

AGENT-BASED MODELING OF PAST ANTHROPOGENIC LAND-COVER CHANGE

A case study from Roman North Africa

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BACKGROUND

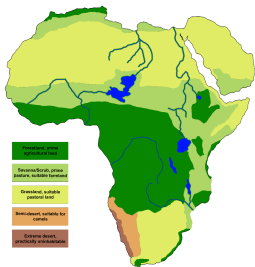
ROMAN NORTH AFRICA

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



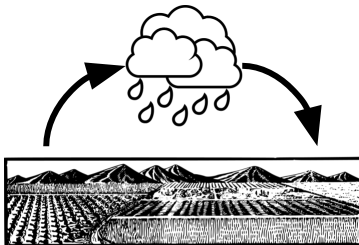
ROMAN NORTH AFRICA

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



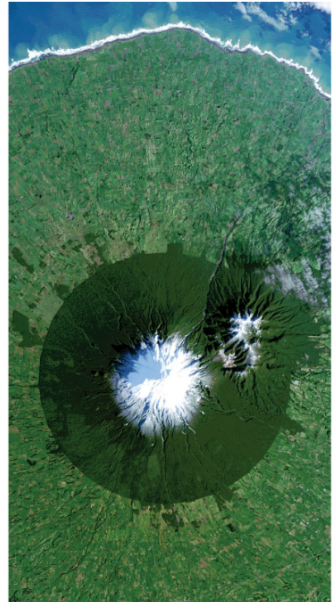
CLOSING THE LOOP

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



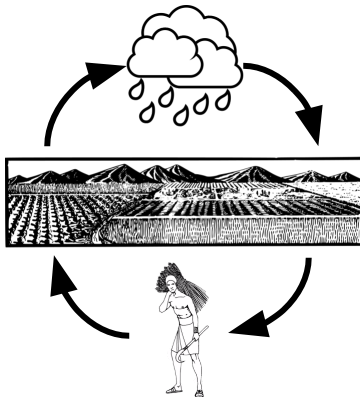
ANTHROPOGENIC LAND-COVER CHANGE

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



CLOSING THE LOOP

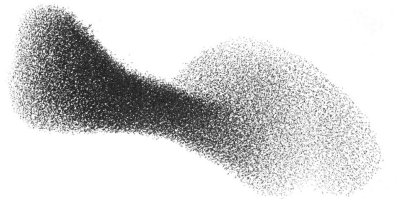
Need for dynamical feedbacks between human and Earth systems in the past, but we lack the data needed for a fully parameterized IAM



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



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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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

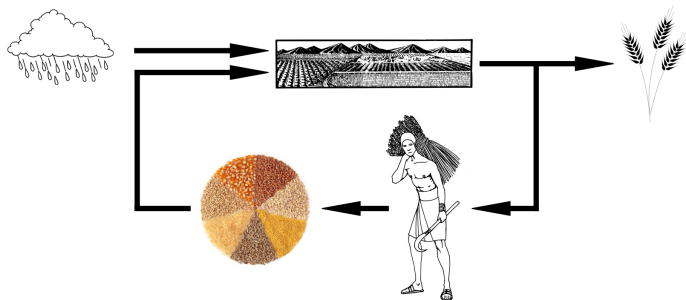
MODELING ROMAN LAND USE

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

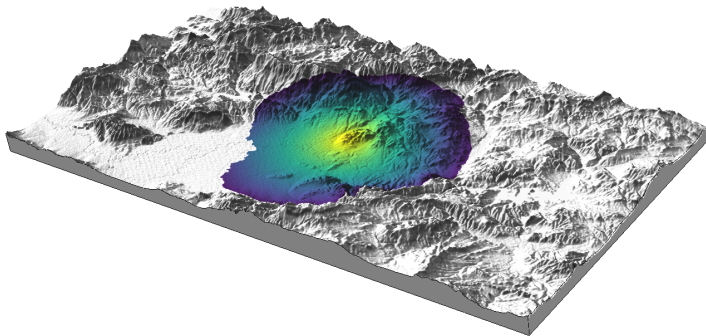


Agents differ in their objectives:

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



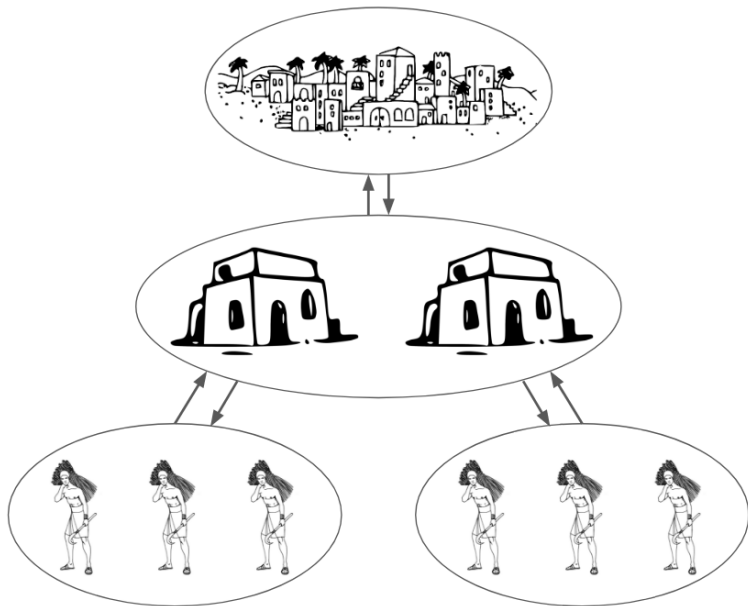
Spatial distribution of land use is mediated by **topography**



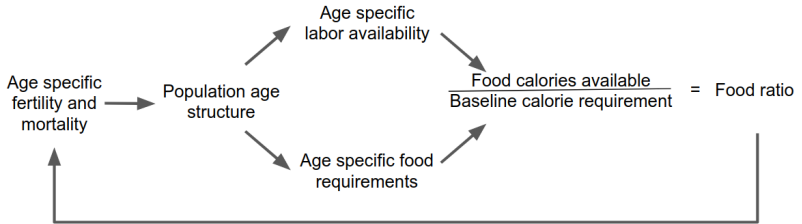
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2. Use a **multilevel modeling** framework to capture both individual-level demography and large-scale migration flows

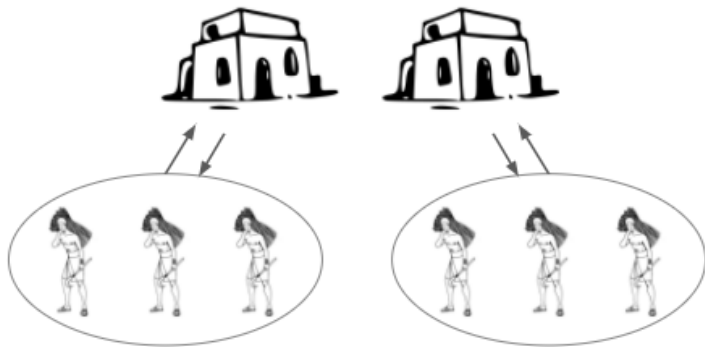
MULTI-LEVEL MODELING



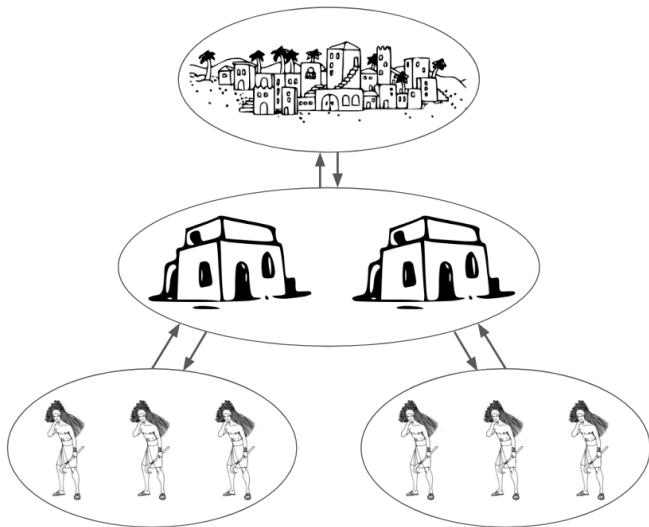
Individual level demography constrained by food production



MULTI-LEVEL MODELING

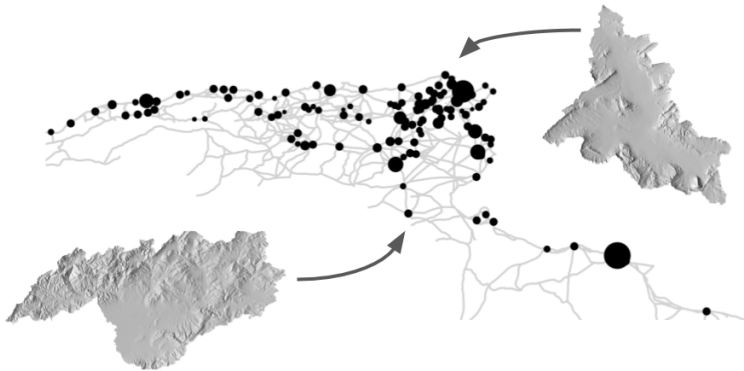


MULTI-LEVEL MODELING



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**



SUMMARY

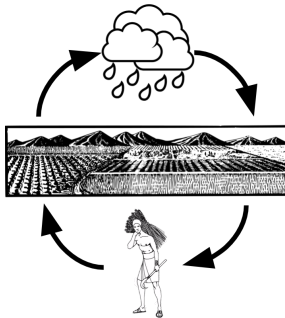
- Static land use maps are insufficient to simulate Holocene paleoclimate scenarios such as Roman North Africa

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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