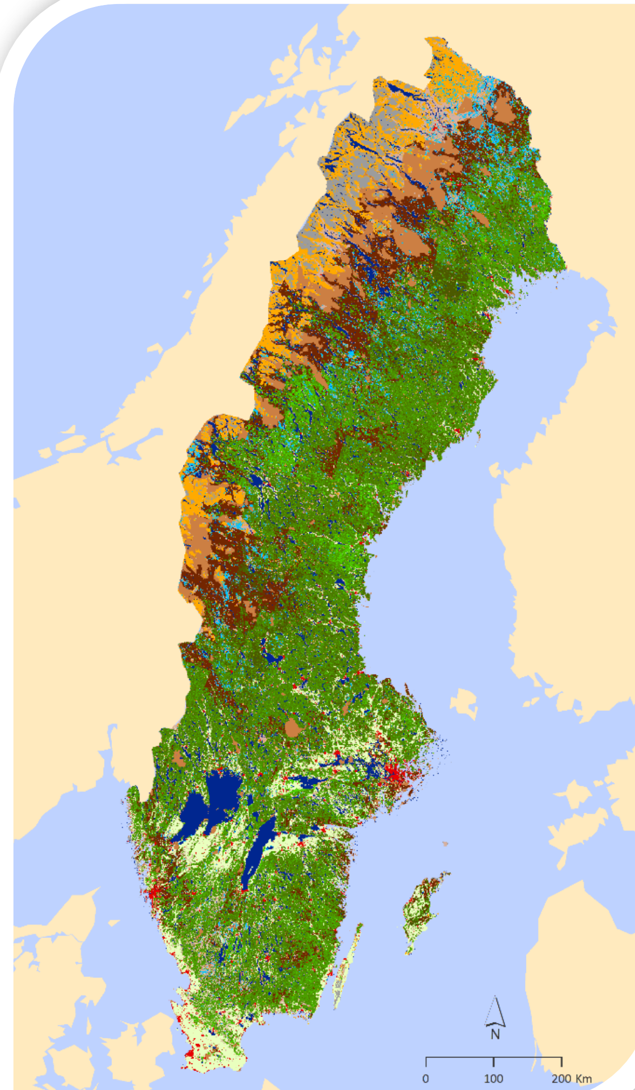
- Pine
- Spruce
- Boreal Broadleaf
- Nemoral Broadleaf
- Pine – Spruce
- Pine – Boreal Broadleaf (≥30%)
- Pine – Boreal Broadleaf (<30%)
- Spruce – Boreal Broadleaf (≥30%)
- Spruce – Boreal Broadleaf (<30%)

- Artificial Surface
- Agriculture
- Protected Area
- Non-productive Forest
- Semi-natural Vegetation
- Open Space
- Wetland
- Water Body
- Unmanaged

Land Owner Types

- Productionist Pine
- Productionist Spruce
- Productionist Pine – Spruce
- Productionist Boreal Br.
- Multi-objective Pine – Spruce
- Multi-objective Pine – Boreal Br.
- Multi-objective Spruce – Boreal Br.
- Multi-objective Boreal Br.
- Recreationalist Pine – Spruce
- Recreationalist Boreal Br.
- Recreationalist Nemoral Br.
- Conservationist Boreal Br.
- Conservationist Nemoral Br.
- Passive Pine – Boreal Br.
- Passive Spruce – Boreal Br.
- Passive Boreal Br.
- Passive Nemoral Br.

- Unavailable
- Farmer (Commer/Non-commer + Cereal/Meat)
- Unavailable
- Unavailable
- Unmanaged
- Unavailable
- Unmanaged
- Unavailable
- Unmanaged



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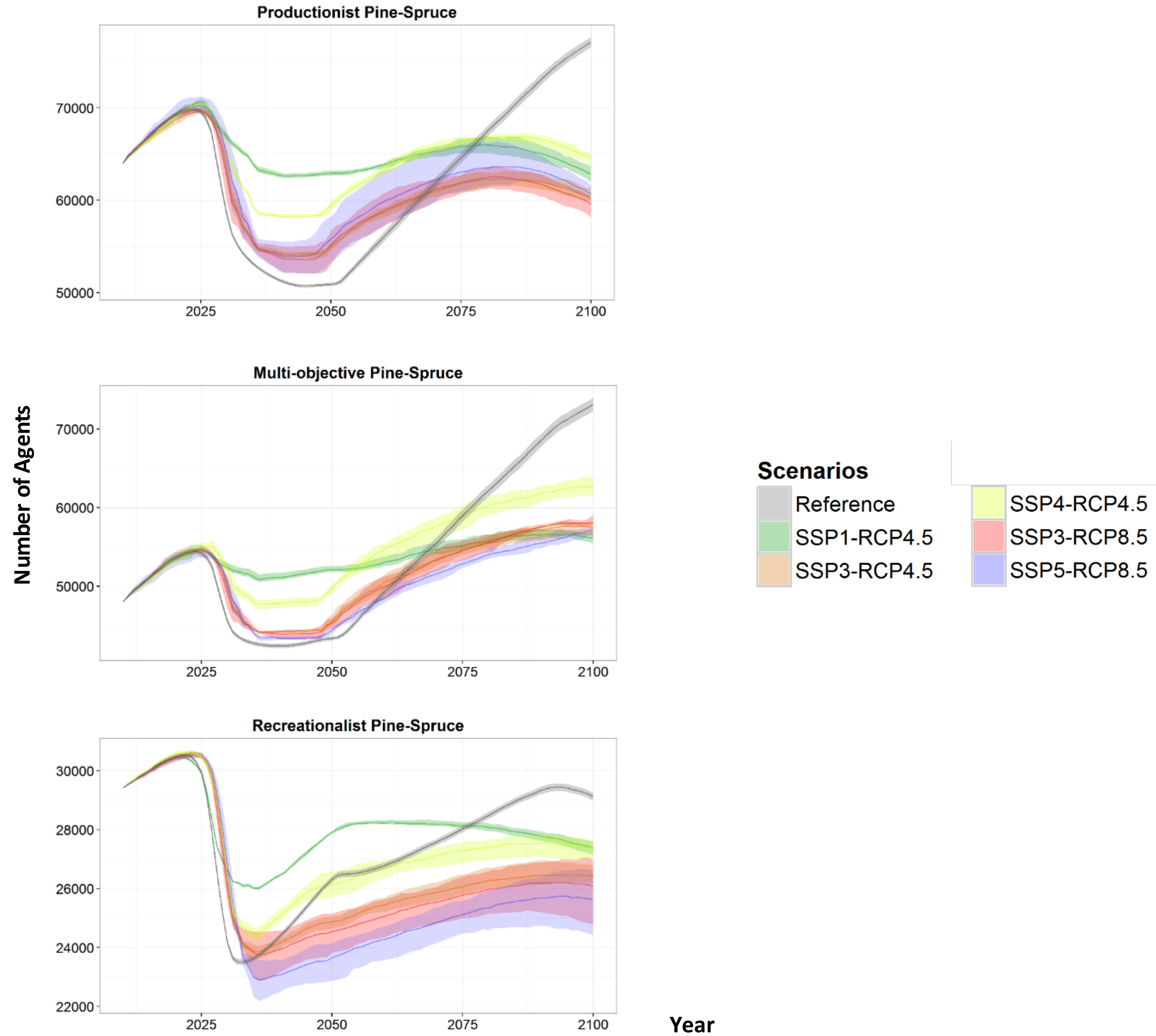
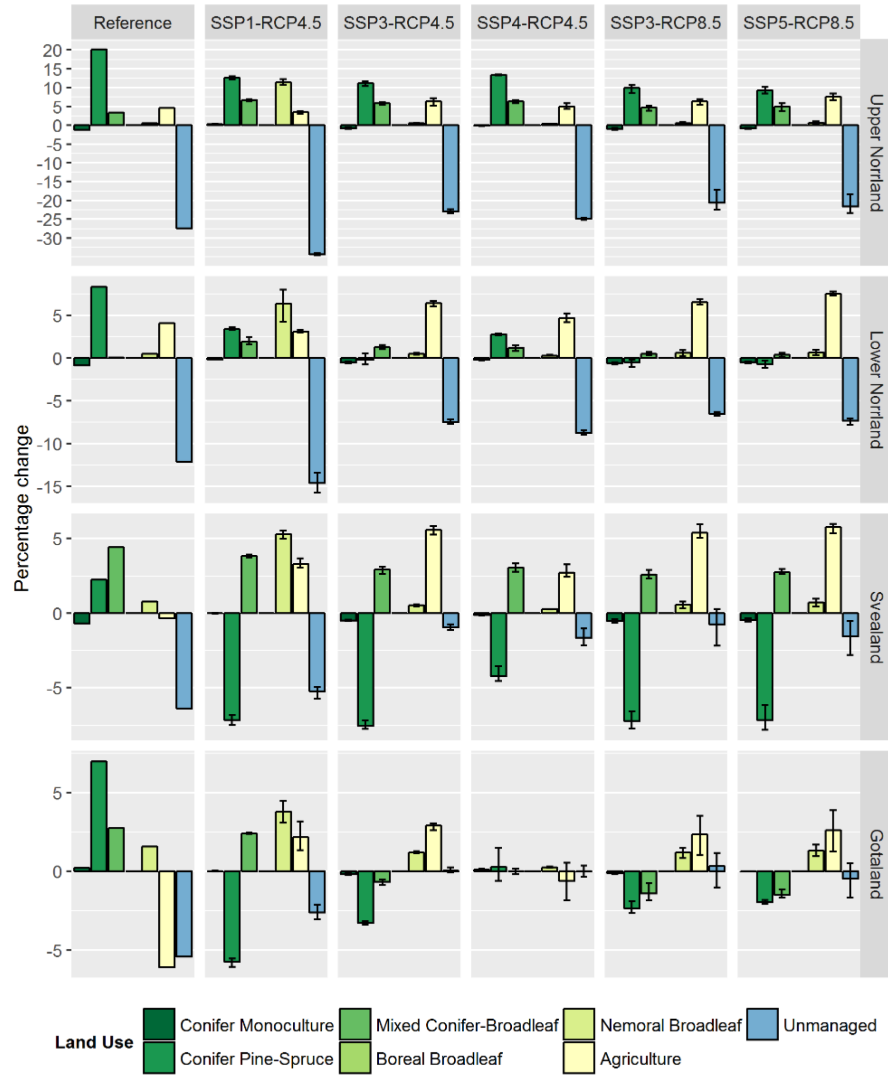
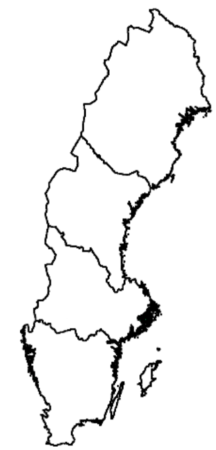
Competitiveness of Forest Owner Types

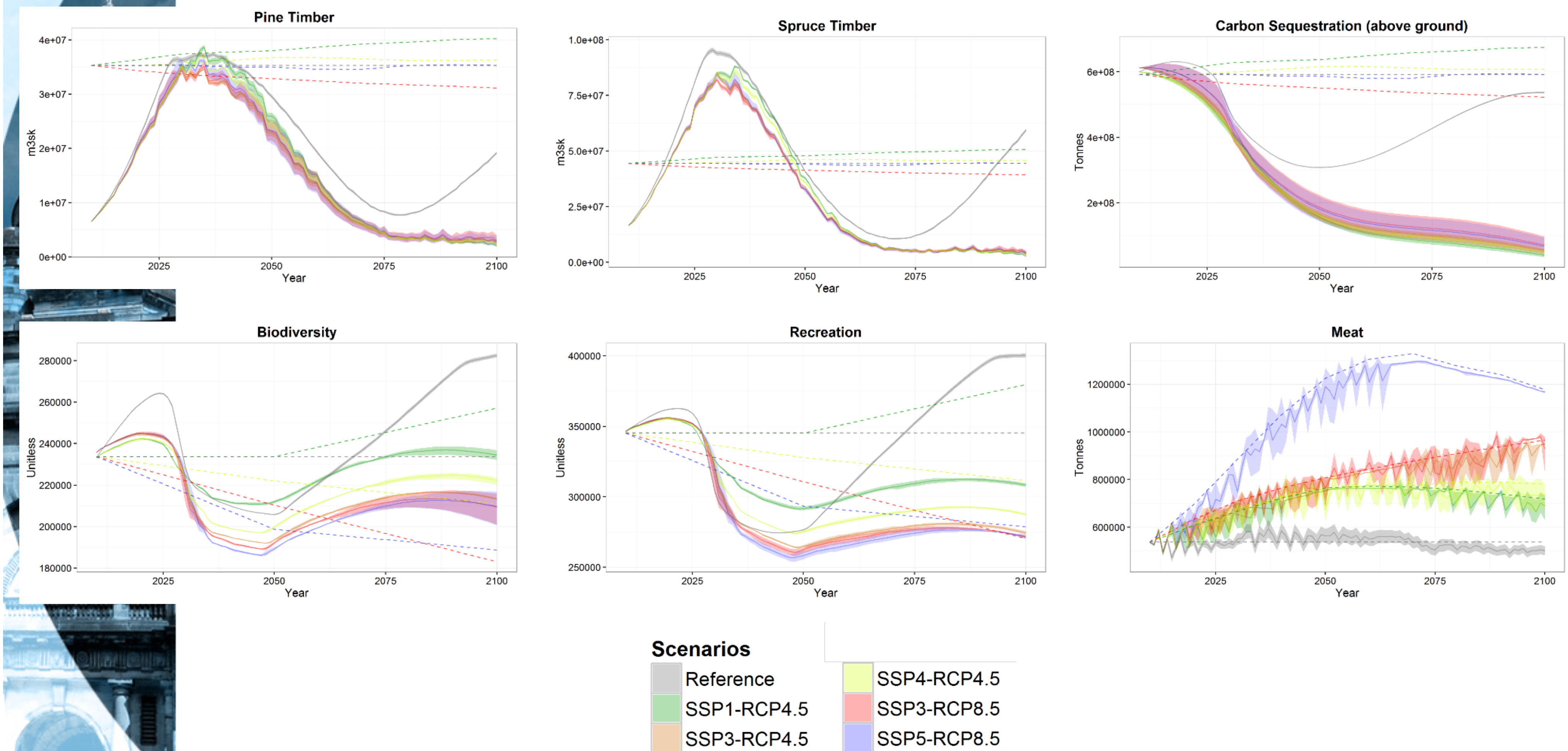


Regional land-use changes (2010-2100)





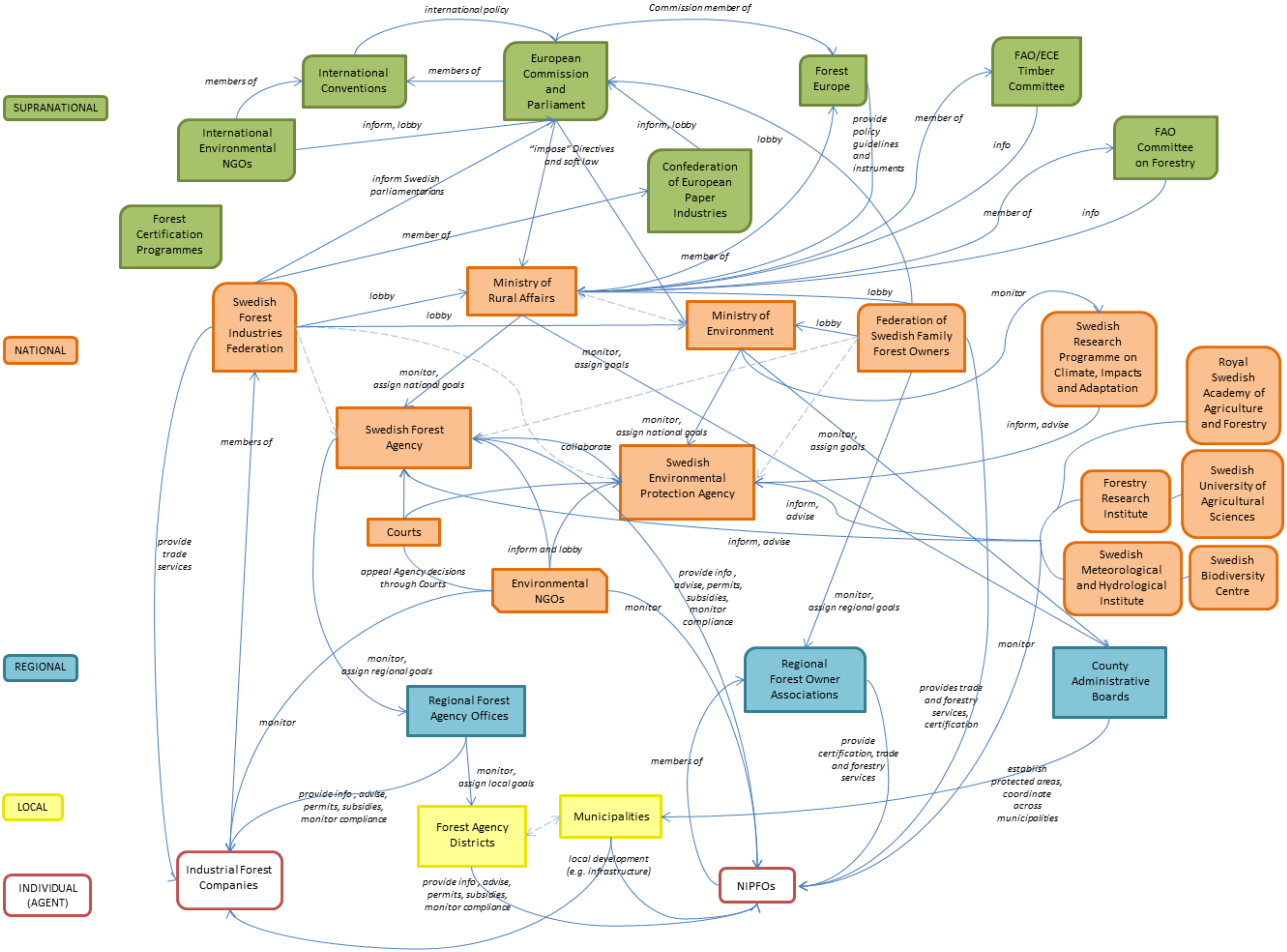
Ecosystem Service Provision (2010-2100)



Coping Ability of Forest Owner Types

Coping Ability:

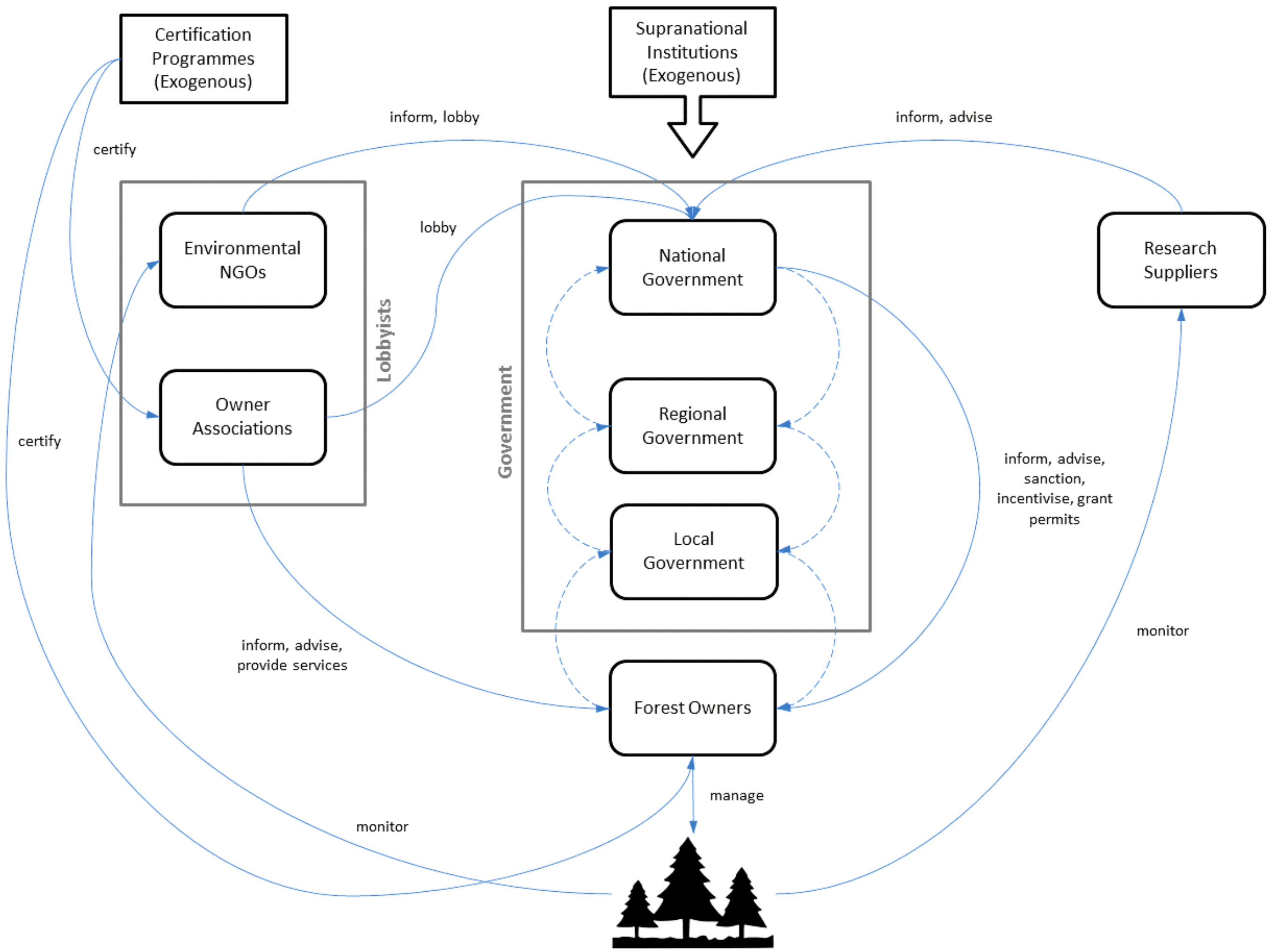
degree to which an owner type can be at least as <u>competitive</u> under a global change future (defined by the scenarios) as under present conditions



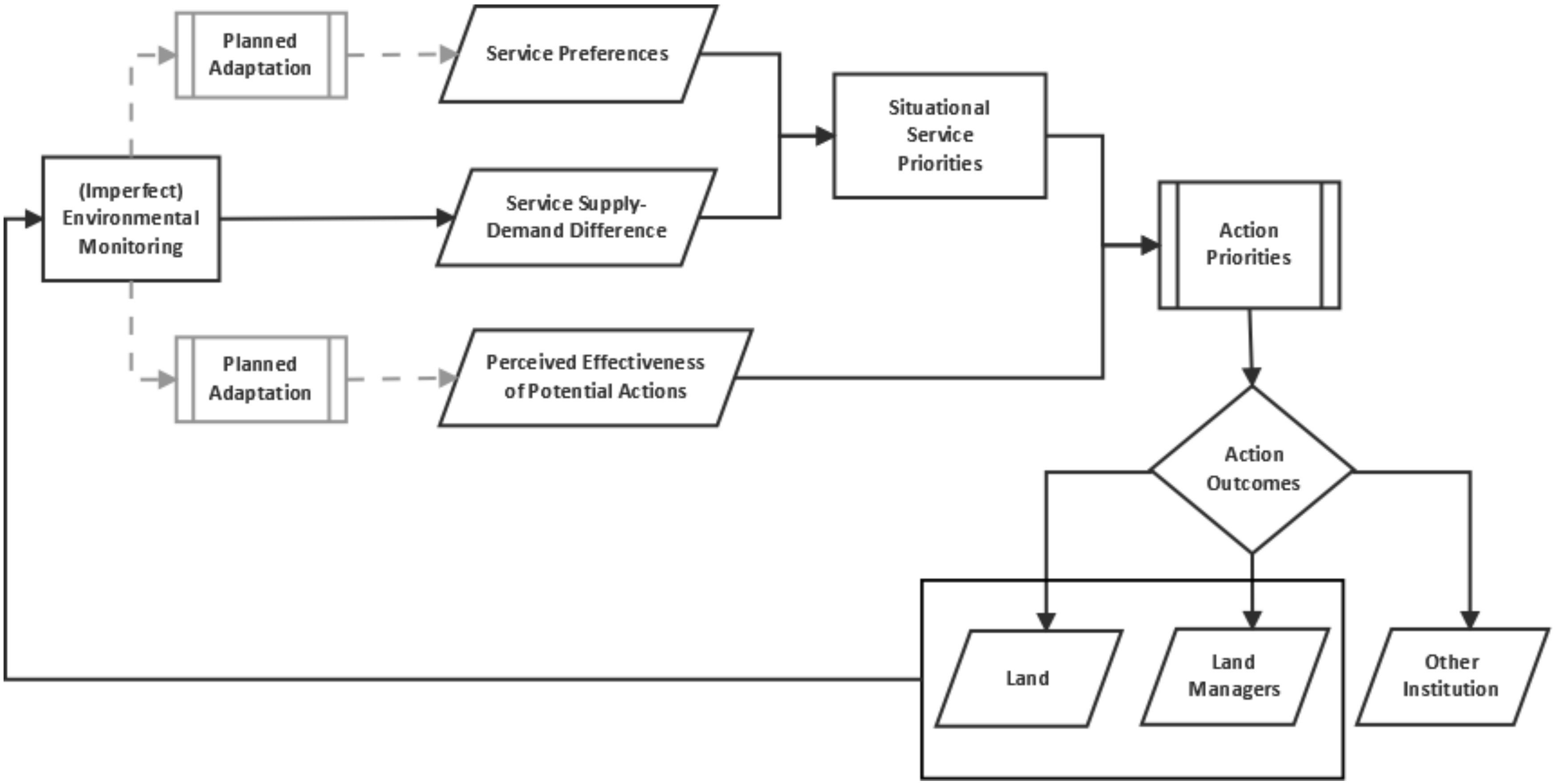
SUPRANATIONAL
NATIONAL
REGIONAL
LOCAL
INDIVIDUAL (AGENT)
International Conventions
European Commission and Parliament
Forest Europe
FAO/ECE Timber Committee
FAO Committee on Forestry
International Environmental NGOs
Confederation of European Paper Industries
Forest Certification Programmes
Swedish Forest Industries Federation
Ministry of Rural Affairs
Ministry of Environment
Federation of Swedish Family Forest Owners
Swedish Research Programme on Climate, Impacts and Adaptation
Royal Swedish Academy of Agriculture and Forestry
Swedish Forest Agency
Swedish Environmental Protection Agency
Forestry Research Institute
Swedish University of Agricultural Sciences
Courts
Environmental NGOs
Swedish Meteorological and Hydrological Institute
Swedish Biodiversity Centre
Regional Forest Owner Associations
County Administrative Boards
Regional Forest Agency Offices
Forest Agency Districts
Municipalities
Industrial Forest Companies
NIPFOs
international policy
Commission member of
members of
members of
inform, lobby
inform, lobby
lobby
"impose" Directives and soft law
inform Swedish parliamentarians
member of
member of
provide policy guidelines and instruments
member of
info
member of
info
lobby
lobby
lobby
lobby
monitor
monitor, assign goals
monitor, assign national goals
monitor, assign national goals
collaborate
monitor, assign goals
inform, advise
members of
inform, advise
inform, advise
provide trade services
inform and lobby
appeal Agency decisions through Courts
provide info, advise, permits, subsidies, monitor compliance
monitor
monitor, assign regional goals
monitor, assign regional goals
monitor
monitor
provides trade and forestry services, certification
members of
provide certification, trade and forestry services
monitor, assign local goals
provide info, advise, permits, subsidies, monitor compliance
establish protected areas, coordinate across municipalities
local development (e.g. infrastructure)
provide info, advise, permits, subsidies, monitor compliance

Institutional Types

Conceptual model of generic institutions in the Swedish forestry sector



Institutional Action Conceptual Model



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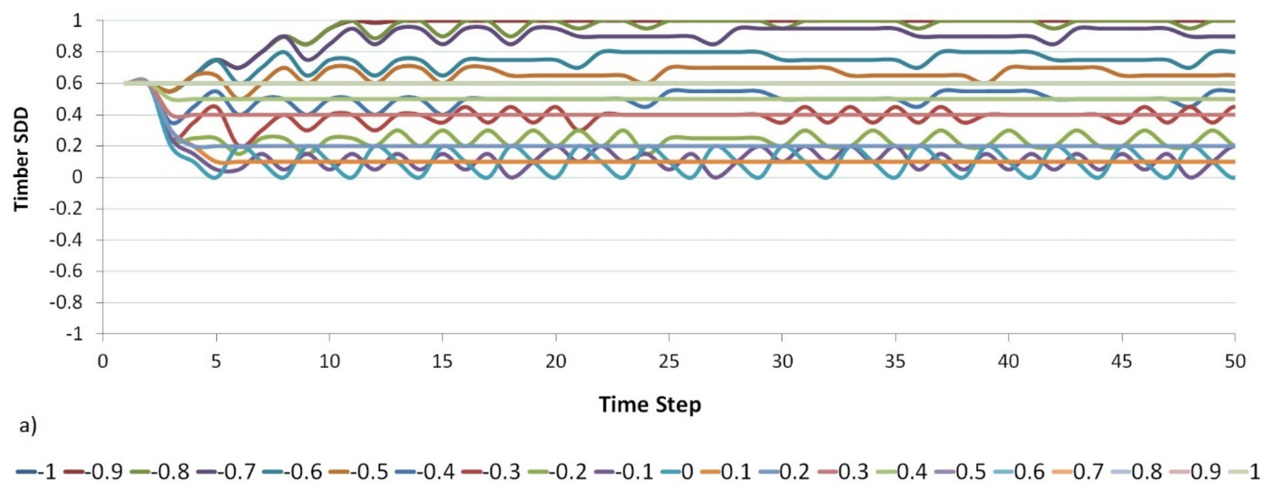
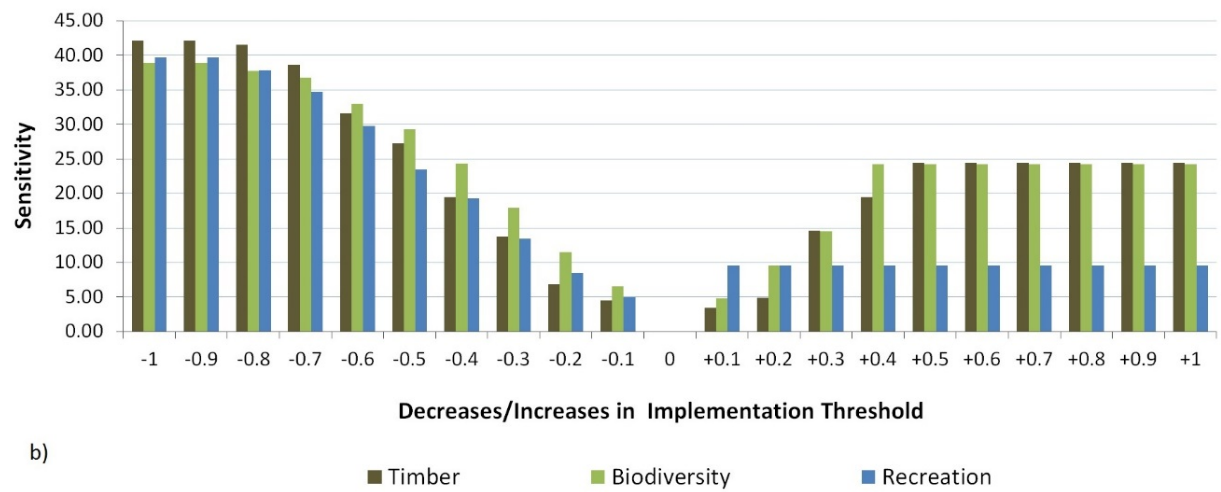
Land planner preference weights for scenarios

Scenario	Description	Service Supply-Demand Differences		
		Timber	Biodiversity	Recreation
TIMBER PROFUSION	Available forest land is managed primarily for timber production while other services are treated as secondary. Timber supply is very high to the point of substantially going beyond the demand. The supply of biodiversity associated with production-oriented forests is low. Under such circumstances some recreation is provided, but it does not meet demand.	0.6	-0.5	-0.1
ENVIRONMENTAL EDEN	A large proportion of the forest land is managed with nature conservation as a primary objective. Supply of timber does not meet demand, while biodiversity is oversupplied. Recreation, being partly associated with levels of biodiversity, is also supplied slightly beyond the demand.	-0.2	0.5	0.1
PERFECT EQUILIBRIUM	Forest land management seeks multi-functionality. Production levels of all three services are equal, but they do not meet the demand.	-0.3	-0.3	-0.3

Example: supply demand difference (SDD)





Institutions as emergent structures?

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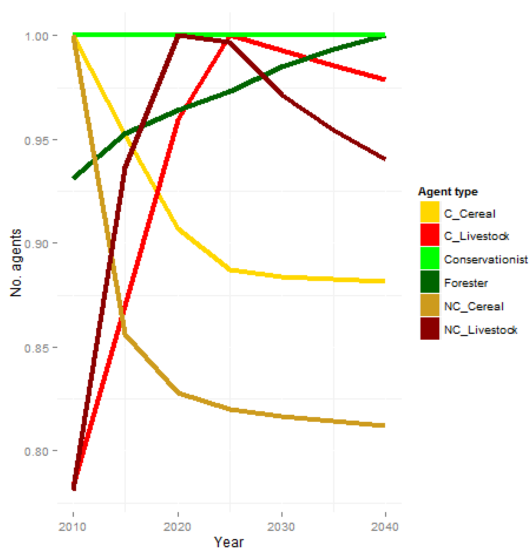
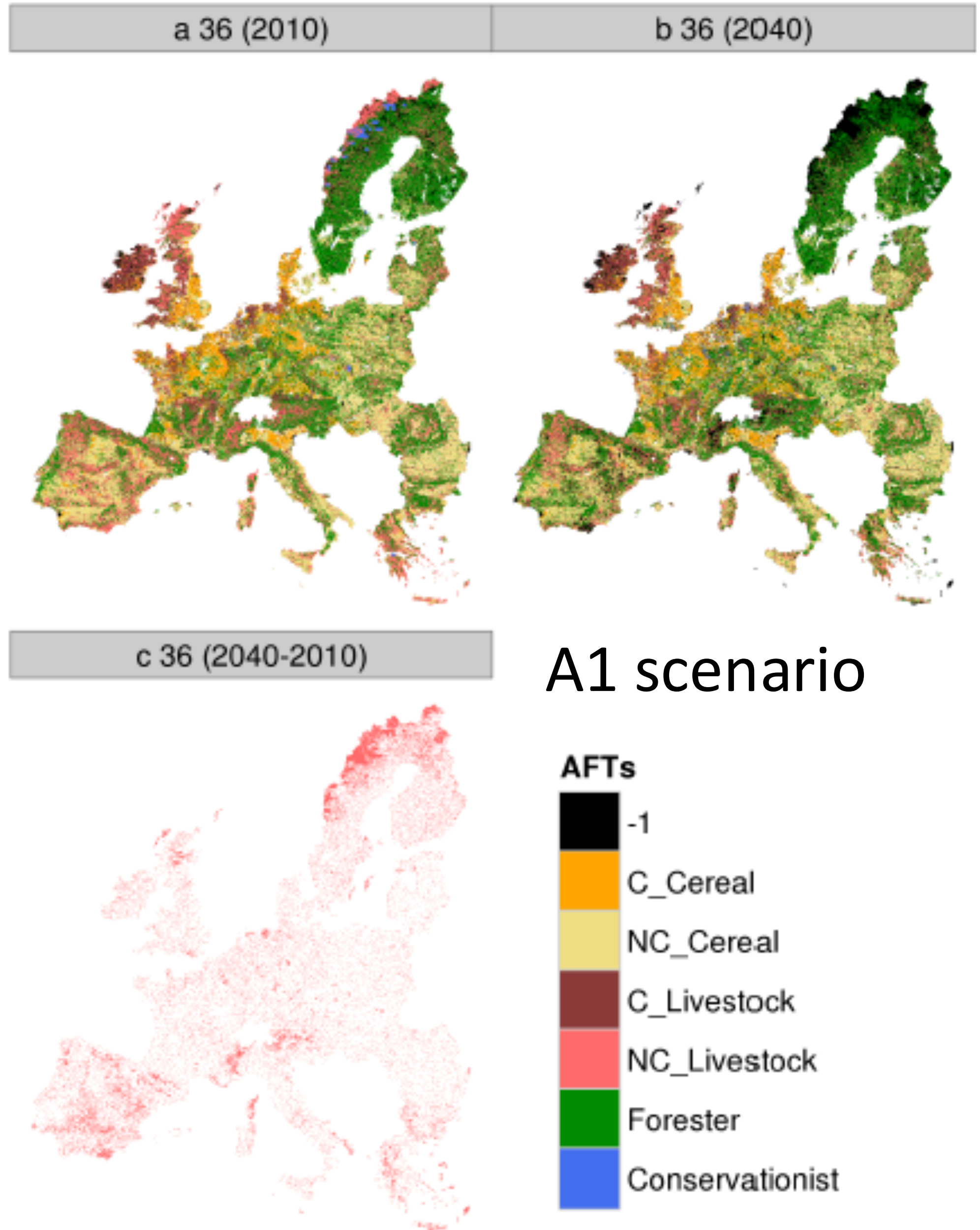
The CRAFTY model: continental scale applications





A1 scenario

Ways forward?

- Building the next generation of human dimensions models that are based on:
  - Better theory
  - More complete process representation, e.g. individual decision making, adaptive learning, agent evolution, institutional emergence, …
  - Multi-scalar dynamics
  - Building from the bottom-up, rather than the top down
- Do we need typologies, or models of 8 billion agents?

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Models in a land use change inter-comparison study

Model name	Key Publication	Spatial resolution data (model, if different)	Spatial extent[+]	Temporal resolution data (model, if different)	Model type (classification)	Scenario descriptions (number of scenarios)
AIM/CGE	Fujimori *et al.* (2012)	17 regions	Global	2005, 2010, 2030, 2050 and 2100 (annual)	CGE	SSP1, SSP2 and SSP3. (3)
CAPS	Meiyappan *et al.* (2014)	0.5 x 0.5 degree grid	Global	2005, 2030, 2050 and 2100	Allocation model using demand from CGE or PE model (Hybrid)	SSP3, SSP5, RCP 4.5 and RCP 8.5, each under estimated model parameters from historical data from Ramankutty et al.(Ramankutty *et al.*, 2008) and HYDE(Goldewijk, 2001). (8)
CLIMSAVE-IAP	Harrison *et al.* (2015)	10 x 10 arc-minute grid	Europe (EU27+2)	2010 and 2050	Rule-based	SRES A1, A2, B1 and B2, each under current baseline and the socio-economic factors for the SRES scenario*. (8)
CLUMondo	van Asselen & Verburg (2013)	9,25 x 9,25 km grid	Global	2000 - 2040; decadal (yearly)	Allocation model using demand from CGE or PE model (Hybrid)	FAO 4Demand, Carbon, Potential Protected Area. (3)
CRAFTY	Murray-Rust *et al.* (2014)	1 x 1 km grid	Europe (EU27)	2010 - 2040; decadal (yearly)	Agent-based model (Rule-based)	SRES A1 and B1. (2)
DynaCLUE	Verburg & Overmars (2009)	1 x 1 km grid	Europe (EU27)	2000-2040; decadal	Allocation model using demand from CGE or PE model (Hybrid)	SRES A1, A2, B1 and B2. (4)
EcoChange	Dendoncker *et al.* (2006)	250 x 250m grid	Europe (EU25+2)	2010, 2020, 2050, 2080	Rule-based	Three core socio-economic scenarios, growth and globalisation, BAU, and sustainable development, and three shock scenarios, climate, energy price and pandemic shocks. (6)
FABLE	Steinbuks & Hertel (2014)	Global	Global	2005-2105; annual	PE	Baseline consistent with SRES A1B and RCP 2.6, with other scenarios adjusting population, climate to RCP 8.5, oil prices, economic growth, and more stringent GHG emission regulations (6)
FALAFEL	Powell (2015)	Global	Global	2000 - 2050; decadal	Rule-based	SSP1, SSP2, SSP3, SSP4 and SSP5. (5)
FARM	Sands *et al.* (2014)	13 regions	Global	2005 - 2050; five year steps	CGE	SSP1, SSP2 and SSP3, each under the current climate and climate scenario RCP 4.5, RCP 6.0 and RCP 8.5, respectively*. (6)
GCAM	Calvin *et al.* (2013)	32 regions	Global	2010 - 2100; decadal	PE	SSP1, SSP2, SSP3, SSP4 and SSP5. (5)
GLOBIOM	Havlík *et al.* (2014)	5 x 5 arc-minute grid	Global	2010 - 2100; decadal	PE	SSP1, SSP2, SSP3 (3)
IMAGE	Stehfest *et al.* (2014)	0.5 x 0.5 degree grid (5 x 5 arc-minute)	Global	2010, 2030, 2050 and 2100 (annual)	Allocation model using demand from CGE model (Hybrid)	SSP2 reference and high bio-energy demand scenario under RCP 2.6. (2)
LandSHIFT	Schaldach *et al.* (2011)	5 x 5 arc-minute grid	Global	2005-2050; five year steps	Rule-based	Fuel and heat scenarios, with both BAU and regulation assumptions for each. (4)
LUISA	Baranzelli *et al.* (2014)	100 x 100m grid	Europe (EU28)	2010 - 2050; decadal (annual)	Cellular-automata and statistical model (Rule-based)	Reference scenario. (1)
MAGNET	van Meijl *et al.* (2006)	26 regions	Global	2007, 2010, 2020, 2030, 2050 and 2100	CGE	SSP1, SSP2 and SSP3. (3)
MAgPIE	Popp *et al.* (2014)	0.5 x 0.5 degree grid	Global	1995-2100, five year steps	PE	Scenarios based on SSP2, with and without bioenergy CCS. (2)
PLUM	Engström *et al.* (2016)	157 countries	Global	1990-2100; annual	Rule-based	SRES A1, A2, B1 and B2 (4)

Notes:
[+] EU27 is current 28 European Union member states (EU28) less Croatia. EU25 additionally excludes Romania and Bulgaria. EU25+2 & EU27+2 includes Norway and Switzerland to EU25 and EU27, respectively.
* CLIMSAVE-IAP and FARM provided results for multiple climate models under otherwise the same scenario; the mean figure for each scenario/model combination was used.

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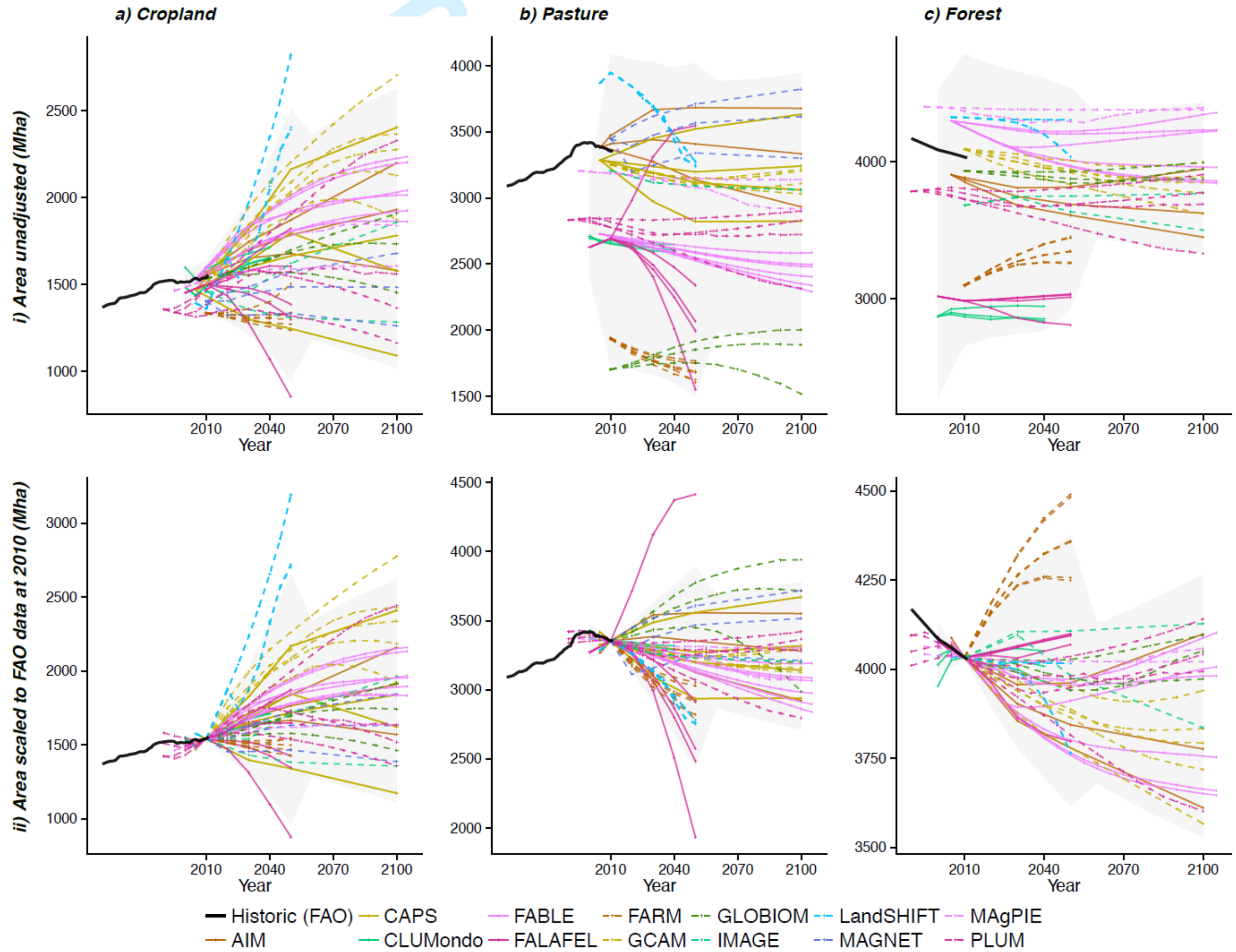
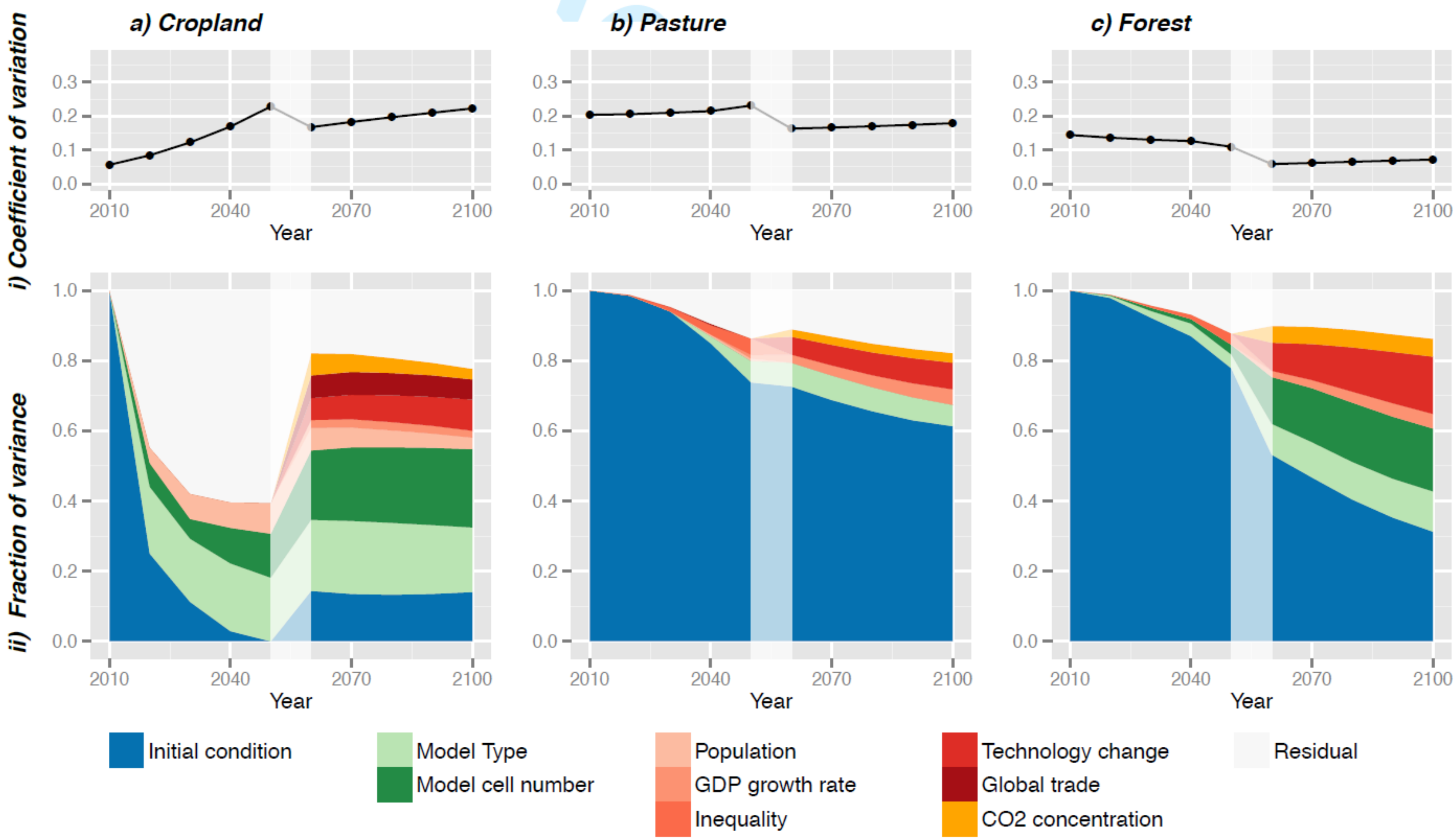
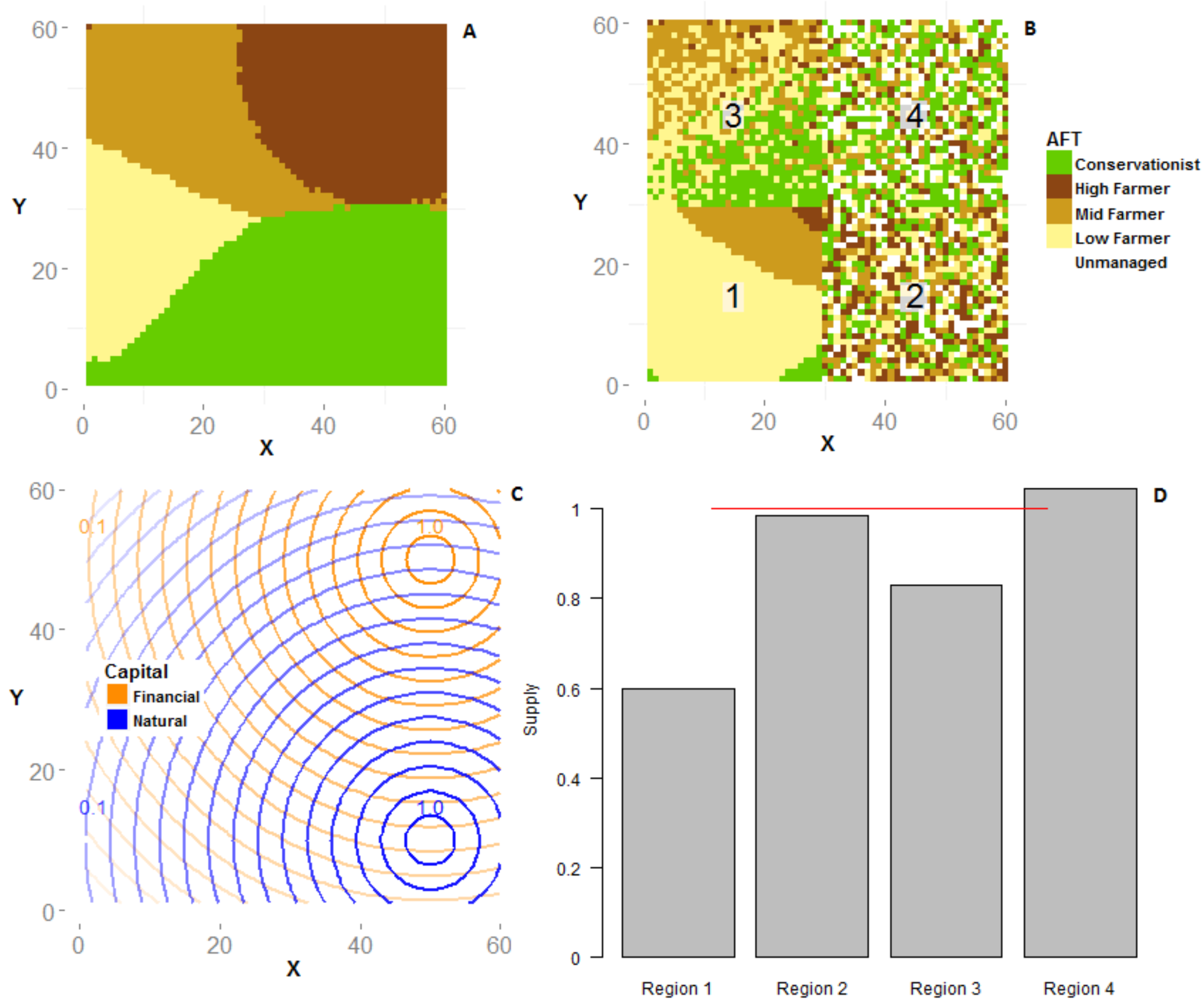
Uncertainties in global scale land use models



Global coefficient of variation and variance components



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



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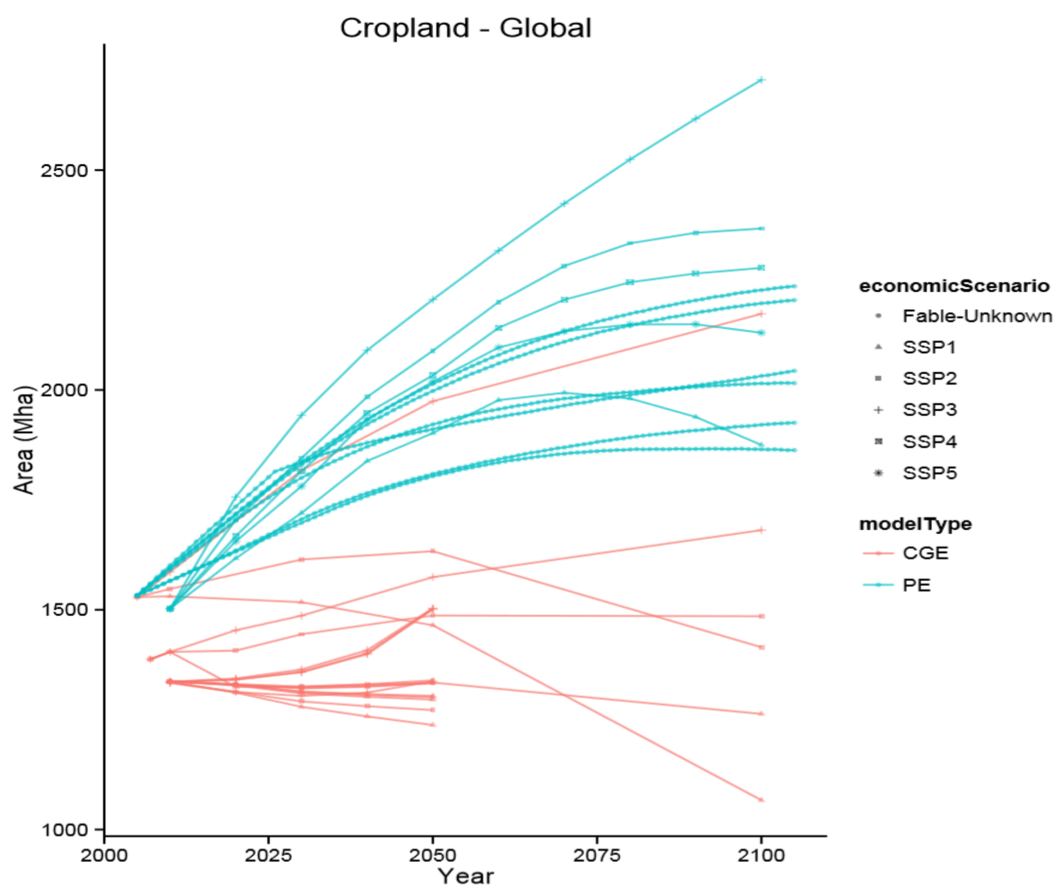
Economic model type (CGE vs PE) for cropland



Source: Peter Alexander, University of Edinburgh