Modeling Long-term Socioecology

the Mediterranean Landscape Dynamics Project

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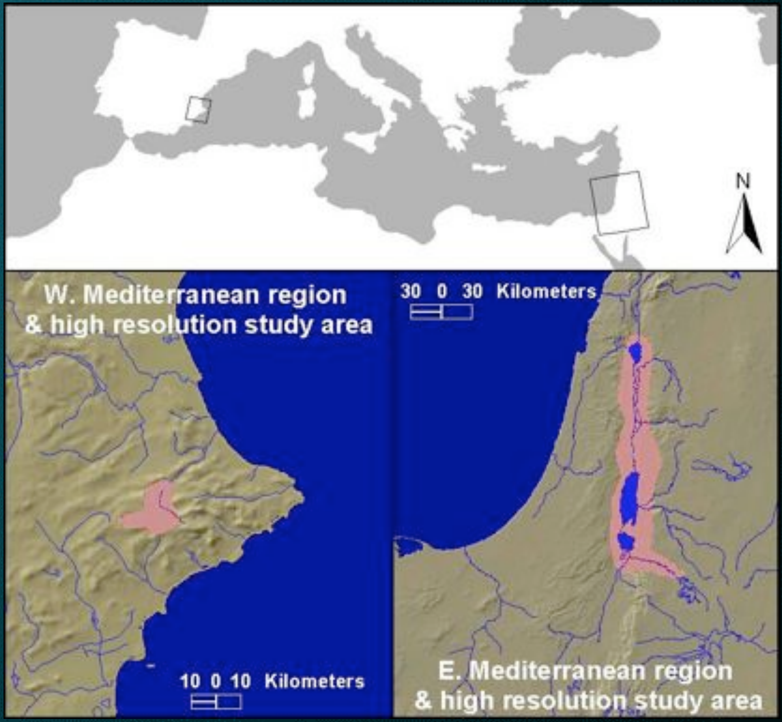
Project Overview

- Develop a modeling laboratory for the long-term recursive dynamics of agropastoral landuse and landscape change
- Mediterranean basin has one of the world's oldest and best studied record of such social-natural interaction
- Project locations at opposite ends of Mediterranean Basin
  - Encompasses wide range of ecological & social variation
  - Tracks initial spread of agriculture & replacement of foraging systems
  - Different trajectories to the appearance of social complexity and urbanism
- http://medland.asu.edu

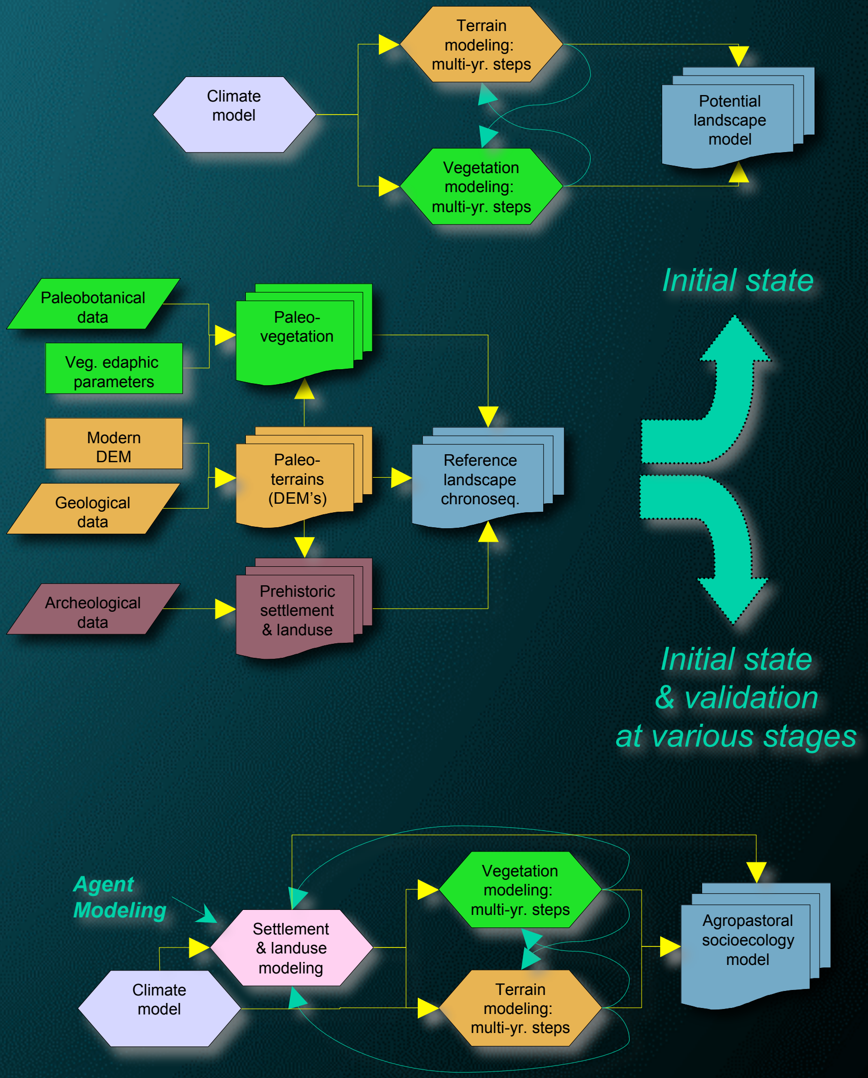


Project Overview

- Agent-based simulation of human landuse: beginning of farming to beginning of urbanism
- Surface process models that integrate
  - Ancient landscapes
  - Landcover (natural and anthropogenic)
  - Synoptic climate models
- Linked within a GIS framework 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

Modeling Laboratory

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



Climate model

Terrain modeling: multi-yr. steps

Vegetation modeling: multi-yr. steps

Potential landscape model

Initial state

Paleobotanical data

Veg. edaphic parameters

Paleo-vegetation

Modern DEM

Geological data

Paleo-terrains (DEM's)

Reference landscape chronoseq.

Archeological data

Prehistoric settlement & landuse

Initial state & validation at various stages

Agent Modeling

Settlement & landuse modeling

Climate model

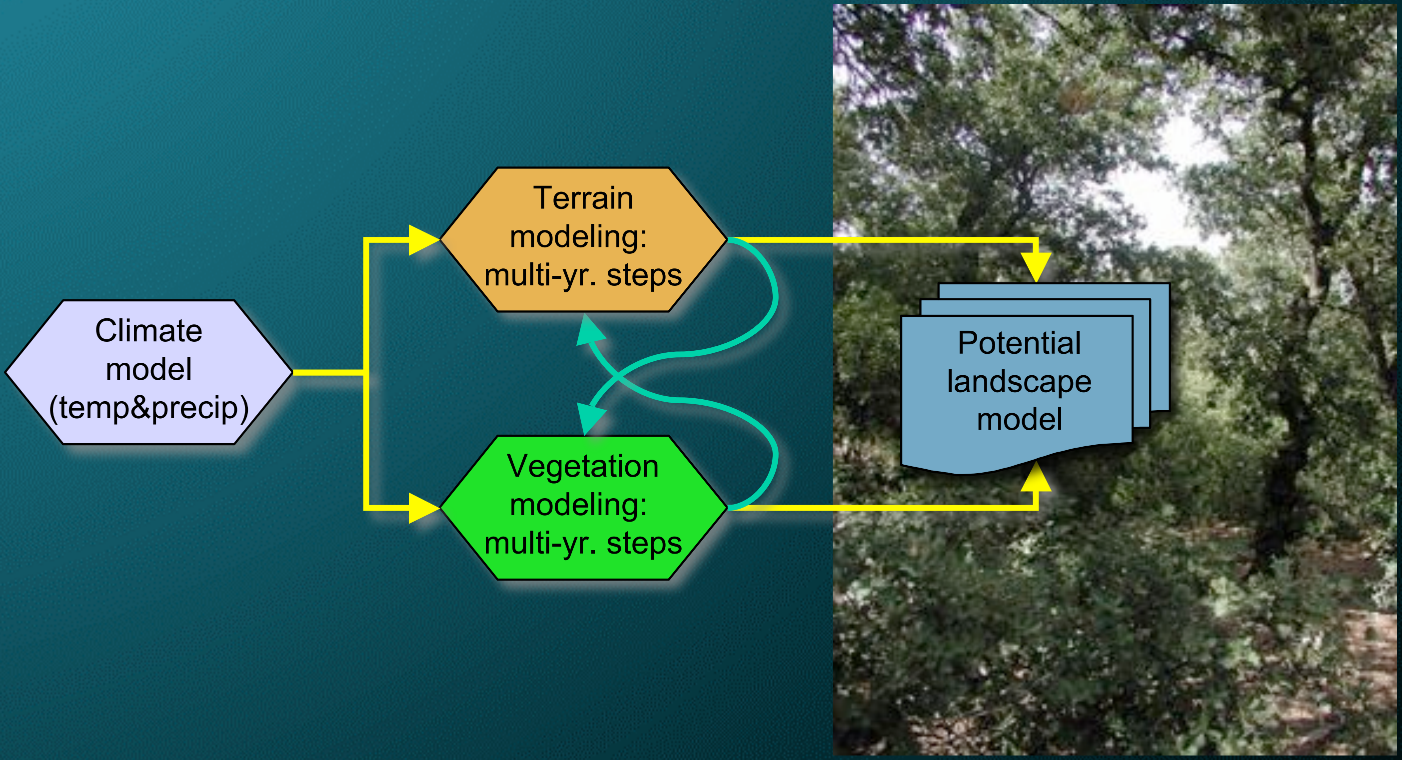
Vegetation modeling: multi-yr. steps

Terrain modeling: multi-yr. steps

Agropastoral socioecology model

Project Overview

- Potential landscape model: surface processes and landcover



Climate model (temp&precip)

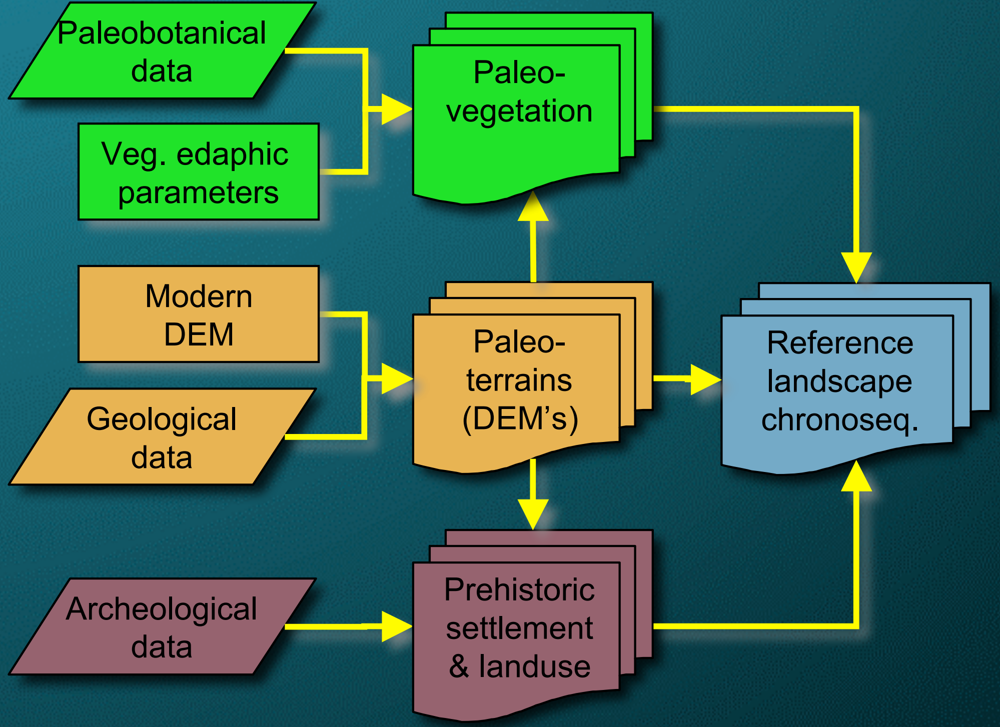
Terrain modeling: multi-yr. steps

Vegetation modeling: multi-yr. steps

Potential landscape model

Project Overview

- Reference landscape chronosequence: surface processes and landcover



Paleobotanical data

Veg. edaphic parameters

Paleo-vegetation

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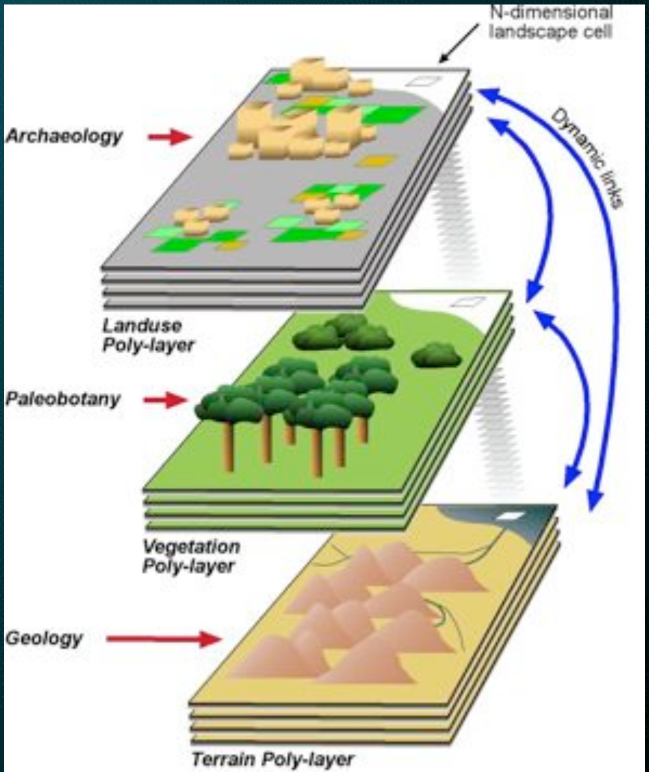
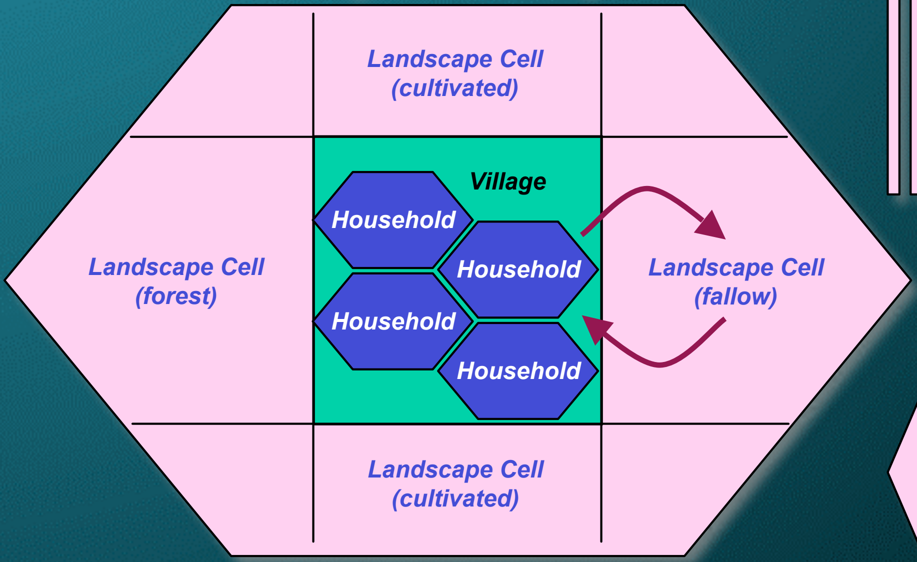
Prehistoric settlement & landuse



Project Overview

- Human landuse: agent simulation

Agent Modeling



Landscape Cell (cultivated)

Landscape Cell (forest)

Village

Household

Household

Household

Household

Landscape Cell (fallow)

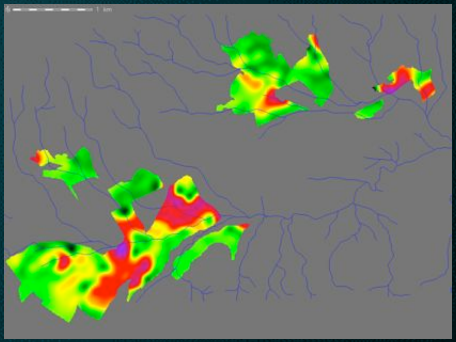
Landscape Cell (cultivated)

Landuse outputs
impacts on
vegetation & terrain

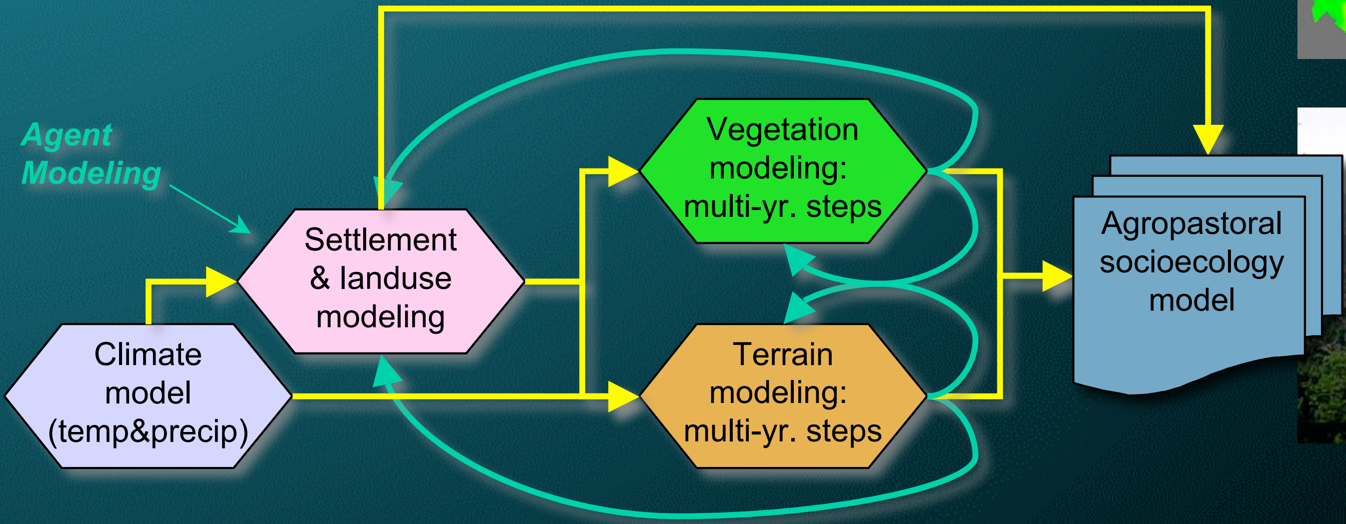
Information Inputs
terrain characteristics
current vegetation
temp. extremes
precip. amt & dist

Project Overview

- Climate ⟺ surface processes & landcover ⟺ agent simulation
- Landscape socioecology



Polop Valley Landuse Intensity
M. Paleolithic to Neolithic II



Current Status

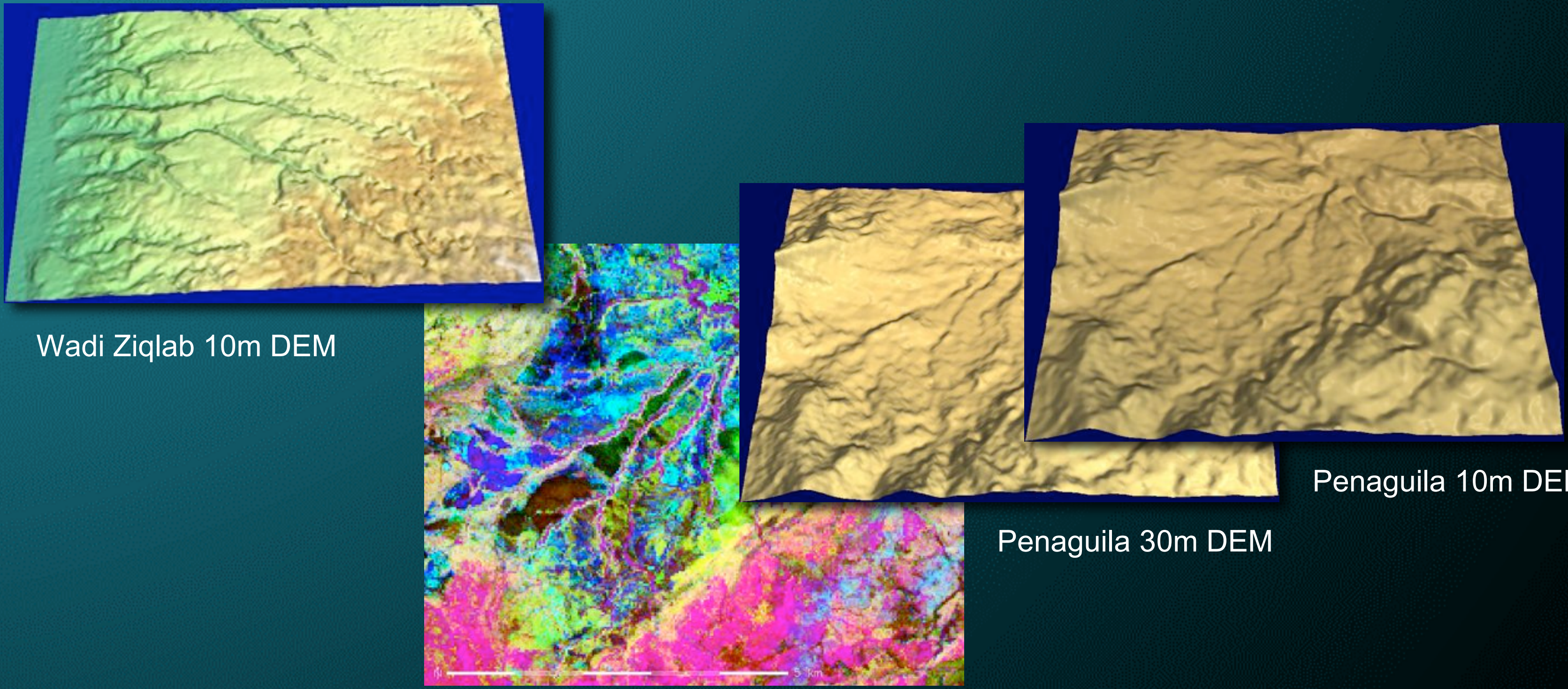
- First full year of research beginning in Fall 2005
- Goals
  - Develop dynamic landscape models
  - Develop paleoclimate models
  - Develop human landuse models
  - Begin vegetation models
- Overview of current status and challenges for landscape, climate, and landuse models

Landscape Modeling Overview

- Basic components
  - Topography
  - Soils
  - Landcover
  - Climate

Topography

- 30 M DEMs created from Terra ASTER band 3, level 1a imagery
- Reinterpolated to 10m using GRASS v.surf.rst



Wadi Ziqlab 10m DEM

Penaguila 10m DEM

Penaguila 30m DEM

Penaguila Valley Terra ASTER VNIR PCA

Landcover

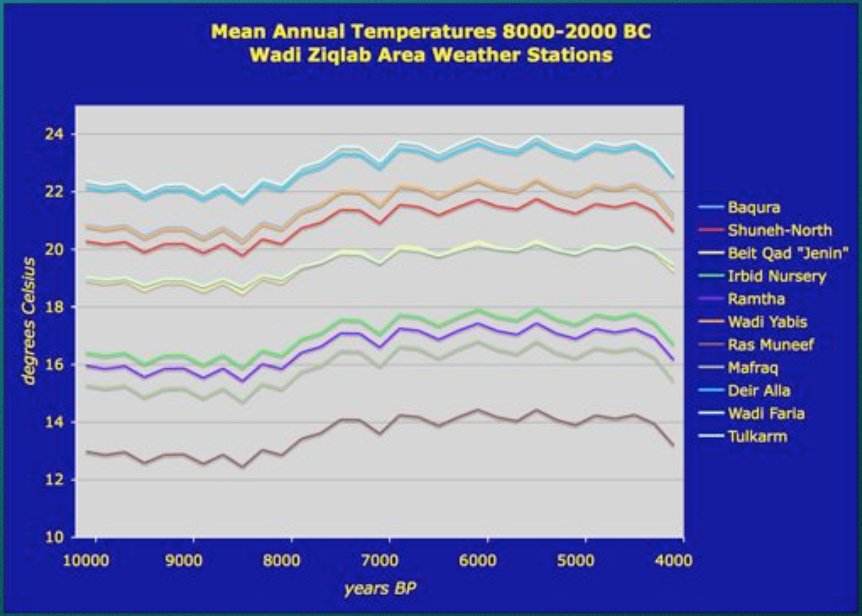
- In process
- Developing from 2 directions
  - Top-down macro-vegetation based on general vegetation community maps, topography, and climate
  - Bottom-up vegetation communities generated from edaphic requirements of key species, topography, and climate
  - Initially using forest/woodland cover for Spanish pilot area

Climate

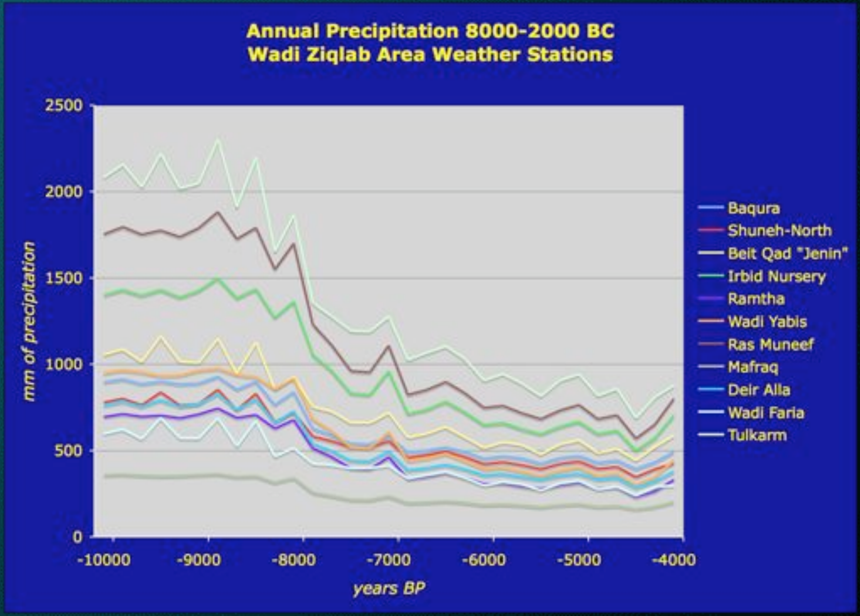
- Initial climate modeling completed for Jordan, in process for eastern Spain
- Includes annual and monthly values at 200 yr intervals for…
  - Mean temperature
  - Days above 40° C
  - Days below 0° C
  - Total precipitation
  - Precipitation intensity

Climate

- Example from Wadi Ziqlab in northern Jordan



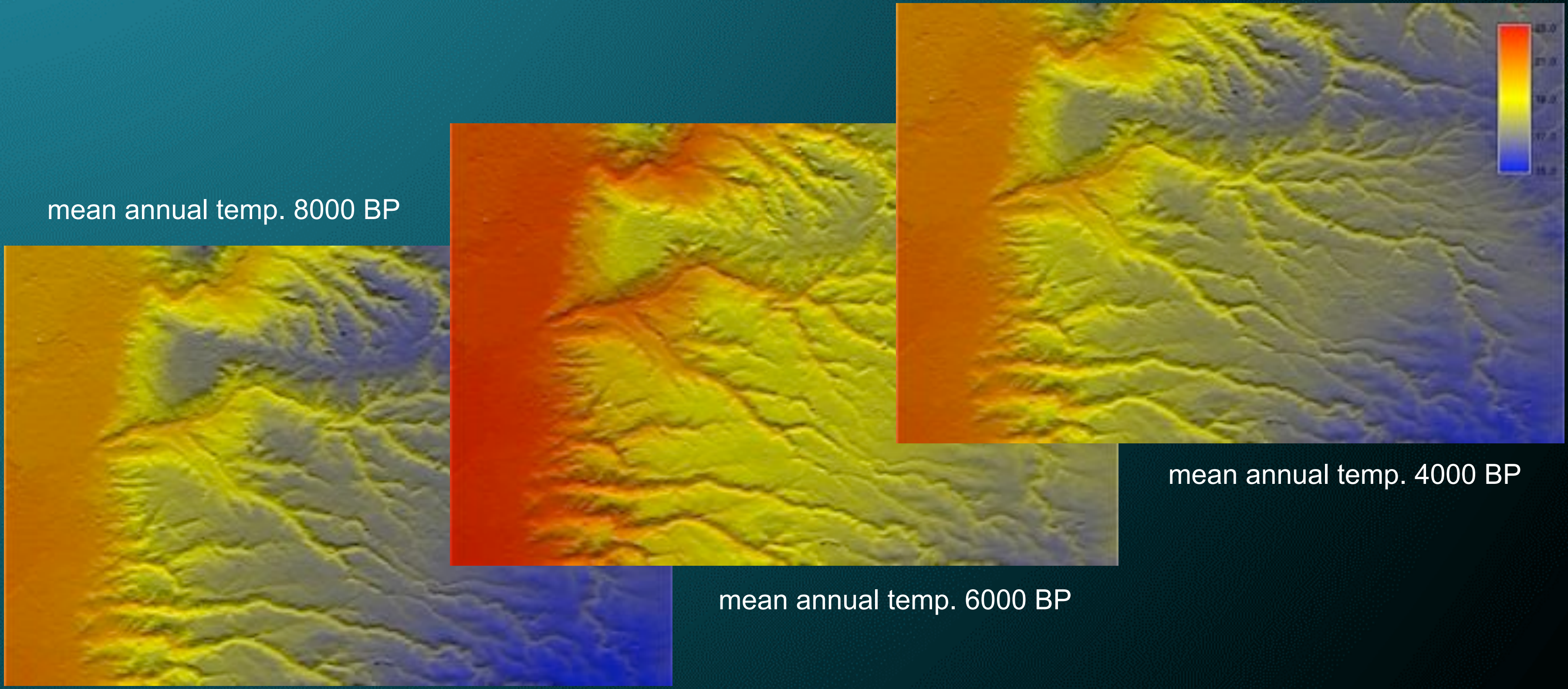
**Mean Annual Temperatures 8000-2000 BC
Wadi Ziqlab Area Weather Stations**



**Annual Precipitation 8000-2000 BC
Wadi Ziqlab Area Weather Stations**

Climate

- Multiple regression used as basis for interpolating values across space and producing raster maps of climatic parameters



mean annual temp. 8000 BP

mean annual temp. 6000 BP

mean annual temp. 4000 BP

Landscape Modeling Overview

- Simple models
  - Averaged estimates of soil loss and sediment transport
  - Useful as input for decision making in agriculture but not suitable for terrain change
  - RUSLE - 3D (“Universal Soil Loss Equation”)
    - Erosion potential.
    - Hillslope soil detachment
    - Location of gullies
    - Averaged soil loss in watersheds
  - USPED (“Unit Stream Power - Erosion/Deposition”)
    - Net erosion and deposition on hillslopes
    - Location of gullies
- More complex, physics-based models
  - Simulate wider range of effects, but will need enhanced for the scale of project
  - SIMWE (SIMulated Water and Erosion modeling): r.sim.water & r.sim.sediment in GRASS.
- Dynamic modeling of landscape change
  - r.terradyn: iterates SIMWE modules to estimate erosion/deposition and modify terrain
  - SIBERIA, CHILD, etc.: may or may not need depending on requirements for fluvial, landslide, and debris flow modeling.

Erosion Potential (RUSLE)

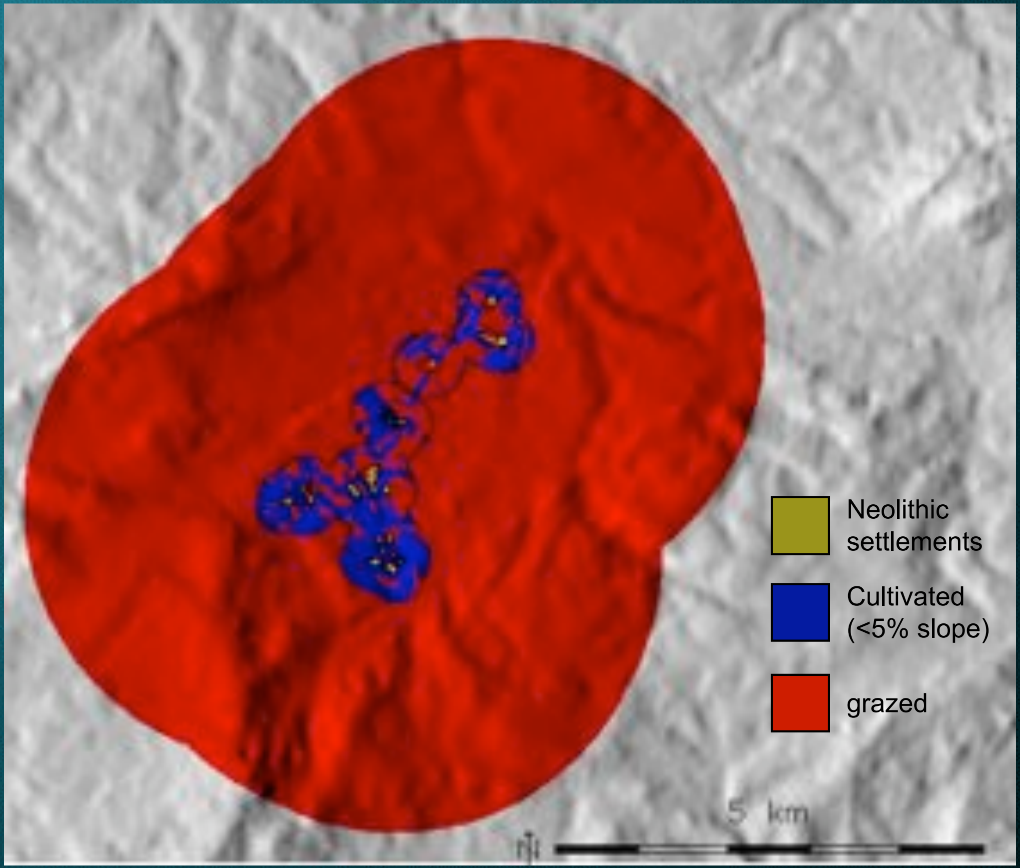
- Revised universal soil loss equation
  - Measures potential for soil loss due to erosion given a number of relevant environmental parameters
- Equation
  - $E = R \times K \times LS \times C \times P$
  - where …
    - E is the average soil loss,
    - R is the rainfall intensity factor,
    - K is the soil factor,
    - LS is the topographic (length-slope) factor,
    - C is the vegetation/landcover factor
    - P is the prevention practices factor.

Erosion Potential (RUSLE)

- Example from Río Penaguila valley, Spain
- Parameters
  - R = 548mm (constant; 200 year avg. annual rainfall for region)
  - K = 0.35 (constant; approximate value for Mediterranean-type soil of silty clay loam)
  - LS calculated by r.flow in GRASS
  - C includes forest, cultivated fields, bare soil, and pasture
    - based on modeling team estimates (Falconer & Sarjoughian) for agricultural land/person and I. Ullah's estimates for grazing (ethnoarchaeology and historic texts)
    - 0.3 km^2 buffer of land with slope < 5° around all known Neolithic I settlements, classified as cultivated (C=0.5) or bare soil (C=1.0)
    - 3.0 km^2 buffer around settlements for grazing, divided randomly into 50% degraded grassland (C=0.6) and 50% forest (C=0.01).
  - P factor not used

Erosion Potential (RUSLE)

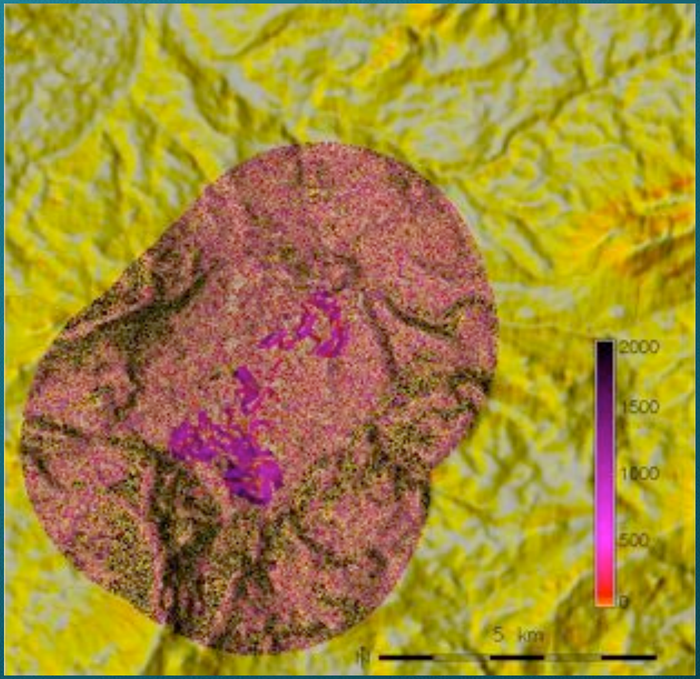
- Example from the Río Penaguila Valley



Creating c-factor map by buffering for cultivated and grazed zone around early Neolithic settlements

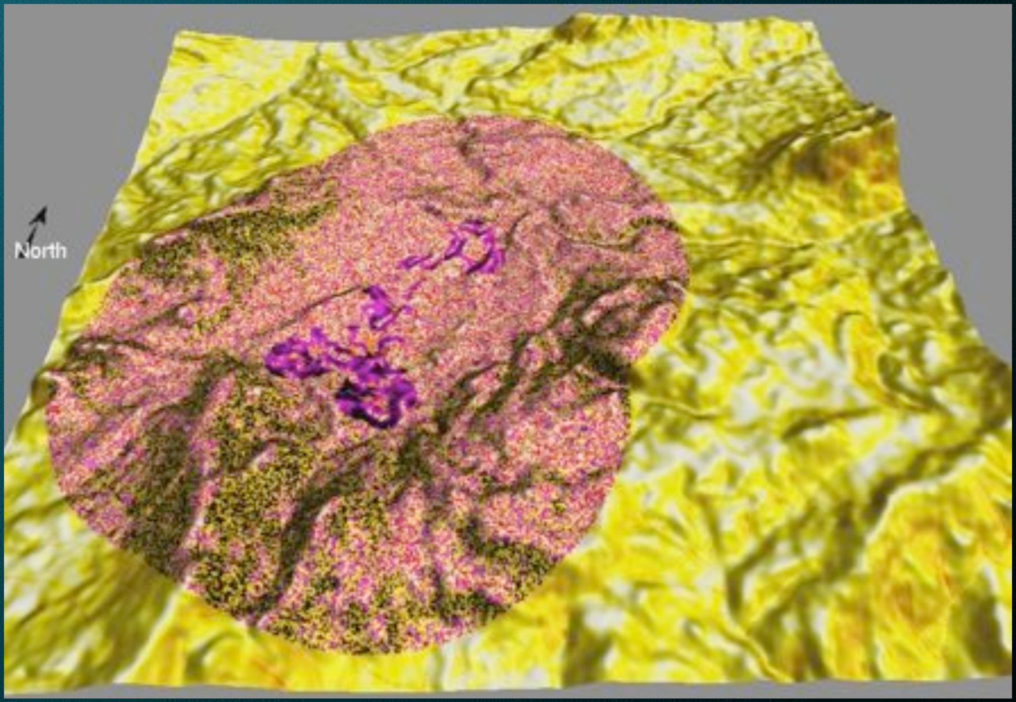
Erosion Potential (RUSLE)

- Example from the Río Penaguila Valley



C-factor for agricultural land coded as cultivated

C-factor for agricultural land coded as bare soil

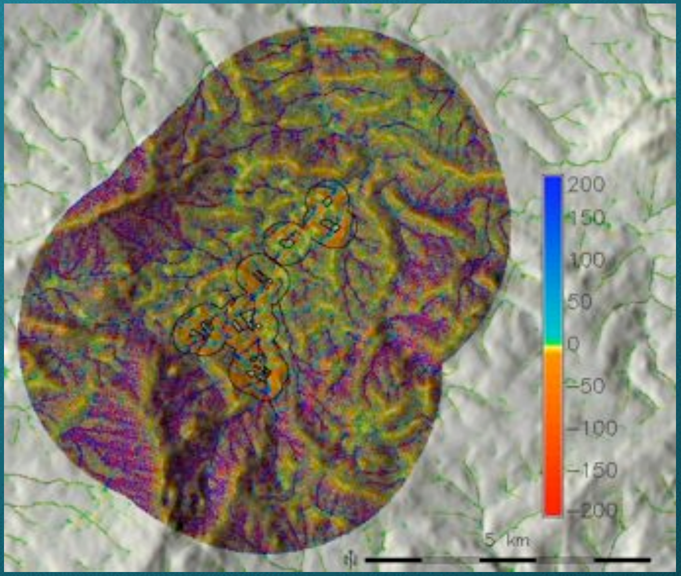


Net Erosion & Deposition (USPED)

- Erosion & deposition potential (USPED)
- $ED = \mathrm{d}(T \times \cos a)/\mathrm{dx} + \mathrm{d}(T \times \sin a)/\mathrm{dy}$
  - ED is net erosion or deposition of sediment
  - T (sediment transport) is RUSLE value
  - a is topographic aspect
- Example from Río Penaguila valley uses same paremeters as RUSLE example

Net Erosion & Deposition (USPED)

- Example from the Río Penaguila Valley



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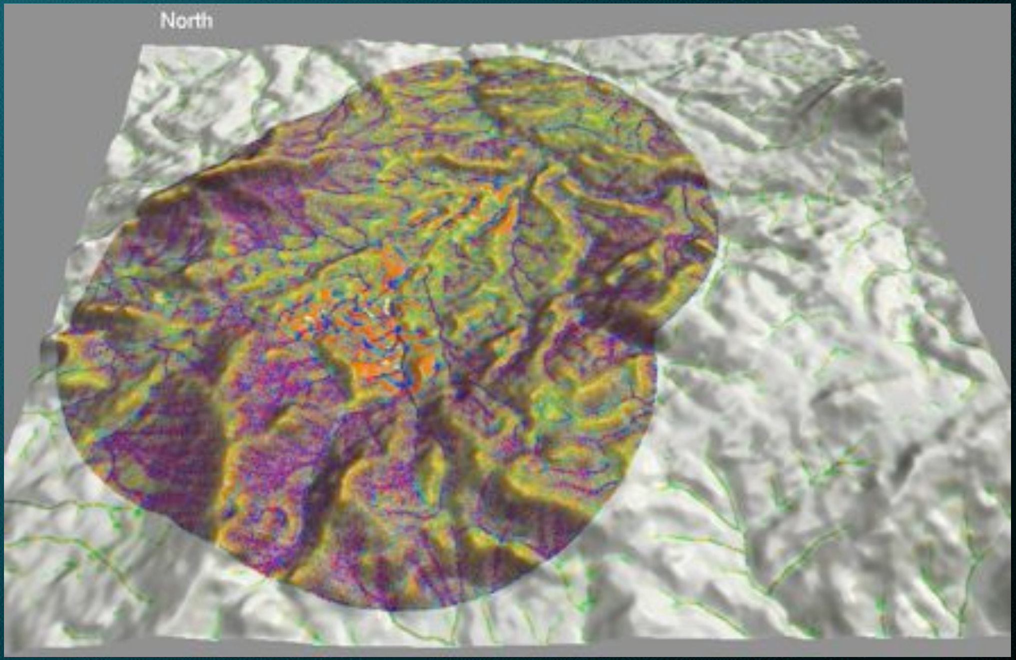
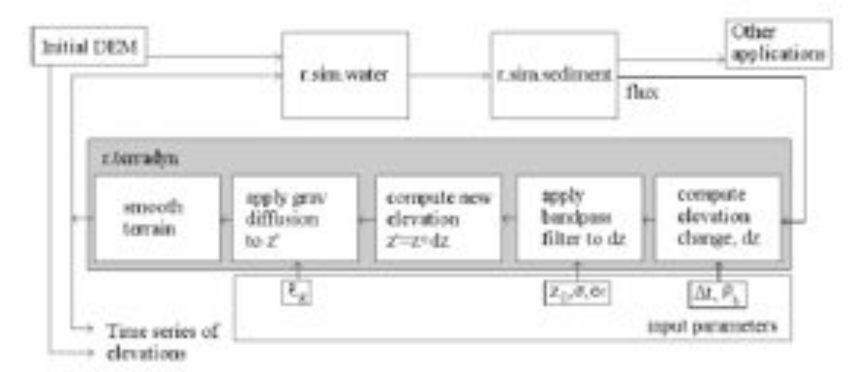


Landscape Modeling Roadmap

- Erosion Potential (RUSLE3D) to estimate soil detachment rates E:
  - Where E>T soil is not capable to renew itself and fertility goes down.
  - We use RUSLE3D for a quick estimate of spatial distribution of high erosion areas and to check the values against USPED
- USPED to estimate erosion and deposition pattern
  - Where net |E|>T we are losing soil
  - Where E>0 we have deposition and usually fertile soil
  - Results of USPED can be used in the agent based models.
  - USPED can probably be used for terrain evolution in small watersheds (no big rivers)
- SIMWE to estimate erosion/deposition with more realistic water flow
  - Accounts for spatial variability in rainfall excess, flow velocity, incorporates flow diffusion etc.) and more sophisticated erosion/deposition modeling so more effects can be captured.
  - RUSLE and USPED are two special cases of SIMWE
- May need to explore external models if we much account for fluvial transport

Landscape Modeling Roadmap

- Dynamic modeling of landscape change
  - r.terradyn (C. Thaxton and H. Mitasova)
  - http://skagit.meas.ncsu.edu/~chris/terradyn/lw.html
  - Iterates SIMWE erosion and deposition to produce cumulative landscape change
  - Filters extreme values and smoothes erosion/deposition to make more realistic



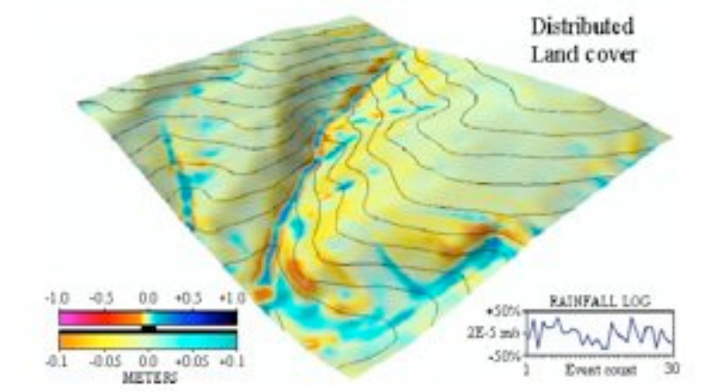


Figure 4.29: The modified DEM of the Lake Wheeler sub-watershed after 30 r.terradyn iterations with distributed land cover per table 4.4 and distributed infiltration values for CNII-D. The rainfall rate was twice the rainfall rate of figure 4.28 which produced a substantial elevation increase in the wooded area (bottom right).

Landscape Modeling Roadmap

- Dynamic modeling of landscape change (r.terradyn)

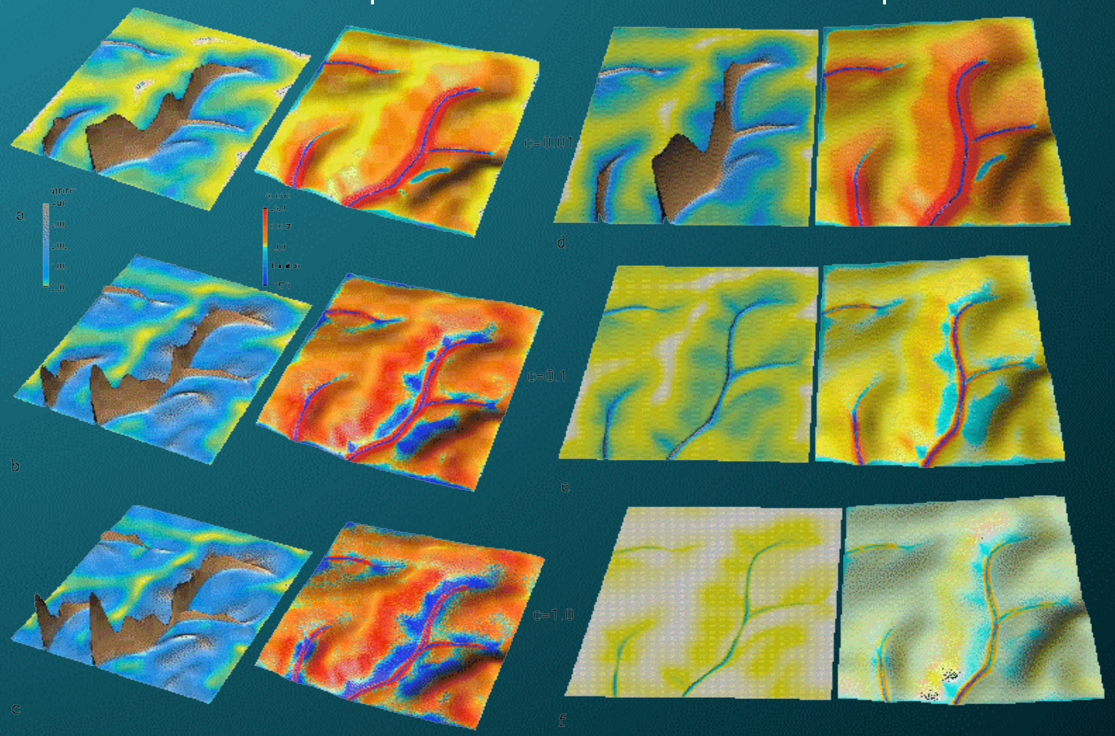


Figure 6. Impact of change in erodibility a)Kd=0.003, c=0.01; b) Kd=0.03, c=0.1; c)Kd=0.3, c=1.0; while transportability Kt=const=0.3.

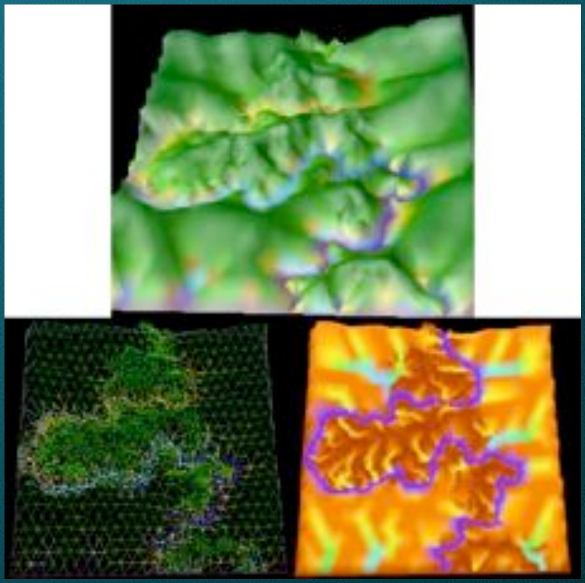
Impact of change in transportability, d) Kt=0.3, c=0.01; e) Kt=0.03, c=0.1; f) Kt=0.003, c=1.0 while erodibility Kd=const=0.003.

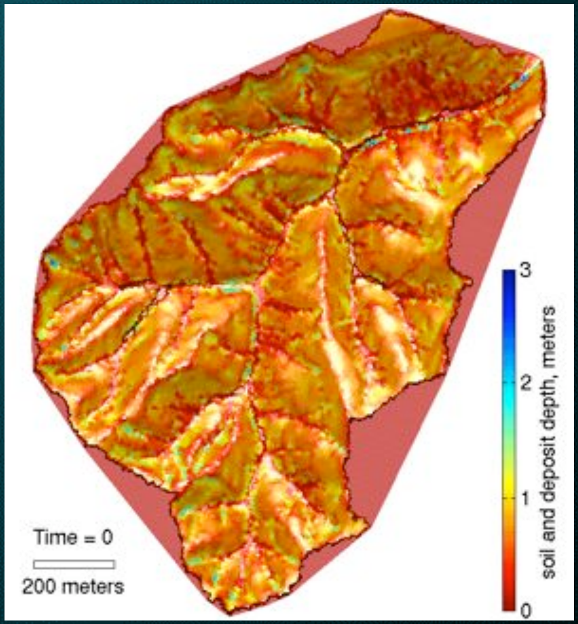
Erodability

Transportabiity

Landscape Modeling Roadmap

- Dynamic modeling of landscape change
  - CHILD (channel-hillslope integrated landscape development)
  - N. Gasparini, S. Lancaster, and G. Tucker http://www.colorado.edu/geolsci/gtucker/child/
  - External model - most complete simulation of landscape change



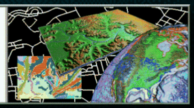


Data Management and Access

- Critical due to large volume of geospatial data files being acquired AND generated.
- Initial project data server and spatial data server (link from http://medland.asu.edu)
- Collaboration with ASU Libraries
  - **Fedora** data archive system
  - Data management and retrieval (multiple data types)
  - Metadata management
  - Differing levels of access
  - Versioning system to track changes

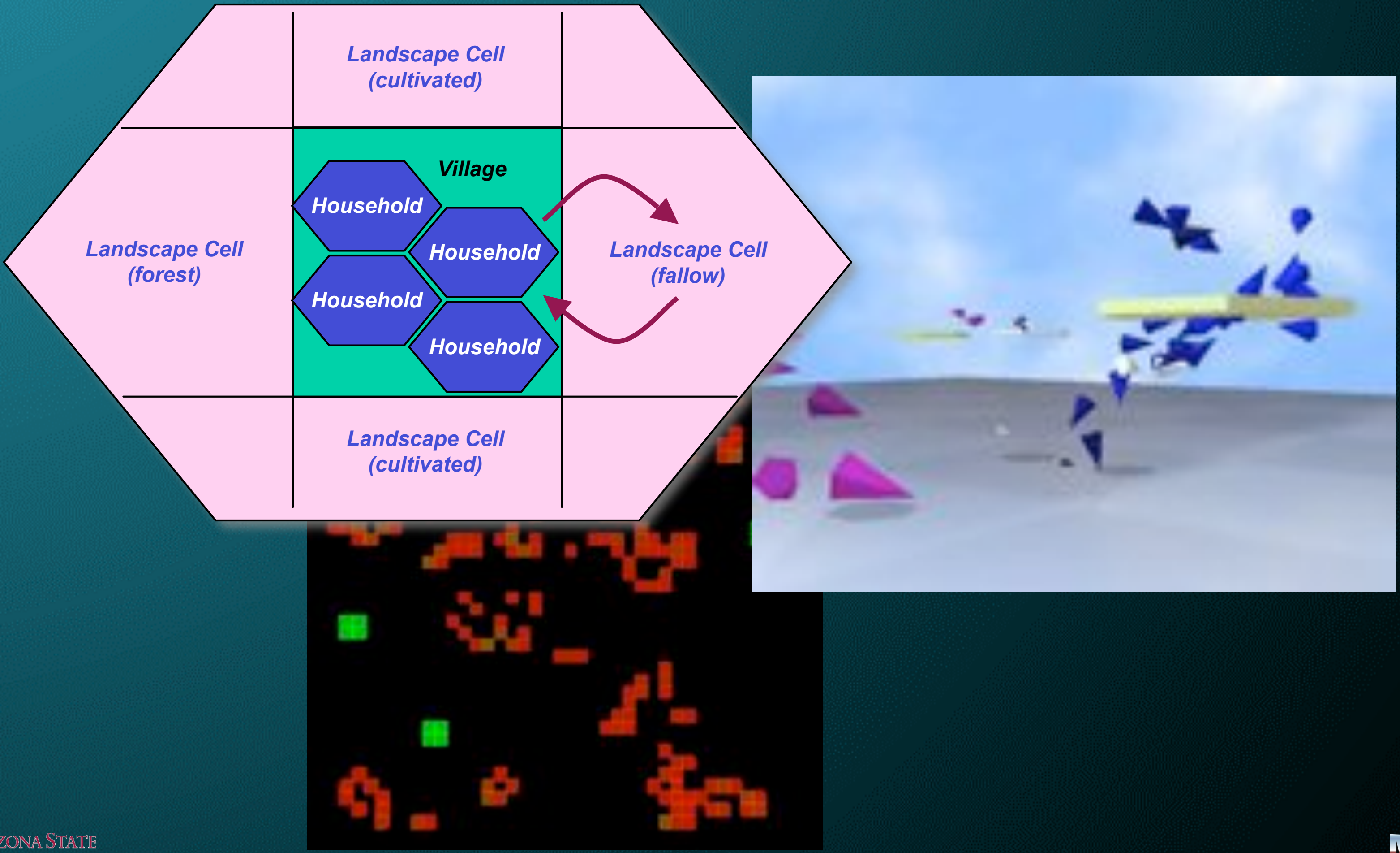
Support & collaboration

- NSF: ERE Biocomplexity in the Environment Program, grant BCS-0410269
- ASU: School of Human Evolution and Social Change, School of Earth and Space Exploration, School of Computing and Informatics, Geographical Sciences, International Institute for 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



Landuse Modeling

- Hessam Sarjoughian (this afternoon)



Landscape Cell (cultivated)

Landscape Cell (forest)

Village

Household

Household

Household

Household

Landscape Cell (fallow)

Landscape Cell (cultivated)