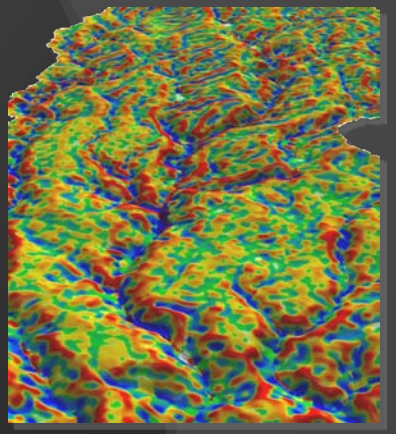
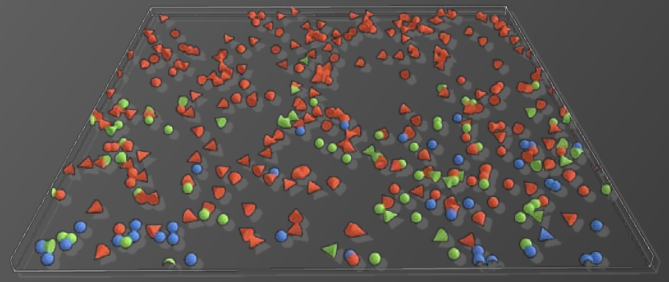


Protocols for studying dynamic systems

AGENT-BASED MODELING IN SOCIOECOLOGICAL RESEARCH



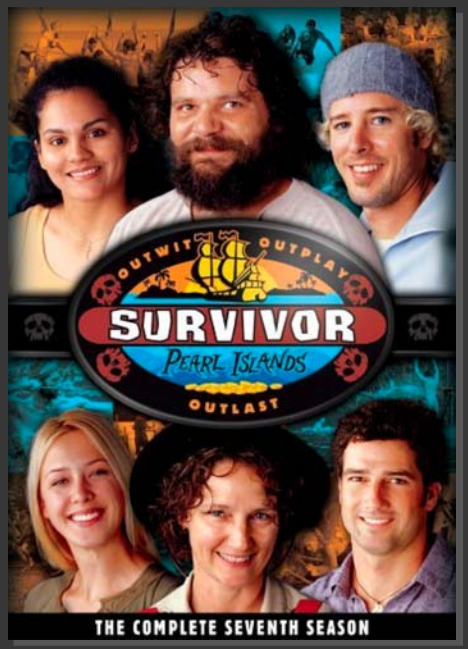
Michael Barton
School of Human Evolution & Social Change
Center for Social Dynamics & Complexity

Observational Social Science

- Social science inherently observational
- Can only observe societies ‘in the wild’

Observational Social Science

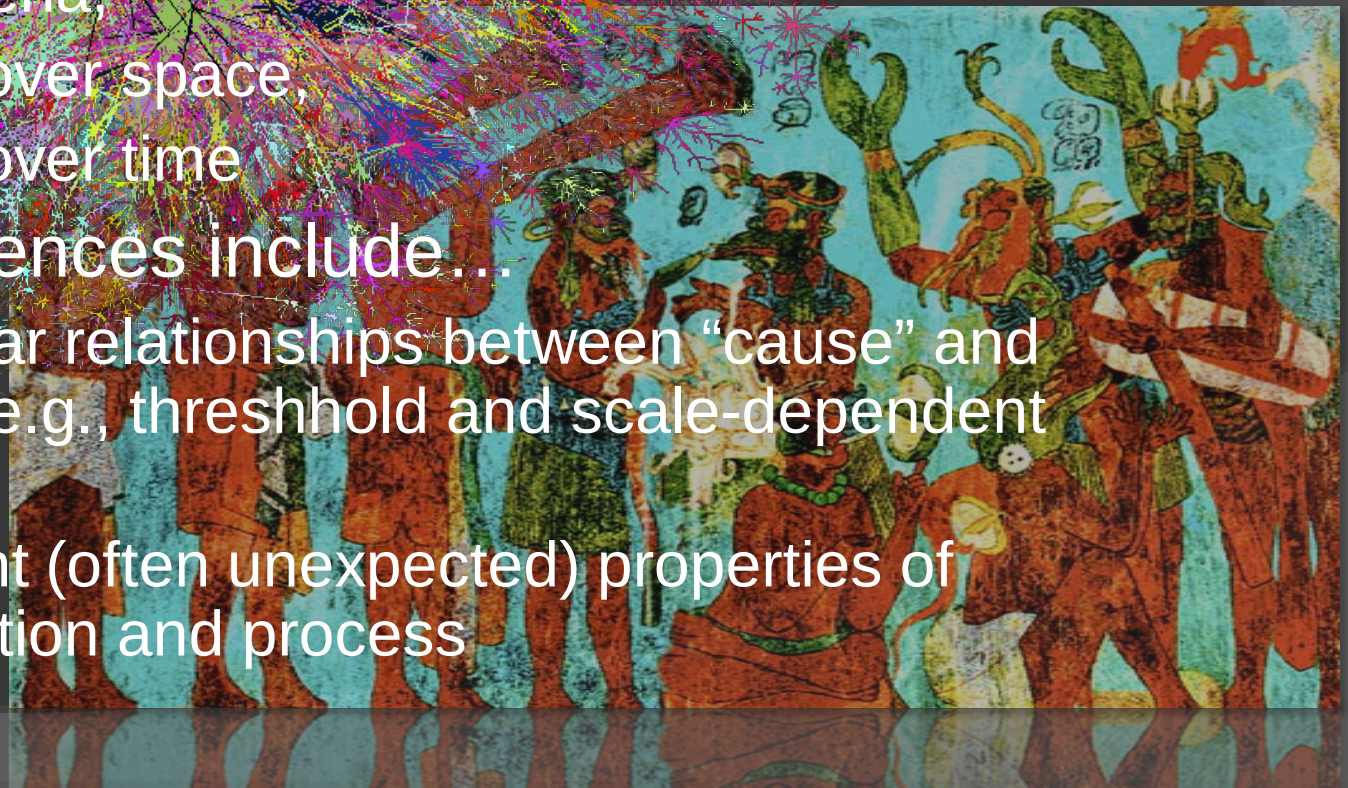
- Cannot carry out controlled social "experiments" due to ethics, pragmatic issues



…and questions of good taste

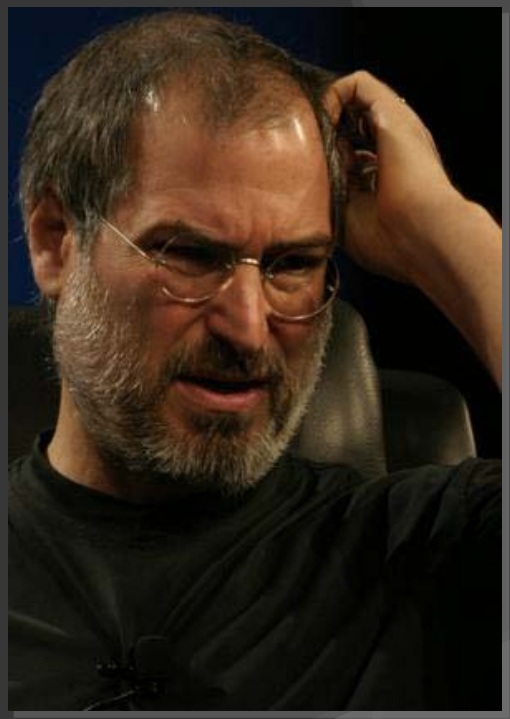
Social Systems are Complex

- Even simple social systems are complex
- Amplified by
  - interactions of social and geophysical phenomena,
  - change over space,
  - change over time
- Consequences include…
  - Non-linear relationships between "cause" and "effect" (e.g., threshhold and scale-dependent effects)
  - Emergent (often unexpected) properties of organization and process



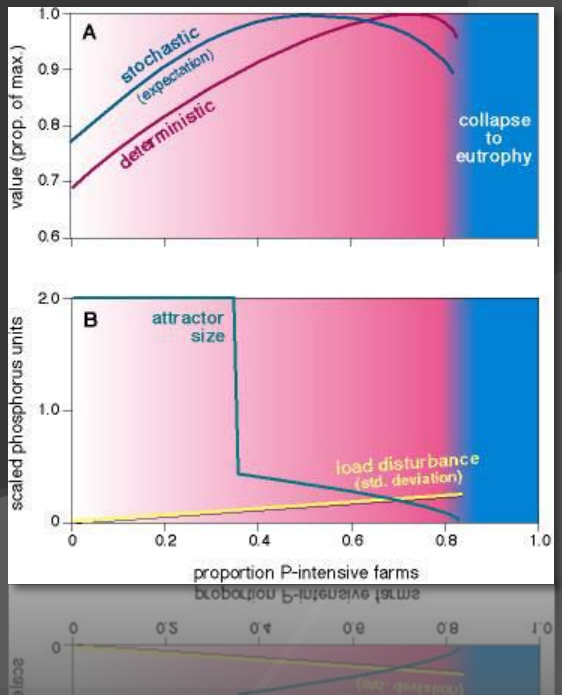
Social Systems are Complex

- Human intuition often insufficient for making sense of data from complex socioecological systems
- We are accustomed to thinking in linear cause and effect
- Sheer quantity of interactions, feedbacks, and dynamics more than unaided minds can comprehend reliably



Social Systems are Complex

- Most common mathematical models inadequate to deal with this level of complexity
- Many treat social systems like chemical systems
- Most inferential statistics deal with static relationships
- Even dynamic systems models aggregate over space



Consequences for Social Sciences

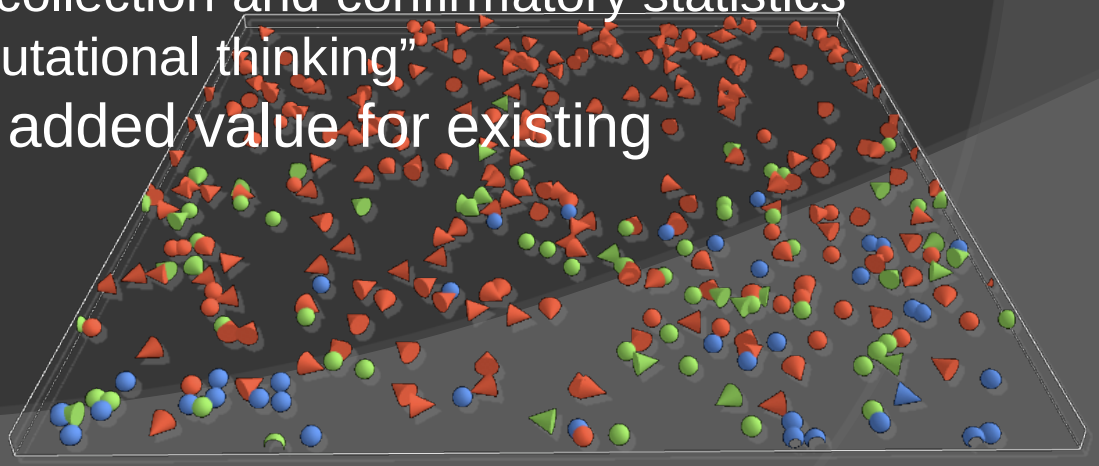
- Emphasis of inductive over deductive research
- Intuitive interpretations of complex phenomena that appeal to ‘common sense’
- Empirical generalizations substitute for explanation– as if society operated like chemical reactions; lack of history
- *Post hoc* accounts predominate over predictive explanation of process
- Lack of replicability, and common sense interpretations make evaluation of results difficult
- Inability to characterize societies and their dynamics in *other* than narrative form
- Math restricted to supporting narrative; quantitative expressions of social phenomena often trivial

Consequences for Social Science

- External (and internal) perceptions of social science
  - Little confidence in reliability of explanations of social phenomena and especially of change
  - Ironically considered a “soft science” because of the difficulty of systematic study of its subject matter
- Limited contribution to policy

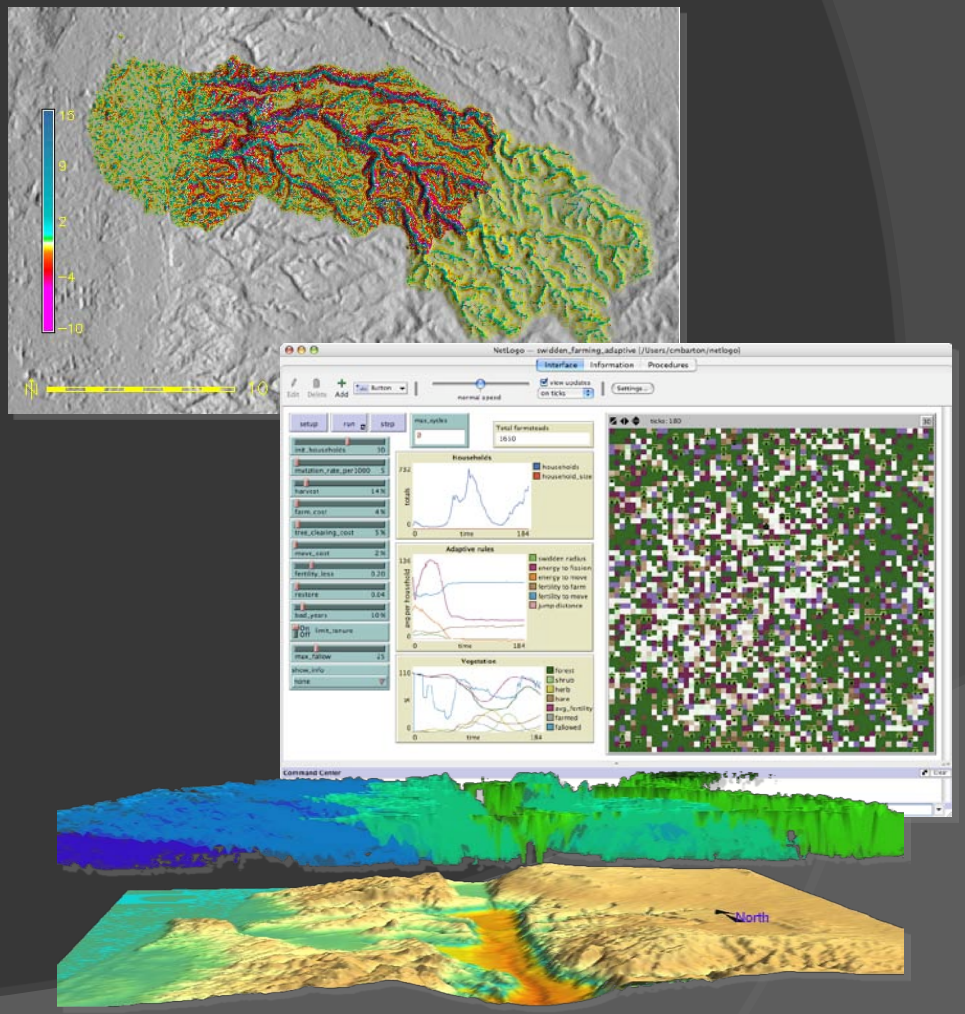
A Science of Social Dynamics

- A new kind of social science is needed
- Theory and concepts
  - Focus on social dynamics
  - Reconceptualize sociality and societies as complex systems
- Research protocols
  - Represent social organization, interaction, and change as explicit, algorithmic models
  - Add emerging cybertools to traditional research protocols of observational data collection and confirmatory statistics
  - Greater use of "Computational thinking"
- New dimensions and added value for existing approaches and data



A Science of Social Dynamics

- New cybertools allow us to explicitly and quantitatively represent complex human systems and their rich variation across space and time
- Important examples include
  - GIS and geospatial models
  - Agent based models
  - New forms of interactive visualization of multivariate data
- Provide opportunity to develop a new science of social dynamics

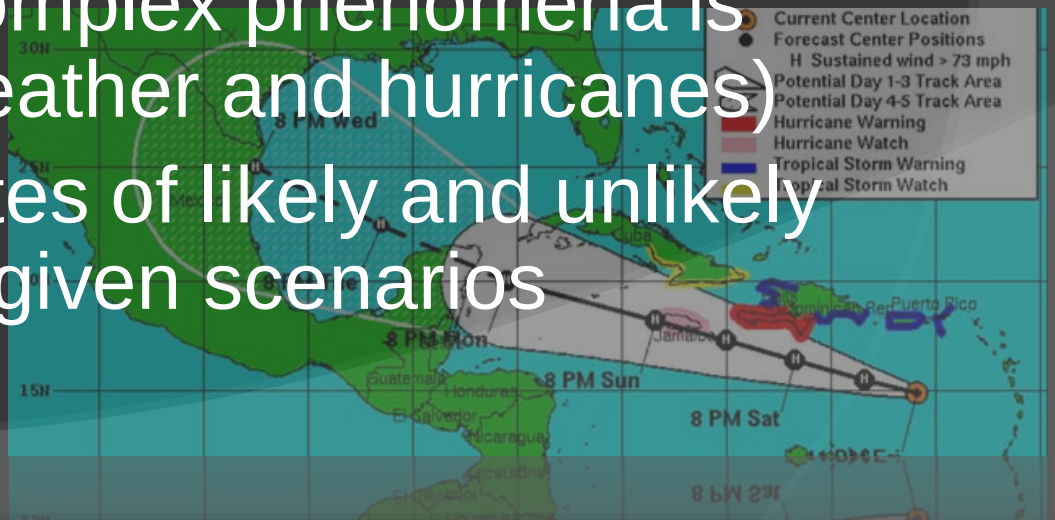


A Science of Social Dynamics

- Express complex interactions and dynamics in quantitative form that can be better communicated and independently evaluated
- Transparently test ideas about process and change in social systems
- Develop more explicit and testable hypotheses about social dynamics
- Create an experimental social science where modeling permits controlled replication of social processes. ‘Re-run the social tape’ (*sensu* R. Gould)

A Science of Social Dynamics

- Encourage robust hypothesis testing and verification—and explanations that are predictive (i.e., “forecasts”)
  - Except for economics, social science leery of forecasting or even rejects it
  - Required, at some level, for policy input
- Forecasting of complex phenomena is possible (e.g., weather and hurricanes)
- Focus on estimates of likely and unlikely outcomes under given scenarios



Examples of Research Protocols for a Science of Social Dynamics

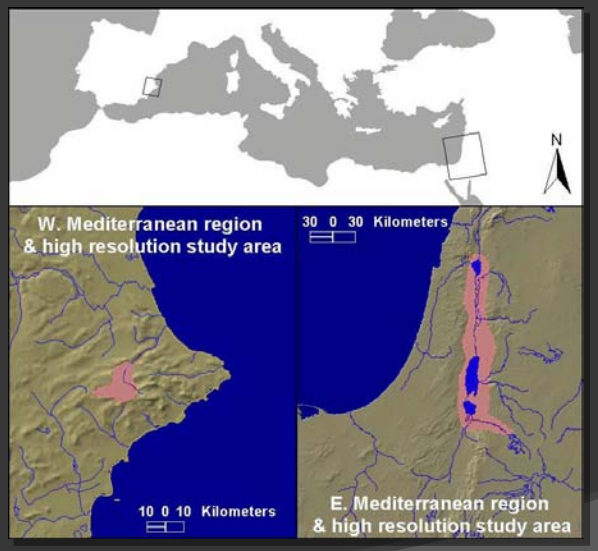
- Mediterranean Landscape Dynamics project
  - Large-scale research, spanning Mediterranean
  - Supported by NSF Biocomplexity program (BCS-0410269)
  - More details tomorrow
- Mogollon Rim Small Sites project
  - Small-scale research in Apache-Sitgreaves National Forests
  - Supported by US Forest Service
  - Will build on this example for hands-on sessions Friday

Mediterranean Landscape Dynamics

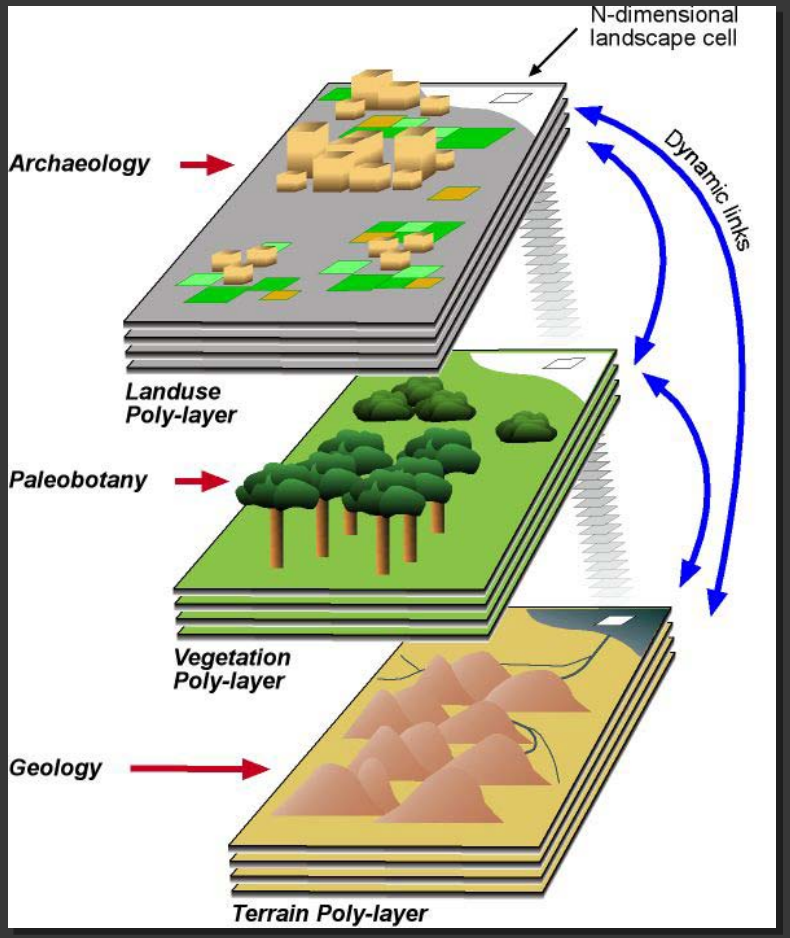
- A modeling laboratory for studying socioecological system dynamics
- Bottom-up complex systems approach to study the large-scale landscape consequences of small-scale landuse decisions, and their feedbacks
- Interdisciplinary collaboration
  - Archaeology, geosciences, life sciences, climatology, computer science, geospatial methods and statistics

Mediterranean Landscape Dynamics

- Spans Mediterranean socioecosystems
  - Arid East
  - Moister West
  - Range of social configurations



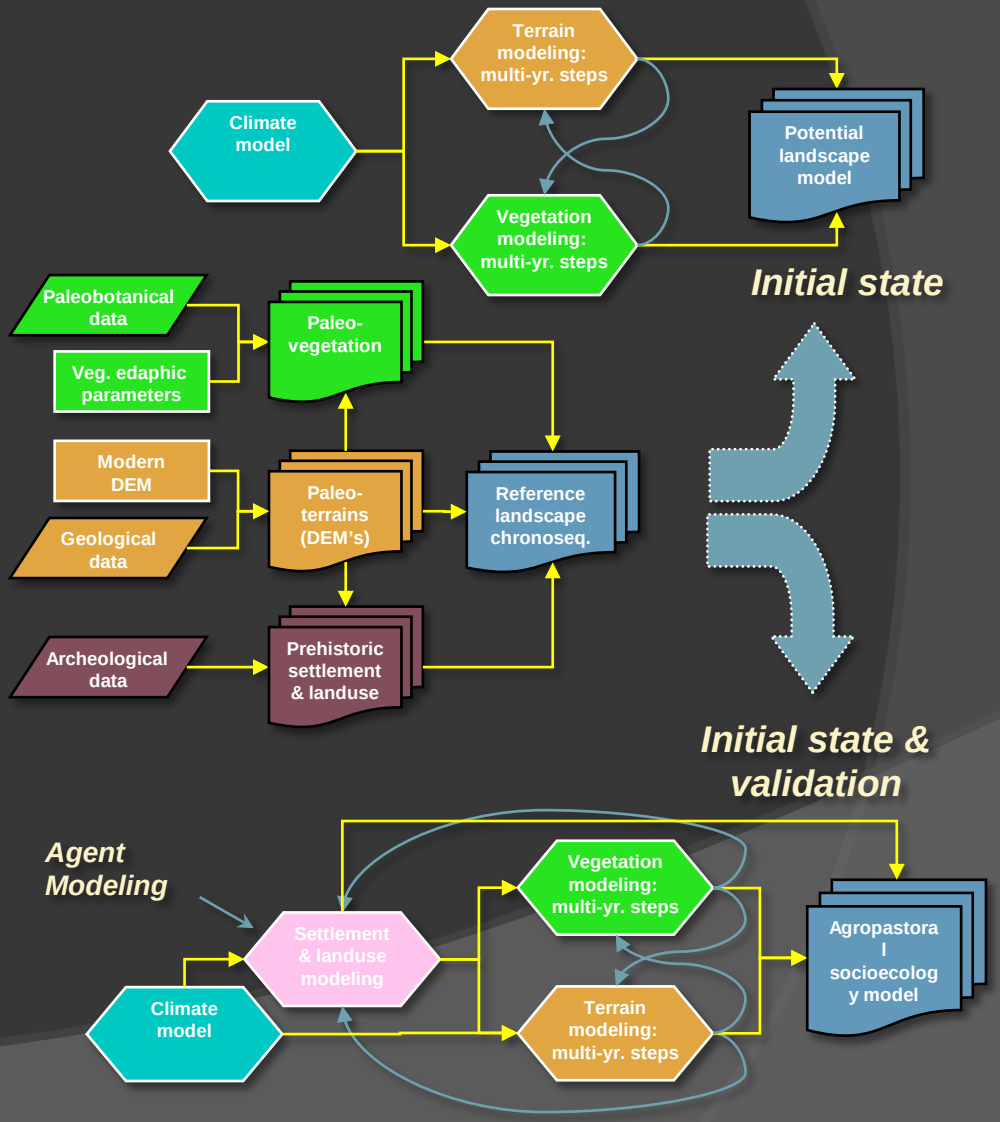
MedLand Modeling Laboratory



- Agent-based simulation of human landuse: beginning of farming to beginning of urbanism
- Surface process models of ancient landscape and climate within a GIS framework
- Linked in a hybrid, coupled model environment so that change in one module can affect state variables that serve as input to another
- Test and refine against rich archaeological and paleoecological record of Mediterranean basin

MedLand Modeling Laboratory

- 3 interlinked modeling environments
  - Potential landscape model
  - Reference landscape chronosequence
  - Agropastoral socioecology model

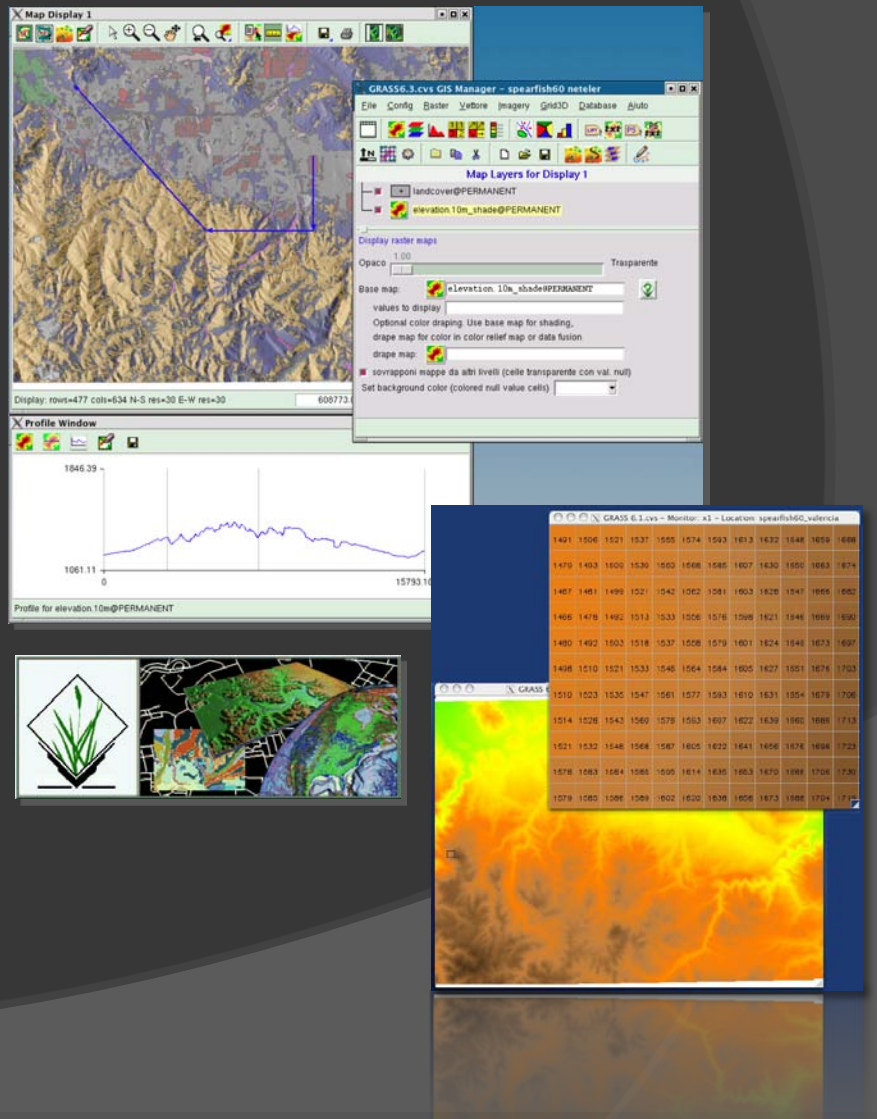


Hybrid ABM & Landscape Model

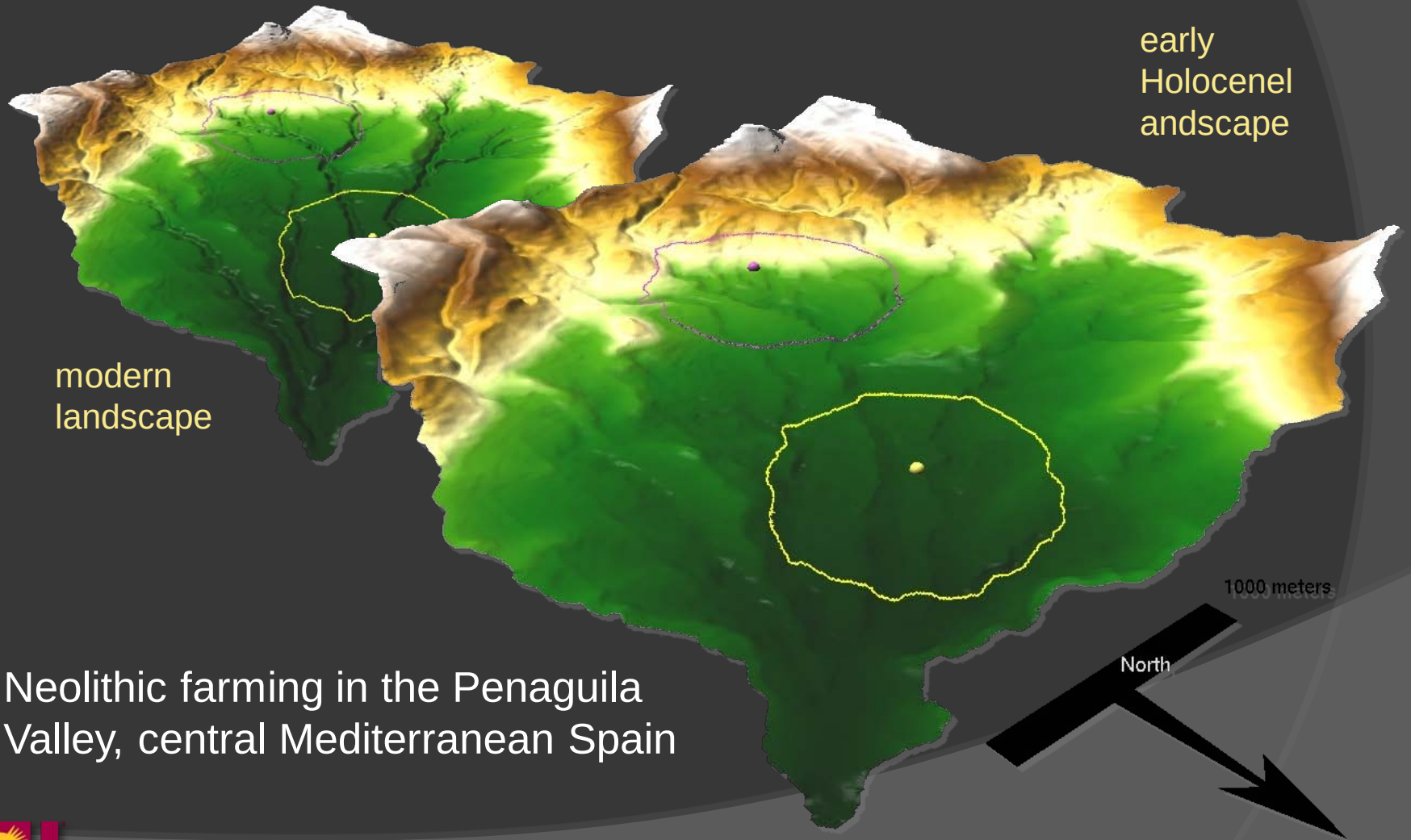
- Household is basic unit (agent)
- Landuse decisions (GIS➔ABM)
  - Potential productivity
  - Distance from village
  - Labor investment needed (e.g., clear land or simply cultivate)
- Landuse activities (ABM➔GIS)
  - Clearing land
  - Cultivating crops
  - Fallowing
  - Harvesting crops
  - Gathering wood
- Returns (GIS➔ABM)

Hybrid ABM & Landscape Model

- Landscape modeling environment
  - Built in GRASS
  - Open source GIS, anaysis, and modeling environment
  - Raster (cellular) landscape
- Surface processes modeled with unit stream power erosion/deposition model(USPED)
- PDE in ± cellular autonoma environment

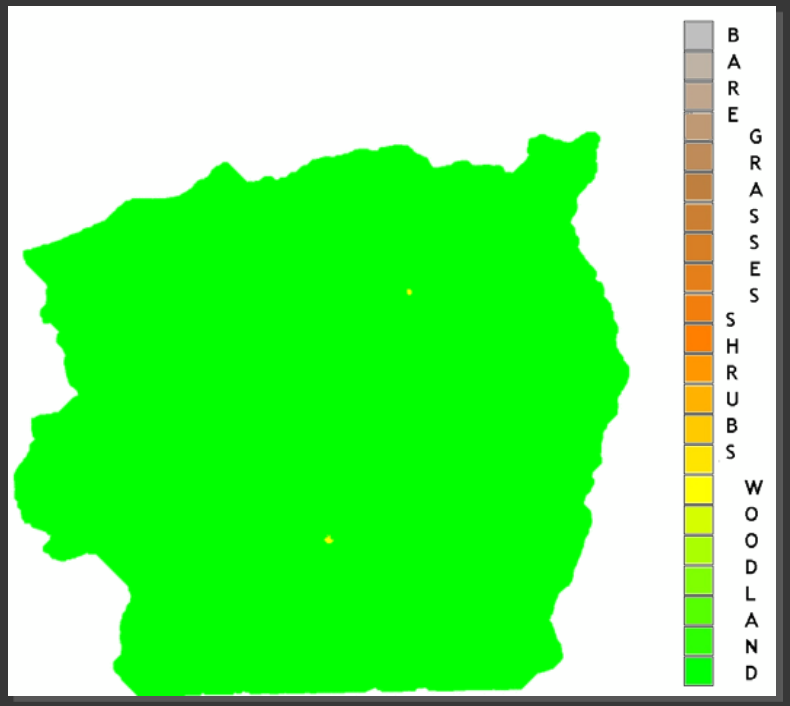


Experiments in Socioecological Dynamics: Spain

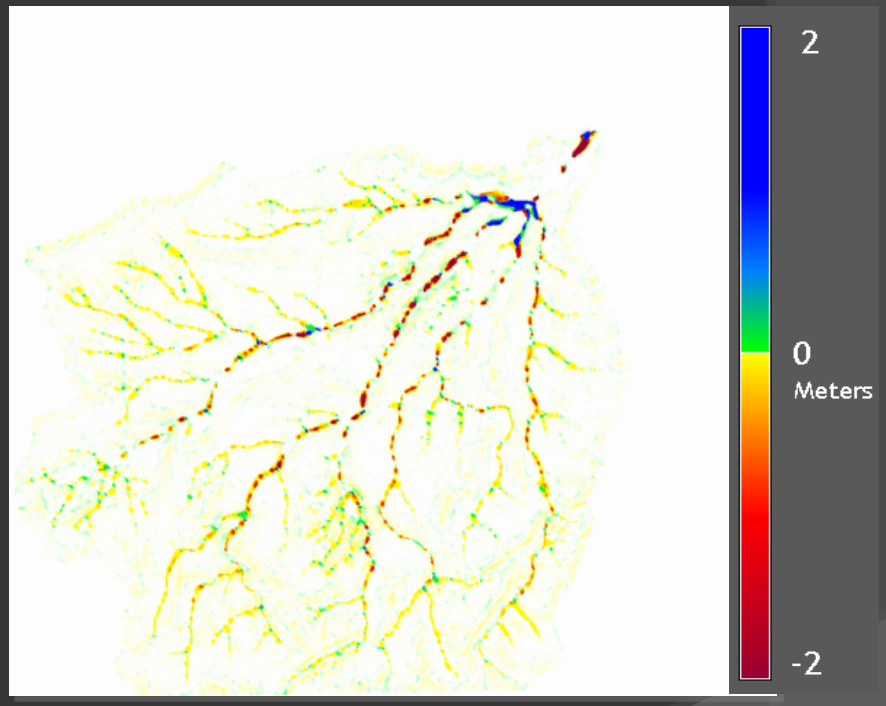


Neolithic farming in the Penaguila Valley, central Mediterranean Spain

Experiments in Socioecological Dynamics: Spain



ABM land cover/landuse



GIS landscape (erosion/deposition)

200 year coupled landuse-landscape simulation

Experiments in Socioecological Dynamics: Jordan

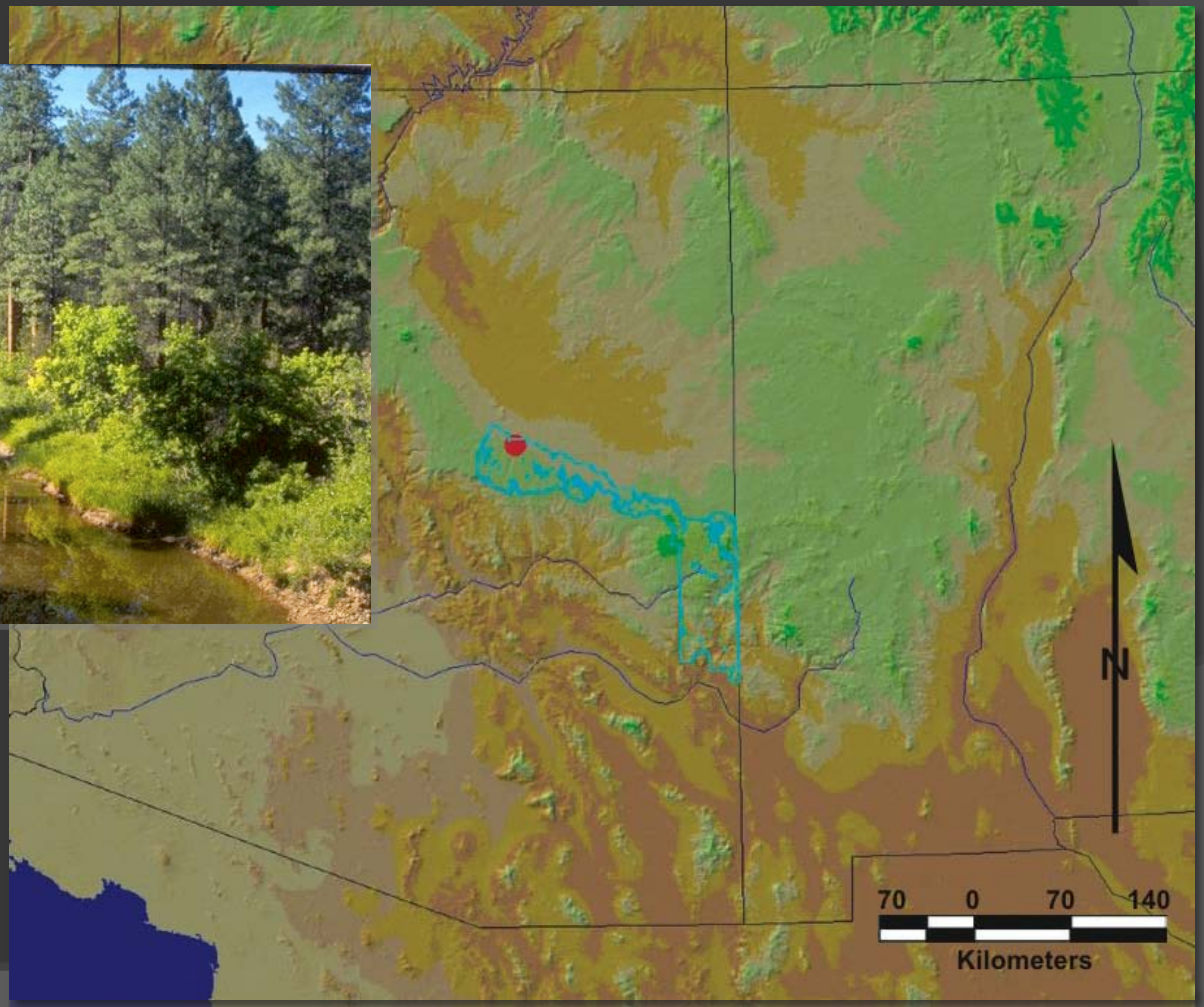
Modeled Wadi Ziqlab. 200 yrs shifting cultivation & grazing

Wadi Ziqlab today

Tell Rakkan: channel incision (shifting cultivation, grazing, low rainfall)

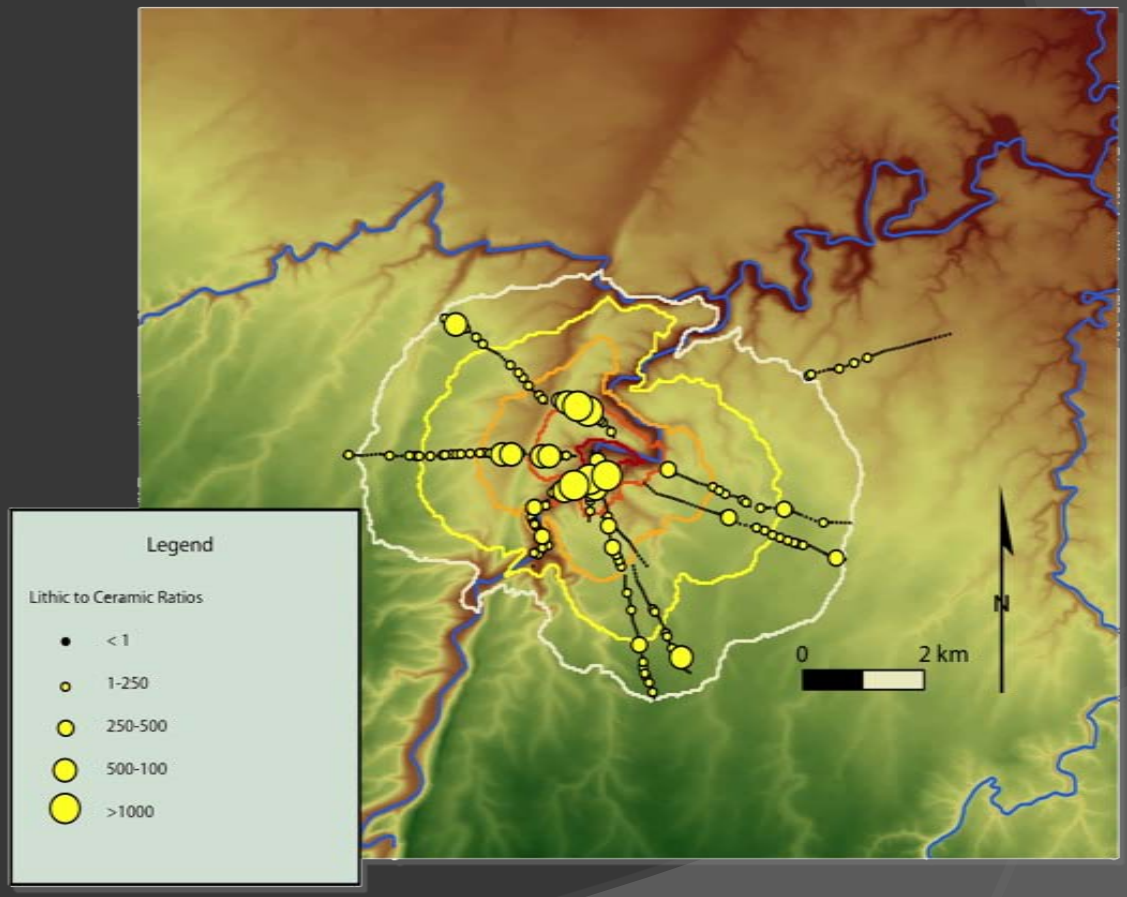
Mogollon Rim Small Sites

Project location



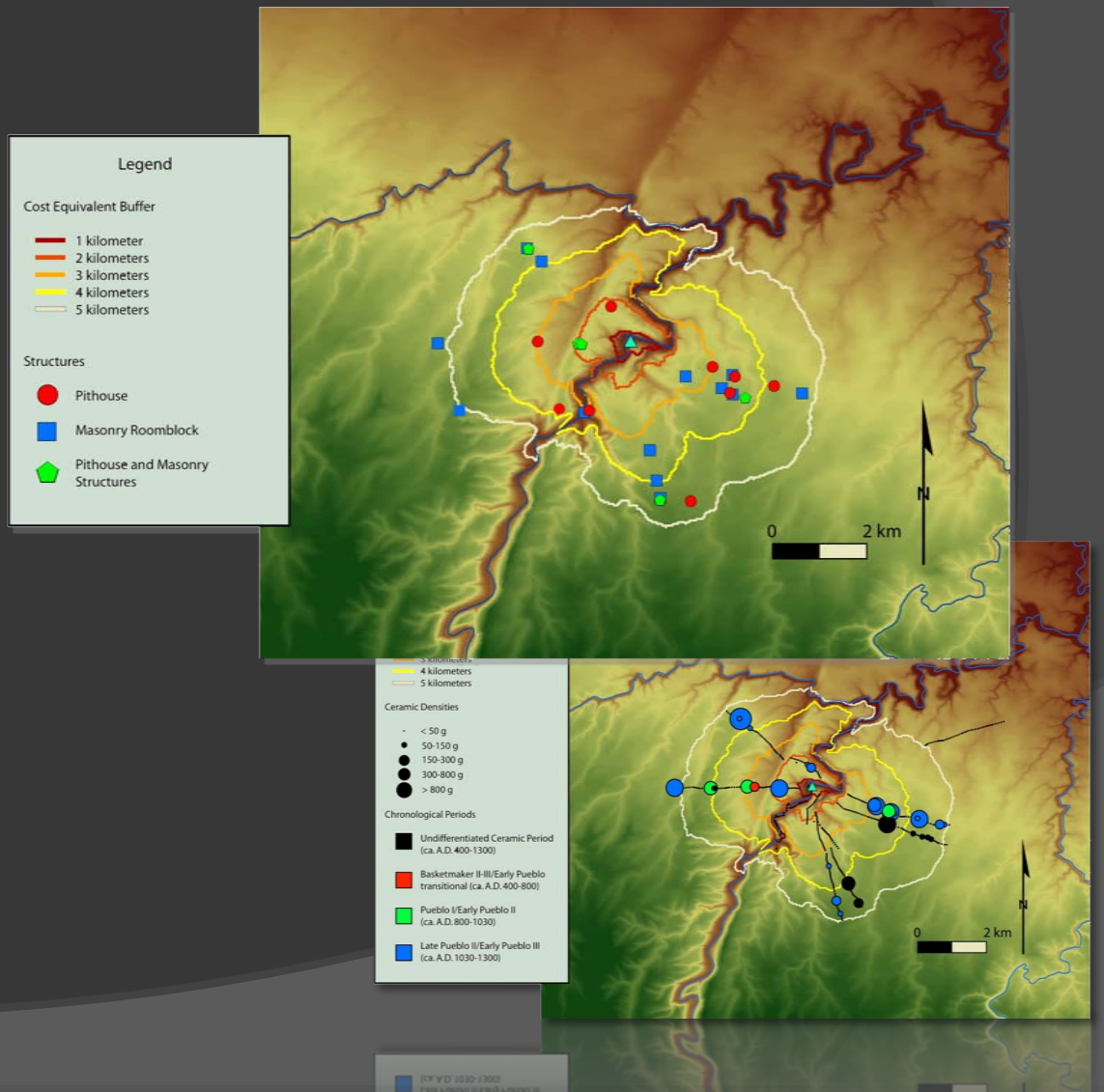
Mogollon Rim Small Sites

- Patch-based survey
- Pre-ceramic settlement clustered near canyons



Mogollon Rim Small Sites

- Socioecomic change with agricultural subsistence
- Evenly distributed sites in inter-canyon uplands

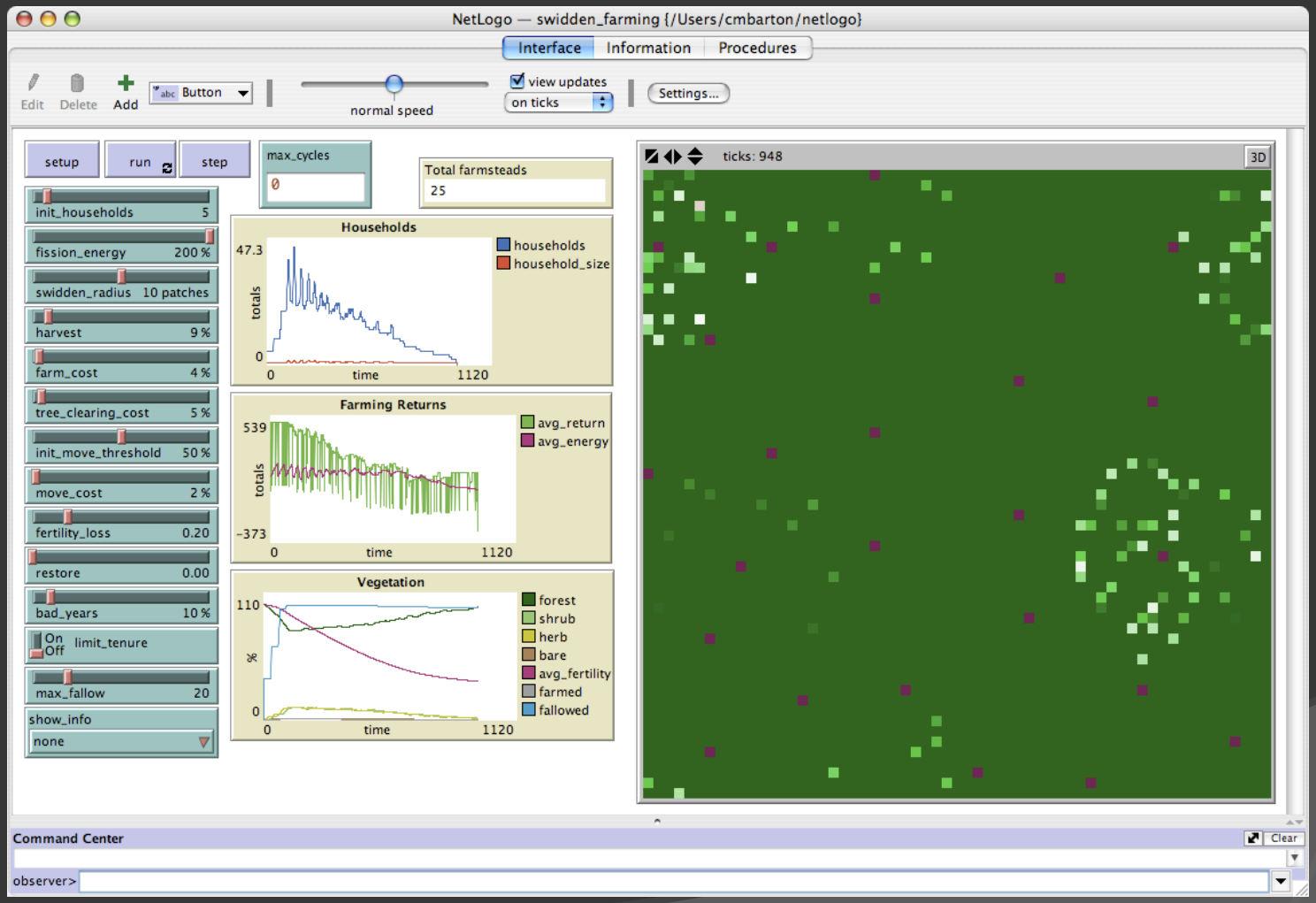


Testing Models of Dynamics

- Shifting cultivation in vulnerable landscape
- Serial movement of farmsteads
- Constrained by zones of exhausted soil caused by prior cultivation
- Resulting pattern of evenly spaced sites

Peeples, M., C. M. Barton and S. Schmich (2006). Resilience lost: intersecting landuse and landscape dynamics in the upland southwest. *Ecology and Society* 12(22).

Testing Models of Dynamics



Testing Models of Dynamics

- Brief demonstration

Modeling Not Just for 'Big Science'

- Can help to develop testable hypotheses
- Can test conceptual models about dynamics
- Potential for applicability at many scales
- BUT requires…
  - "Computational thinking" about social dynamics (*models* vs. *simulations*)
  - Familiarity with computer-based tools
  - Investment of time for 'intellectual retooling'
  - Investment of institutional human resources

New Uses for Extant Data

- Enormous and rich corpus of social science data–and more being created annually
- Modeling offers a new way to use these data
  - Not as the basis of empirical generalizations that rely on uniformitarian assumptions about human behavior
  - But as the means to parameterize and validate dynamic models of human society

New Uses for Extant Data

- Add experimental component largely lacking in social science
  - Conduct experiments about scenarios that did and did not happen—or scenarios that have not yet happened
  - Compare with known outcomes.
  - Examine long-term consequences of decisions
  - Apply to decisions and policy.
- Improve theory
  - Test theoretical propositions about dynamics.
  - Study linkages between individual/small-scale and group/large-scale phenomena

Tools for Science of Social Dynamics

- Modeling software is rapidly changing
  - Better response to needs of domain specialists rather than computer specialists
  - Improvements to interfaces and installation
  - Access to external data and programs
- Examples
  - NetLogo 4 http://ccl.northwestern.edu/netlogo/
  - Repast Symphony http://repast.sourceforge.net/
  - Metascape http://www.metascapeabm.com/

Tools for Science of Social Dynamics

- Social scientists need to be involved with the development of these important tools for our research (e.g., geography and archaeology with GIS)
- Need to train our students (and ourselves) in the use of new research methods
- Need to jumpstart a science of social dynamics through sharing information and expertise in forums like this one.

Infrastructural Challenges

- Existing venues for information dissemination and scientific scaffolding not well suited for complex system modeling
- Lack of training in relevant concepts and methods in social science
- Underdeveloped reward structure for social dynamics science
- Young technology that is rapidly changing
- Articulation with existing approaches in social and natural sciences

Open Agent Based Modeling Consortium

- Community of researchers in social and ecological sciences
- Improving access to computational tools for complex systems modeling
- Sharing experiences and strategies
- Promoting a science of social dynamics
- Get involved: http://www.openabm.org