Composing Agent and Landscape Models

an Example from the Mediterranean

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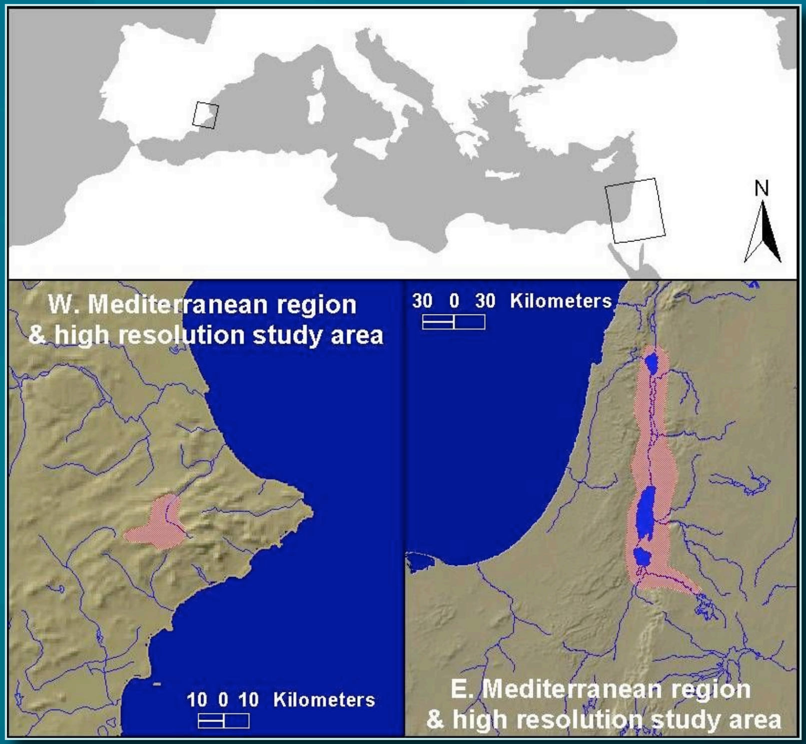
Mediterranean Landscape Dynamics Project



- Supported by NSF ERE Biocomplexity in the Environment program (BCS-0410269)
- Creating a modeling laboratory for studying socioecological consequences of landuse decisions

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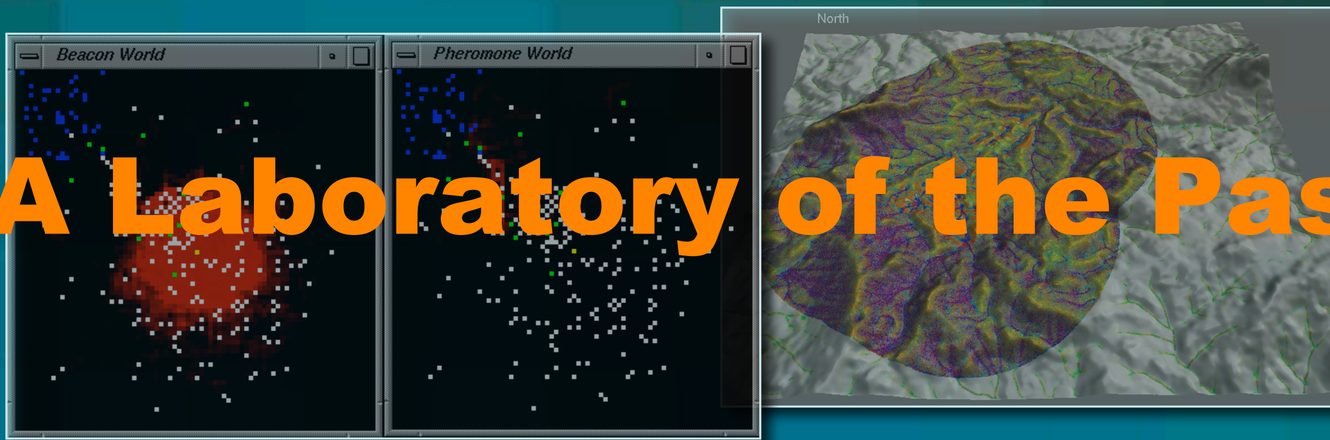
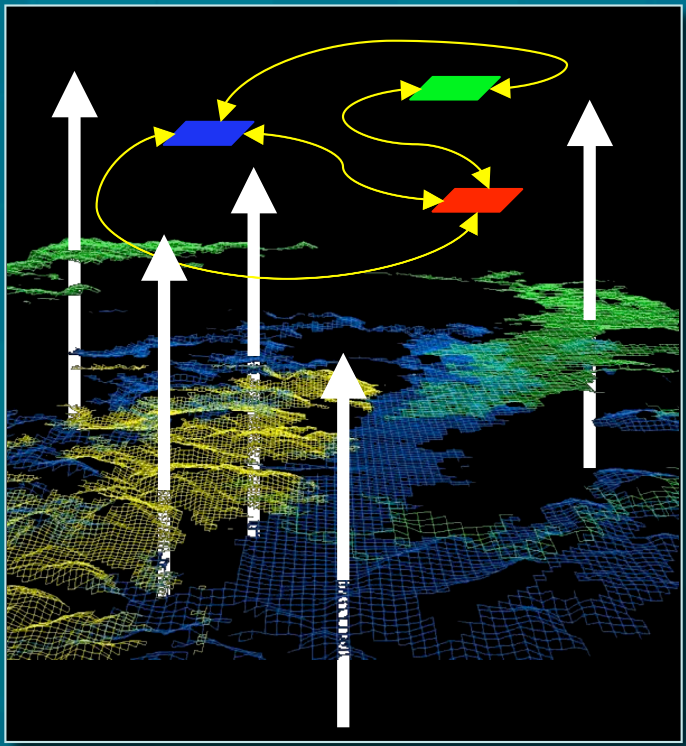
A Laboratory of the Past



- Transdisciplinary international research
- Developing a modeling laboratory for studying the long-term recursive dynamics of human landuse and landscape change
  - Test hypotheses about social dynamics
  - Evaluate social and ecological consequences of human decisions and action

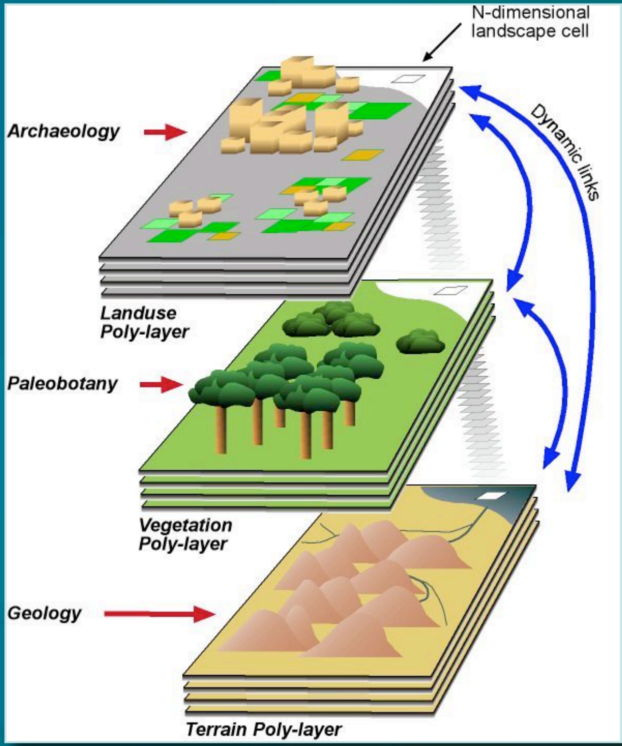
A Laboratory of the Past



- Develop dynamic computer simulation models based on…
  - anthropological insights about social and ecological process—past and present
  - biophysical landscape processes
- Treat models as hypotheses and test against archaeological and paleoecological records
- Models must pass through known ‘points’ of record that are scattered in both time and space.

Modeling Laboratory

- Agent-based simulation of human landuse: beginning of farming to beginning of urbanism
- Surface process models of ancient landscape and climate in GIS framework
- Dynamically compose disparate models so that change in one can affect state variables that serve as input to another



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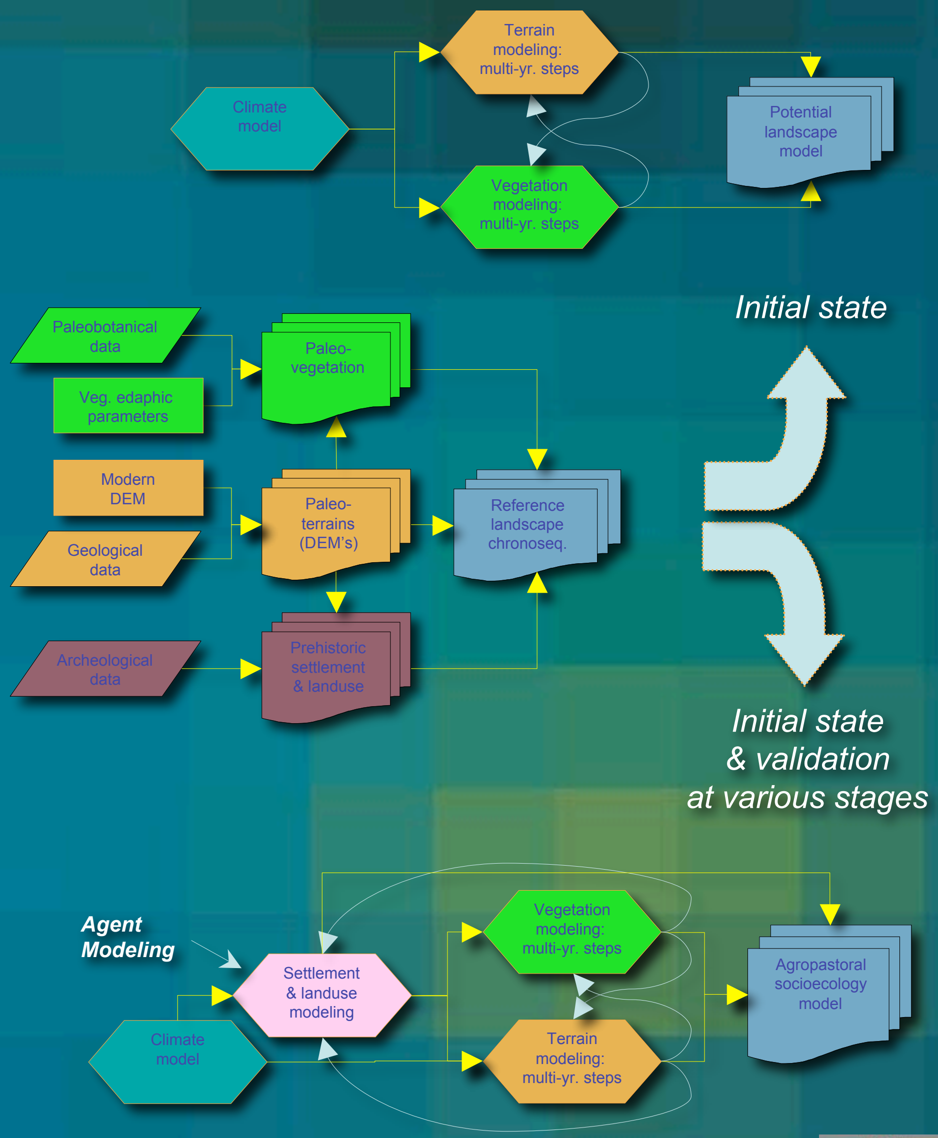
Modeling Laboratory

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



Surface Process Dynamics

- USPED (Unit Stream Power Erosion/ Deposition) model for landscape change
- Iterated to simulate cumulative change
- Model parameters
  - Landuse
  - Topography
  - Landcover
  - Climate
  - Soils

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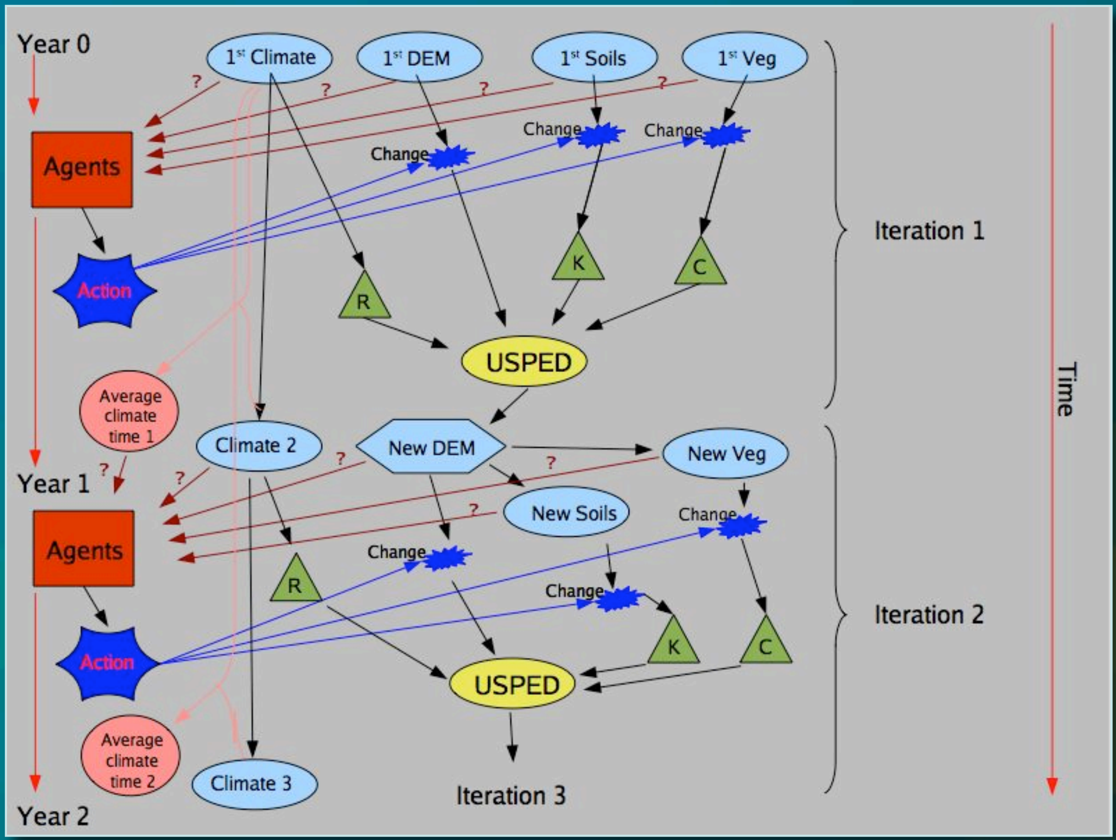
Surface Process Model



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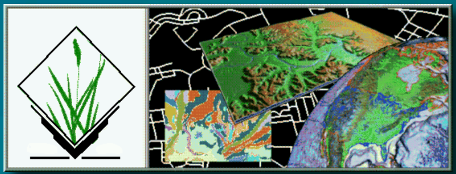
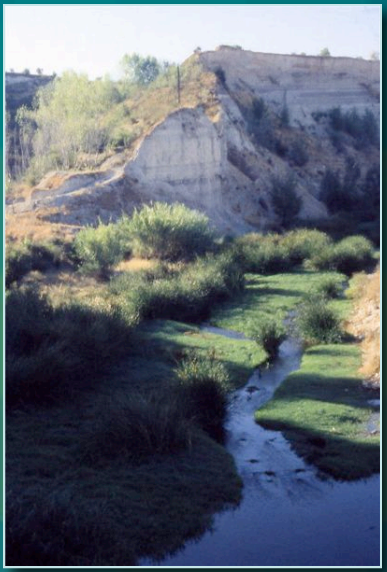
Surface Process Model

- Modeling environment built in GRASS
  - Geographic Resource Analysis Support System
  - Raster (cellular) landscape
  - Implemented in *bash* scripts



- USPED (implemented in GRASS)
  - $ED = d(E_p \cdot q_{sx})/dx + d(E_p \cdot q_{sy})/dy$
  - ***ED*** *is net erosion or deposition of sediment in any landscape cell*
  - q_{sx} *and* q_{sy} *are the sediment transport capacity coefficients in x and y directions (a function of slope, aspect, and flow accumulation) for a given surface process across the cell*
  - E_p *(potential erodability) is modified a RUSLE value that includes rainfall intensity, land cover, and soil characteristics for that cell*



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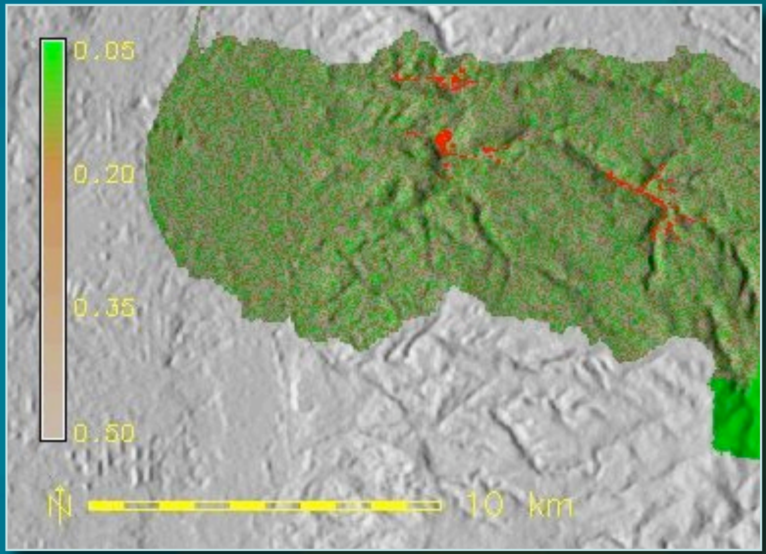
Landuse Dynamics in GRASS

- Dynamic stochastic modeling
- Agropastoral catchments
  - Iteratively 'grown' outward from settlement
  - Specify catchment size desired (e.g., ha/person in settlement)
  - Anisotropic cost surface for walking across terrain
  - Can limit by slope

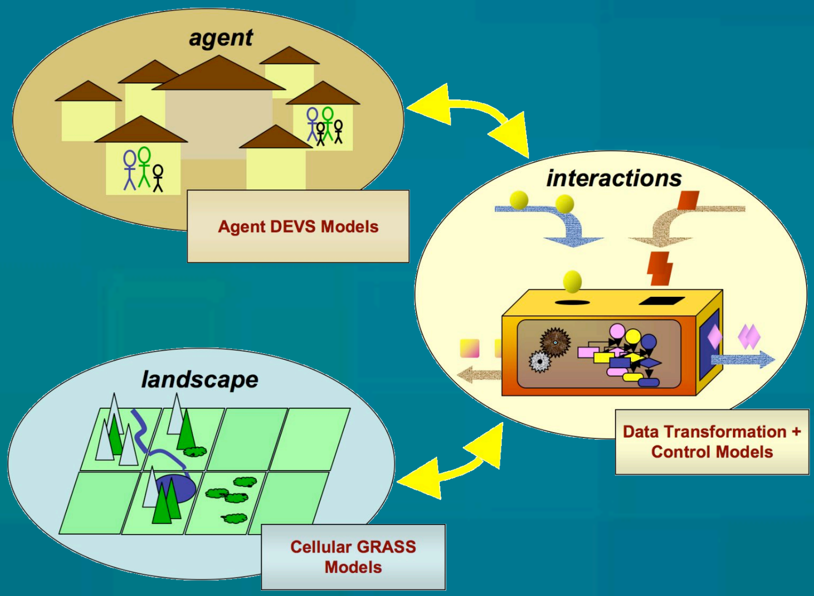


Landuse Dynamics in GRASS

- Shifting agropastoralism (simple model)
  - Specify catchment 3x size needed
  - Randomly seed 30% as cultivated (or grazed)
  - Iterate each year
- Simple revegetation/succession
  - Allow formerly cultivated (or grazed) patches to return to scrub (after 1 yr) and woodland (after 2 year) when not cultivated (or grazed)
- Landuse and its history alters landcover.

Landuse Dynamics & ABM

- Multiagent simulation (DEVSJAVA) coupled with GIS (GRASS)



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Landuse Dynamics & ABM

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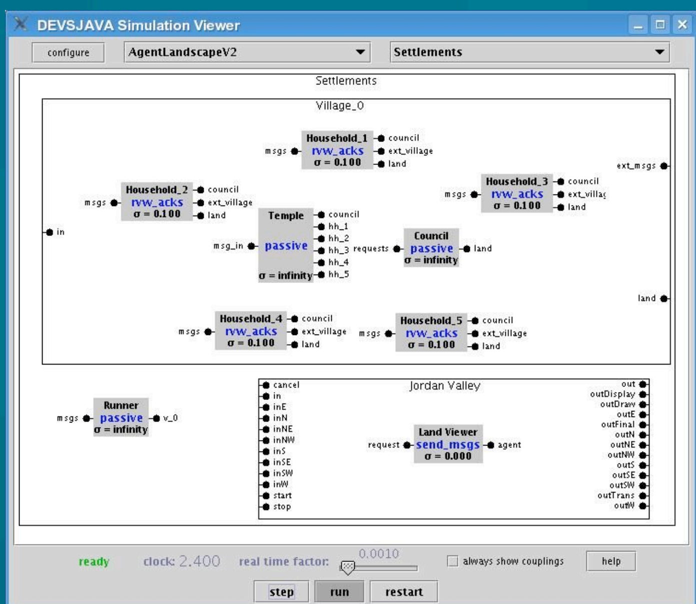

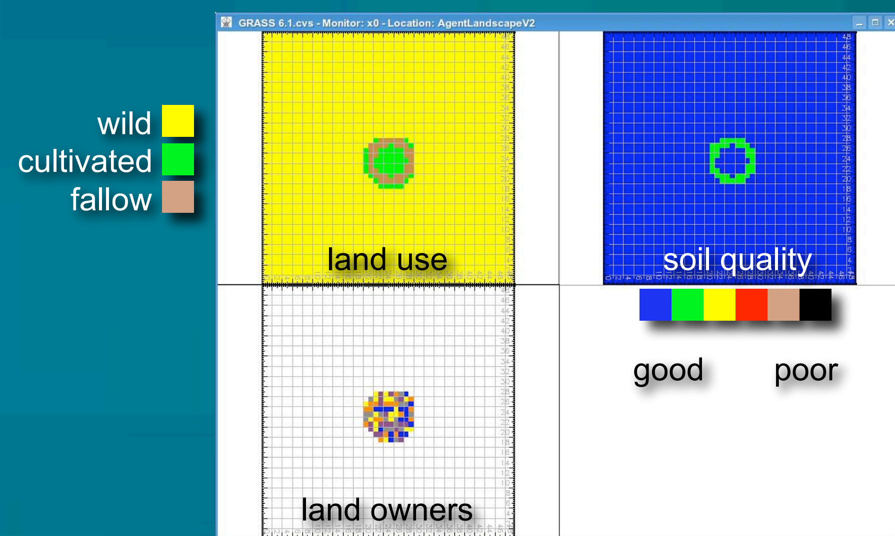

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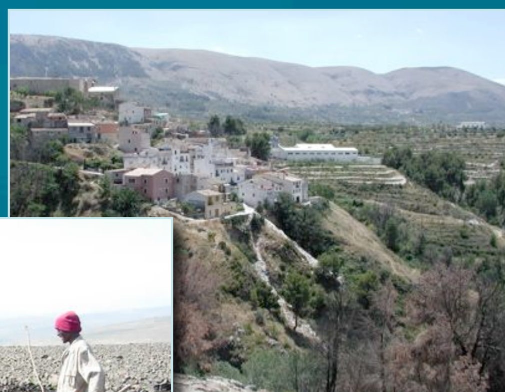
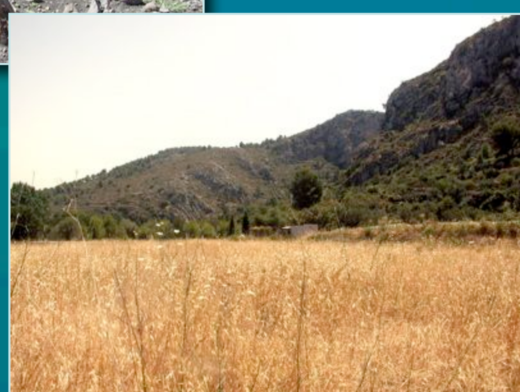
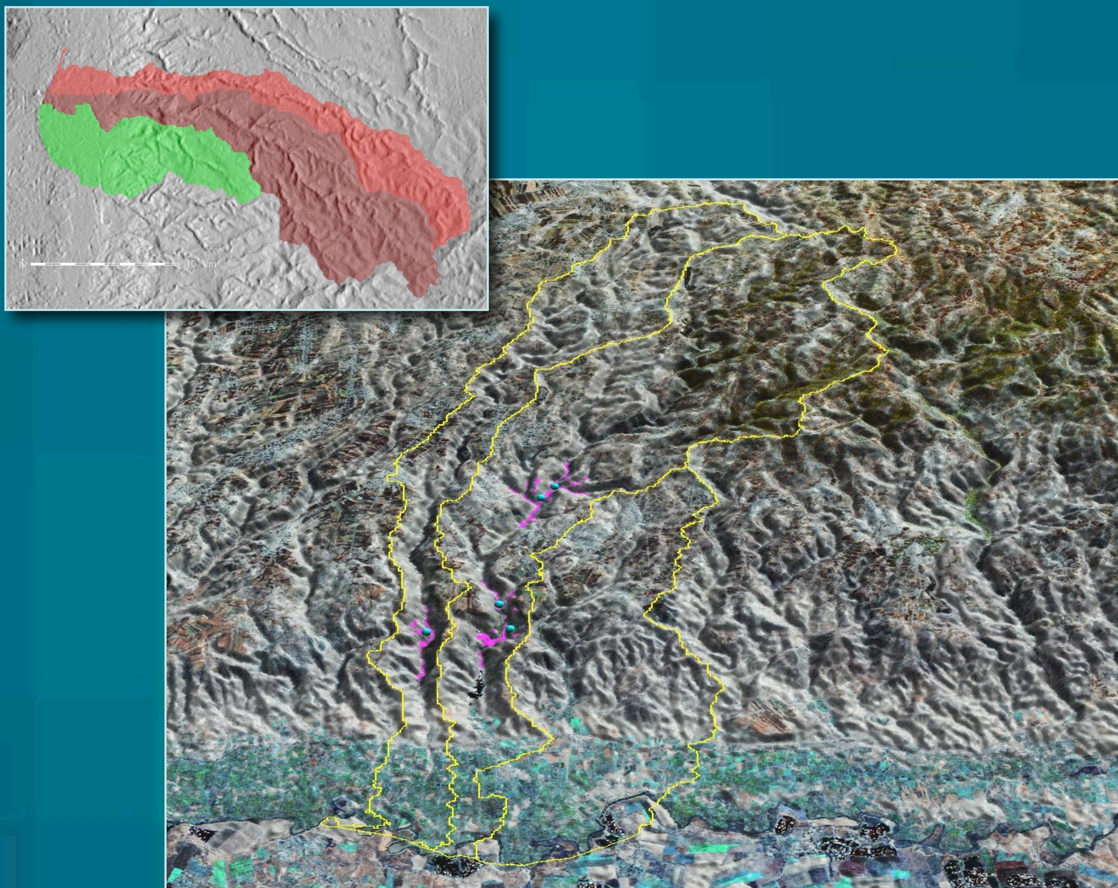
Landuse Dynamics & ABM





- Household is basic unit
- Acquire land
  - Potential productivity
  - Distance from village
  - Labor investment needed (e.g., clear land or simply cultivate
- Manage land
  - Clearing land
  - Cultivating crops
  - Fallowing
- Harvest resources
  - Land management activity
  - Soil productivity
- Allow for stochasticity (e.g., land allocation, crop productivity, demography

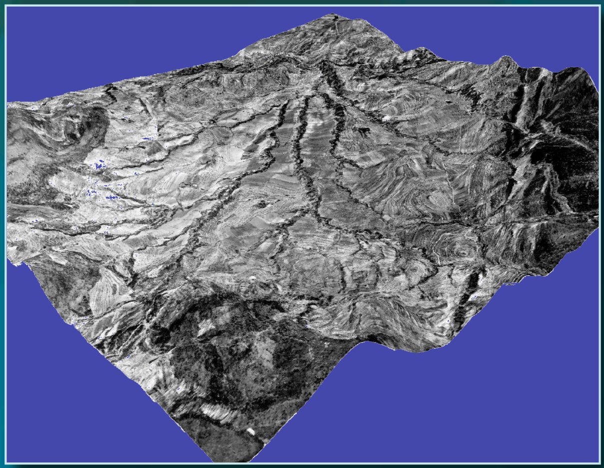
Topography

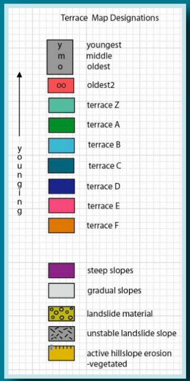


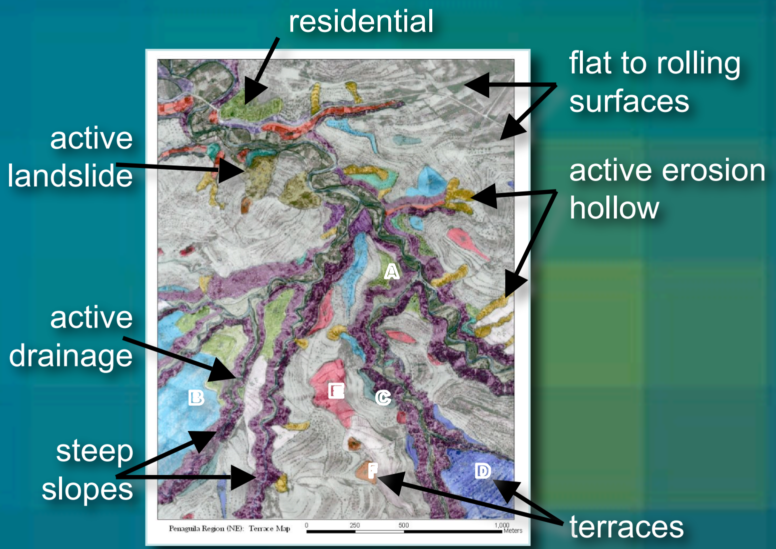
- Terra ASTER DEMs (created from forward and backward band 3)
- Re-interpolated to 15m resolution for surface process modeling
- Study areas defined as watersheds

Topography

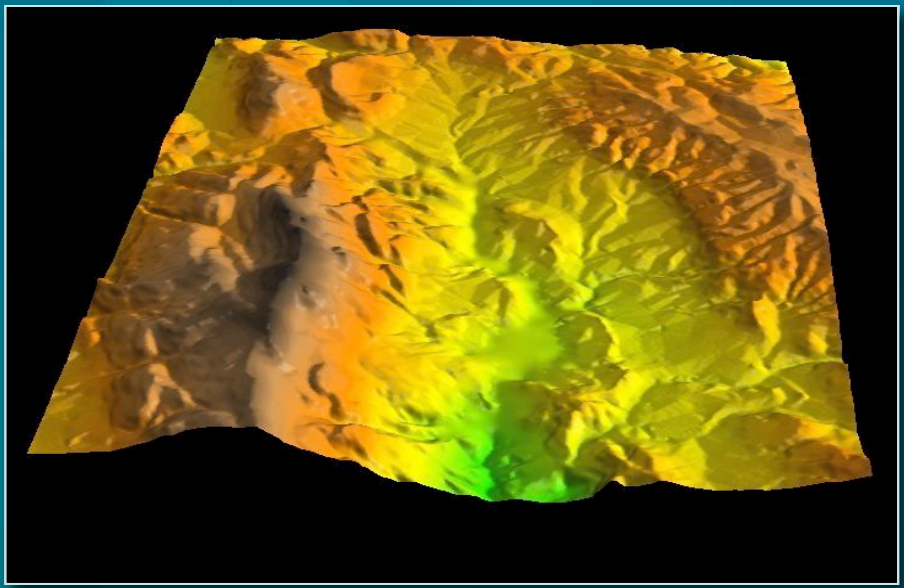
- High-resolution DEM created from stereo aerial photos
- Landform and geomorphic mapping
- Ground truthing in field







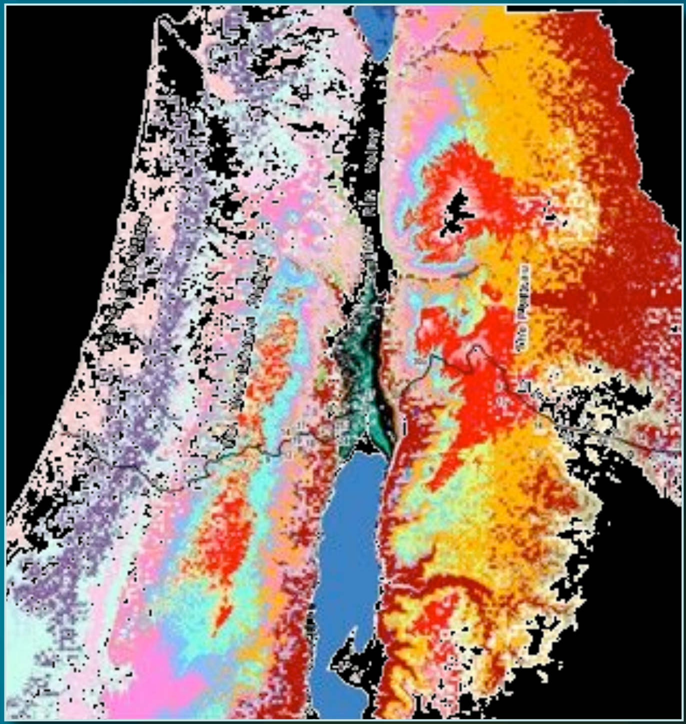
Topography



- Paleolandscape reconstruction
- ID paleosurface remnants
- Connect (or remove) equivalent aged surface remnants using spline interpolation

Landcover

- Simple models of Mediterranean paleovegetation used now
- Community models based on climate and topography (near future)
- Patch models incorporating successional dynamics (next phase)
- NDVI regression to scale vegetation to C-Factor



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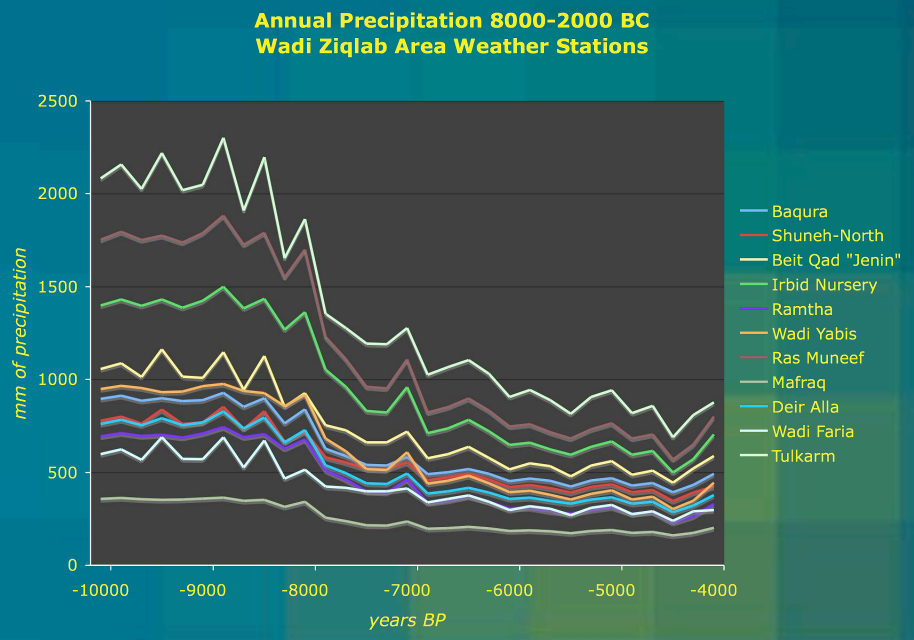
Rainfall Intensity

- Weather station data retrodicted for 14ky at 200yr intervals to produce sequences for…
  - annual and monthly precipitation
  - annual and monthly mean temperature
  - annual and monthly days>40° & days <0
  - annual and monthly storm frequency



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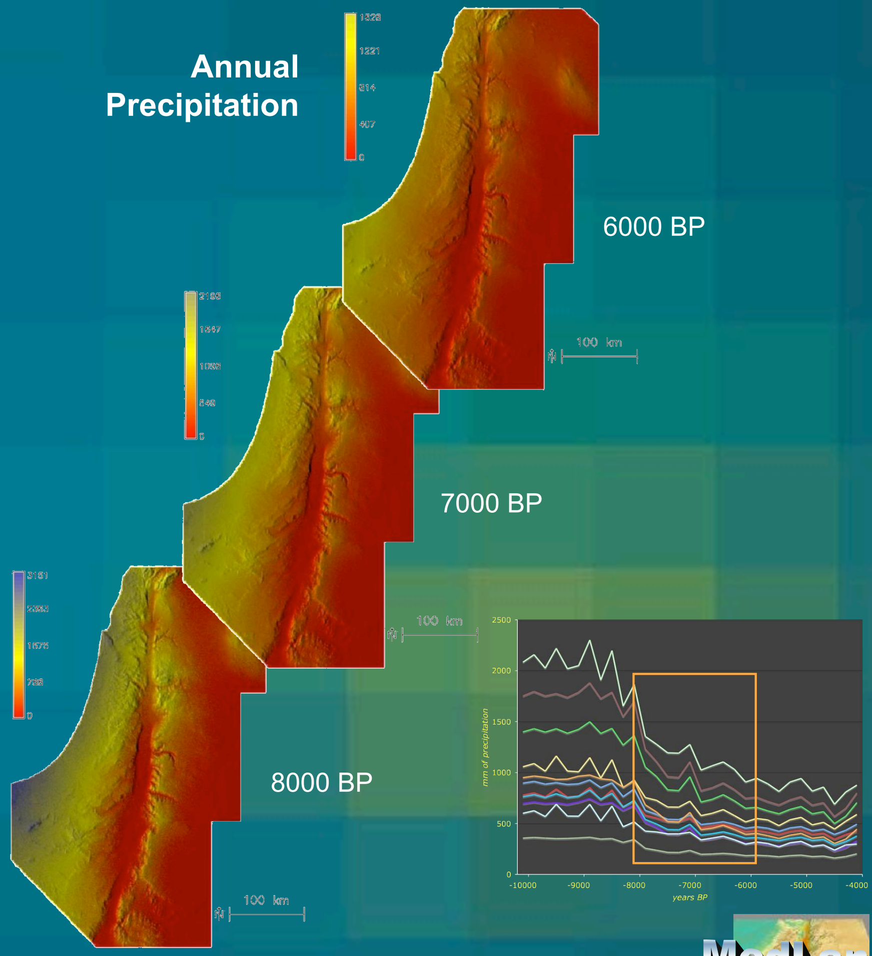
Rainfall Intensity

- Monthly and annual climate sequence models interpolated to create paleoprecipitation surfaces using multiple regression.
- Temperature uses topograpy, latitude and logitude
- Precipitation more complicated. Also uses distance from sea and orographic features between station and sea.
- Regression can predict weather station values with r >> 0.9
- Regression coefficients applied in GRASS map calculator to create climate surfaces with 90m resolution. Some smoothing required for precipitation.
- Transformation to R-Factor surface



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Soil

- Simple constant currently
- Calculate K-Factor from sand:silt:clay ratios
- Dynamically model changing soil thickness and erodability
- Use surface geology and topography to remantle paleosurfaces with Holocene soils.

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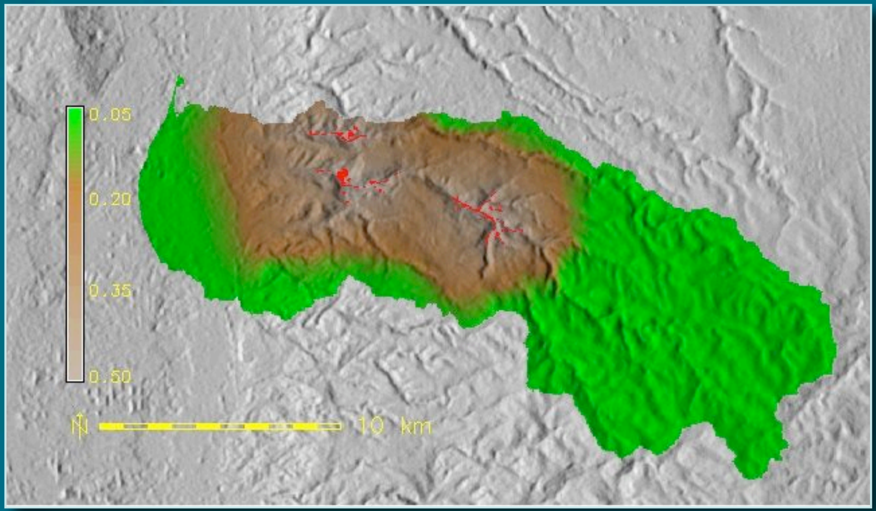
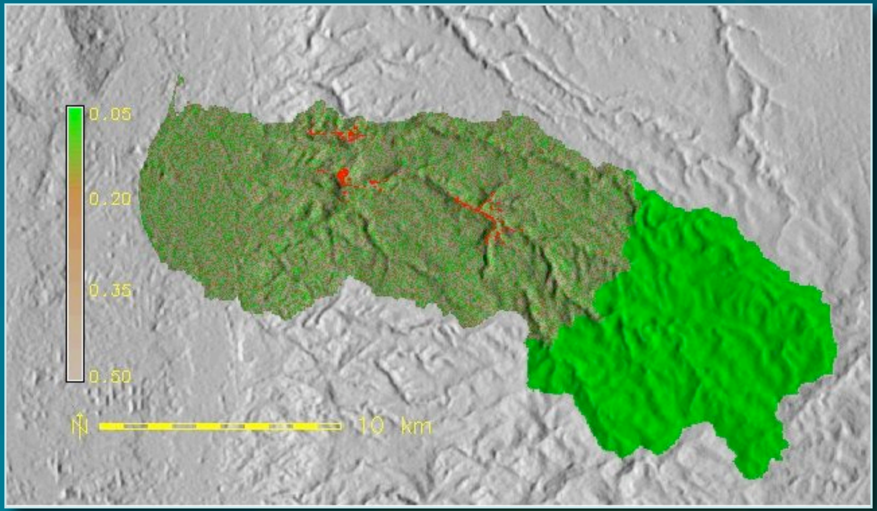
Landuse Models



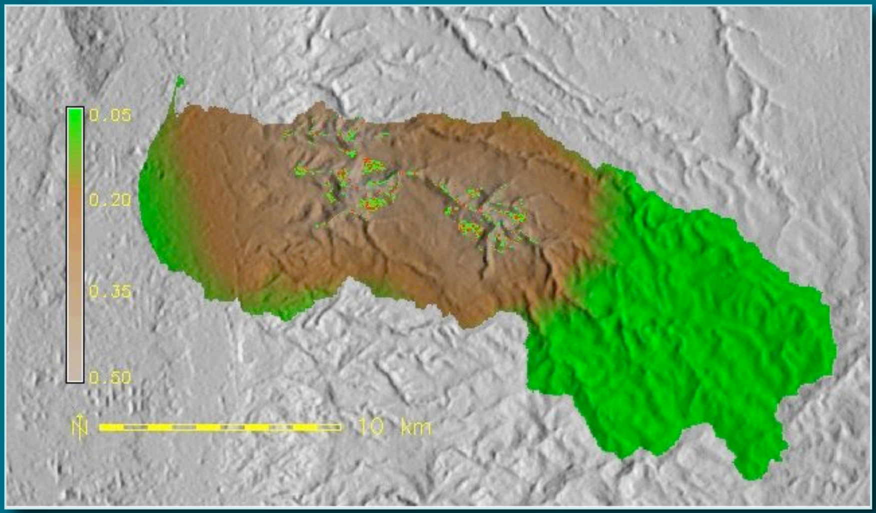
site-tethered grazing



extensive forest grazing

- Intensive horiculture (red culivated)

Landuse Models



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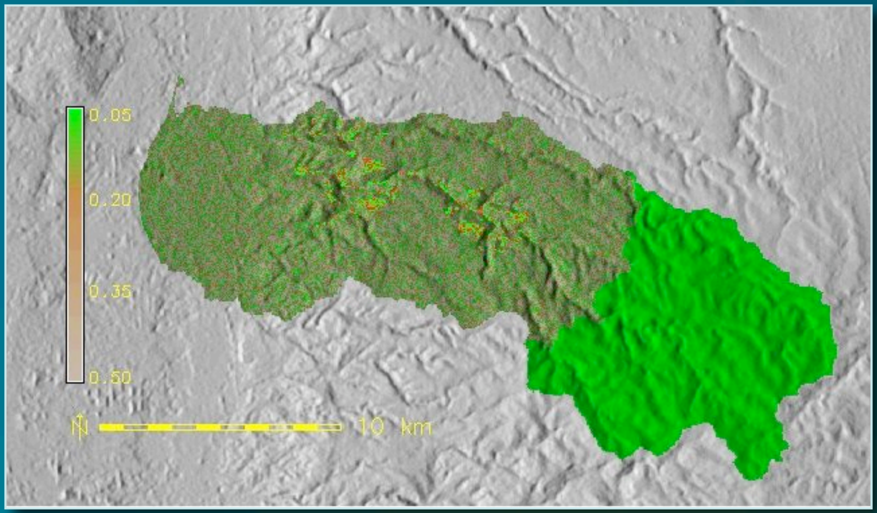
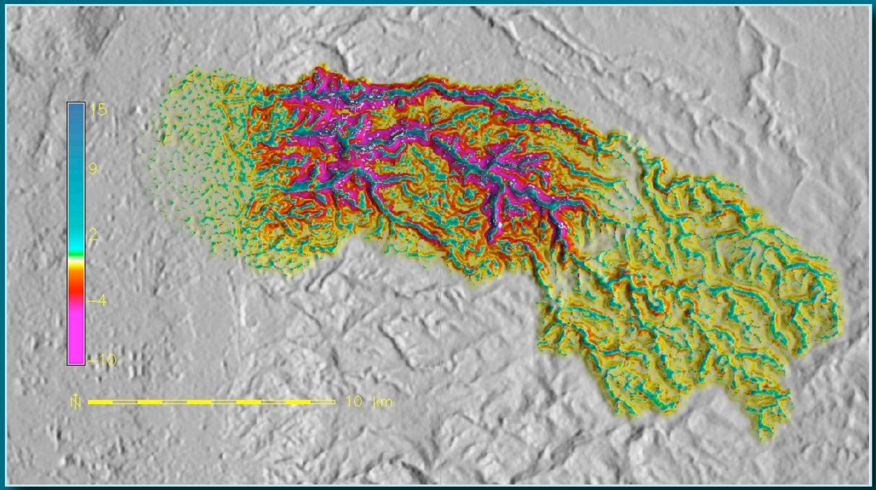


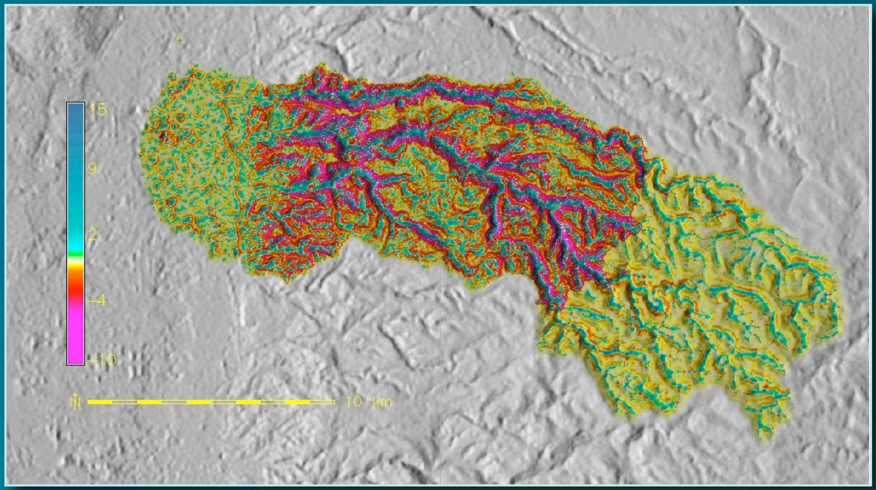
extensive forest grazing

- Shifting cultivation (red cultivated, brown fallowed, green forest)

Landscape Consequences



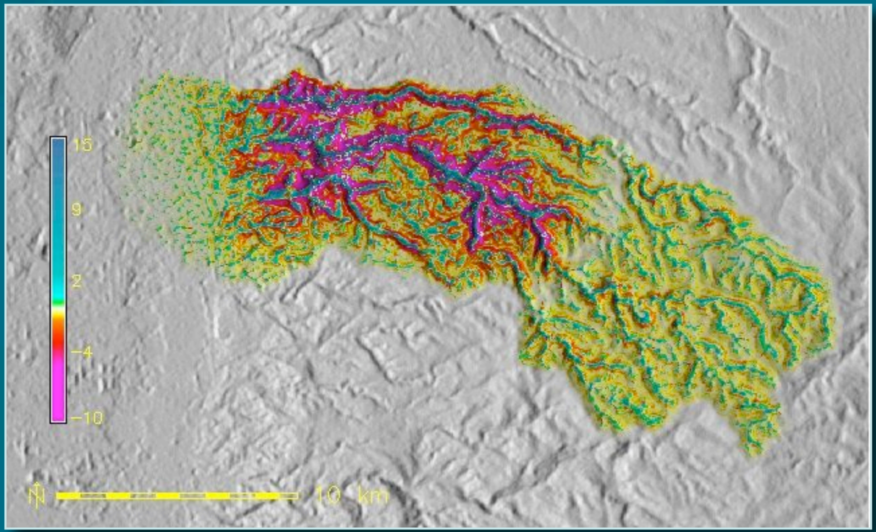
site-tethered grazing



extensive forest grazing

- Intensive horticulture and grazing after 10 years

Landscape Consequences



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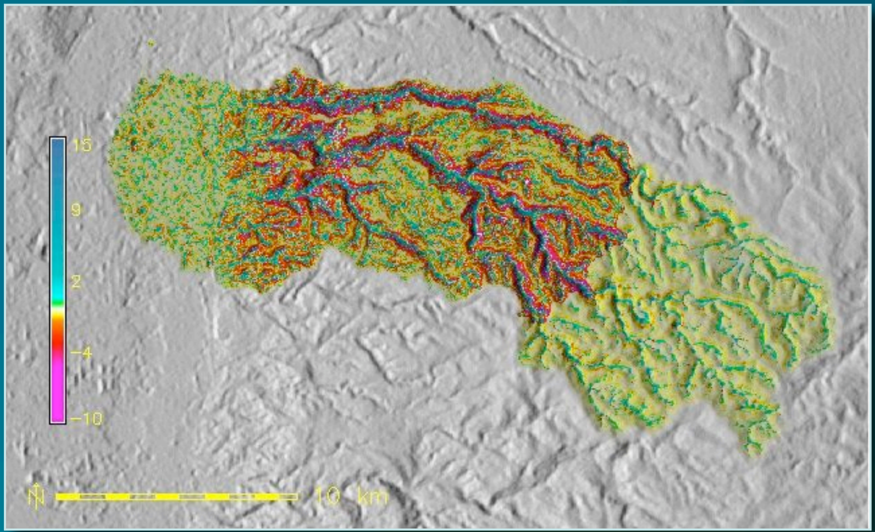

extensive forest grazing

- Shifting cultivation and grazing after 10 years

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Questions for a Socioecological Dynamics Laboratory

- What are the effects of different landuse strategies on biodiversity at different temporal and spatial scales
- Are socioecological dynamics characterized by gradual change or thresholds?
- What are the effects of increasing planning depth of landuse decisions in a changing environment?
- What landuse strategies sustain human populations over the longest time frames?

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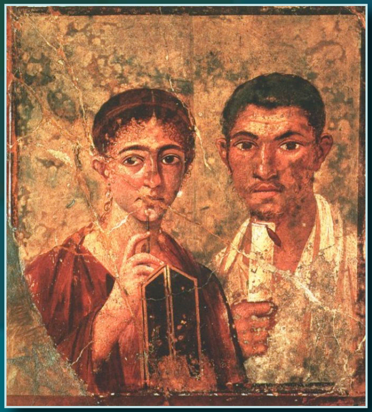
Looking Ahead



- Mediterranean Landscape Dynamics project is an experiment in a new kind of interdisciplinary archaeology
- Developing new ways of studying the rich data of the long human past
- Is the past a key to our future?

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Interdisciplinary Collaboration

- **ASU:** School of Human Evolution and Social Change, Center for Social Dynamics & Complexity, School of Earth and Space Exploration, School of Computing and Informatics, Geographical Sciences, 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