AGENT-BASED MODELING OF PAST ANTHROPOGENIC LAND-COVER CHANGE

A case study from Roman North Africa

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BACKGROUND
The province of Africa Proconsularis – roughly modern day Algeria, Tunisia, and Libya – was the **breadbasket** of the Roman Empire.
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
North Africa is a region of tight land-atmosphere coupling, and experienced massive land-cover change during the 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
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
INTEGRATION WITH CLM

Linkages to CLM/CESM

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

Linkages to CLM/CESM

1. Use ESM outputs as model inputs
   - weather
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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.
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.
1. Allocate land use via decision making of **boundedly rational households**, rather than deterministic functions of population density or land suitability.
CORE DESIGN PRINCIPLES

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

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

![Diagram showing the relationship between age-specific fertility and mortality, population age structure, age-specific labor availability, food calories available, and food ratio.](image)
MULTI-LEVEL MODELING
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Flows of people and resources are routed on a network of cities and roads via an entropy maximizing spatial interaction model.
SUMMARY
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- Agent based models provide a flexible alternative to IAMs where input data are lacking.
• Static land use maps are insufficient to simulate Holocene paleoclimate scenarios such as Roman North Africa
• 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
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.