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Coupling the Past, Present, and Future of Socio-Ecological Systems

The Mediterranean Landscape Dynamics Project

A Complex World

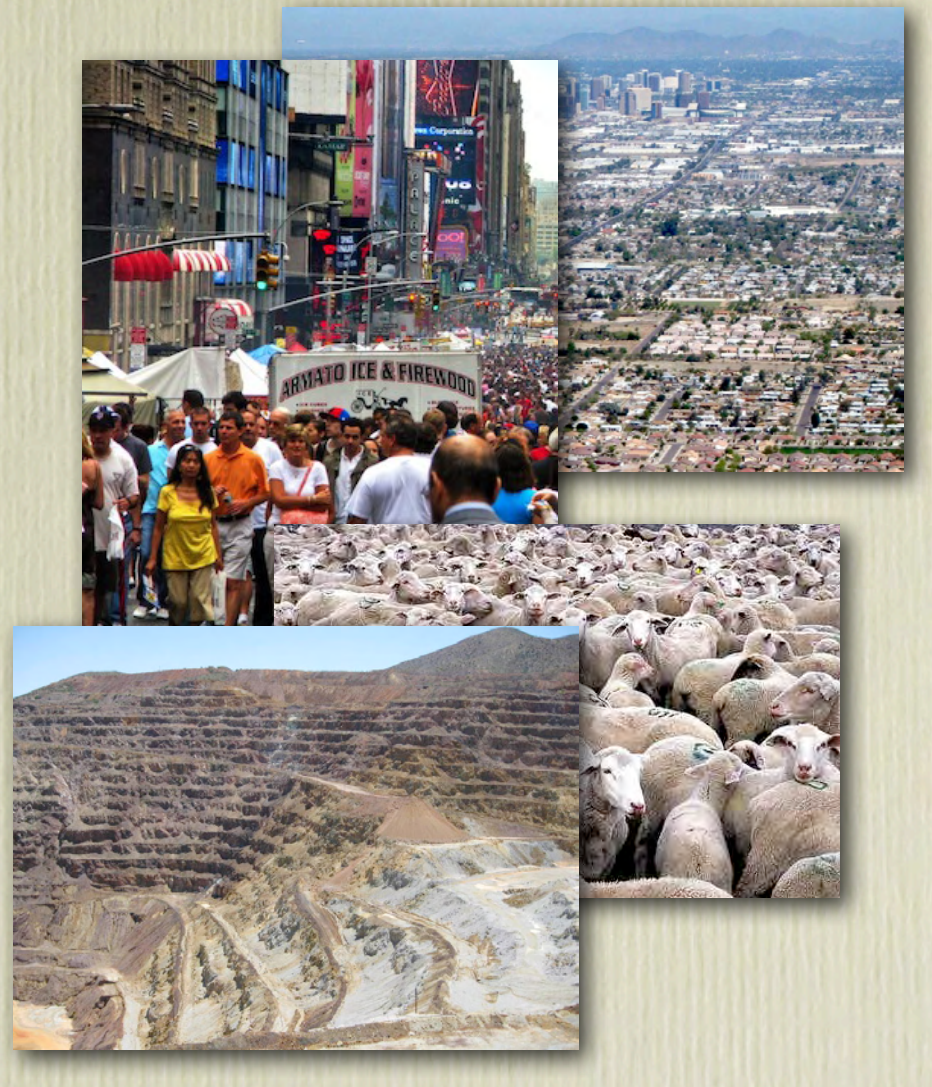
- The world is complicated
- But more importantly, it is complex
  - Ecological systems are complex
  - Human social systems are complex

Complex Coupled Socioecological Systems

- Socioecological Systems, or SES, compound complexity in human and natural systems

Complex Coupled Socioecological Systems

- Urban societies unprecedented in the animals world—rivaled only by social insects
- More federally recognized occupations in USA than species of mammals in the world.
- Manage agro-ecosystems whose biomass exceeds that of all other animals on earth
- Move more terrestrial sediment that all natural processes combined

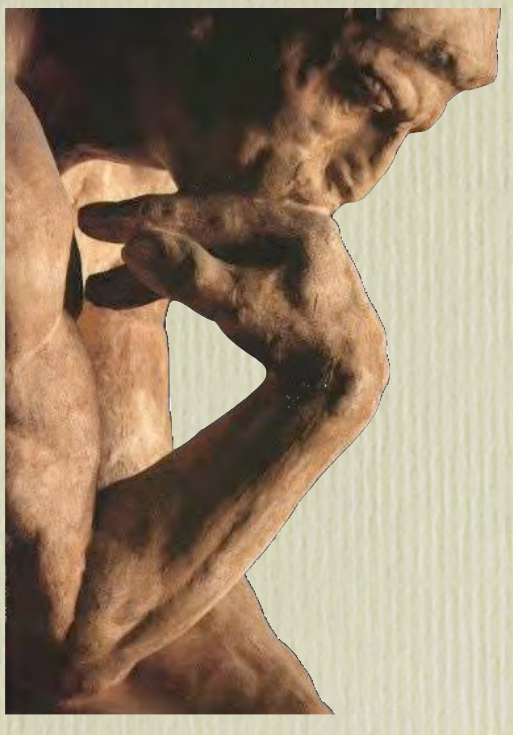


Complex Coupled Socioecological Systems

- Interactions as or more important than the properties of the social and biophysical components.
- Consequences of of human action and non-human environmental change ...
  - Often non-linear
  - Characterized by buffering, thresholds, and unexpected emergent phenomena.

Complex Coupled Socioecological Systems

- Linear cause and effect thinking no longer sufficient to anticipate outcomes of social action
- ...even when applied in scientific context

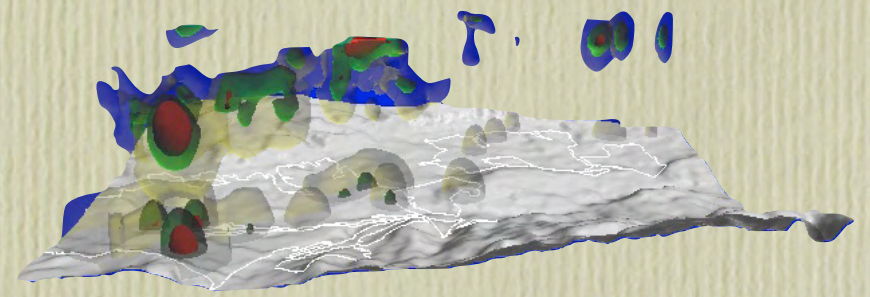


$$2H_2 + O_2 \rightarrow 2H_2O$$

Complex Coupled Socioecological Systems

- SES dynamics and continuously adapting to changing condition
- Need to understand the history of coupled SES in order to understand current behavior.

CNH Science

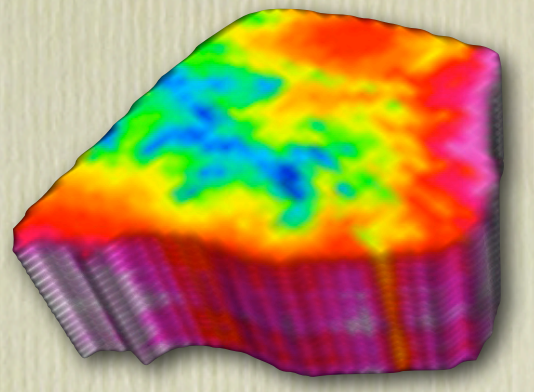


Spacetime volume of 100000 years of human settlement in Polop valley, Spain

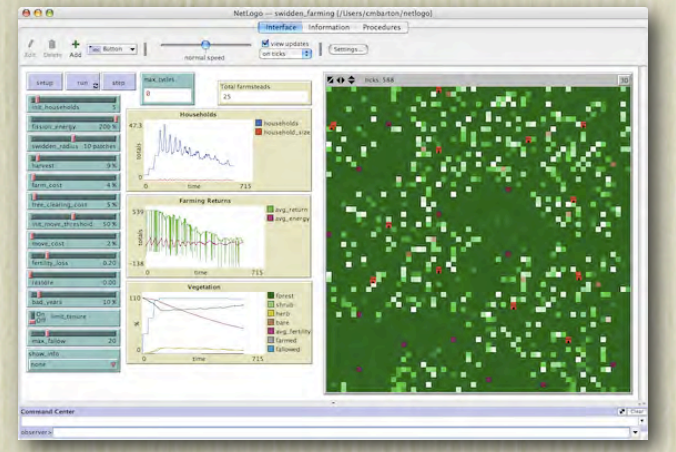
- Nature of SES means that we need to think about them differently than other phenomena.
  - Consider interactions as much as properties
  - Emphasize spatial and temporal dynamics
  - Present and future of SES are contingent on past

CNH Science

- New computationally enhanced methods to go beyond normal linear thinking
  - Systems dynamic modeling
  - Dynamic and space/time GIS
  - ABM



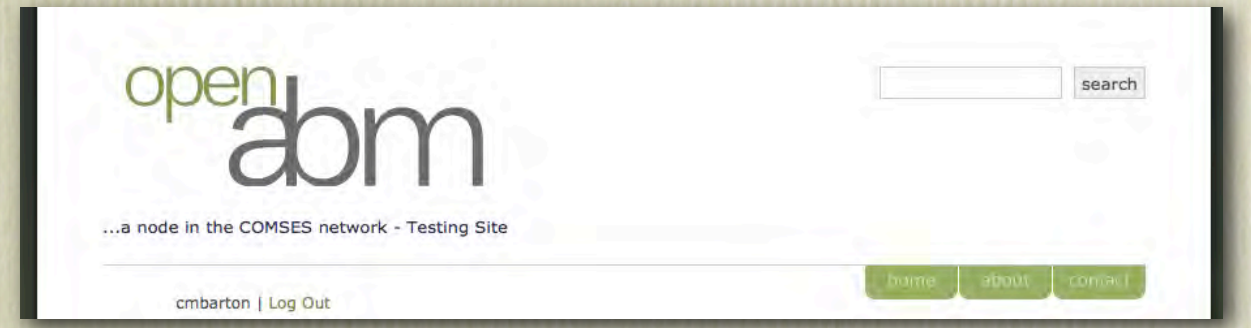
Spacetime volume of annual temperature in eastern Spain, 10000-3000 BP



Netlogo simulation of swidden agriculture

2 Examples of CNH Science

- Mediterranean Landscape Dynamics project (Biocomplexity CNH: BCS-410269)
- CoMSES Network (CNH RCN: GEO-909394)

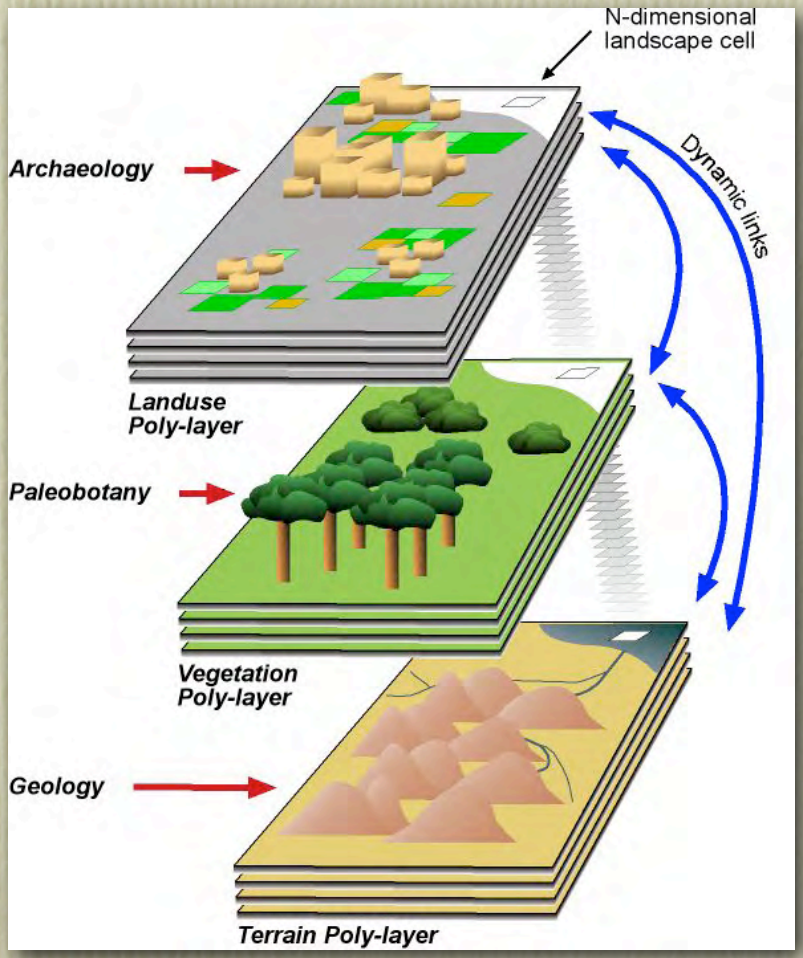


Mediterranean Landscape Dynamics

- Interdisciplinary and international team of scientists
- New research environment for studying recursive interactions of agropastoral landuse and landscape evolution.

MedLand high resolution study areas at opposite ends of the Mediterranean

Mediterranean Landscape Dynamics



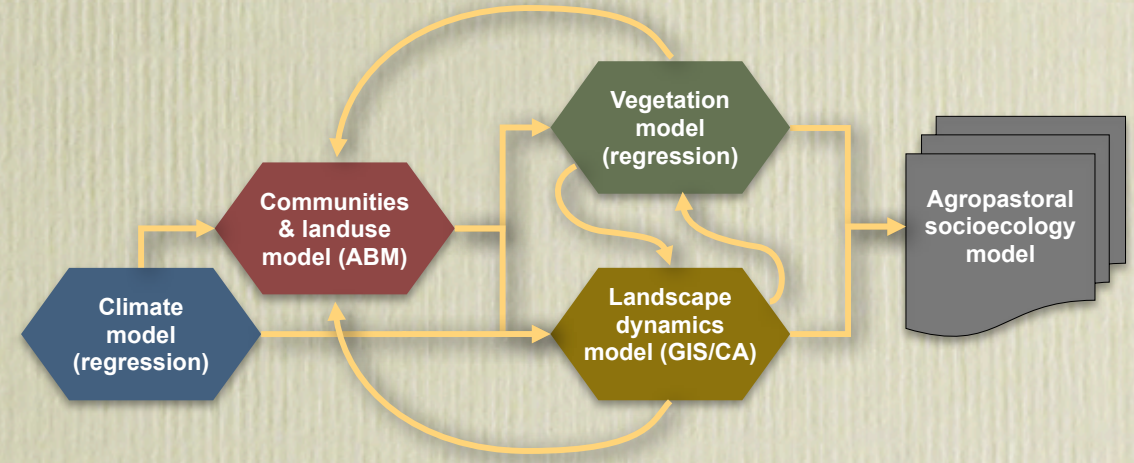
- A computational modeling laboratory for experiments in long-term socioecology,long-term consequences of land-use practices
  - Use advanced computational modeling,
  - Parameterize with data from empirical studies in the past and present
  - Use the record of past SES to validate and refine models of long-term dynamics.

Coupled Models for Coupled SES

- ABM to represent land-use decisions of farming households
- GIS/CA for landscape dynamics, including terrain, soils, land-cover
- ODE/statistical models of paleoclimate and vegetation to parameterize laboratory models
- Open-source software: more scientifically transparent and accessible to planners, researchers, and students globally.

Java based DEVS Suite (http://www.acims.arizona.edu/SOFTWARE/software.shtml)

GRASS GIS (http://grass.osgeo.org)



Models for Complex SES

Eroded barranco in the Penagulia Valley, Spain

- Recent ethnographic and land-use studies for parameterizing models in MedLand Laboratory
  - But these are insufficient for validating model outcomes
- Important SES dynamics take place over the long term and at different time scales
  - e.g., erosion and soil loss vs. social and economic change

Models for Complex SES

- Using rich archaeological and paleoecological record of long term change to validate models
  - Modeling dynamics observed in the archaeological and paleoecological records
  - But not doing this to recreate past societies
  - Simulating past SES to create models that can make more reliable forecasts of the socioecological consequences of land-use practices today.

Iron Age *Edeta* near Valencia, Spain

Rock art near Bayannur, Inner Mongolia

Examples of Medland results

- Summary of 2 experiments
  - Effects of community size and land-use practices on agricultural productivity and land degradation northern Jordan
  - Causes of large-scale barranco erosion in landscapes of Mediterranean Spain

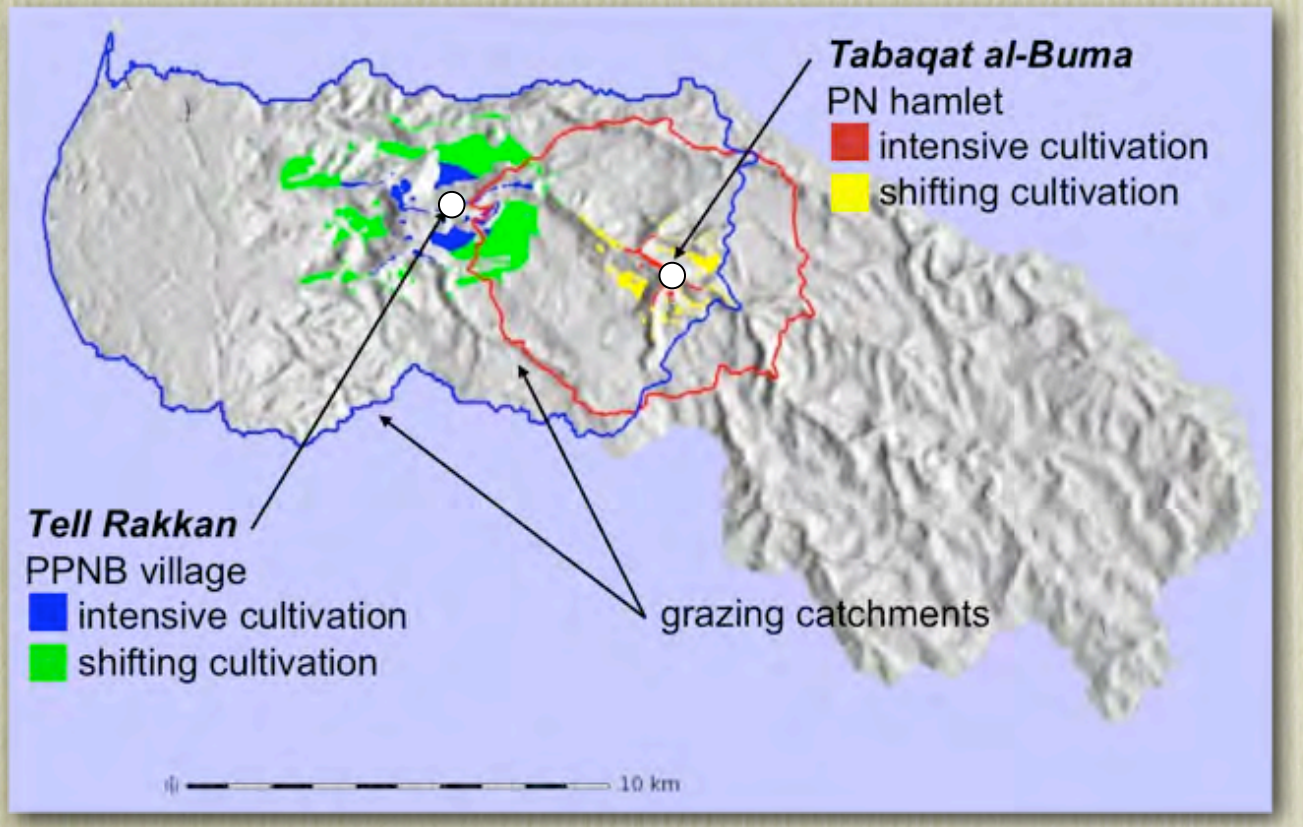
Neolithic Socioecology in Northern Jordan

- Experimental social science

Settlement	Precip. & Soil	Agropastoral Land-Use Experiments	
Small village with 5-20 families. Like Tell Rakkan ca. 8400 cal BP (PPNB)	918.5 mm/yr R-factor = 6.69 K-factor = 0.42	No cultivation	No grazing
		Intensive cultivation	No grazing
			Grazing
		Shifting cultivation	No grazing
			Grazing
Hamlet with 1-5 families. Like Tabaqat al-Bûma ca. 7400 cal BP (PN)	783.7 mm/yr R-factor = 5.26 K-factor = 0.42	No cultivation	No grazing
		Intensive cultivation	No grazing
			Grazing
		Shifting cultivation	No grazing
			Grazing

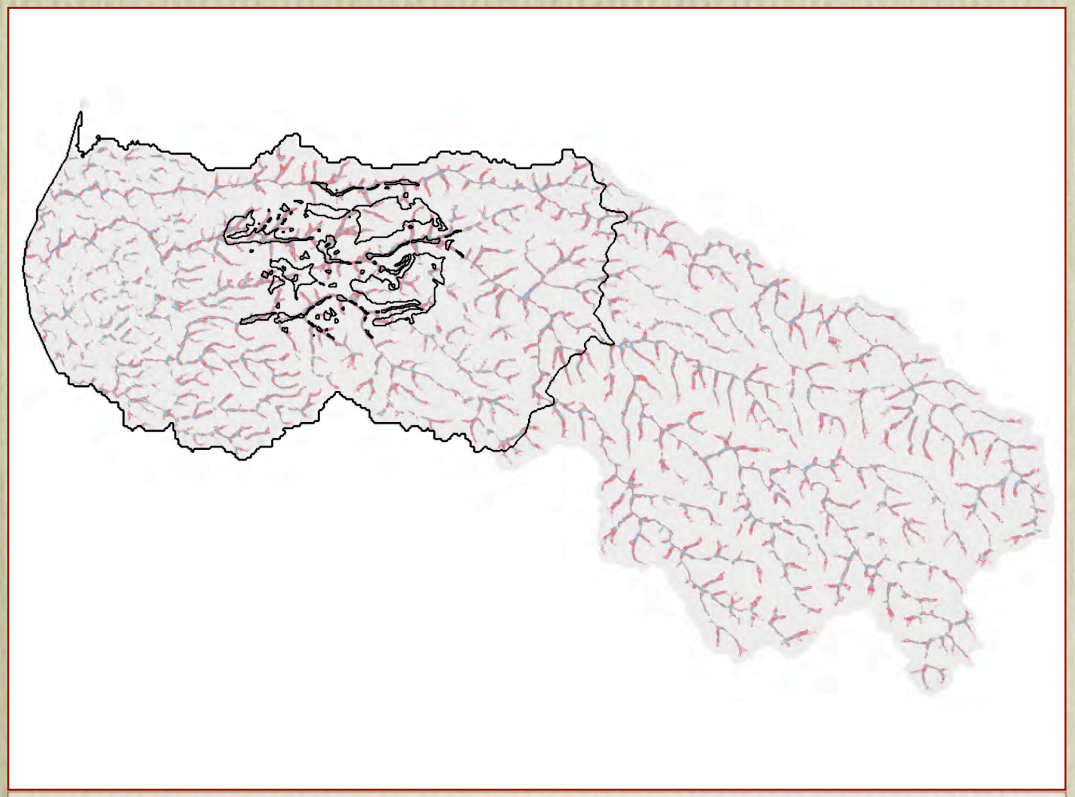
Neolithic Socioecology in Northern Jordan

- Farming & grazing catchments for 2 communities

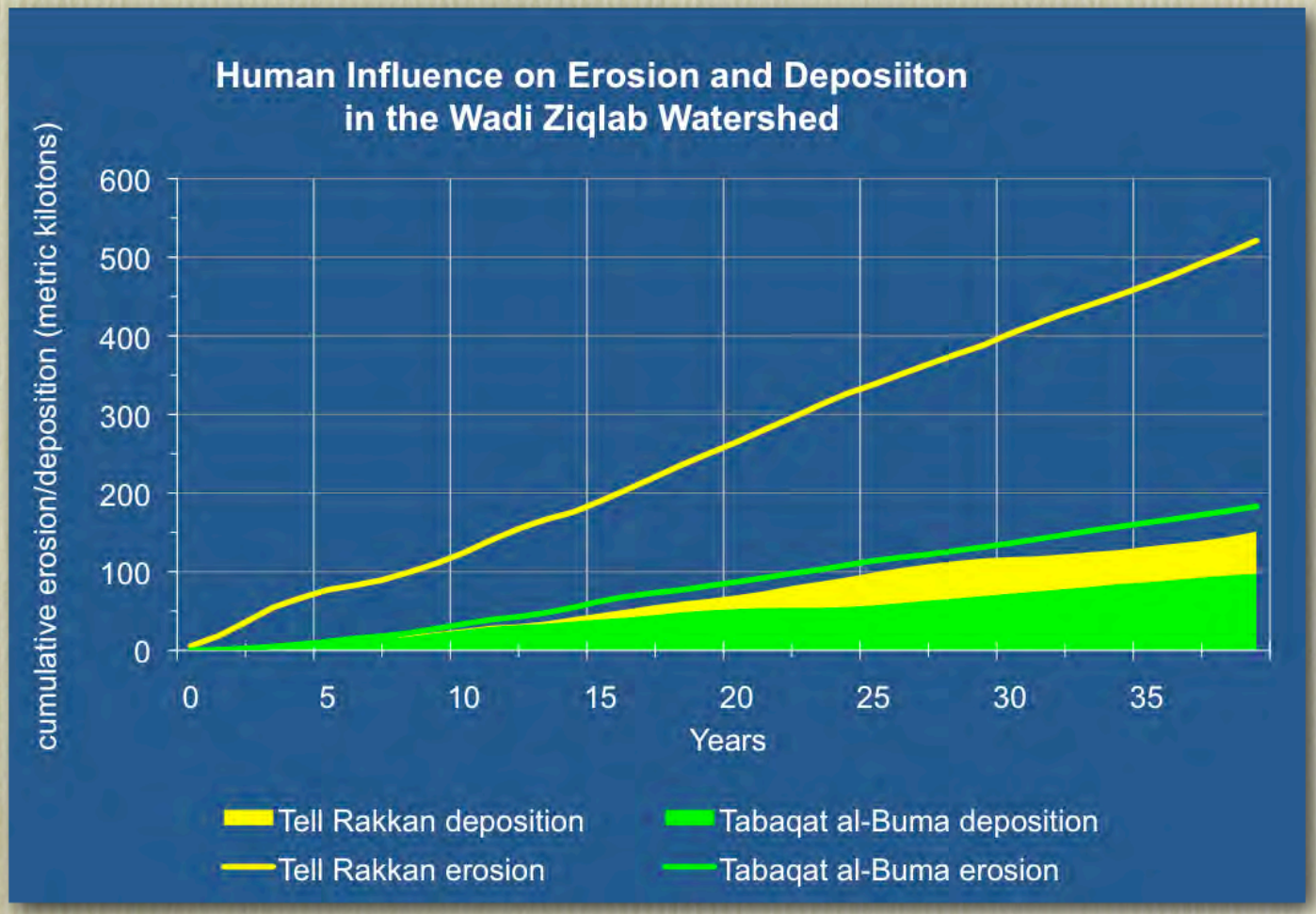


Neolithic Socioecology in Northern Jordan

- Small village, shifting cultivation, grazing for 40 years



Neolithic Socioecology in Northern Jordan

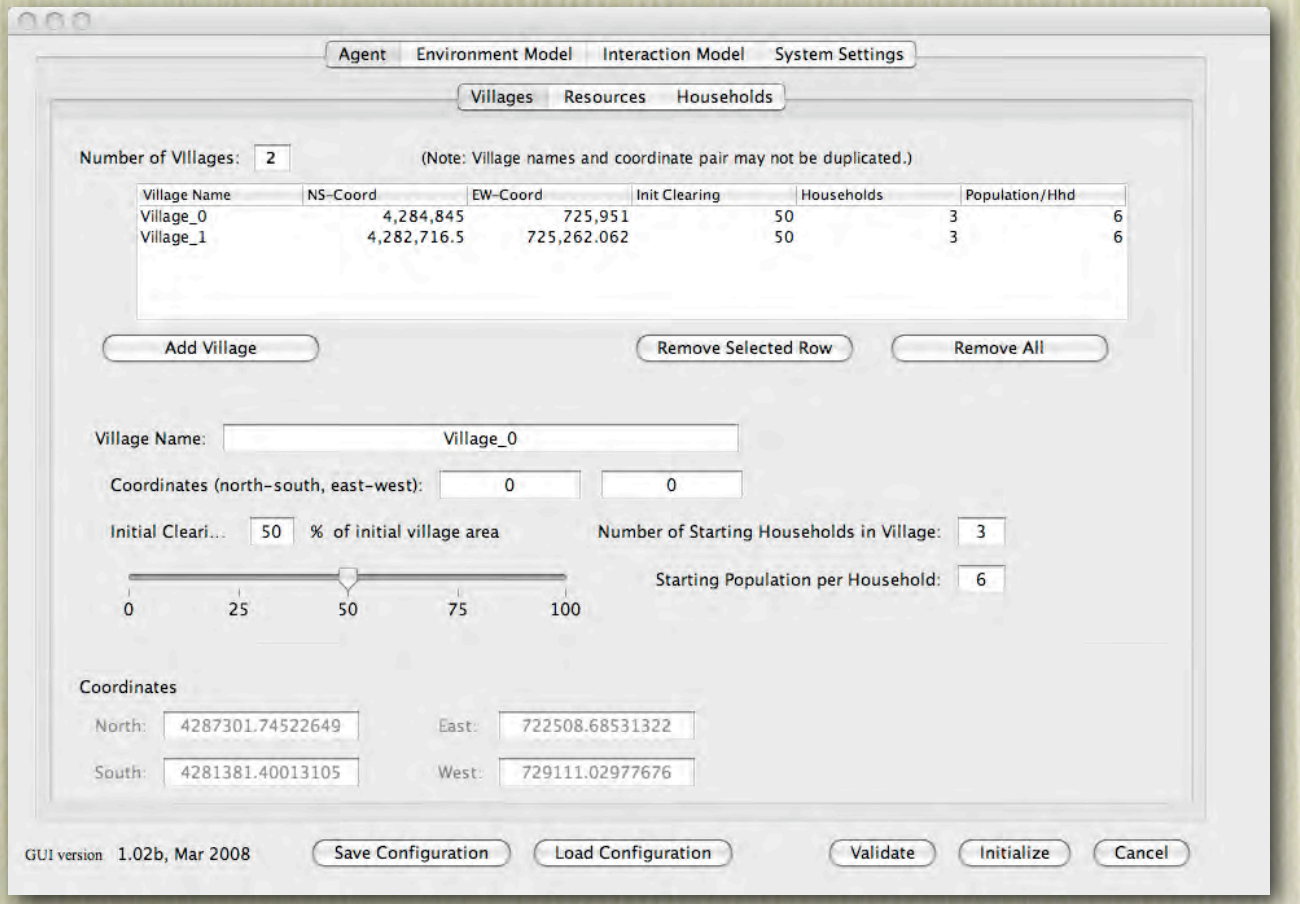


Neolithic Socioecology in Northern Jordan

- Hamlet
  - Cultivation limited to wadi bottoms
  - Grazing causes most erosion
  - Erosion primarily in uncultivated uplands
  - Redeposited sediment in cultivated zones is 53% of erosion
- Village
  - Cultivation in uplands; more extensive grazing
  - Cultivation causes most erosion
  - Erosion in cultivated and uncultivated zones
  - Redeposited sediment only 29% of erosion

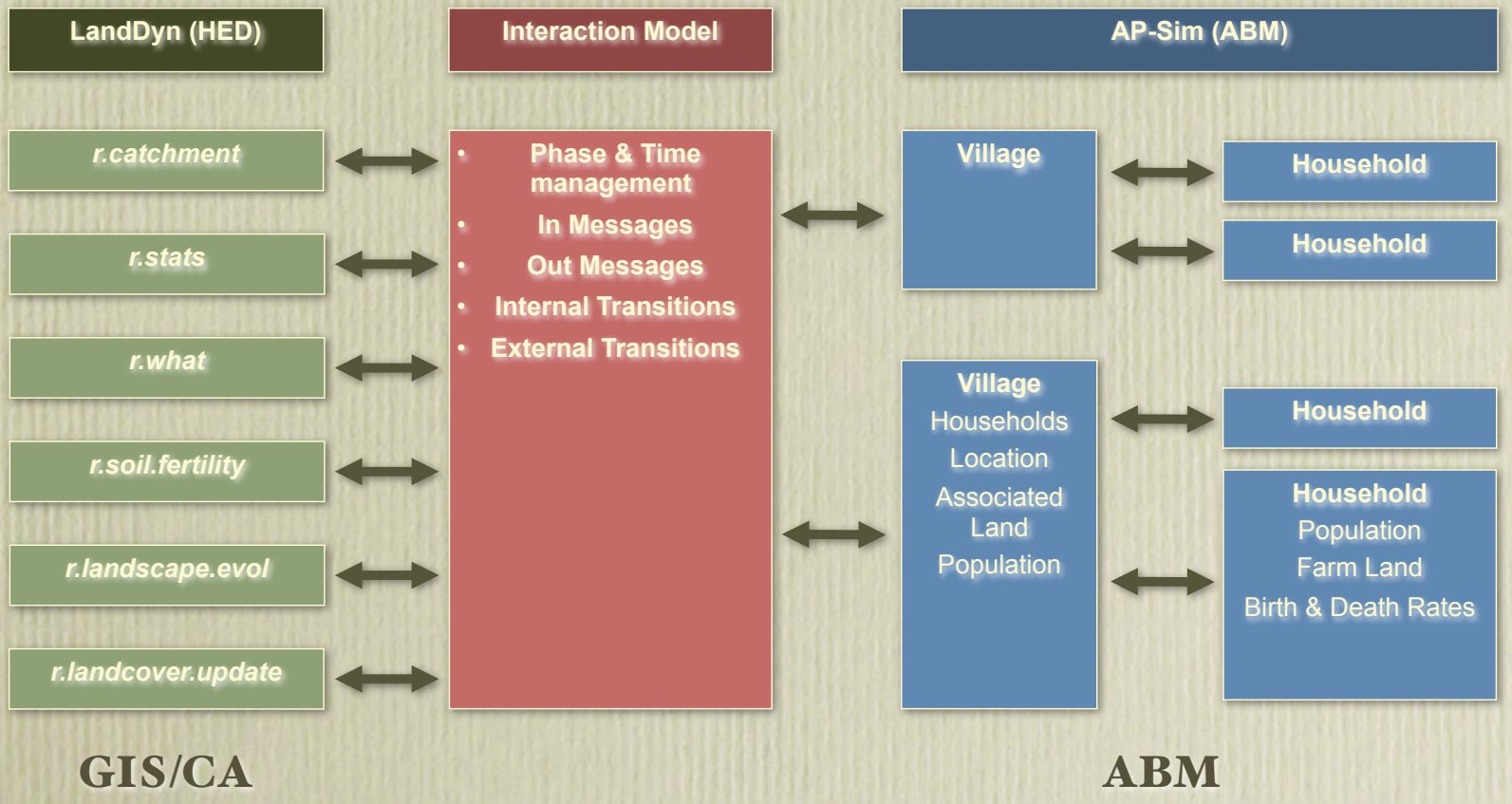
Landscape Dynamics in Mediterranean Spain

- ABM interface

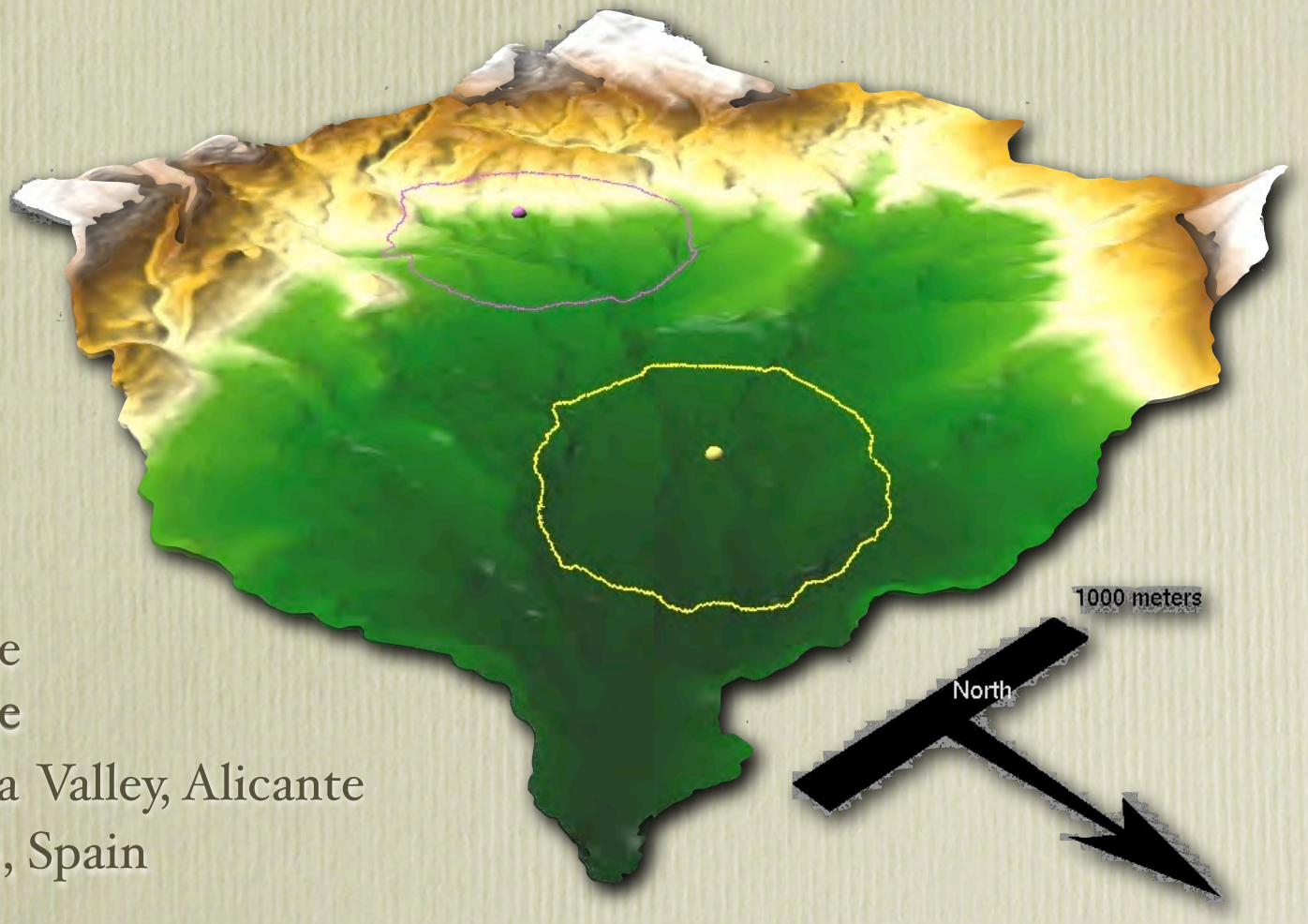


Landscape Dynamics in Mediterranean Spain

- Coupled model



Landscape Dynamics in Mediterranean Spain

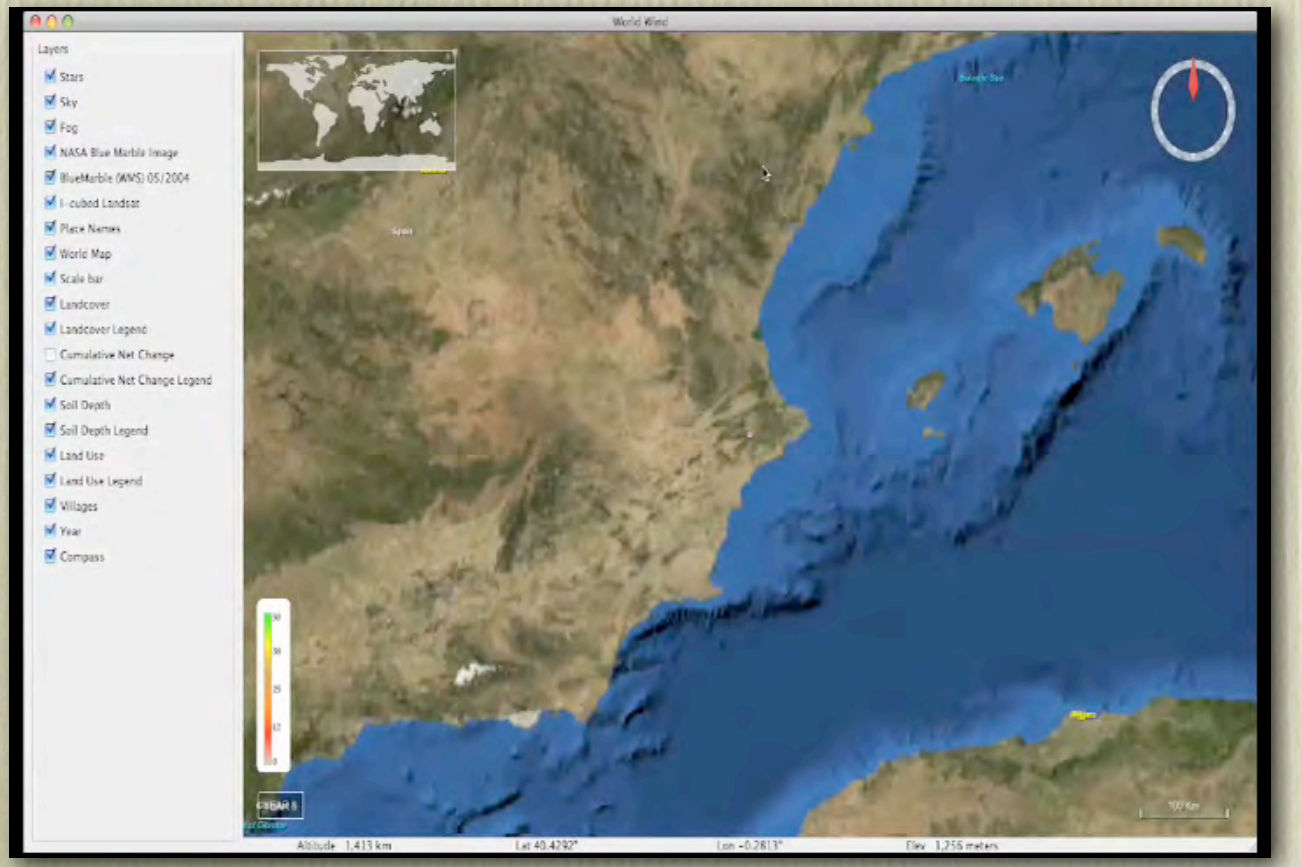


early Holocene landscape

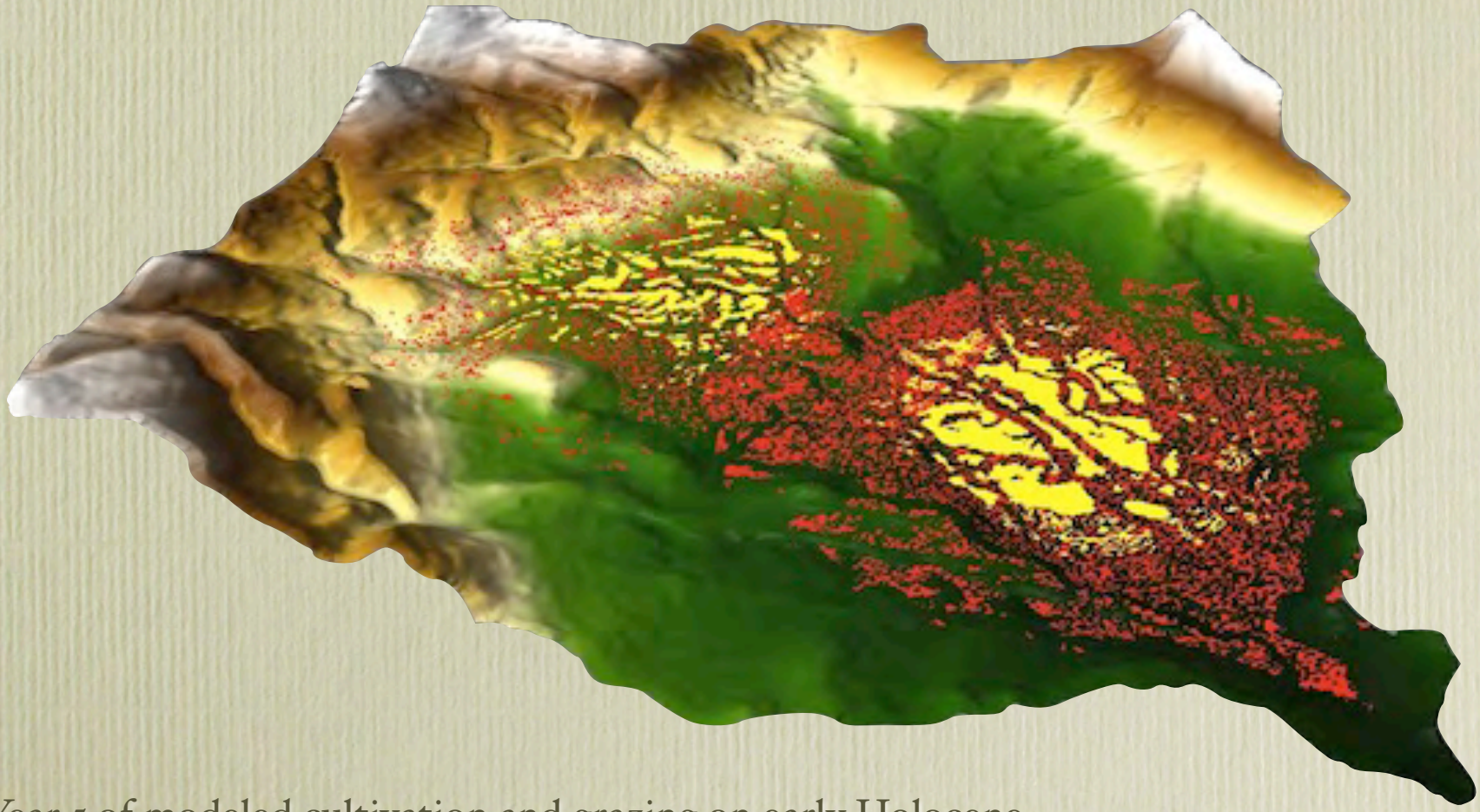
Penaguila Valley, Alicante Province, Spain

Landscape Dynamics in Mediterranean Spain

- Visualization of coupled ABM & landscape models in WorldWind (Open Source platform from NASA)



Landscape Dynamics in Mediterranean Spain



Year 5 of modeled cultivation and grazing on early Holocene landscape, Penaguila Valley, Alicante Province, Spain

Coupling Past and Present for the Future of SES

- MedLand Modeling Laboratory helps us understand long-term change in Mediterranean socio-ecological systems
- Also leads to more robust forecasts of the future consequences of land-use today.
- Exemplifies the broad, potential benefits of CNH research

Photo by I. Ullah

CoMSES Network

- Born in an NSF CNH panel meeting
- Recognition of the importance of computational modeling to the future of CNH science
- But widespread lack of expertise in or access to computational modeling by CNH scientists

OpenABM

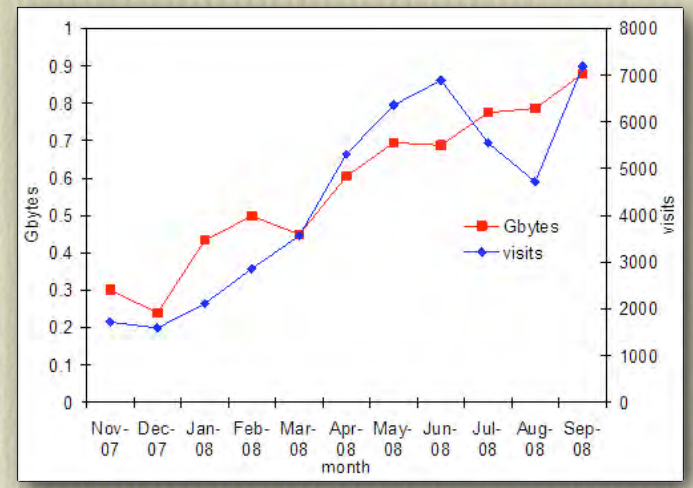
- Pilot project to...
  - ID reasons for lack of use of and access to computational modeling
  - Initiate a community of practice to mitigate these issues

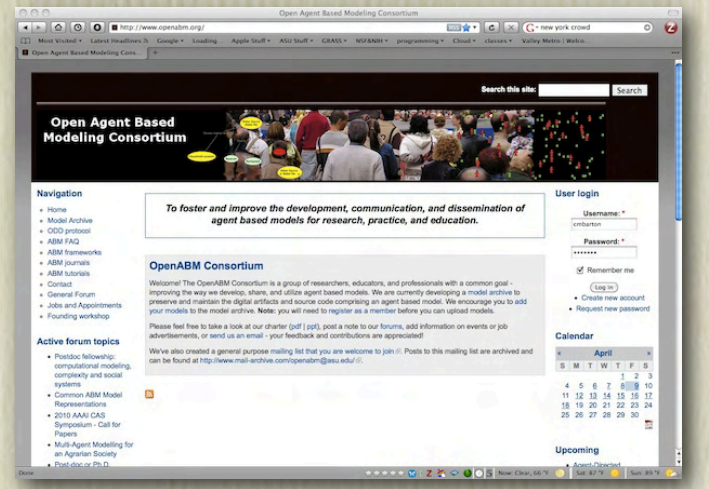
OpenABM

- Barriers to general use of computational modeling in CNH science
  - Standards
  - Logistics of dissemination
  - Evaluation of research
  - Lack of university curricula

OpenABM

- Community of practice
  - Launched as Open Agent-Based Modeling Consortium
  - Web based resource center (http://www.openabm.org)
  - Highly successful
- Led to CNH RCN - CoMSES Network

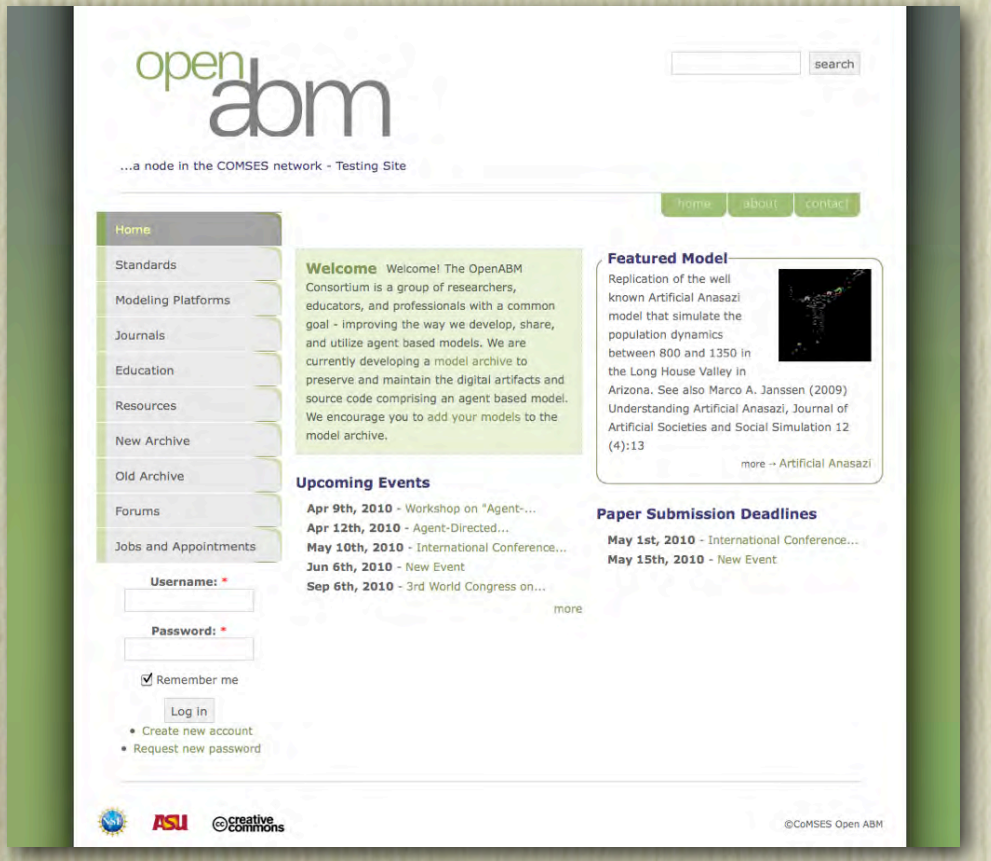




CoMSES Network

- Launched February 2010 with planning workshop
- Creating an international network for...
  - Knowledge sharing
  - Promoting standards and best practices
  - Knowledge scaffolding. New ways to continue the practices that have made science successful.
- Online journal

CoMSES Network



- New internet site
  - NSF SES models library (**to be seeded with CNH projects**)
  - Educational materials library
  - Cyberinfrastructure for scientific networking and information sharing

Research Partners for MedLand

- ASU: School of Human Evolution and Social Change, Center for Social Dynamics & Complexity, School of Earth and Space Exploration, School of Computing Informatics and Decision Systems Engineering, School of Geographical Sciences and Urban Planning, School of Sustainability
- Partners: Universitat de València, Universidad de Murcia, University of Jordan, North Carolina State University, University of Wisconsin, Hendrix College, Geoarchaeological Research Associates, GRASS GIS Development Team

Publications and PhDs

- Barton, C.M. (n.d.) Land-use, water, and Mediterranean landscapes: modeling long-term dynamics of socioecological systems. *Phil.Trans. B Royal Society* (in review).
- Barton, C. M., Ullah, I., & Mitasova, H. (2010) Computational modeling and socioecological dynamics: a case study from southwest Asia. *American Antiquity* 75(2):364-386.
- Janssen, Marco A., Lillian Na'ai Alessa, C. Michael Barton, Sean Bergin and Allen Lee. (2008) Towards a community framework for agent-based modeling. *Journal of Artificial Societies and Social Simulation*, 11(2): no. 6.
- Mayer, G. R., H. S. Sarjoughian, E. K. Allen, S. E. Falconer, and C. M. Barton. (2006) Simulation modeling for human community and agricultural landuse, agent-directed simulation, *Proceedings of the Spring Simulation Multi-Conference*, pp. 65-72. Huntsville, Alabama.

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- Arikan, B. (2010). Reorganization and risk: environmental change and tribal use in marginal landscapes of southern Jordan. PhD Dissertation, ASU.
- In progress doctoral projects: S. Bergin, E. Dimaggio, M. Soto-Berelov, A. Miller, I. Ullah