Modelling forager land-use by close-coupling ABM and GIS

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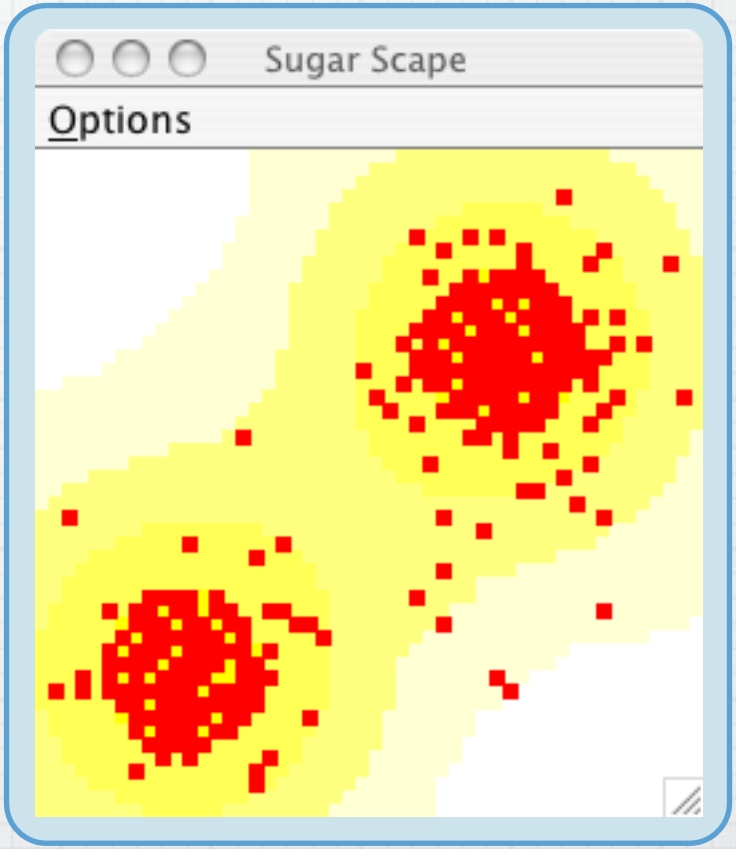
Agenda

- What is agent-based GIS?
- Research problem
- Why take an agent-based approach?
- Overview of the model
- The palaeoenvironmental model
- The agent-based model
- Conclusions

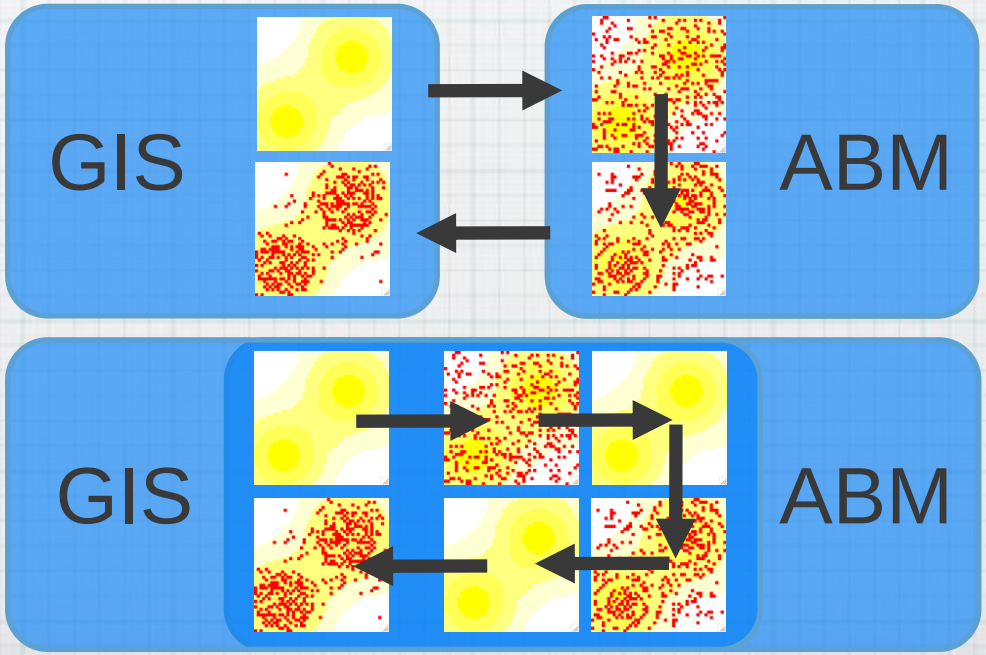
What is agent-based GIS?

- Agent-based model
  - An agent-based computer simulation implements a collection of (often interacting) artificial agents carrying out one or more tasks in an artificial environment
  - Paradigmatic example is Epstein and Axtel's 1996 Sugarscape



What is agent-based GIS?

- Benefits of integrating ABM and GIS
  - GIS provides full range of tools for generating, updating and analysing the artificial environment
- Methods of integrating ABM and GIS
  - Loose coupling
    - 2 separate programs
  - Close coupling
    - 2 separate programs
    - 1 program



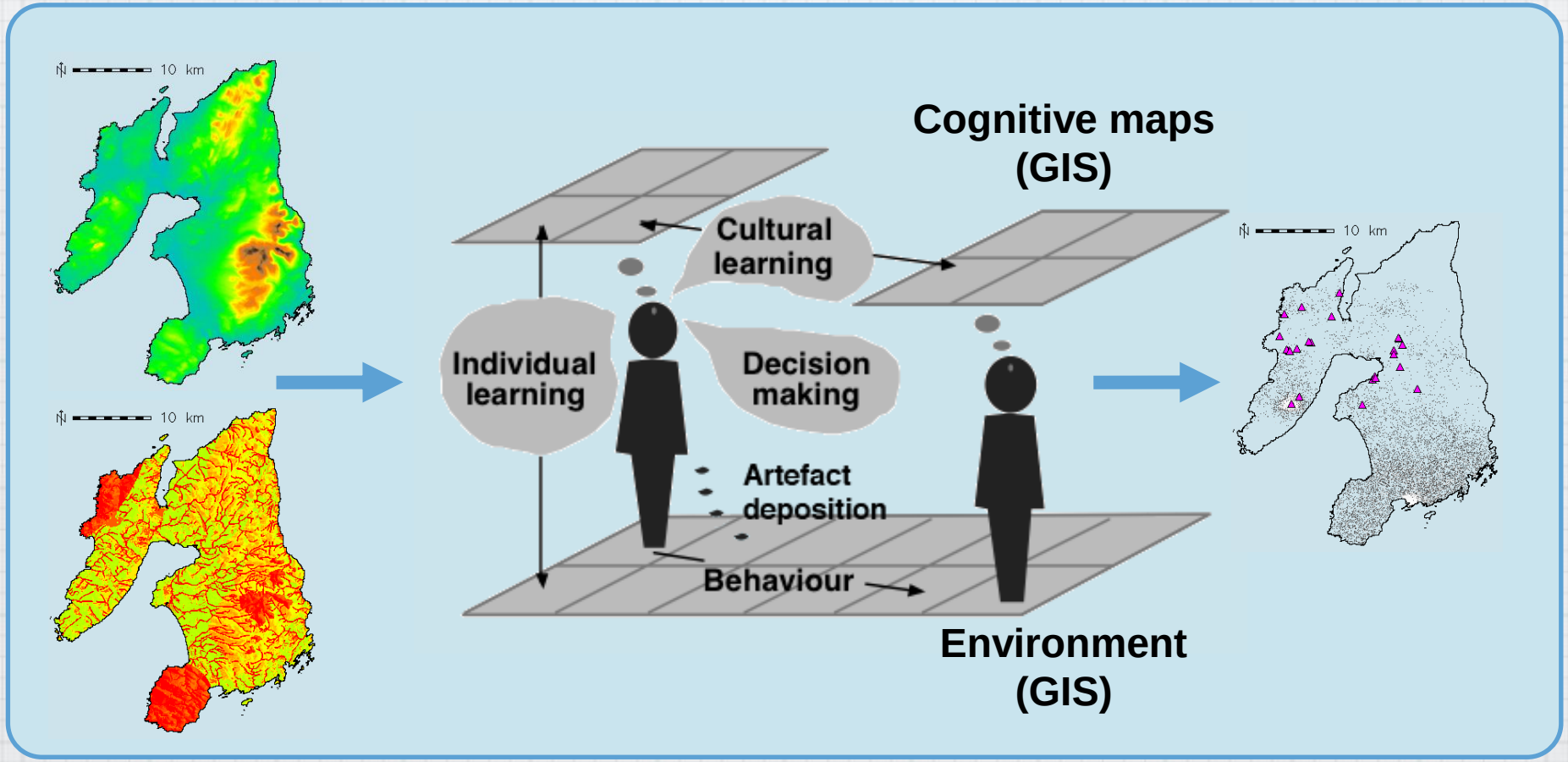
Research problem

- Archaeological problem
  - The Southern Hebrides Mesolithic Project (directed by Steven Mithen) had obtained clear evidence that Mesolithic people on Islay and Colonsay harvested large numbers of hazelnuts
  - Was the distribution of hazelnuts the primary determinant of land-use by relatively mobile foragers who sporadically visited the islands?

Why ABM?

- Traditional predictive model
  - Assumes that foragers have complete knowledge of their environment
  - Inductive, therefore identifies patterns, not necessarily causes
- Agent-based model
  - Allows foragers to learn as they colonise islands
  - Deductive, therefore tests a specific causal hypothesis
    (if used with care)

Overview of the model

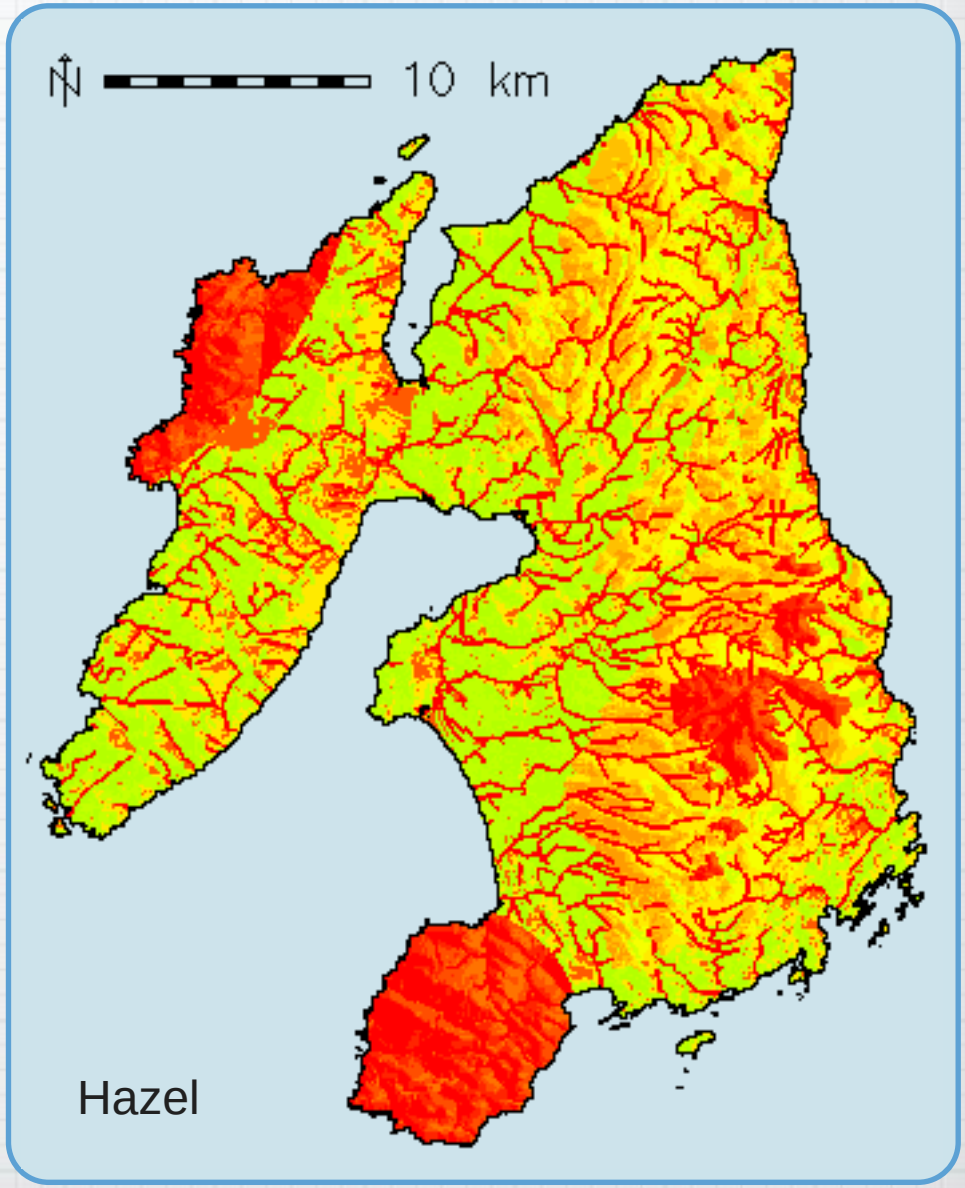


Palaeoenvironmental model

- Requirement for ABM
- Input data and principles
- Quantitative model
  (mathematical and GIS)
- Validation

Requirement for ABM

- Model of the abundance of hazel
- Continuous surface
  - Raster map (interpolatation from point data or theory driven?)
- Ethnographic scale
  - 30km * 40km at 50m x 50m resolution = 480,000 cells



Input data and principles

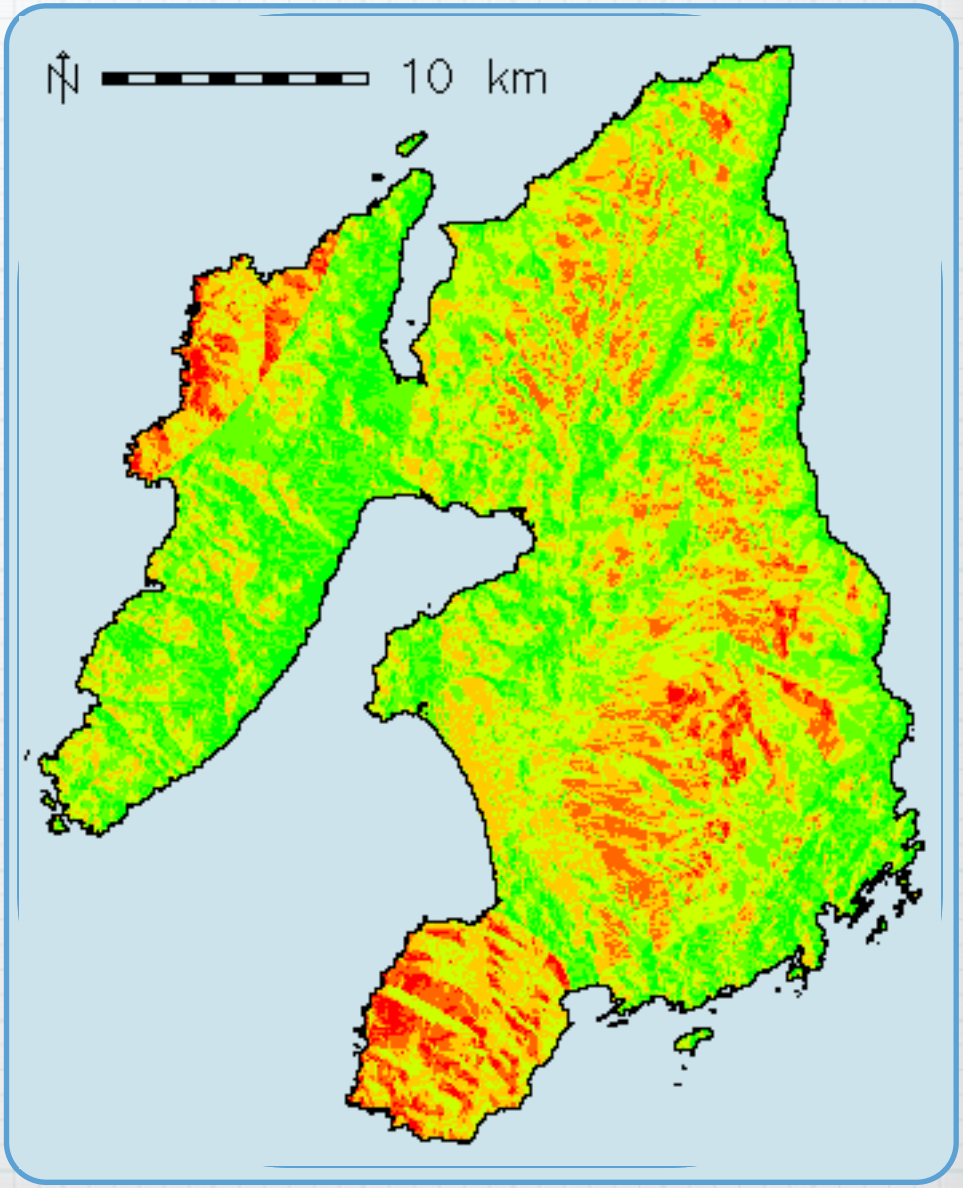
- Pollen maps (Isochrone)
  - Provide: coarse-grained information about regional presence or absence of species
- Environmental factors (soil, climate, etc.)
  - Provide: information about potential of land to support a given species and therefore potential single species abundance
- Ecological principles (competition)
  - Provide: information about extent to which potential species abundance will be realised

Paleoenvironmental model

- Presence or absence of species at 7000BP
  - Previous broad scale reconstructions largely based on pollen isochrone maps
    - McVean & Ratcliffe (1962) birch, oak/birch
    - Bennett (1988) birch, oak, no trees > 200m
    - Tipping (1994) birch/hazel/oak
    - Edwards and Whittington (1997) birch/hazel/oak
  - This model will include: oak, hazel, birch, ash

Paleoenvironmental model

- Environmental factors
  - Land capability for woodland
    - Basic features of the postglacial climate established by 7000BP
    - Climate is a good ‘first sieve’
    - Exposure is a proxy forwindthrow, droughtiness and wetness
    - Final model combines climate and exposure (omits nutrients)



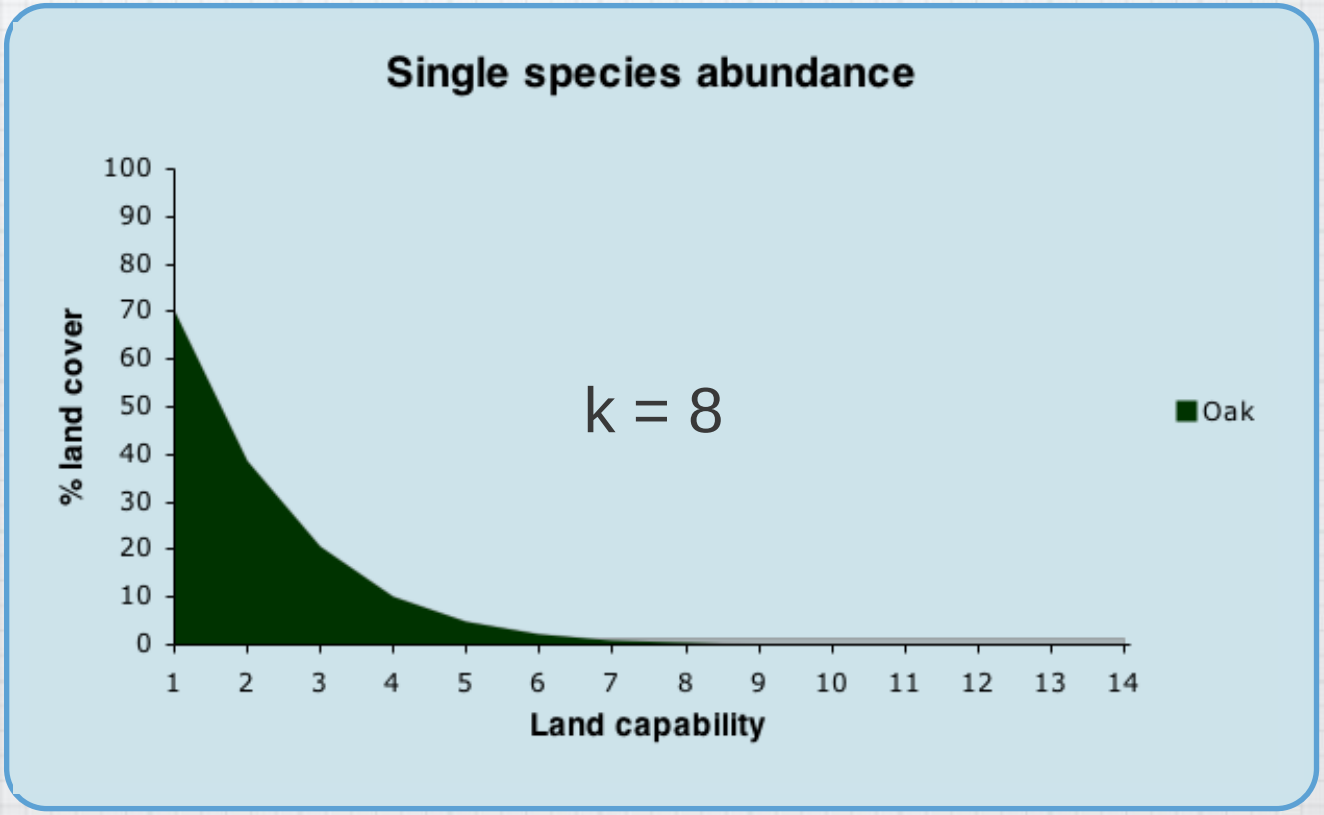
Paleoenvironmental model

- Single species abundance
  - Mathematical model

Intolerant species

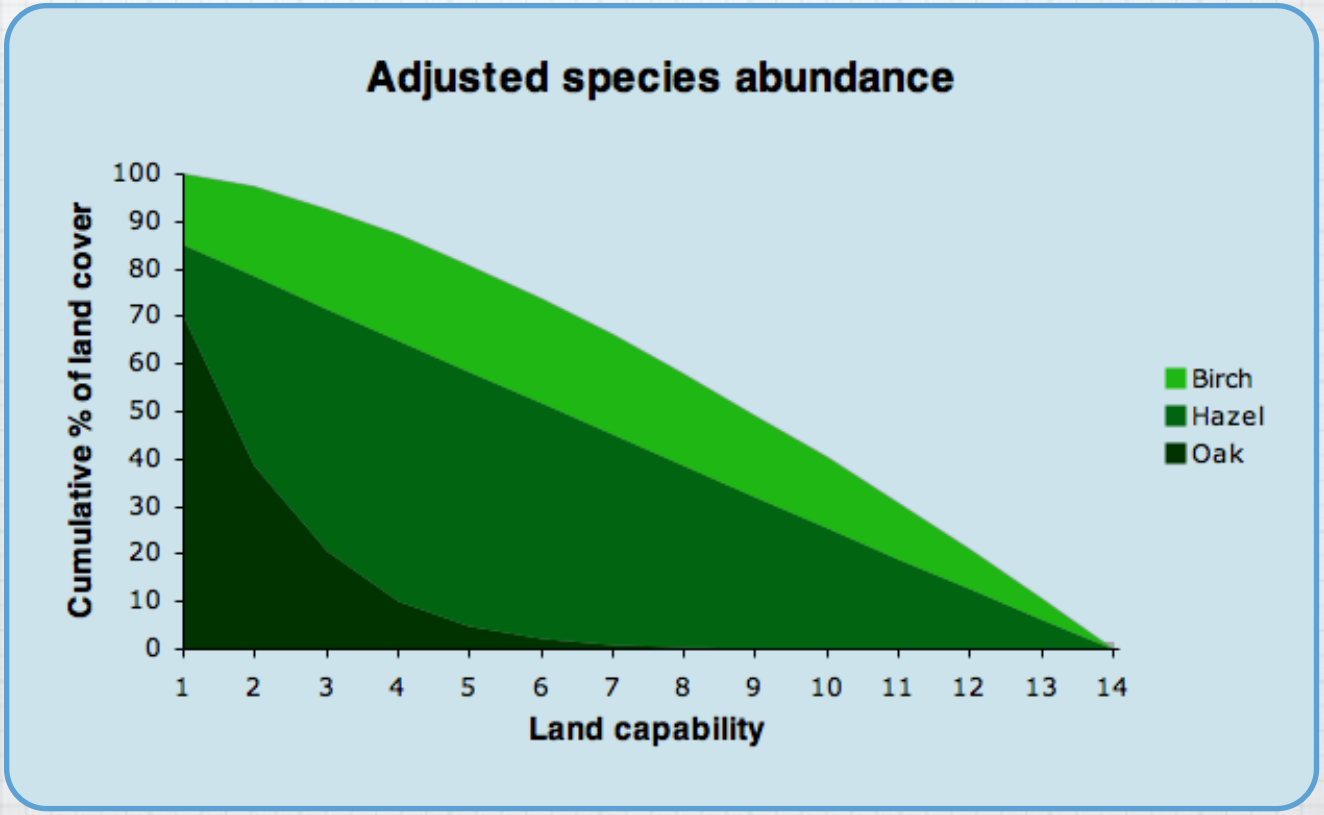
$$D = \frac{b(a - C)^k}{(a - 1)^k}$$

b = 70
a = 9



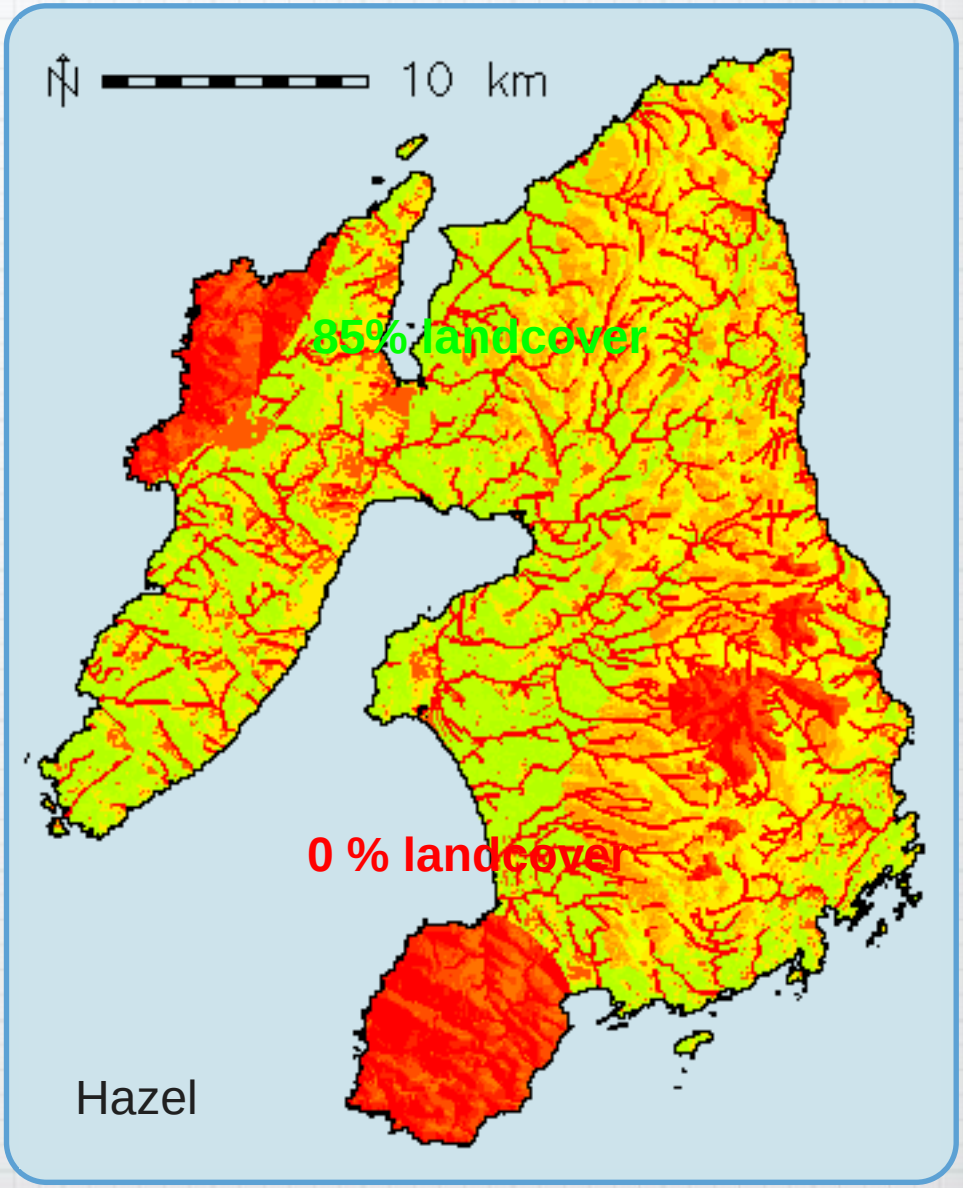
Paleoenvironmental model

- Adjusted species abundance
  - Mathematical model
  - Succession = birch ↓ hazel ↓ oak ↓ alder (in wet)



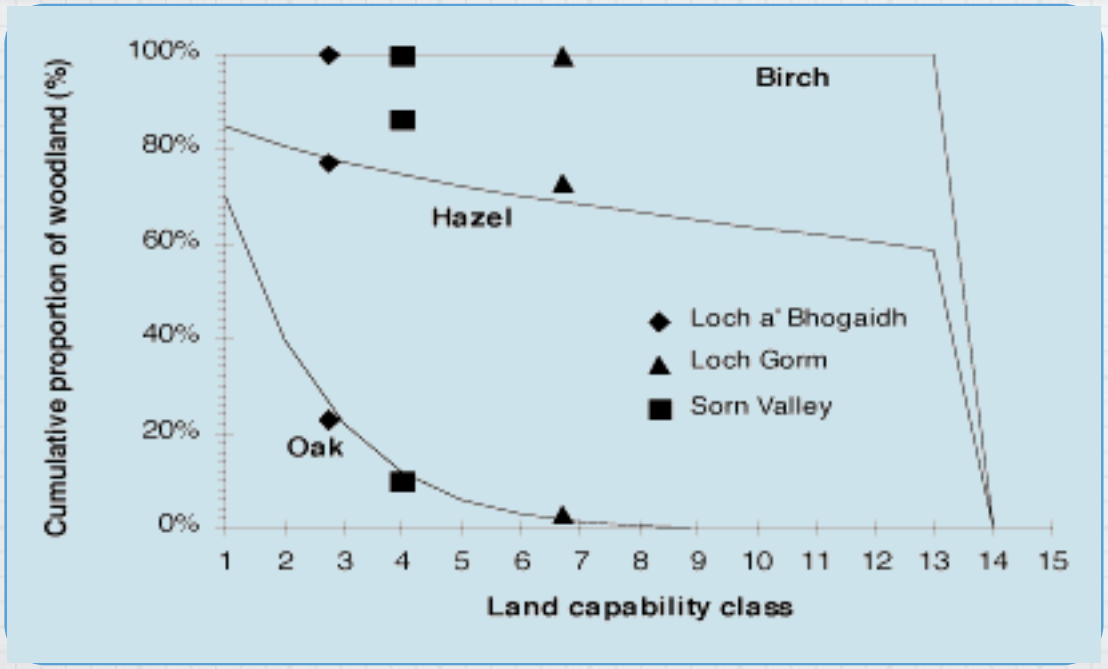
Paleoenvironmental model

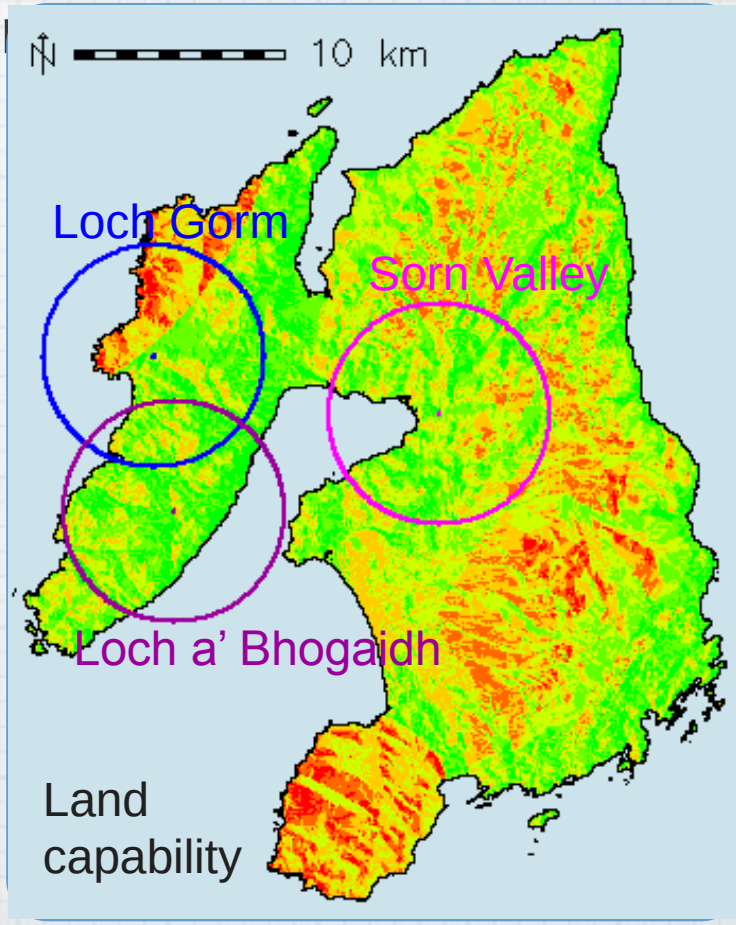
- Adjusted species abundance
  - GIS model
    - Create single species models for birch, hazel, oak, ash
    - Combine using map algebra to model the effect of competition



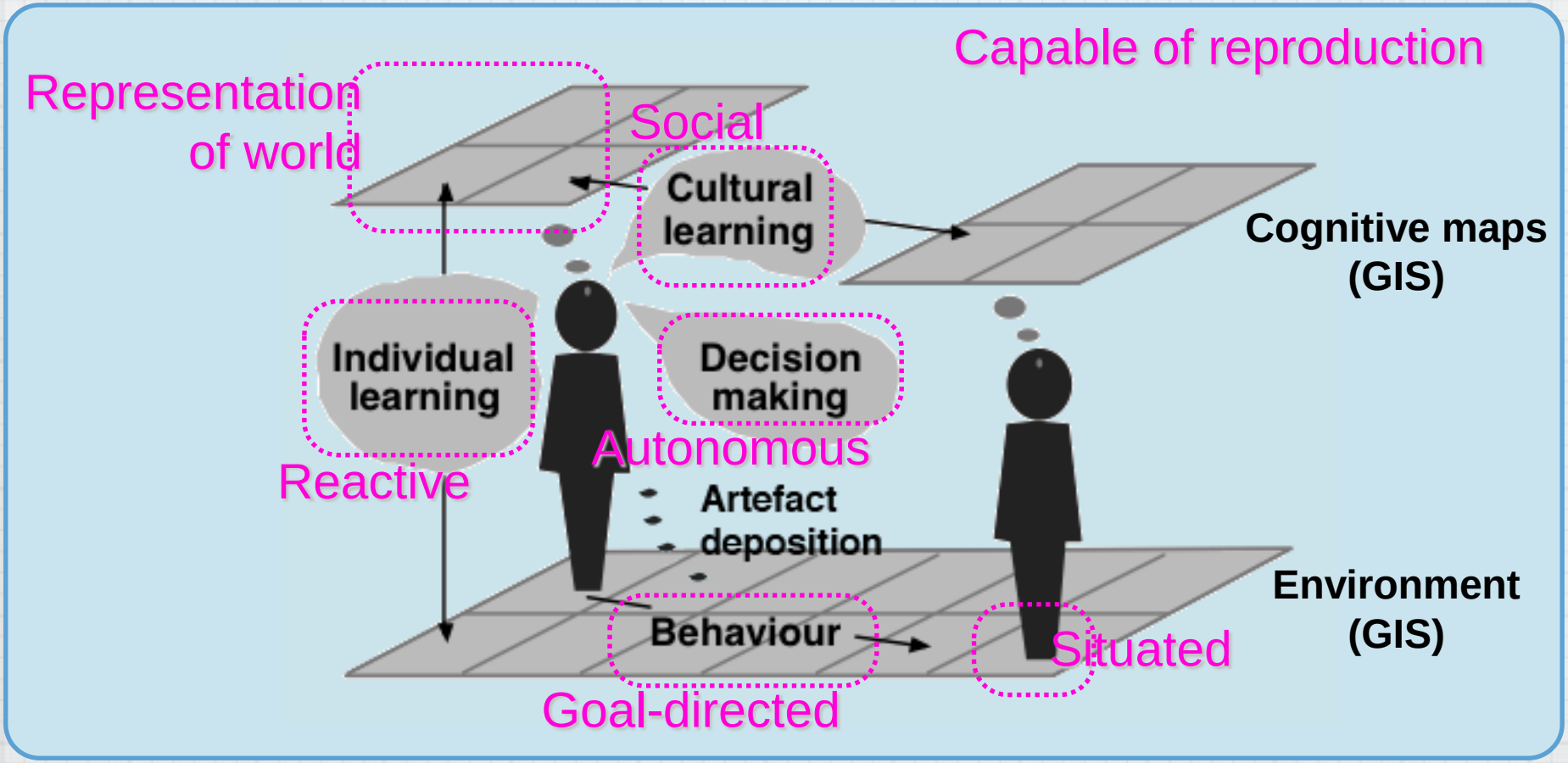
Validation

- Relative species abundance
  - Predicted by applying model to aver land capability within 5000m of pollen cores

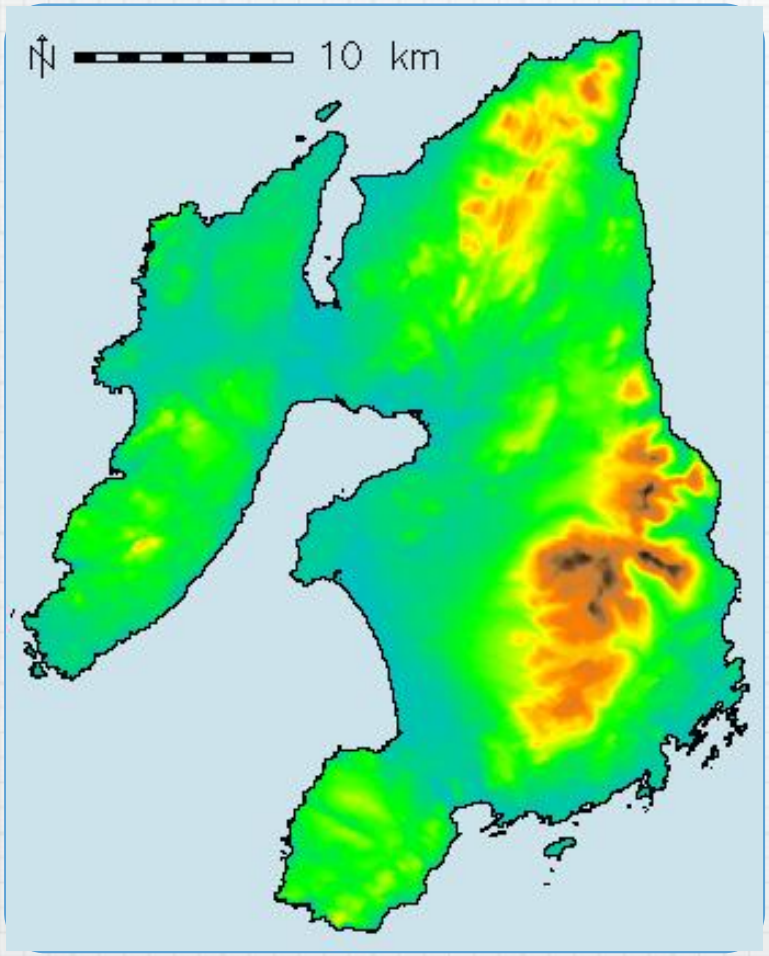


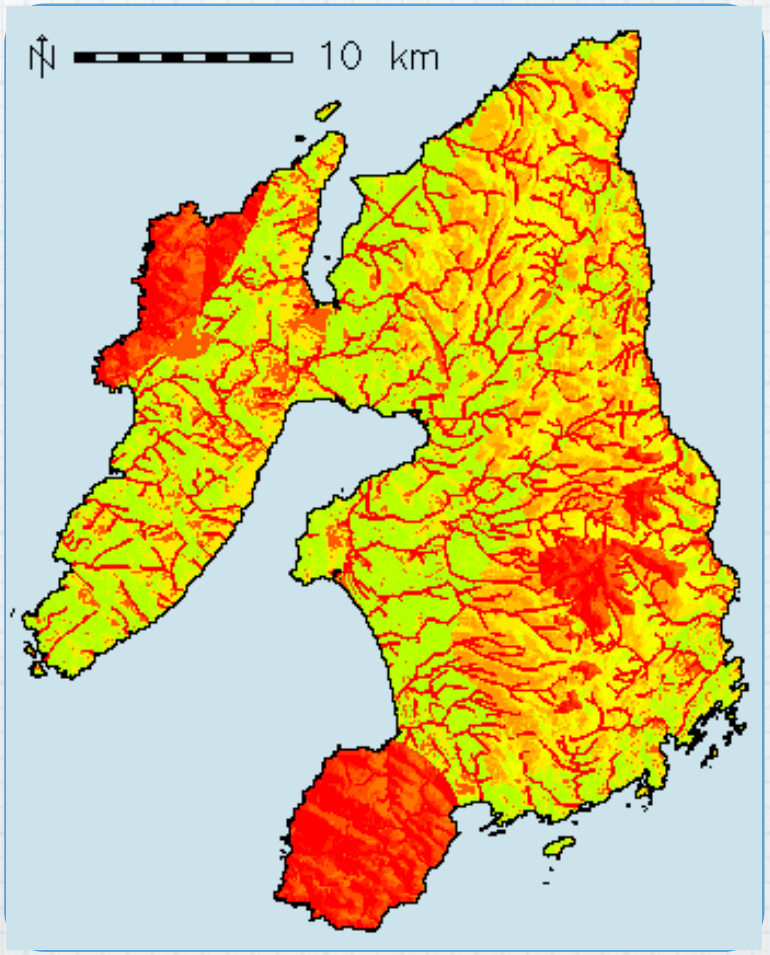


Agent-based model



Agent environment





Digital elevation model

Hazel abundance model

Agent behaviour

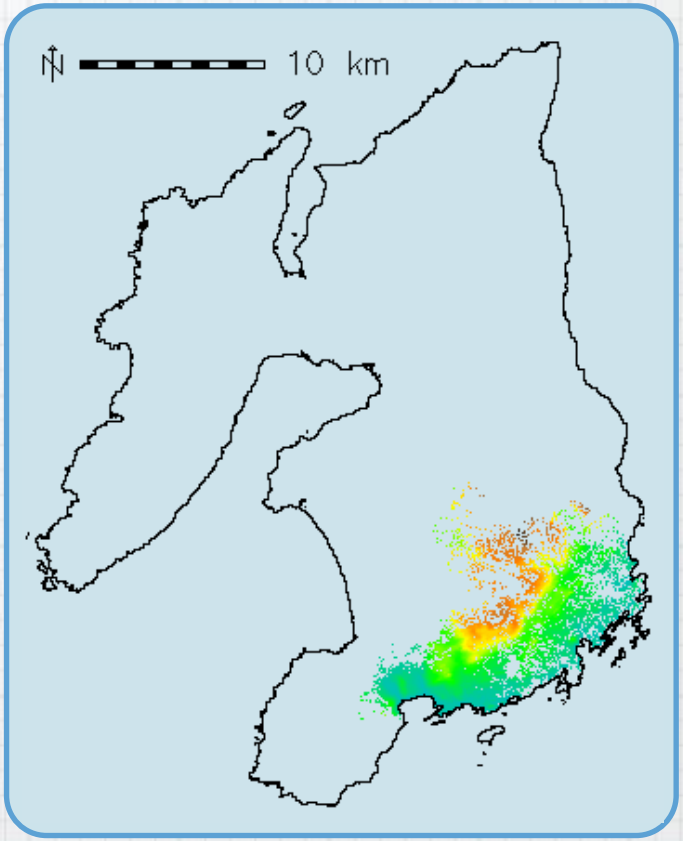
- During the hazelnut season
  - Agents forage forage around a base camp
  - Agents return to a base camp at the end of each day
  - The group moves the base camp at the end of each month
- Outside the hazelnut season
  - The group disperses
  - Agents move through the environment without reference to hazelnut abundance

Agent decision-making

- Agents
  - Attempt to increase the energetic rate of return from foraging for hazelnuts
  - Some are risk-takers, others are risk-averse (OFT problem of lost opportunity)
- Group
  - Votes to move the base camp to the location which is expected to maximise the energetic rate of return from foraging for hazelnuts

Agent learning

- Individual learning
  - Agents learn about their environment as they move through it
  - Each agent stores its current knowledge in its ‘cognitive map’
- Cultural learning
  - At the end of each day agents share information about their environment
  - Effect is to update each agent’s individual cognitive map



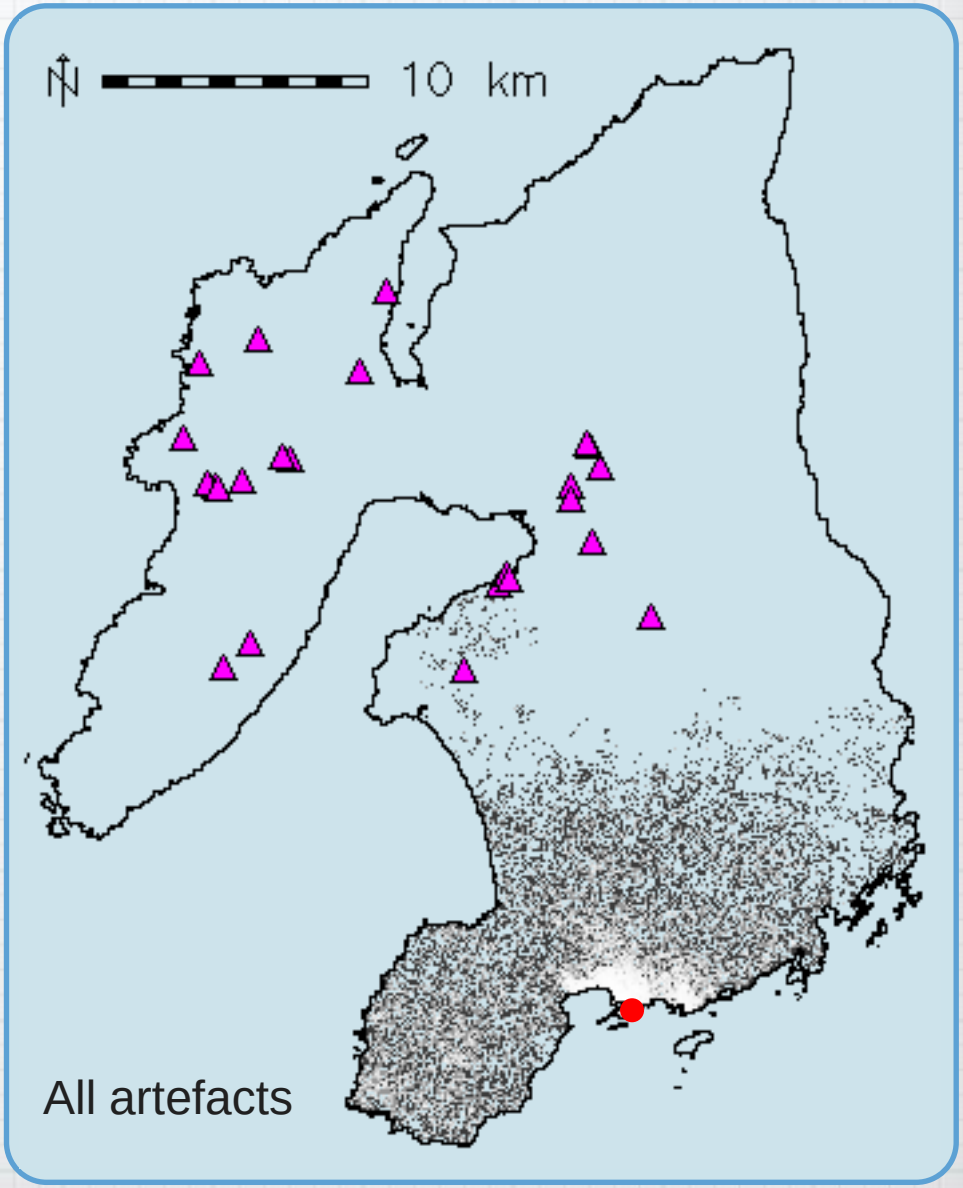
Artefact deposition

	Primary debitage	Secondary debitage	Microliths	Scrapers
Base camp	X	X	X	X
Foraging for hazelnuts		X		X
Foraging outside hazelnut season		X	X	



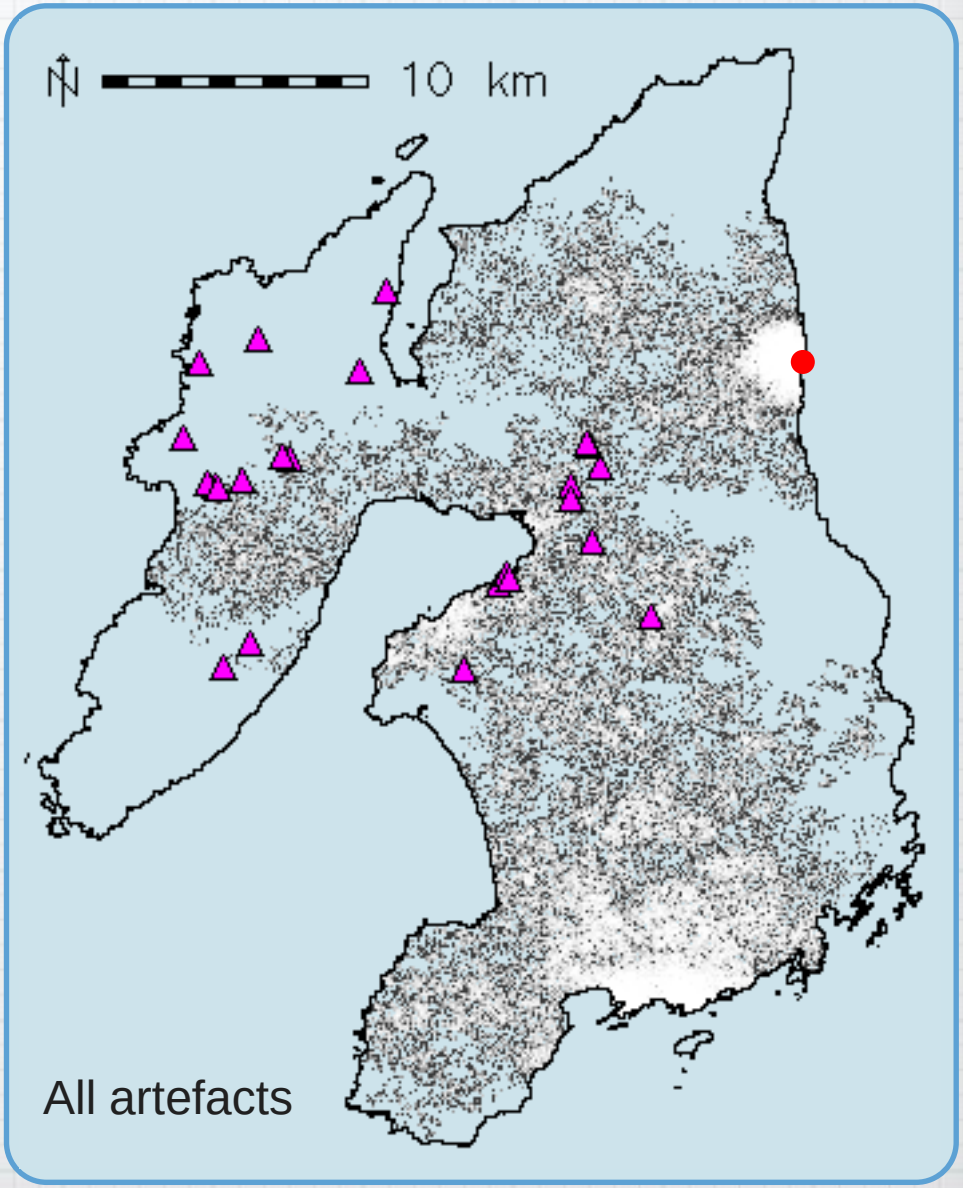

Experiments example 1

- Agents arriving at Port Ellen
  - Risk-taking agents remain in south of island



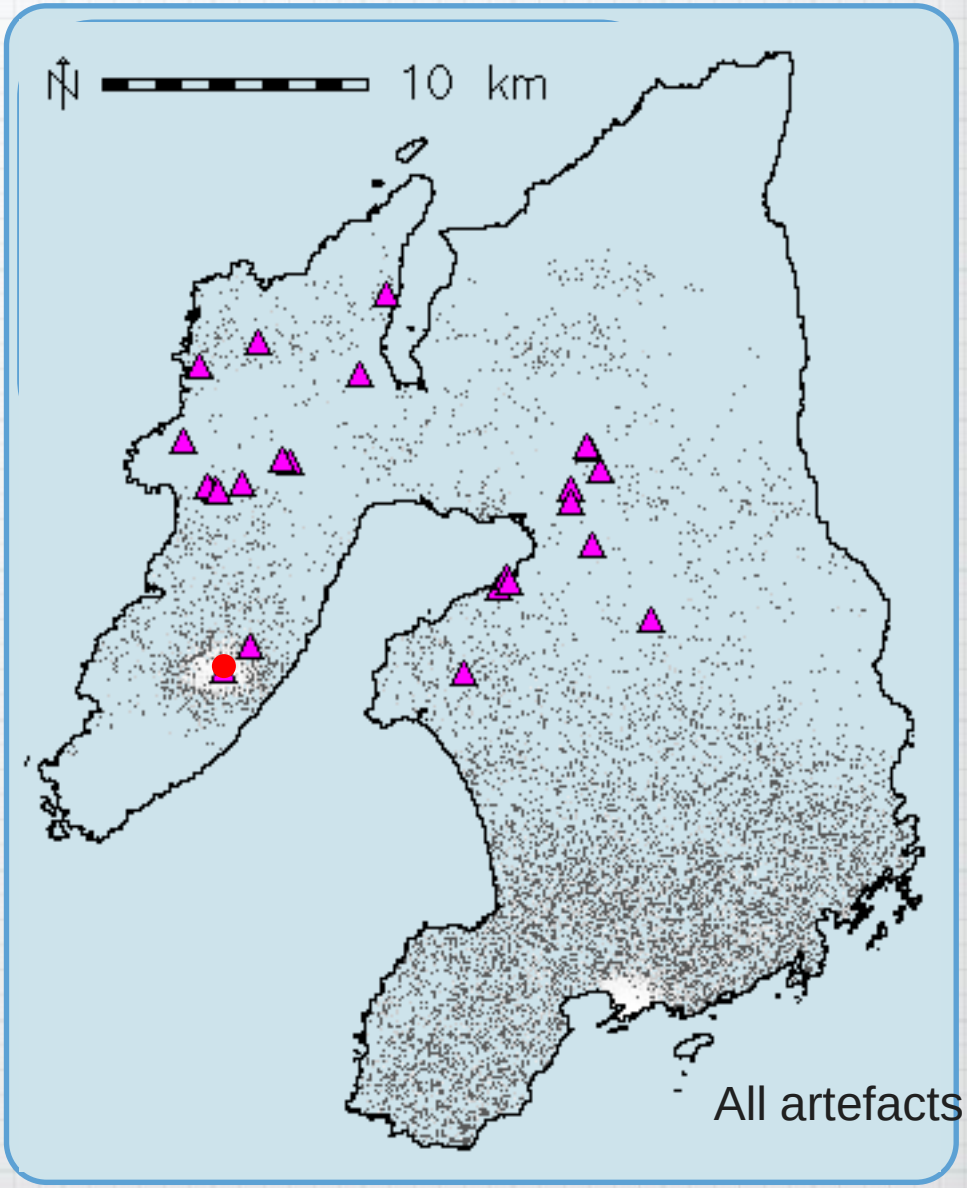
Experiments example 2

- Agents arriving at Port Askaig
  - Risk-averse agents explore more widely, but ultimately move to south of island



Experiments example 3

- Agents starting at Bolsay Farm
  - Risk-averse foragers remain on the Rhinns of Islay
  - Risk-taking foragers explore the Rhinns, but ultimately move to south of island



Conclusion

- In this case
  - Distribution of hazelnuts was not the primary determinant of land-use by Mesolithic foragers visiting Islay, or the palaeoenvironmental model is wrong and/or the ABM assumptions are wrong
- More generally
  - ABM shows that the degree of risk-taking and the degree of information sharing in the face of incomplete knowledge significantly affects the distribution of activity
  - Static modelling is inappropriate for studying colonisation when the time taken to learn is long relative to the total occupation

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