AGENT-BASED MODELING OF PAST ANTHROPOGENIC LAND-COVER CHANGE

A case study from Roman North Africa

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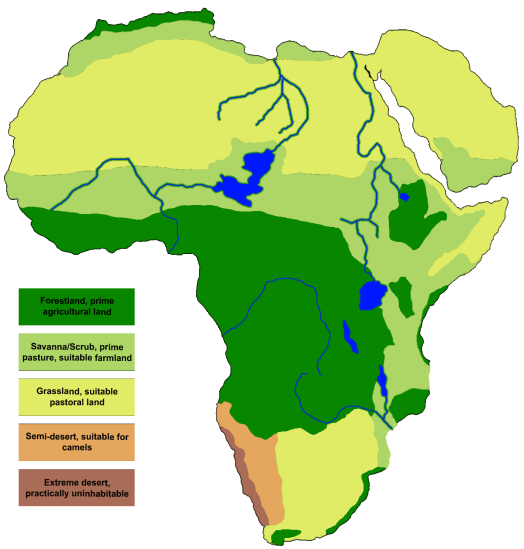
BACKGROUND

ROMAN NORTH AFRICA

The province of Africa Proconsularis – roughly modern day Algeria, Tunisia, and Libya – was the breadbasket of the Roman Empire

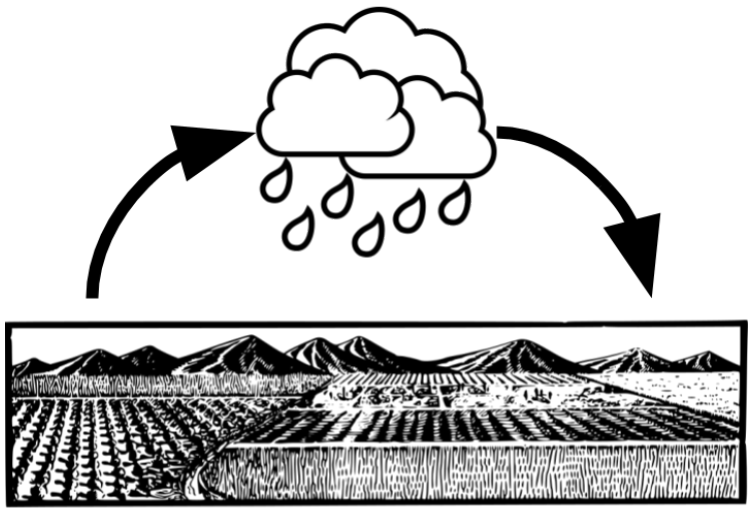
ROMAN NORTH AFRICA

Was the region's productivity the result of climate or irrigation?



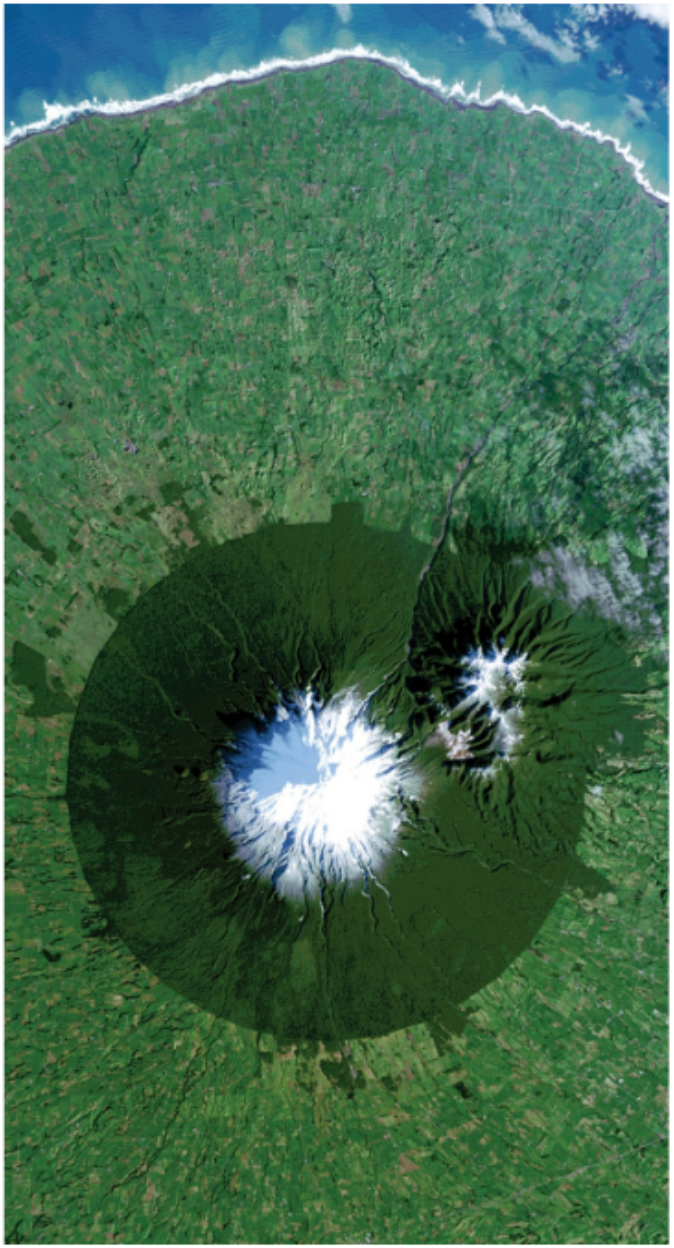
CLOSING THE LOOP

Land cover prescribed from population-based hindcasts lack feedbacks between humans and climate



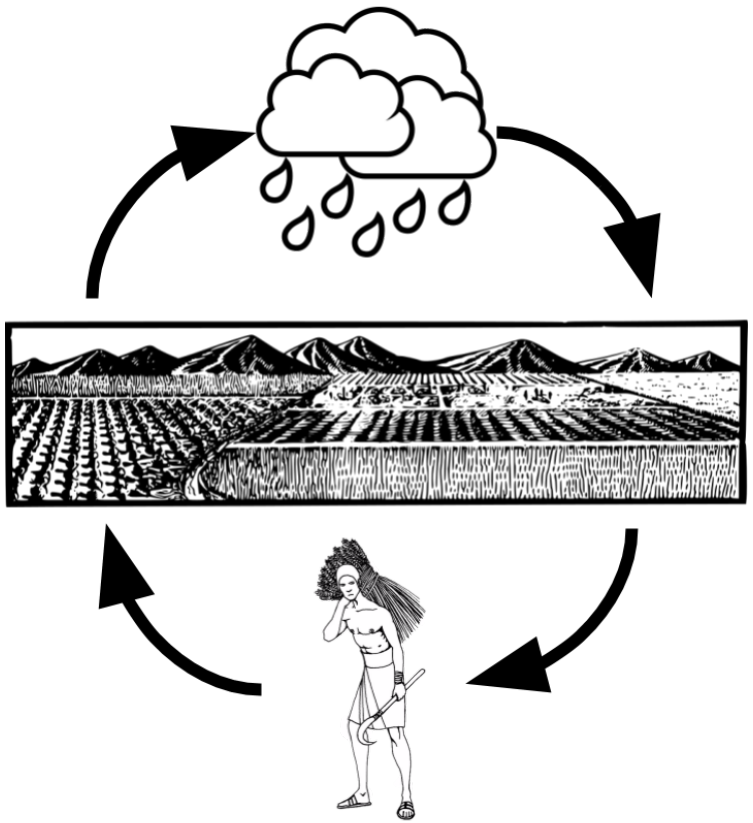
ANTHROPOGENIC LAND-COVER CHANGE

North Africa is a region of tight land-atmosphere coupling, and experienced massive land-cover change during Roman Imperial period



CLOSING THE LOOP

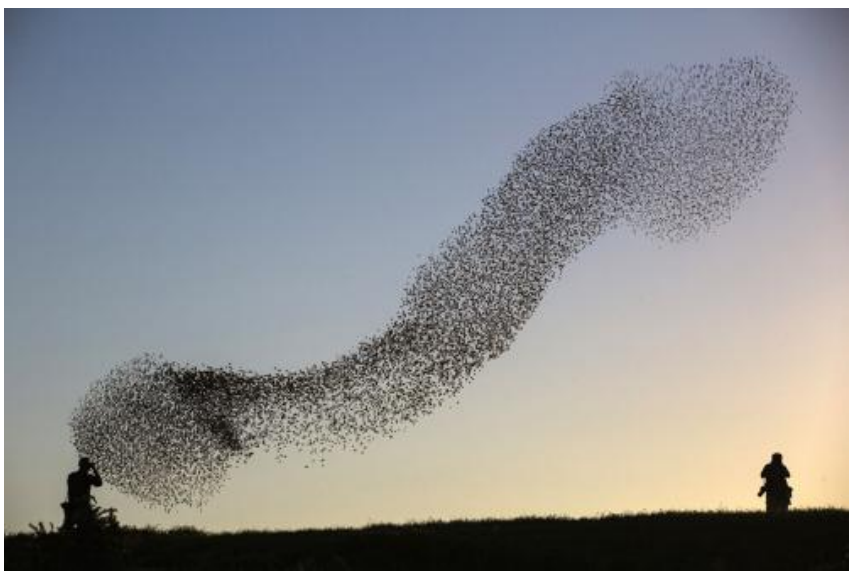
Need for dynamical feedbacks between human and Earth systems in the past, but we lack the data needed for a fully parameterized IAM



Multi-agent simulation

AGENT-BASED MODELING

Complexity arises when simple agents with heterogeneous information, objectives, and resources interact



ADDING SOCIAL COMPLEXITY

Need more flexible representations of the complex social dynamics that drive land-use and land-cover change

INTEGRATION WITH CLM

Linkages to CLM/CESM

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1. Use ESM outputs as model inputs
    - weather
    - maximum potential crop yields
    - vegetation initial conditions at equilibrium with climate

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    - weather
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    - vegetation initial conditions at equilibrium with climate

2. Output maps of that can be read into a Land Surface model
    - agriculture and pasture land
    - wood harvest intensity
    - population density
    - land equipped for irrigation

MODELING ROMAN LAND USE

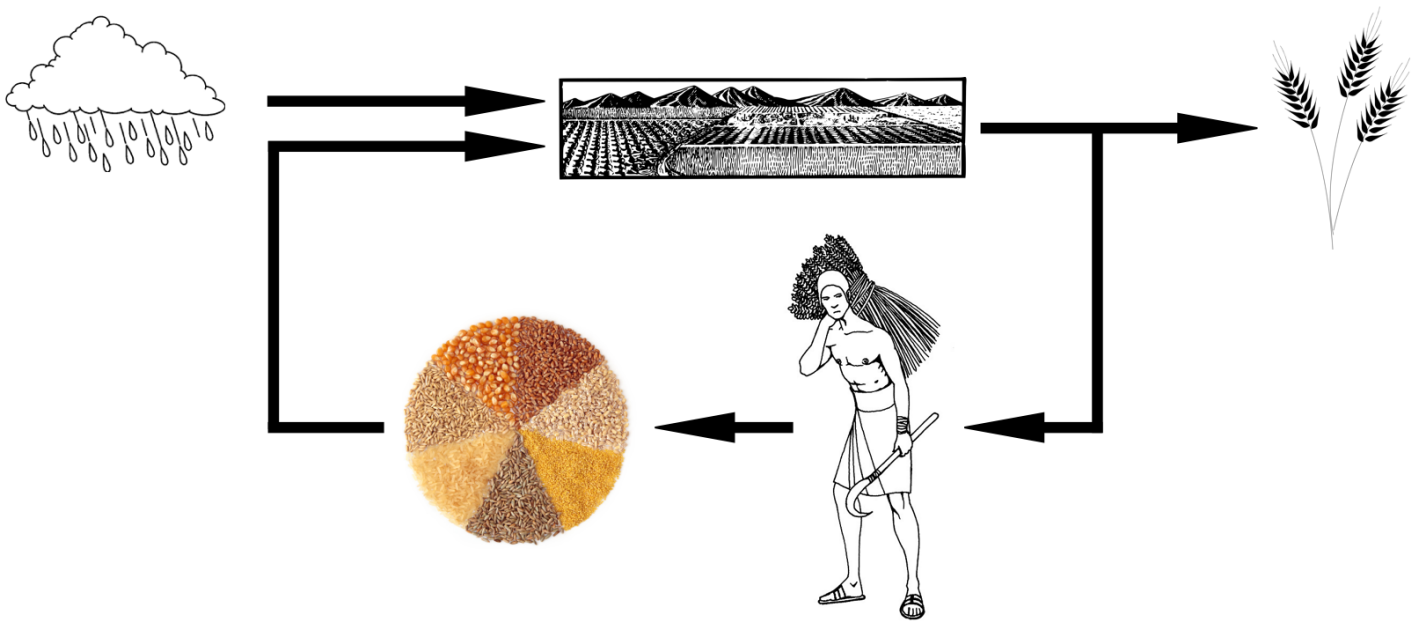
CORE DESIGN PRINCIPLES

1. Allocate land use via decision making of boundedly rational households, rather than deterministic functions of population density or land suitability

AGENT-LEVEL DECISION MAKING

Households allocate labor to:

1. Make food by farming (wheat and olive) or herding (sheep and goat)
2. Invest in infrastructure by repairing irrigation canals or maintaining social ties



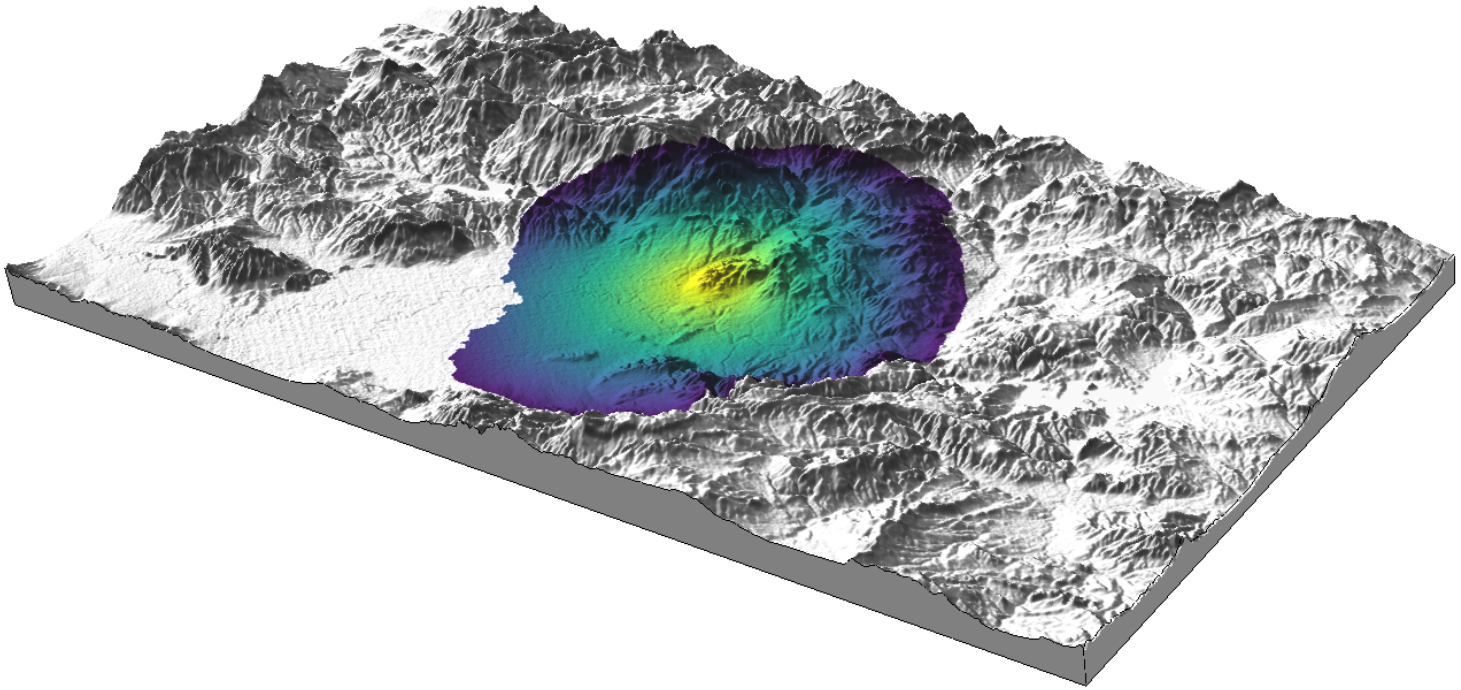
AGENT-LEVEL HETEROGENEITY

Agents differ in their objectives:

- Maximizers - maximize food, subject to labor constraints
- Satisficers - minimize labor, subject to food constraints

SPATIAL LAND USE IMPACTS

Spatial distribution of land use is mediated by topography



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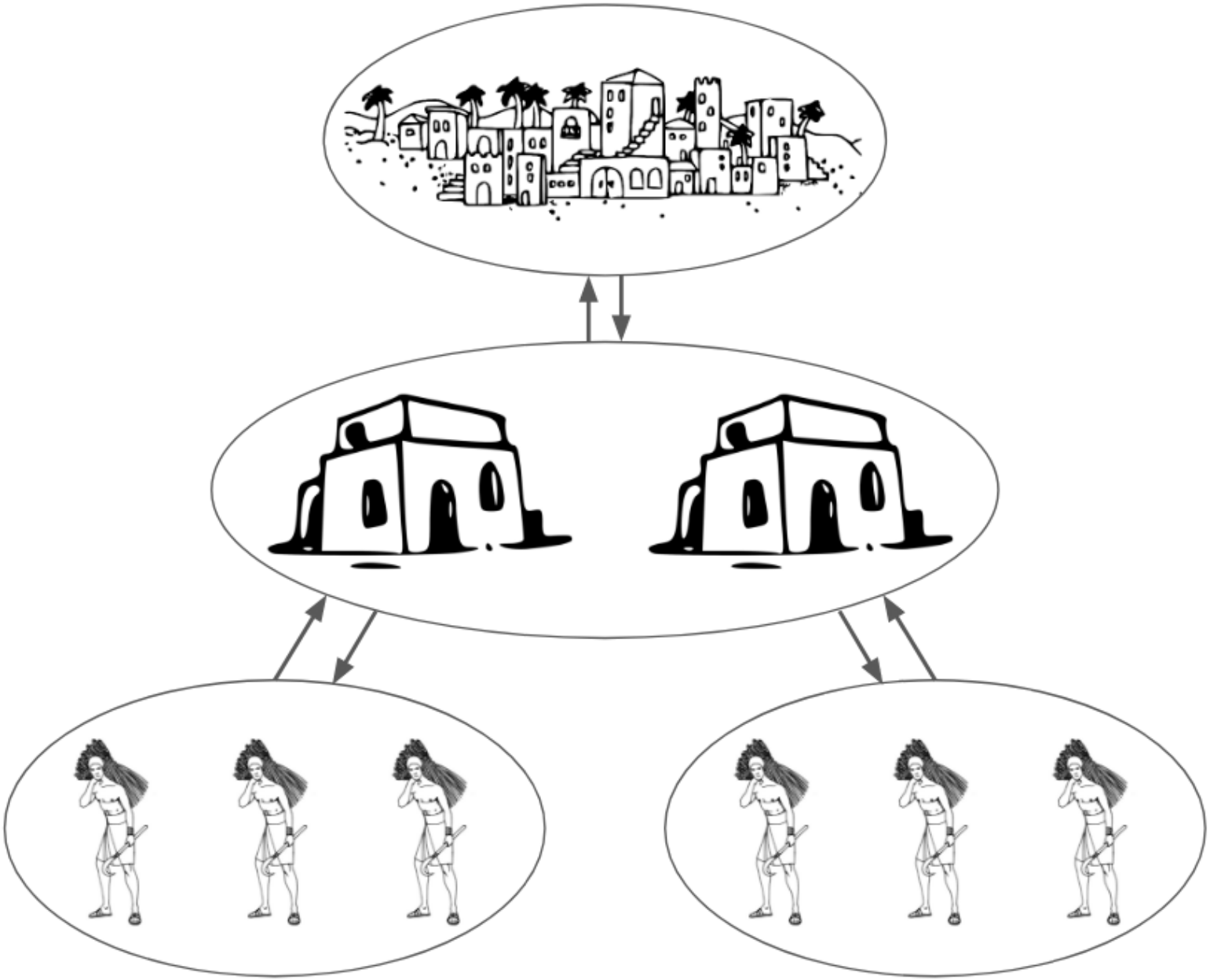
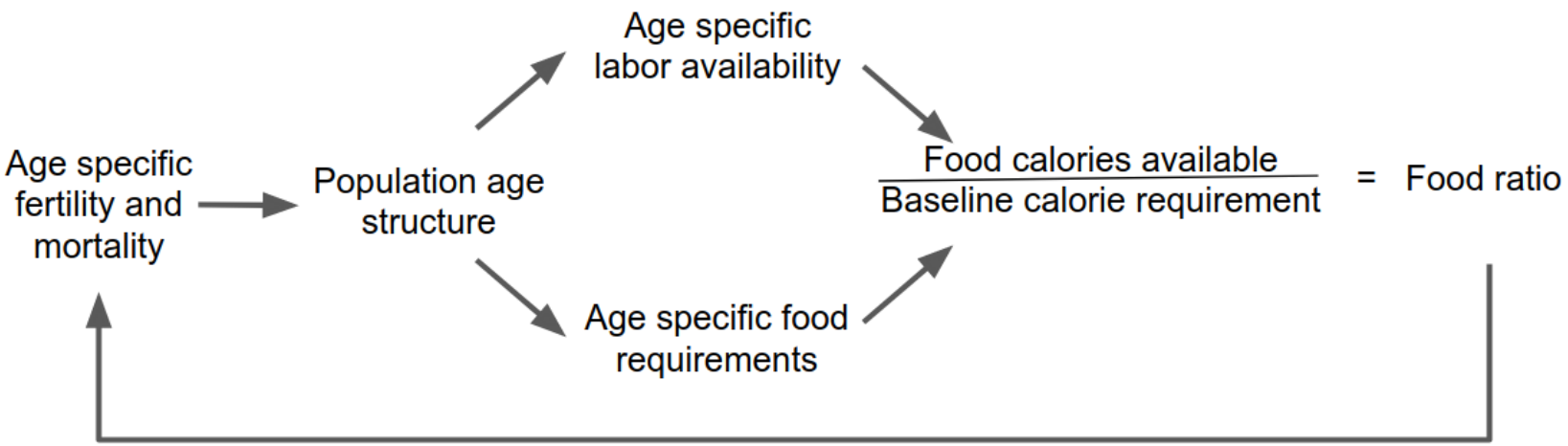
2. Use a multilevel modeling framework to capture both individual-level demography and large-scale migration flows

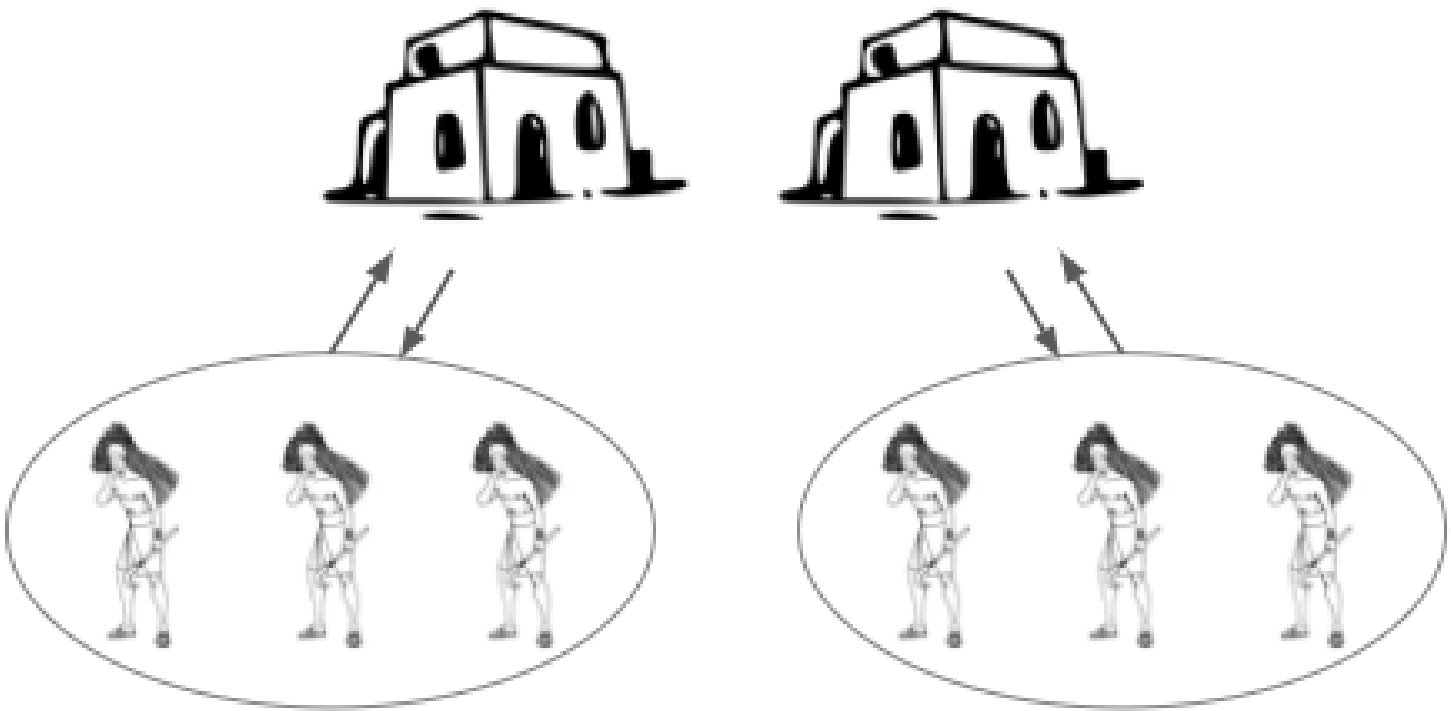
MULTI-LEVEL MODELING



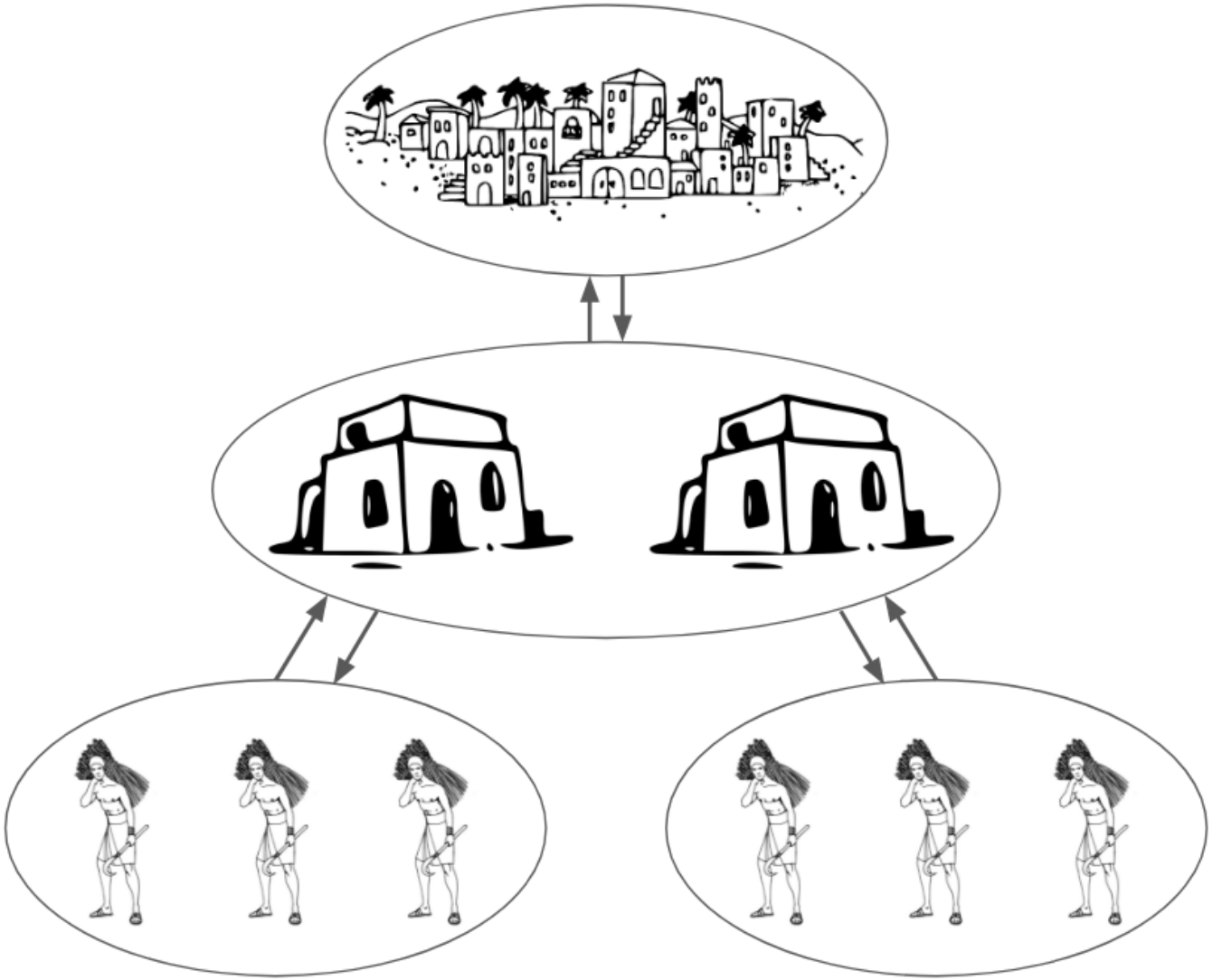
Individual level demography constrained by food production



MULTI-LEVEL MODELING

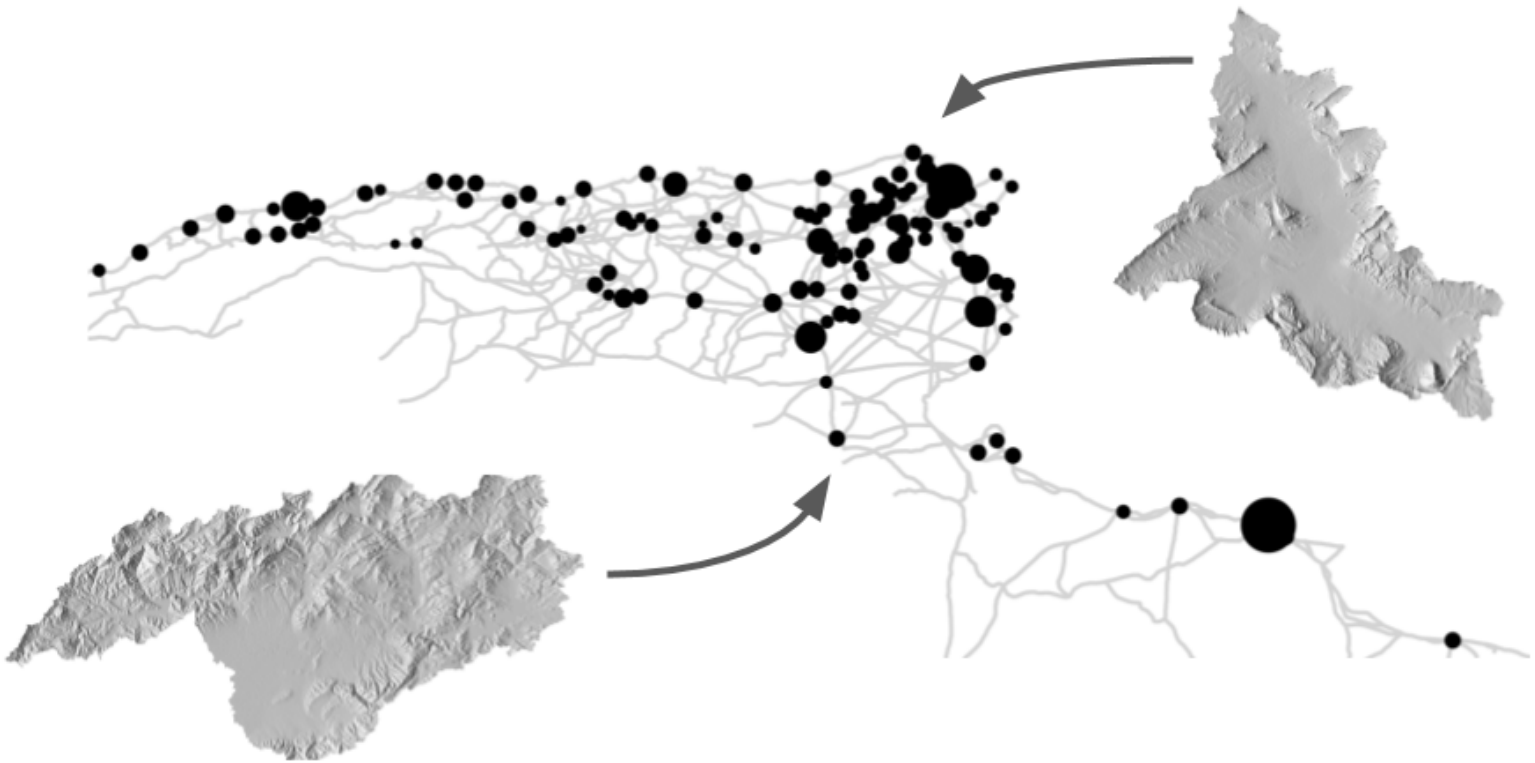


MULTI-LEVEL MODELING



MIGRATION AND SPATIAL INTERACTION

Flows of people and resources are routed on a network of cities and roads via an entropy maximizing spatial interaction model



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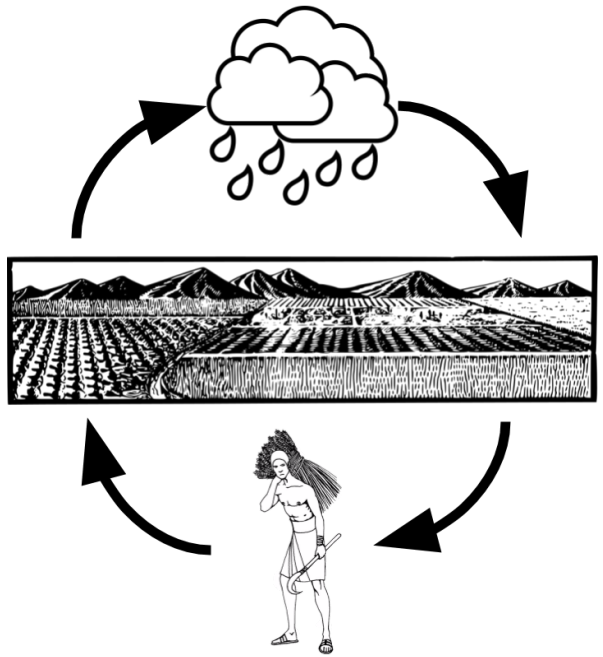
- Agent based models provide a flexible alternative to IAMs where input data are lacking
- Land surface modelers can draw on anthropology and archaeology to better understand past land-use dynamics on multiple scales

CLOSING THE LOOP

ESMs provide physically consistent representations of land-atmosphere feedbacks using scientifically validated models with well-engineered software components



ABMs allow for bottom-up generation of land-use maps that continuously contribute to and adapt to environmental variability