



Social Simulation Modelling within Landscape Systems

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Outline

- Brief introduction to agent-based modelling
- Semantic integration
- Example of FEARLUS-SPOMM
 - Simulating incentivization of biodiversity measures

Agent-Based Modelling

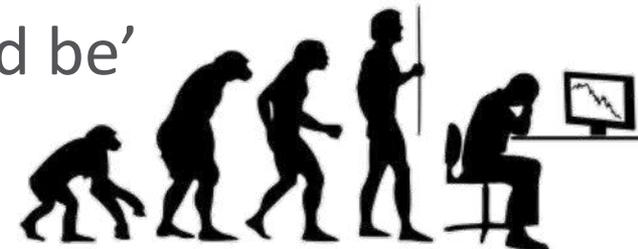
- Various origins, including
 - **Complex systems:** Heterogeneity and Interactions matter
 - **Economics:** Dissatisfaction with *Homo economicus* model
 - **Social Science:** More formal exploration of theory
 - **DAI:** Exploitation of social and psychological theory in artificial systems
- Agent-based modelling is **computer simulation** that explicitly represents **individual heterogeneity** and **interactions**

Agent-Based Modelling

- What is an agent?
 - An explicit **representation** of an individual (person / animal / plant / household / company / government) in a simulation
- Interactions are any effect that one individual may have on another
 - Interpersonal: Negotiation, Markets, Norms, Imitation
 - Stigmergic (indirect – mediated through physical persistence): Ant Trails, Signs, Writing, Traps, Recordings
 - Landscapes
- Interactions form a multi-layered social network
 - Each layer is a relationship

Motivations for ABSS

- A ‘third way’ to do social science
 - More formal than qualitative
 - Less constrained than quantitative
 - Less need to make ‘heroic assumptions’ about human cognition (e.g. *H. economicus*)
 - Less reliance on calculus and preoccupation with equilibria
- Greater transparency
- General applicability
 - ABSS has been used to model diverse case studies
 - Farming, Land Use Change, Afforestation and Deforestation, Transport, Water Use, ...
- Enables explorations of ‘life as it could be’
- Test theories



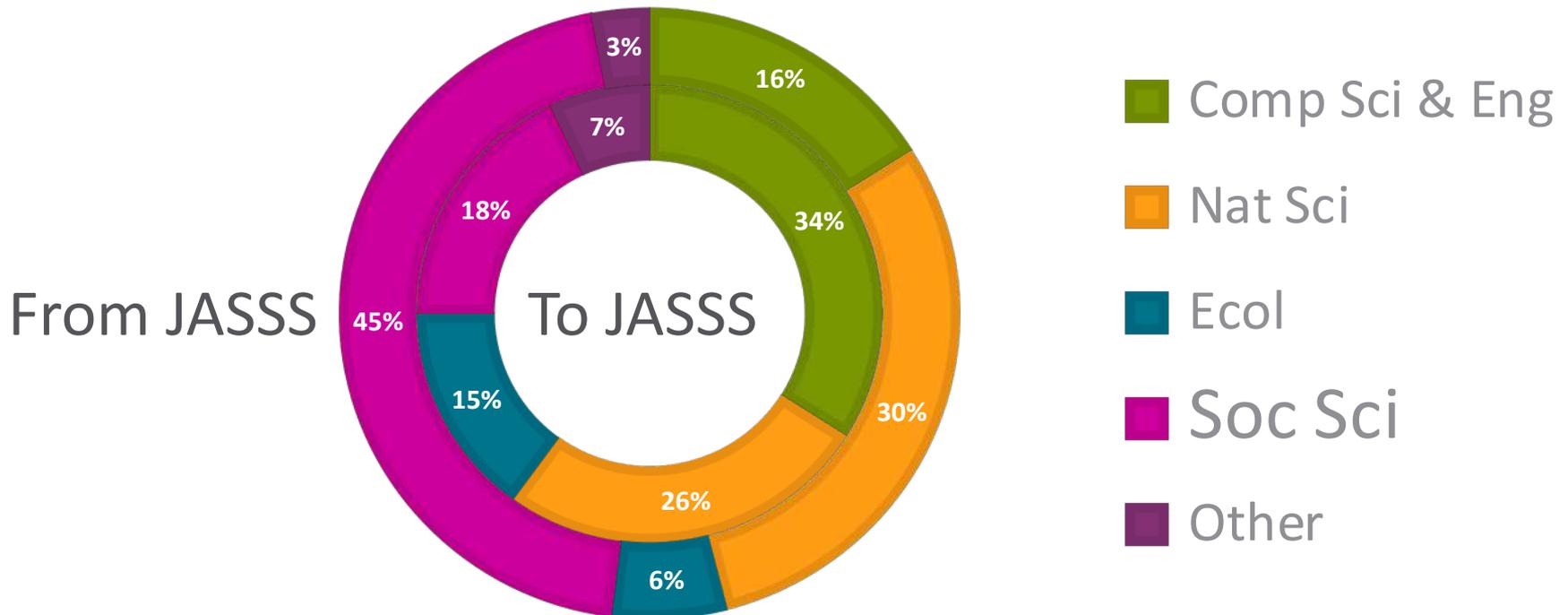
Homo Economicus

Issues

- Long-ish history of ABMs but not routinely used ([Polhill et al. 2019](#))
 - ~ 50 years since Schelling/Sakoda ([Hegselmann 2017](#))
 - ~ 30 years since [Lansing](#) & Kremer
 - ~ 20 years since [Parker et al. \(2003\)](#)
- ‘Complicated’ in social-ecological systems ([Sun et al. 2016](#))
 - Many kinds of agent operating at different scales
 - Coupling ecological, biophysical & social processes
 - Significant data requirements in empirical contexts
- Methodology not established
 - Difficult to learn... Difficult to teach...
- Interdisciplinary expertise needed
 - Should be a ‘good thing’, right...?

Social sciences ‘blind spot’ around ABM

- Squazzoni & Casnici (2013) JASSS
 - Citations of JASSS articles 2002-2012
 - versus citations from JASSS articles
 - ABM not recognised in ‘mainstream’ social science



Decision-making issues

- [Huber et al. \(2018\)](#): diversity of approaches, but...
 - (p. 157): “The lack of consideration of many values, social interactions, norm consideration, and learning in farmers’ decision-making across **European agent-based models** leaves **considerable room to improve the representation of farmers’ decision-making** and a better representation of an agricultural systems perspective in ABM.”
- Other kinds of agent: planning, government, developers, agencies, ...
 - Methodological individualism...

Issues with coupling models

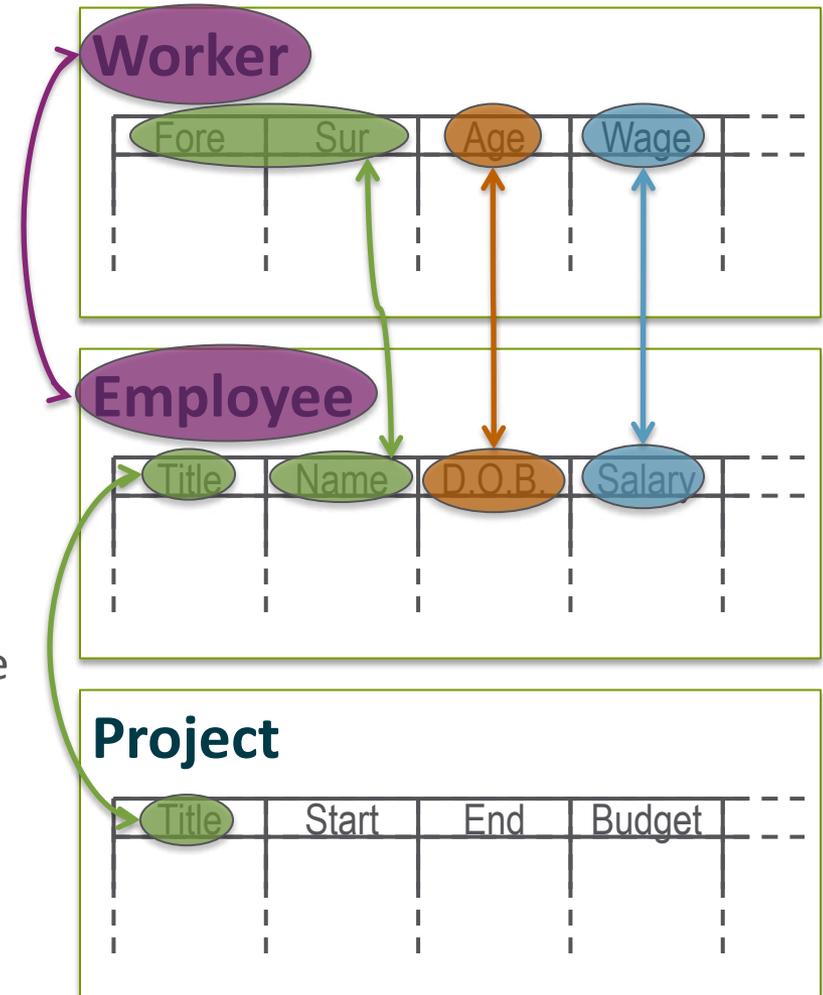
- Various levels of coupling ([Antle et al. 2001](#)):
 - Loose coupling: exchange of variables
 - Issue: Mars Climate Orbiter
 - Close coupling: +linked common subprocesses
 - Issue: Components still not specifically designed to work together
 - Full integration: **one** model with appropriate scales
 - Issue: Less reuse, more expensive
- Risks with loose/close ([Voinov & Shugart 2013](#))
 - ‘Integronsters’

The coupled-model approach to shed building...



Semantic Integration

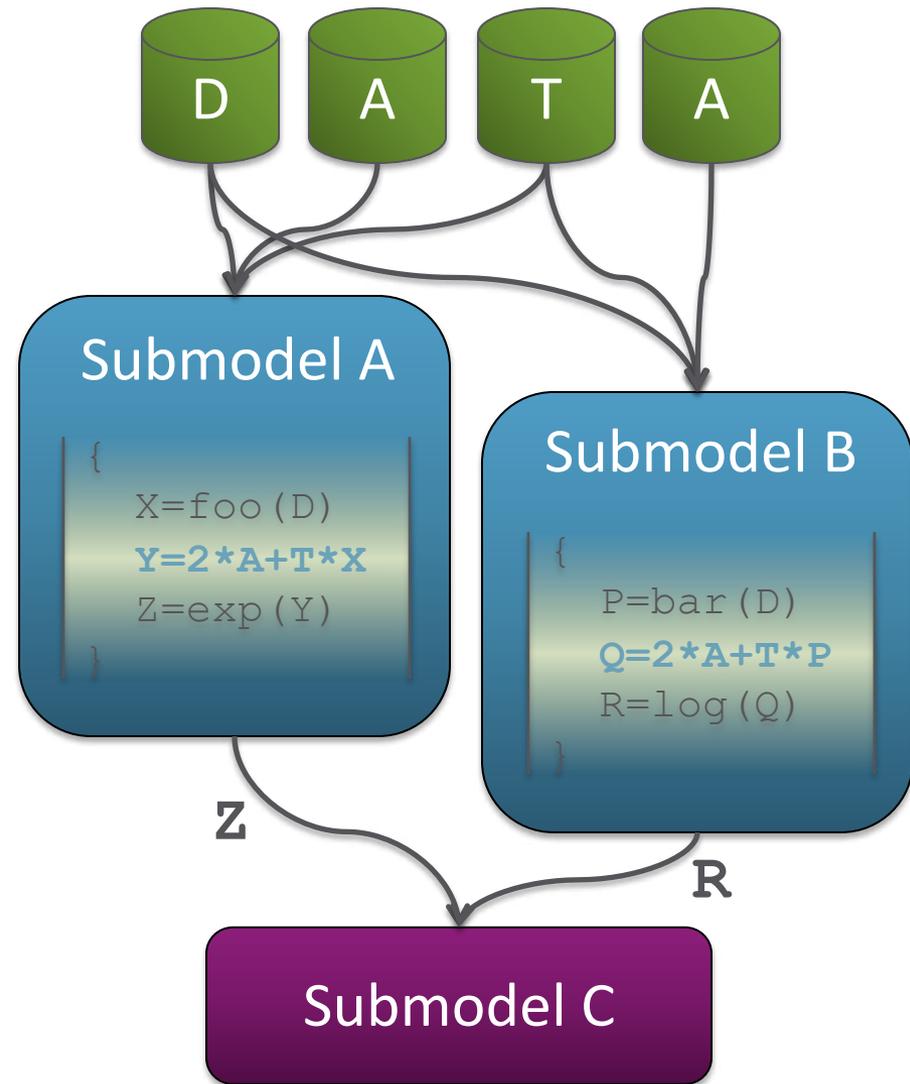
- Problems caused when merging heterogeneous databases...
 - Naming conflicts
 - Scaling conflicts
 - Wage typically paid weekly, Salary monthly
 - Confounding conflicts
 - Workers and Employees have different rights in UK employment law
 - Representation conflicts
- ...and integrating models



([Goh et al. 1999](#), cited in [Bellatreche et al. 2006](#))

Algorithmic conflicts

- Models add dynamics
 - Extra semantic integration issues
 - What if two submodels use a similar concept as an intermediary computation?
- Big problem for black-box model integration environments
 - You've no idea it is even happening
 - Especially if submodels have protected IPR...



Ontologies

- Gruber (1993); Fensel (2001)
 - Formal specifications of shared conceptualizations
- Are ontologies ‘discovered’ or ‘constructed’?
 - Klein & Hirschheim (1987): philosophical objections to objectivist, ‘entity-based’ approaches (Frege, Wittgenstein, Austin)
 - Grubic & Fan (2010, p. 783): “Classification structure is not inherent to the real world but constructed by human, therefore the optimal class structure does not exist.”
- Shared by whom?
 - Project team? Landscape Ecologists? Economists? Psychologists? Sociologists?
 - Political implications of imposed meanings...



Tain
(pop 3590)



Disputation in land use



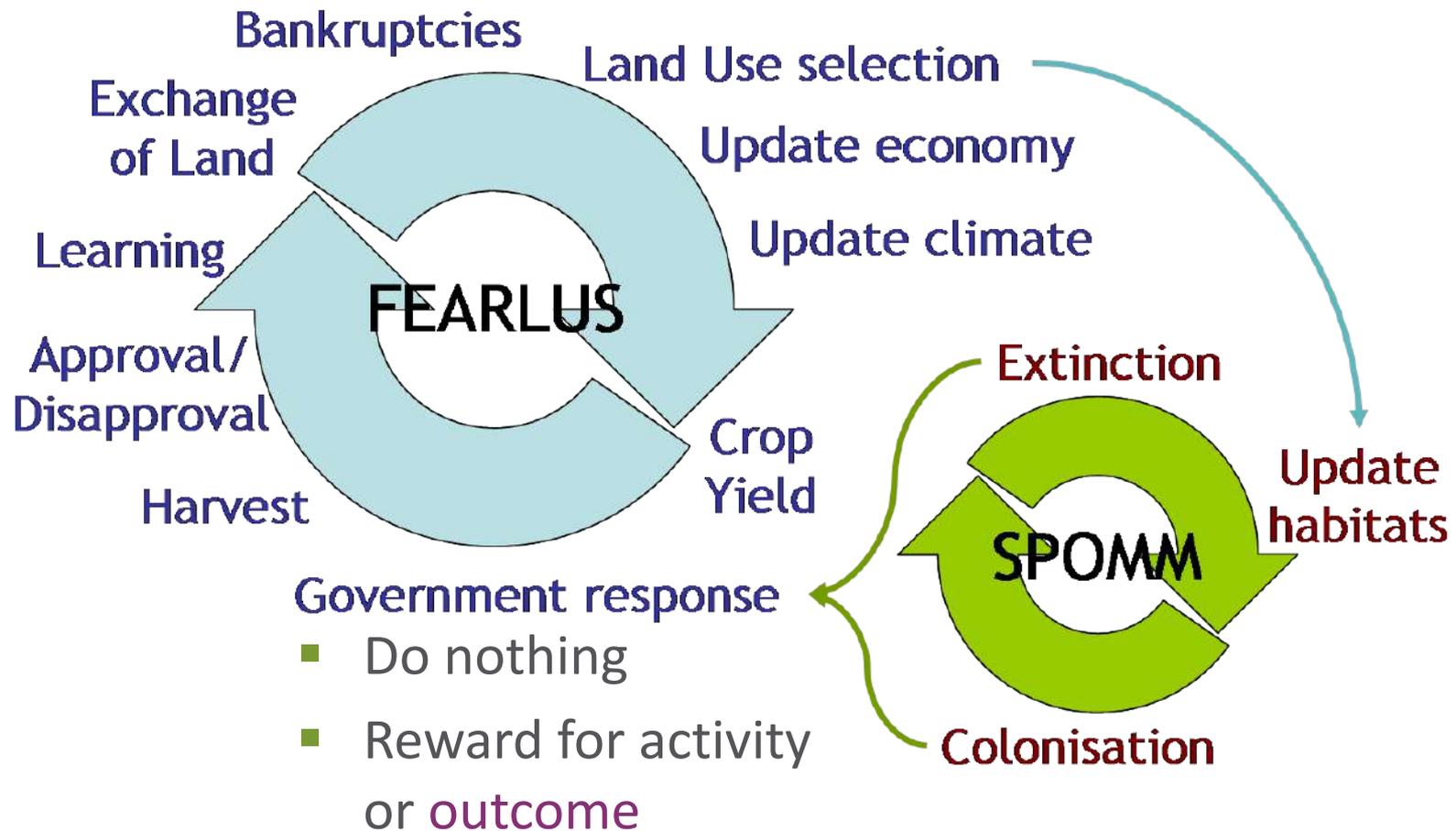
- What is a forest?
 - [Chazdon et al. \(2016\)](#), p. 539): “forests can be seen as a **source of timber** products, an **ecosystem** composed of **trees** along with myriad forms of **biological diversity**, a **home** for indigenous people, a repository for **carbon** storage, a source of multiple **ecosystem services**, and as **social-ecological systems**, or as all of the above. ... **No single operational forest definition can, or should, embody all of these dimensions.**”
 - Political implications of classifications: “By **privileging tree cover...**, species-based classifications **serve the purposes of both extraction-based forestry and modern conservation**” ([Wong et al. 2007](#), p. 650)
- What is a farmer?
 - Search for farm typology...
- What is urban?
 - In Scotland: a settlement of 3,000 or more people...
- Definitions are non-neutral, and can embed imbalances of power

Coupling FEARLUS-SPOMM

- Key points for coupling models
 - Similar levels of abstraction/detail
 - No duplication of subprocesses
 - Compatible spatial and temporal scales
 - Compatible underlying assumptions
- Further requirements for this work
 - SPOMM to be a credible biodiversity model in its own right
 - Suggests coupling rather than integration
 - FEARLUS-SPOMM to be a credible model
 - Suggests integration rather than coupling
- Approach
 - Design SPOMM for integration with FEARLUS
 - Maintain separate (coupled) and integrated versions



FEARLUS SPOMM



- Feedback from species

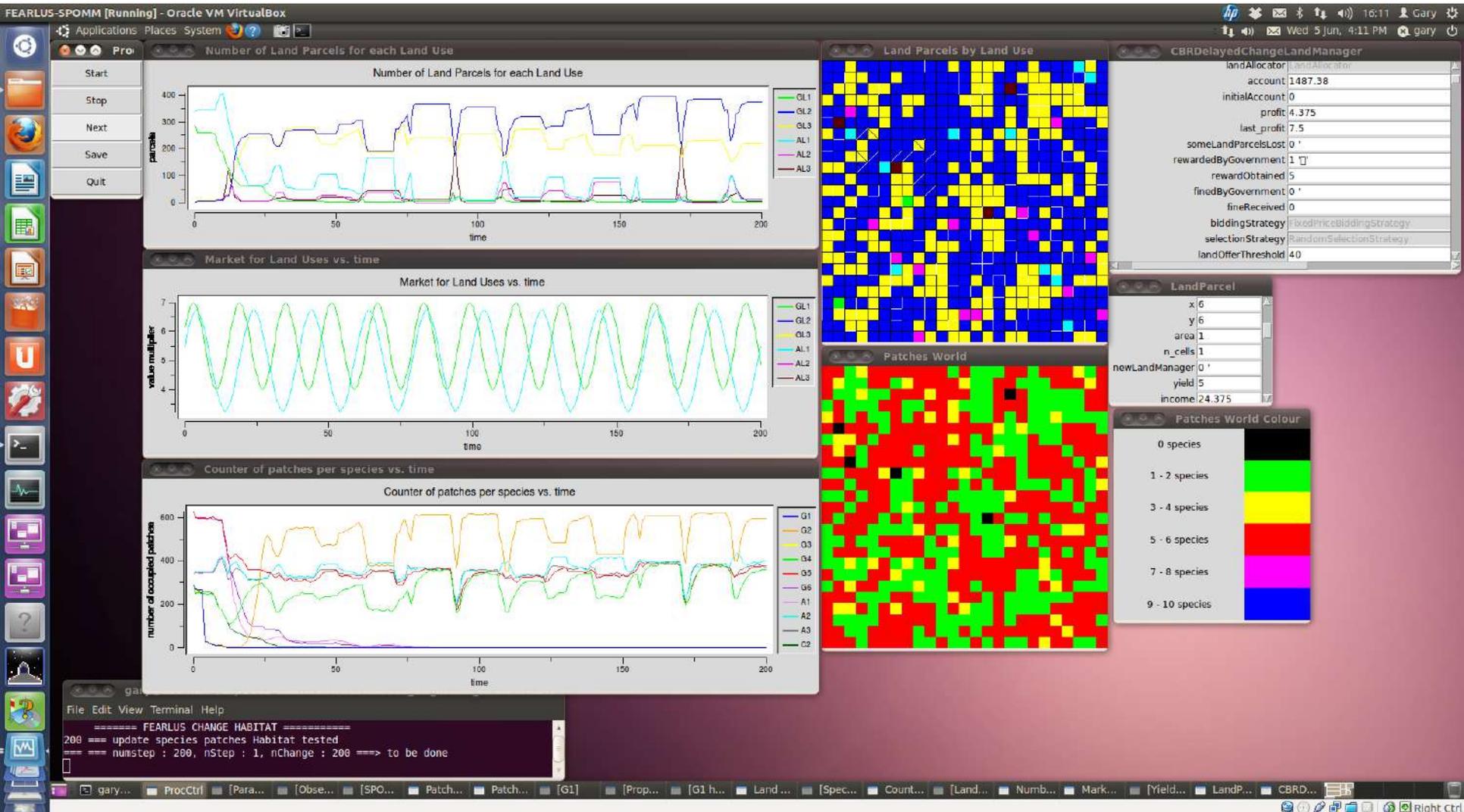
- Reward individually or 'clustered'

- Feedback from neighbours

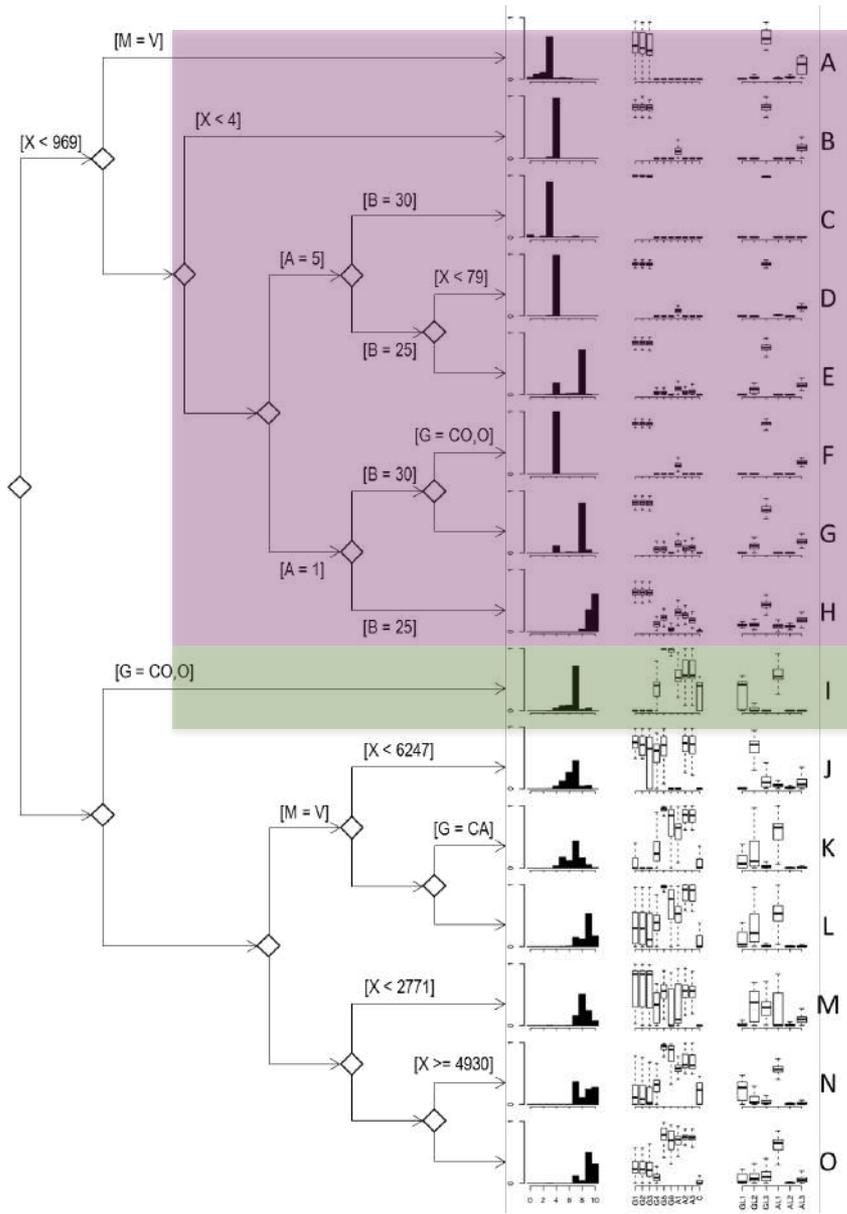
Screenshot



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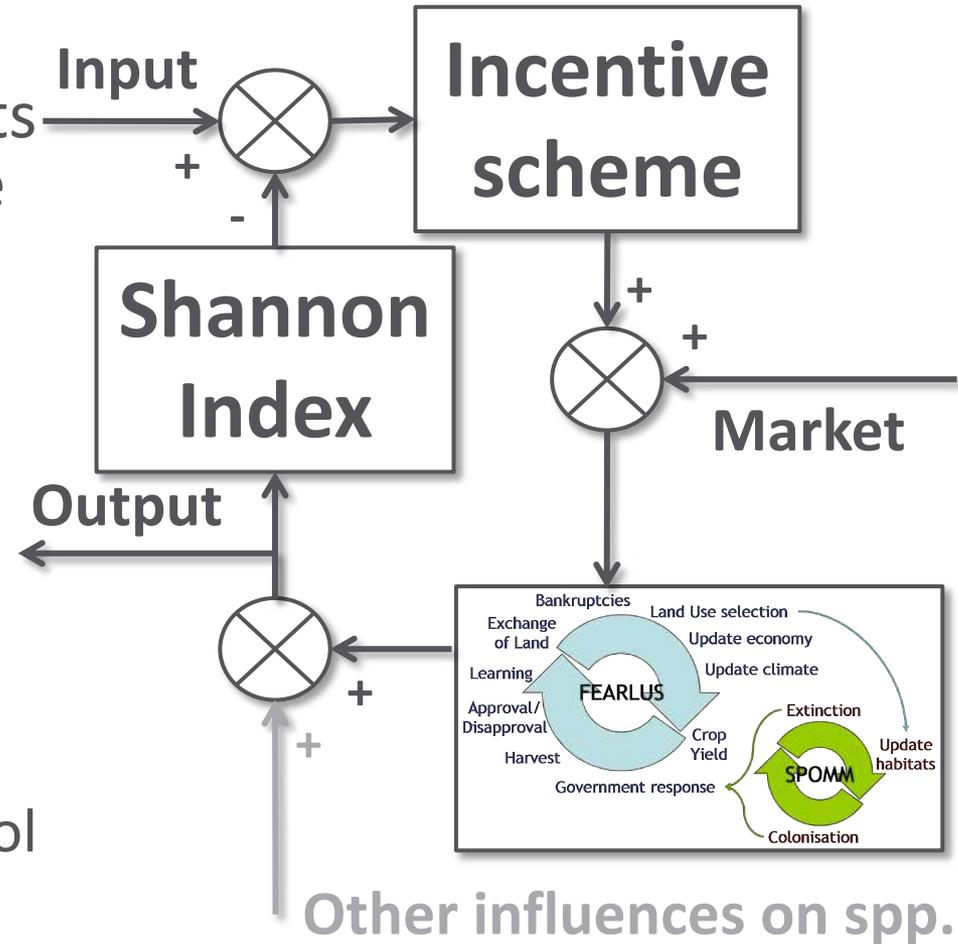
Decision tree analysis



- Below a threshold of government expenditure, the market drives outcomes, and species richness is lower
 - Above the threshold, policy is the main driver
 - Outcome based incentives seem more robust to other influences (market, input costs, aspirations)
- ([Polhill, Gimona and Gotts 2013](#))

Using control theory with FEARLUS-SPOMM

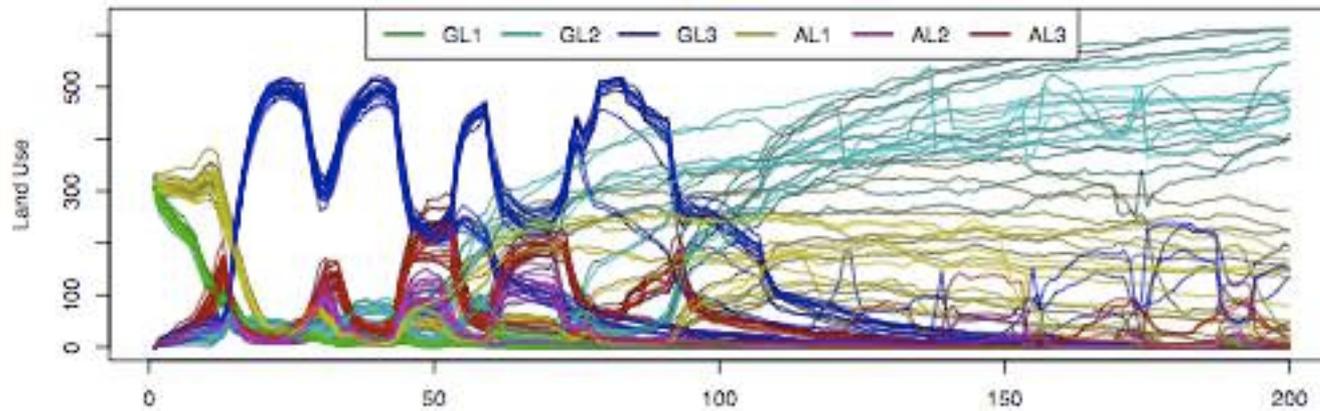
- Government receives Shannon (H) and adjusts incentive (u) to achieve target Shannon
 - N.B. Government omniscient about the Shannon
- FEARLUS-SPOMM:
 - Lots of complex behaviour
 - 80,000 lines of Obj-C
 - Modelled by the control engineer thus:



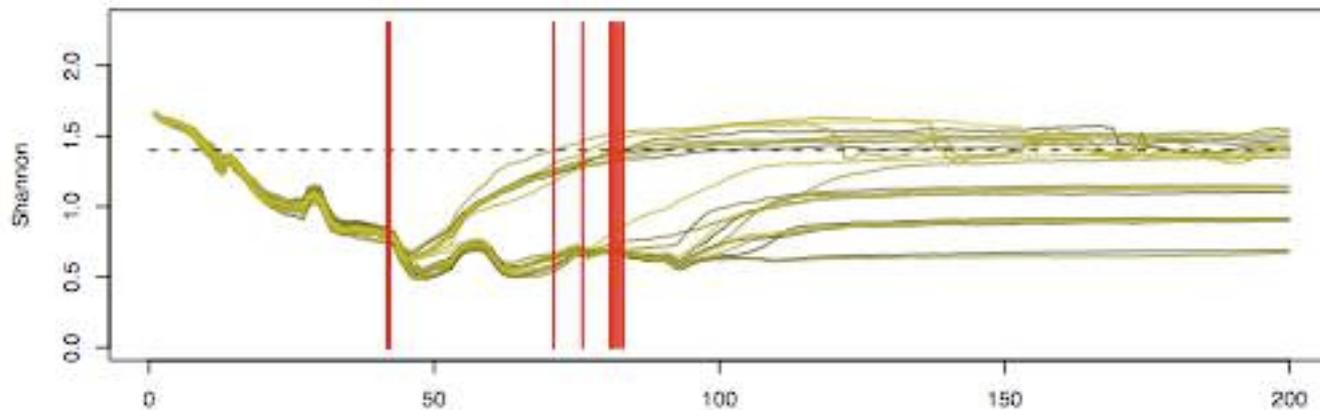
$$\hat{H}_t = a\hat{H}_{t-1} + bu_{t-1}$$

Using a control theoretic government

- Online adaptation of incentive
- Outcome sensitive to when government acts



Land Use



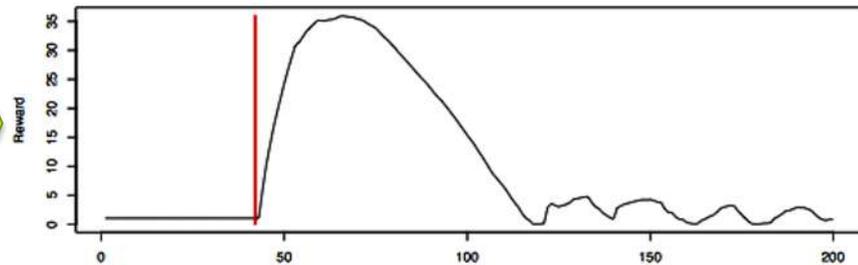
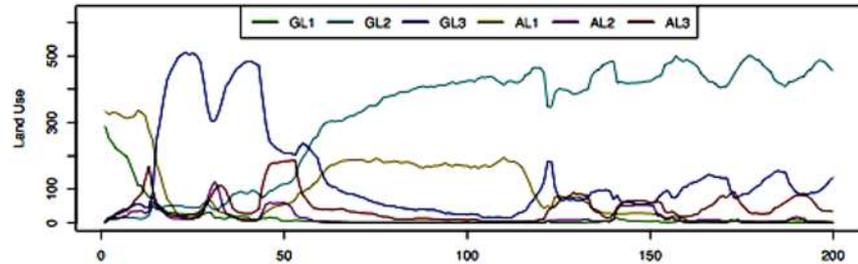
Shannon

Early detection

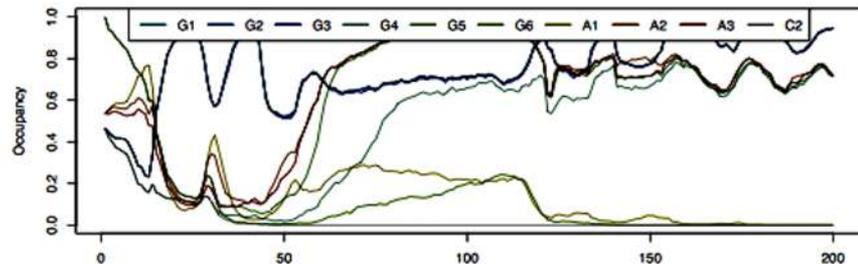
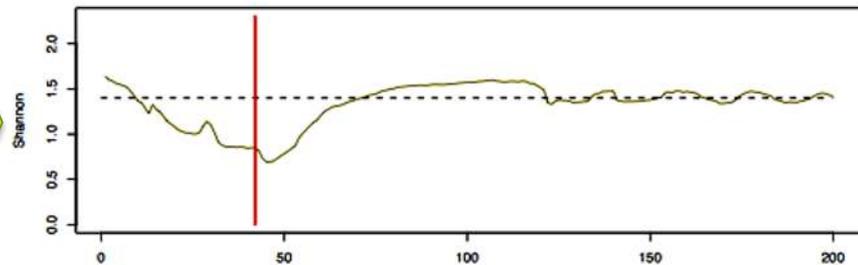


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Incentive jumps up, then drops nearly to zero; reward has to adjust to respond to market changes



Shannon target overshoot slightly, then Shannon drops to target

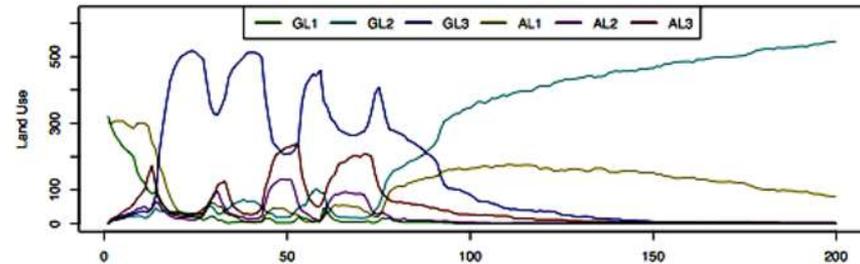


Later detection

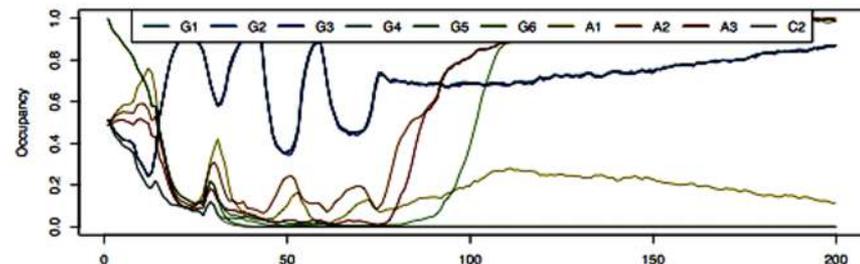
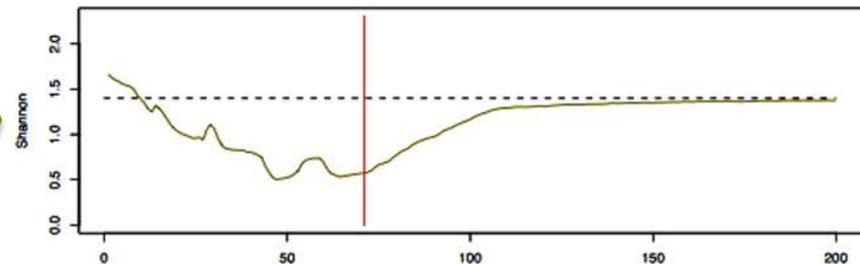
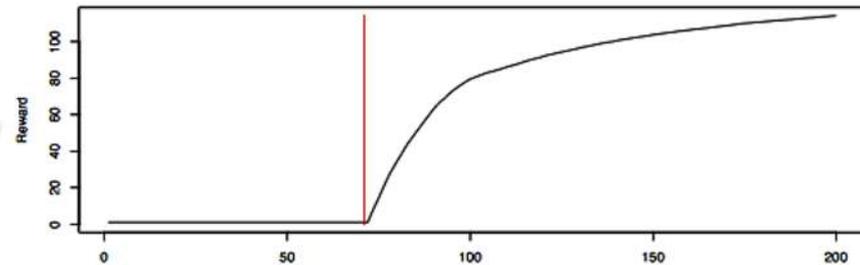


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Incentive has to rise rapidly and keep rising

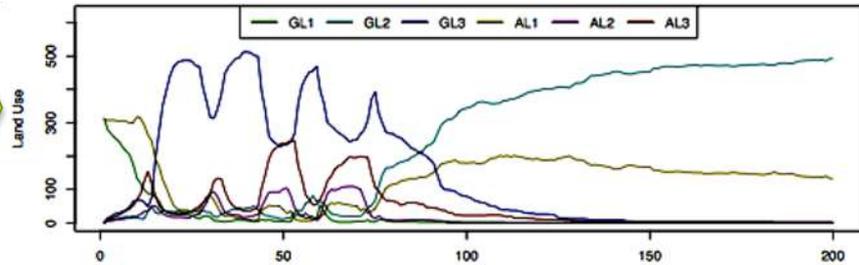


Shannon target just starting to be met at the end of the run

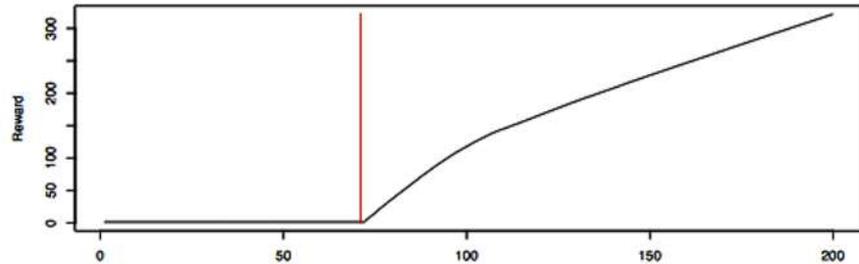


Too late...

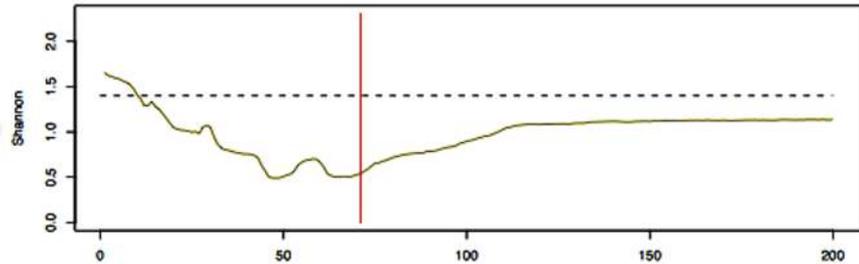
Land uses in good mix
for biodiversity



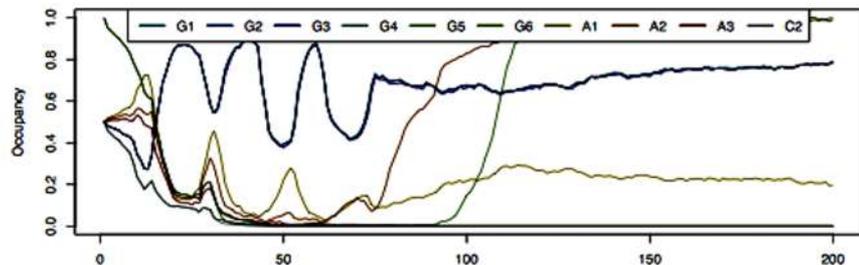
Incentive keeps rising



Shannon target not met

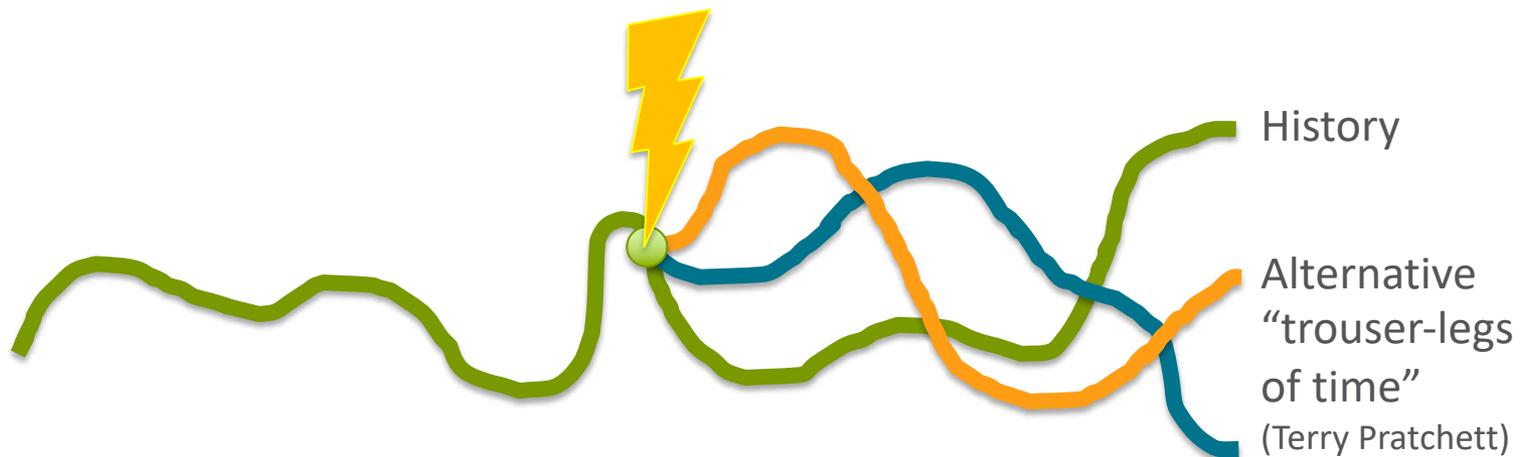


Too many extinctions for
target to be achievable



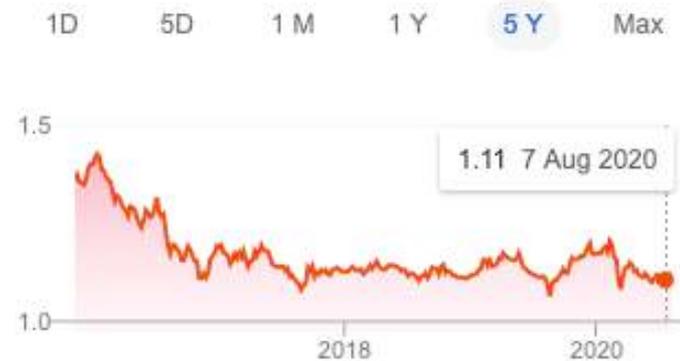
Models and history

- Which model's predictions would you prefer?
 - Model A, few parameters, only follows the green line
 - Model B, many parameters, can follow all three lines
- Ockham's razor says Model A...
 - But this could have been a one-in-a-million chance!



Generating social phenomena

- Curves can be fitted to social data
 - e.g. Neural networks can approximate any function to within an arbitrary degree of error
- Pointless (scientifically)
 - The curves tell you nothing about the *fundamental* relationships among the variables
 - Fitting parameters (e.g. constants of proportionality) are not universal constants
 - The curves are emergent from micro interactions
- Can you 'grow' that graph?
 - Much harder than curve fitting!
 - Grimm et al. ([1996](#))
 - 'Pattern Oriented Modelling'

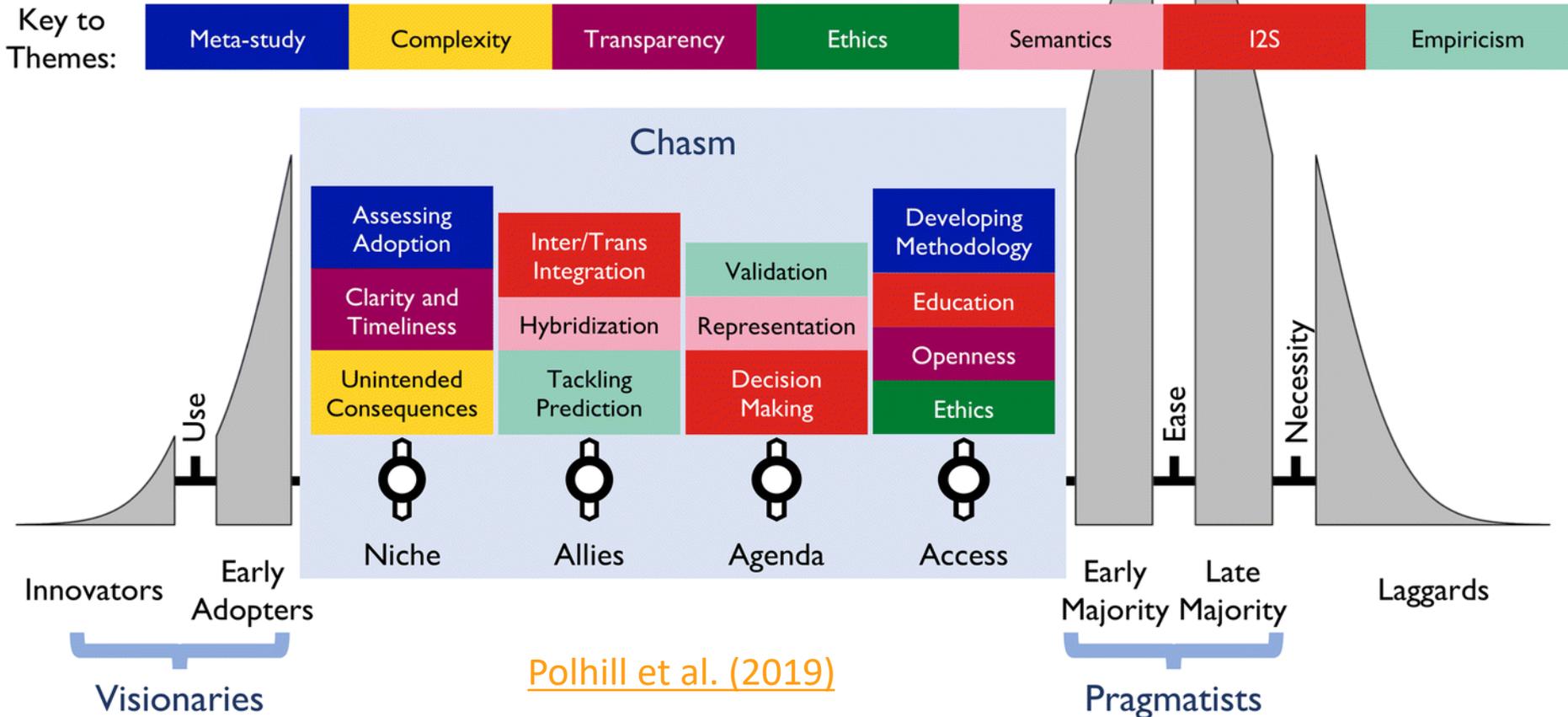


EUR/GBP exchange rate reflects:

- Beliefs of traders
- Political activities
- News stories
- Industrial relations
- Trade negotiations
- Automatic trading algorithms
- Imitation

Towards mainstreaming ABM...

“ABM will remain a cross-disciplinary endeavour, requiring researchers to be willing to work together in ways that do not necessarily speak to their core disciplinary audiences”



Roles for mathematics & statistics

- New modelling paradigm, new methods...
- Calibration and validation
 - Approximate Bayesian Computation?
 - Graph-based methods for comparing ontologies
- Population synthesis
- Typologies
 - Decision-making rules from data?
 - With adaptation? (e.g. from panel data)
- Metamodelling
 - Using ABMs as data sources



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