Land-Use, Water, & Mediterranean Landscapes

Modeling Long-Term Dynamics of Complex Socioecological Systems

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Water & Society

- Just enough water in the right places
  - Not too little
  - Not too much

Water & Society

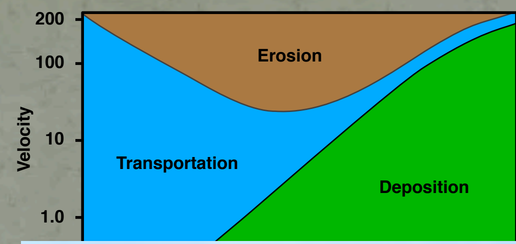
- Water & landscapes
  - Most powerful, long-term impacts of social practice on the earth
  - Transformed most of earth's surface and altered its productivity
  - Reshaped rivers and coasts

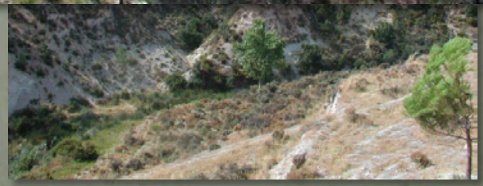
Flowing Water & Land-Use Practice

- Balance of
  - Amount & velocity of water
  - Surface topography
  - Soil characteristic
- Farming alters
  - Vegetation
  - Soil
  - Topography

Flowing Water & Land-Use Practice

- Water flow well understood in abstract, but is complex in real landscapes.
- Complexity compounded by human land-use.
- Small-scale activities can have large-scale consequences over long time frames but are difficult to predict
- Complex socioecological systems





Mediterranean Landscape Dynamics

- Computational modeling laboratory for socioecological systems research
- Parameterization and empirical testing against archaeological record
  - Eastern Spain
  - Western Jordan
  - Neolithic – Bronze Age

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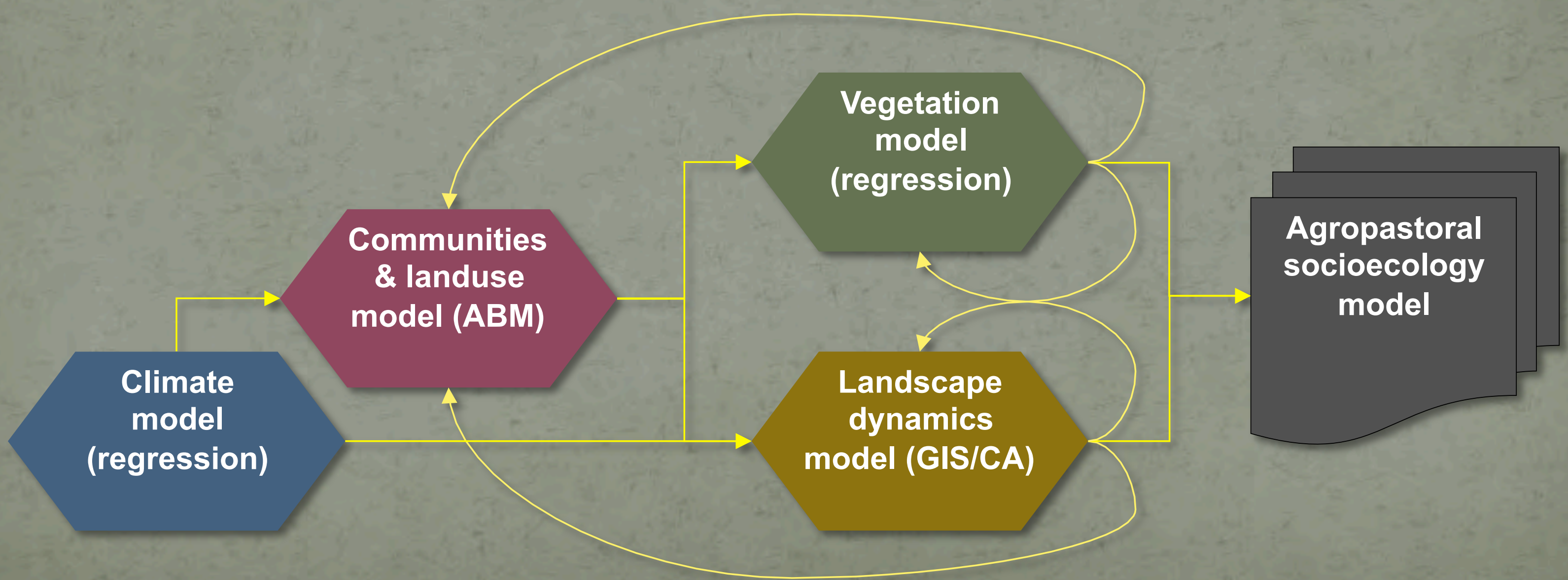
Mediterranean Landscape Dynamics

- Hybrid modeling approach
  - Human communities and decisions: ABM
  - Landscape dynamics: GIS cellular automata
  - Climate and vegetation: regression-based models



Modeling Landscape Dynamics

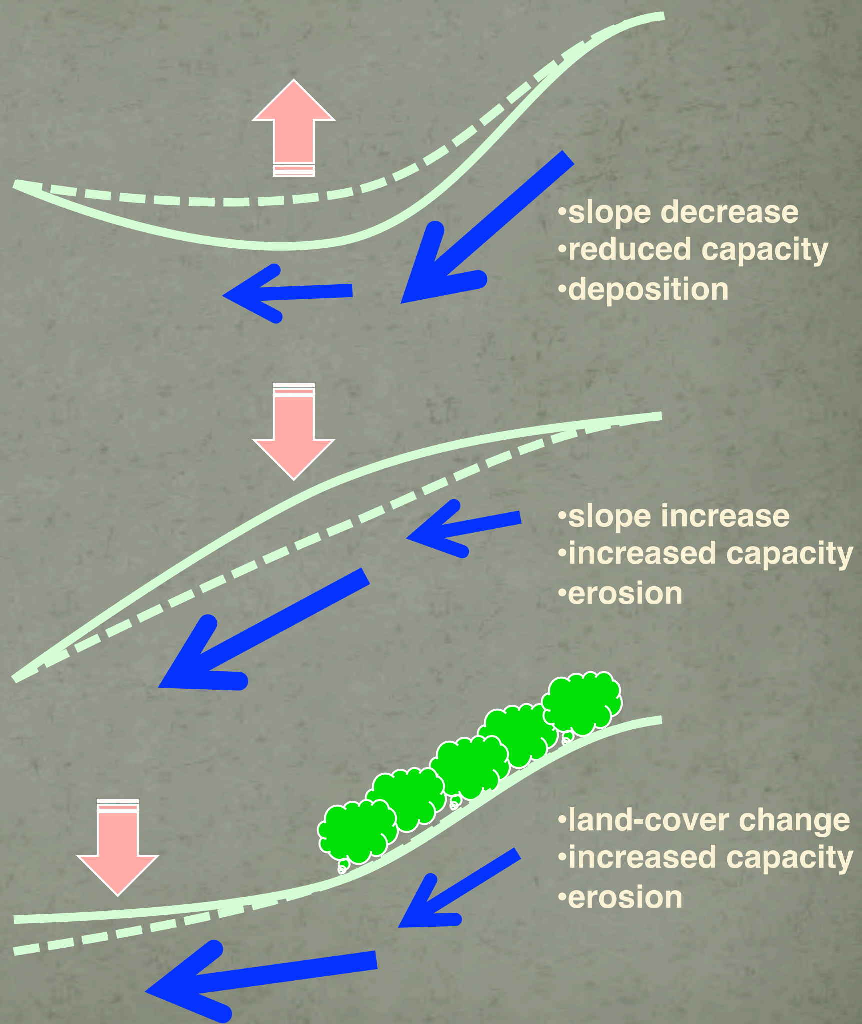
- Hillslope erosion/deposition (HED) model
  - Extension of USPED and RUSLE
  - Not applicable to larger channels and streams

$$HED = \frac{d(T \cdot \cos(a))}{dx} + \frac{d(T \cdot \sin(a))}{dy}$$

- *HED* = net erosion/deposition per landscape cell
  - *a* = topographic aspect [flow direction]
  - $T = R\,K\,C\,A^m\,(\sin \beta)^n$ [modified RUSLE]
    - R = rainfall coefficient
    - K = soil erodibility coefficient
    - C = landcover coefficient
    - A = upslope area contributing to flow
    - m,n = empirical coefficients for different flow regimes
    - β = slope

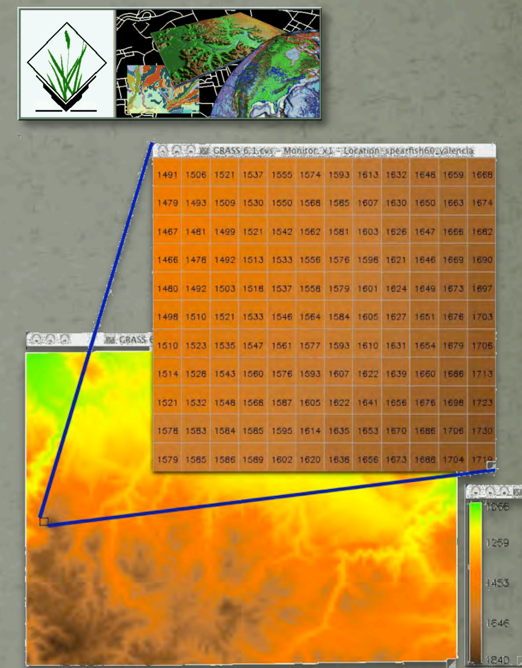
Modeling Landscape Dynamics

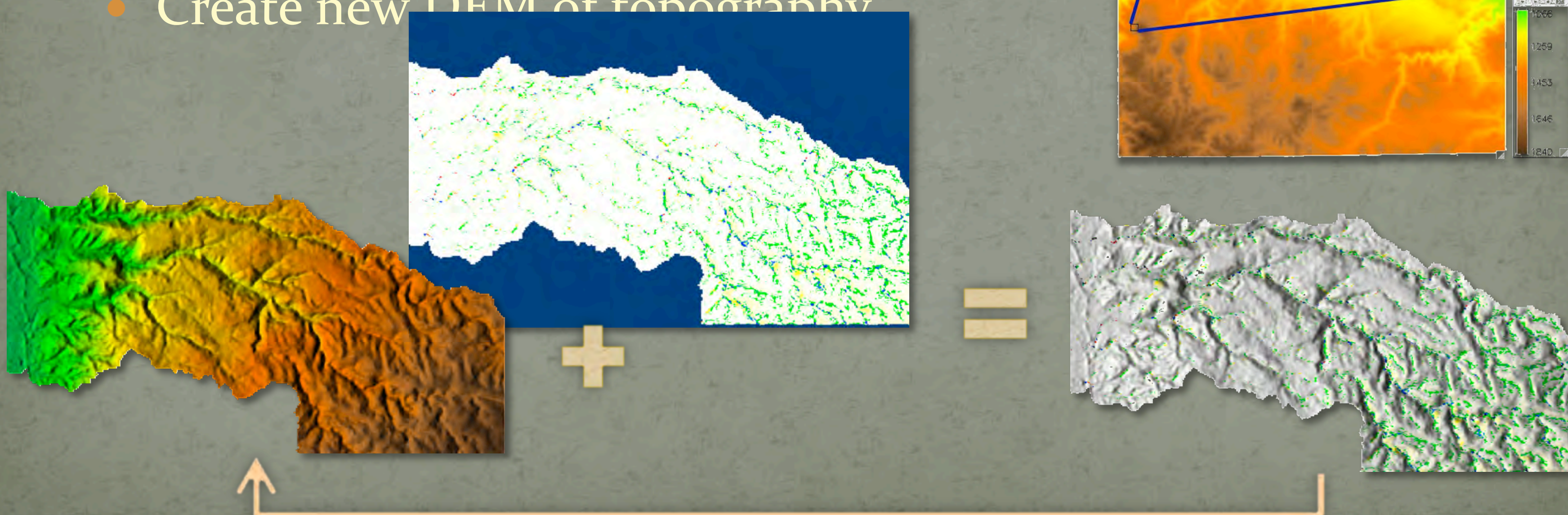
- Basic assumption
  - flowing water carries sediment at capacity
- Dynamics
  - Changes to hydrology affect transport capacity
  - Water will erode or deposit sediment until its load reaches its new capacity



Modeling Landscape Dynamics

- Recursive scripts in open source GRASS GIS
  - Start with DEM of topography
  - Calculate HED (net erosion/deposition) for each landscape cell
  - Add/subtract net erosion/deposition to DEM
  - Create new DEM of topography





Modeling Human Land-Use

- Experimental design

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
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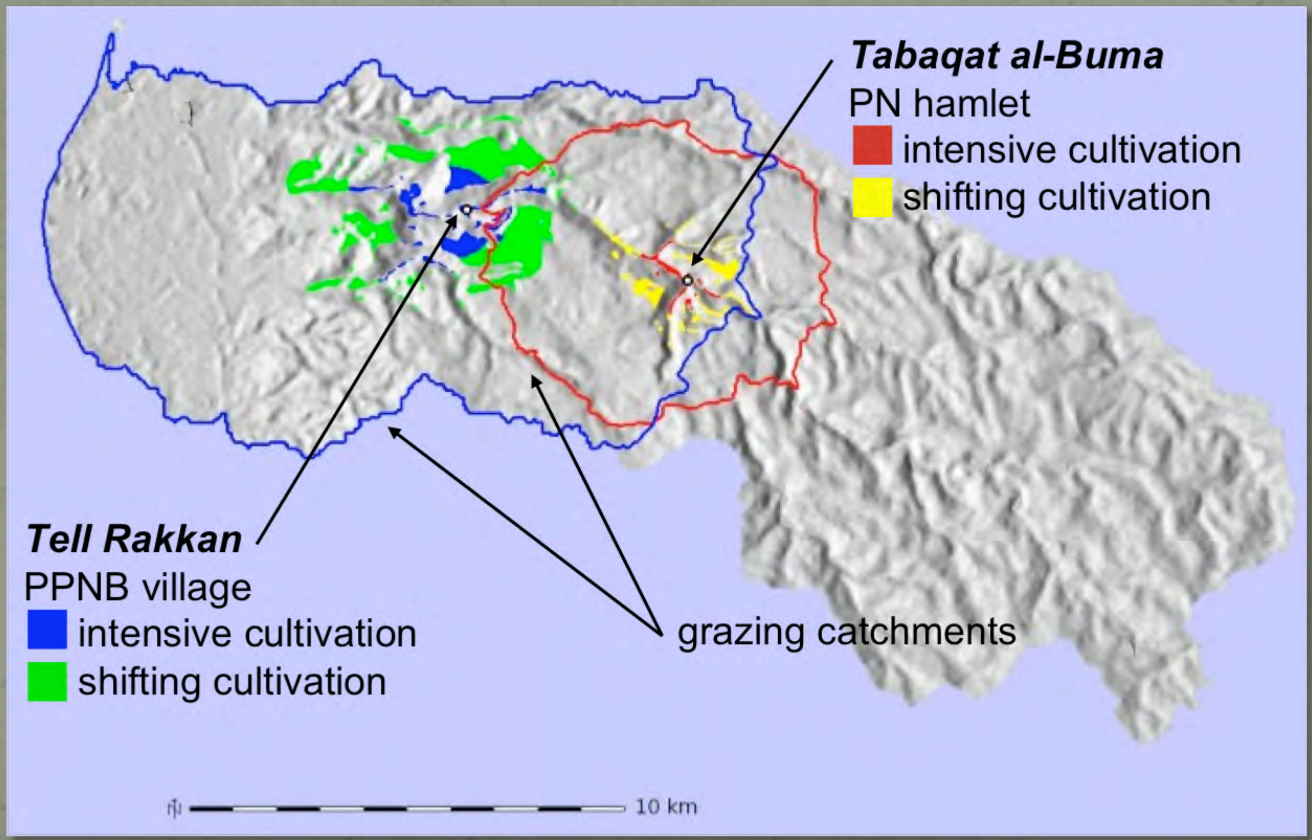
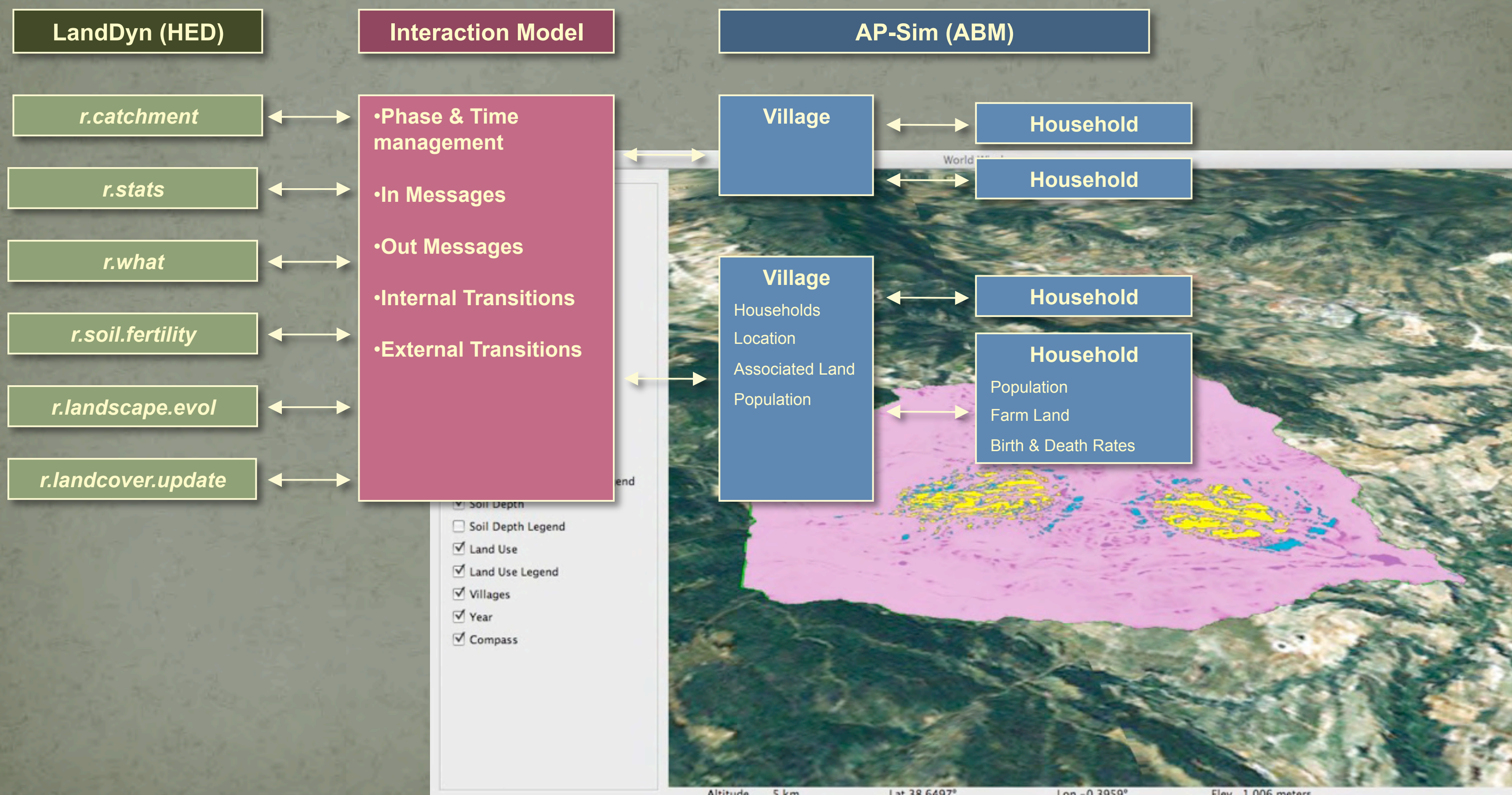
Modeling Human Land-Use

- Stochastic land-use modeling



Modeling Human Land-Use

- Agent based land-use modeling



Visualization

- Coupled with open source WorldWind (NASA)

Neolithic Socioecology in N. Jordan

- Results of initial experiments (40 & 200 year simulations)
  - Barton, C. M., Ullah, I., & Mitasova, H. (*in press)* Computational modeling and socioecological dynamics: a case study from southwest Asia. *American Antiquity*.

Photo by I. Ullah

Neolithic Socioecology in N. Jordan

- Control model

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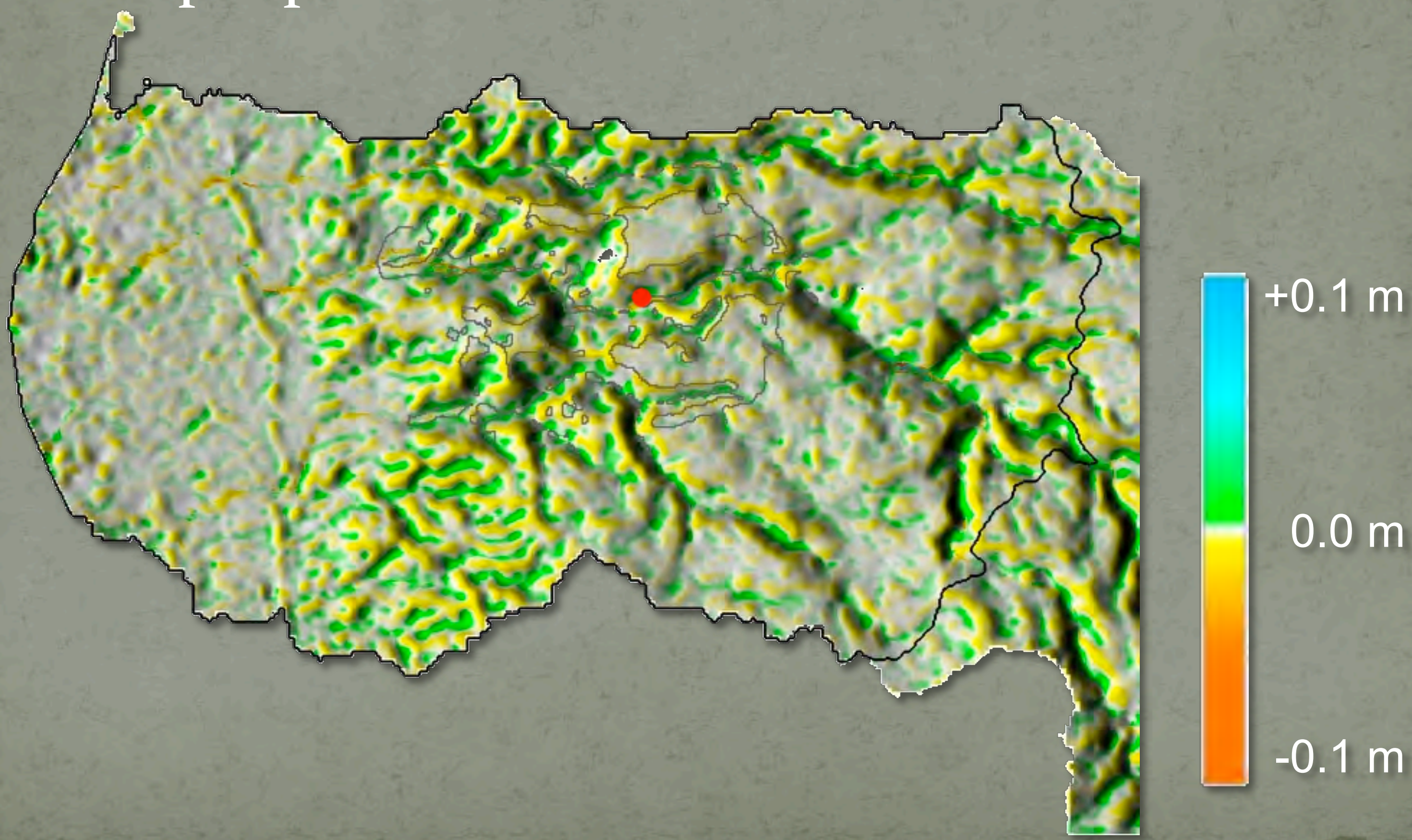
Neolithic Socioecology in N. Jordan

- Control model after 40 years. Landscape dynamics without people



Neolithic Socioecology in N. Jordan

- Small village, shifting cultivation, grazing

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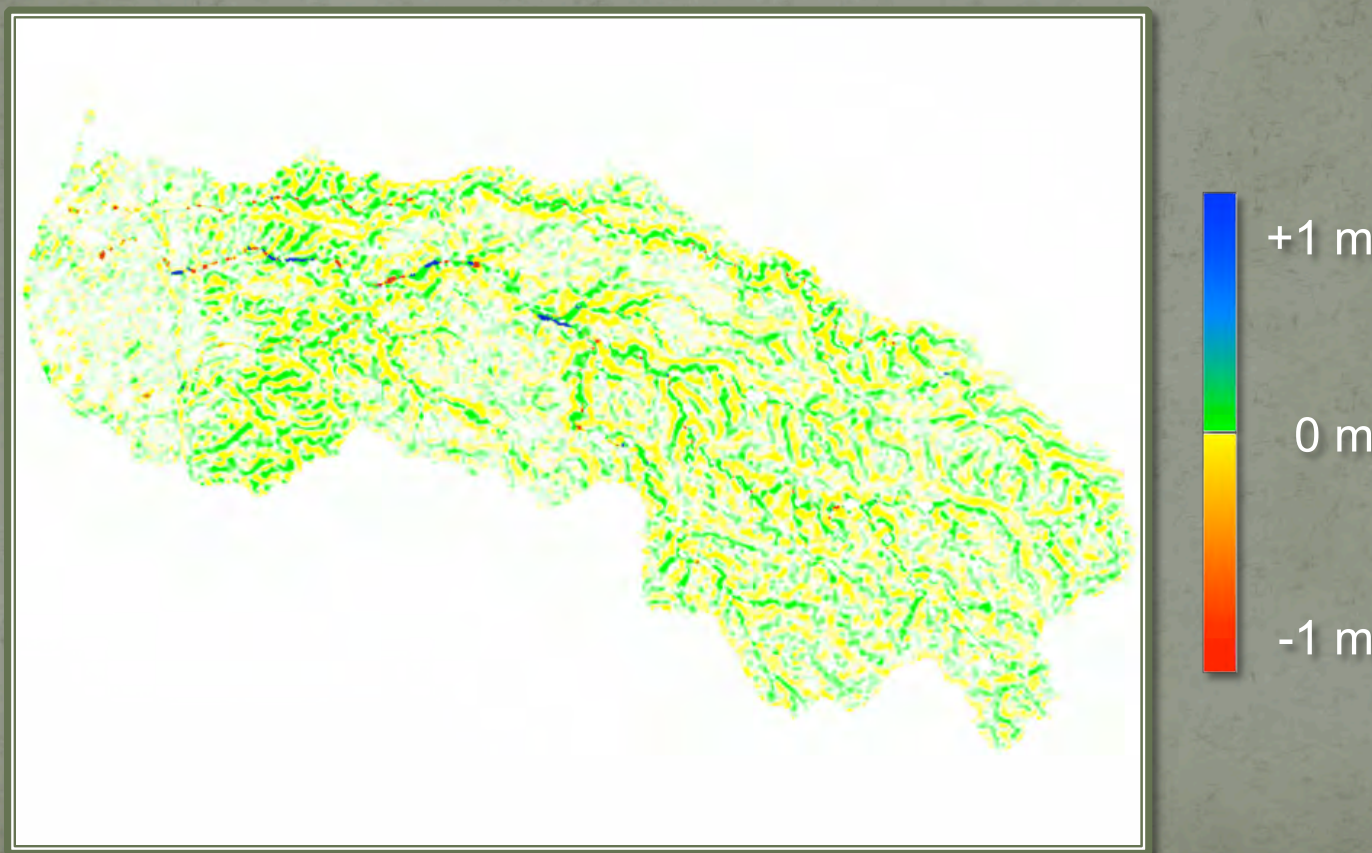
Neolithic Socioecology in N. Jordan

- Small village, shifting cultivation, grazing (40 years)



Neolithic Socioecology in N. Jordan

- Comparing consequences of population change

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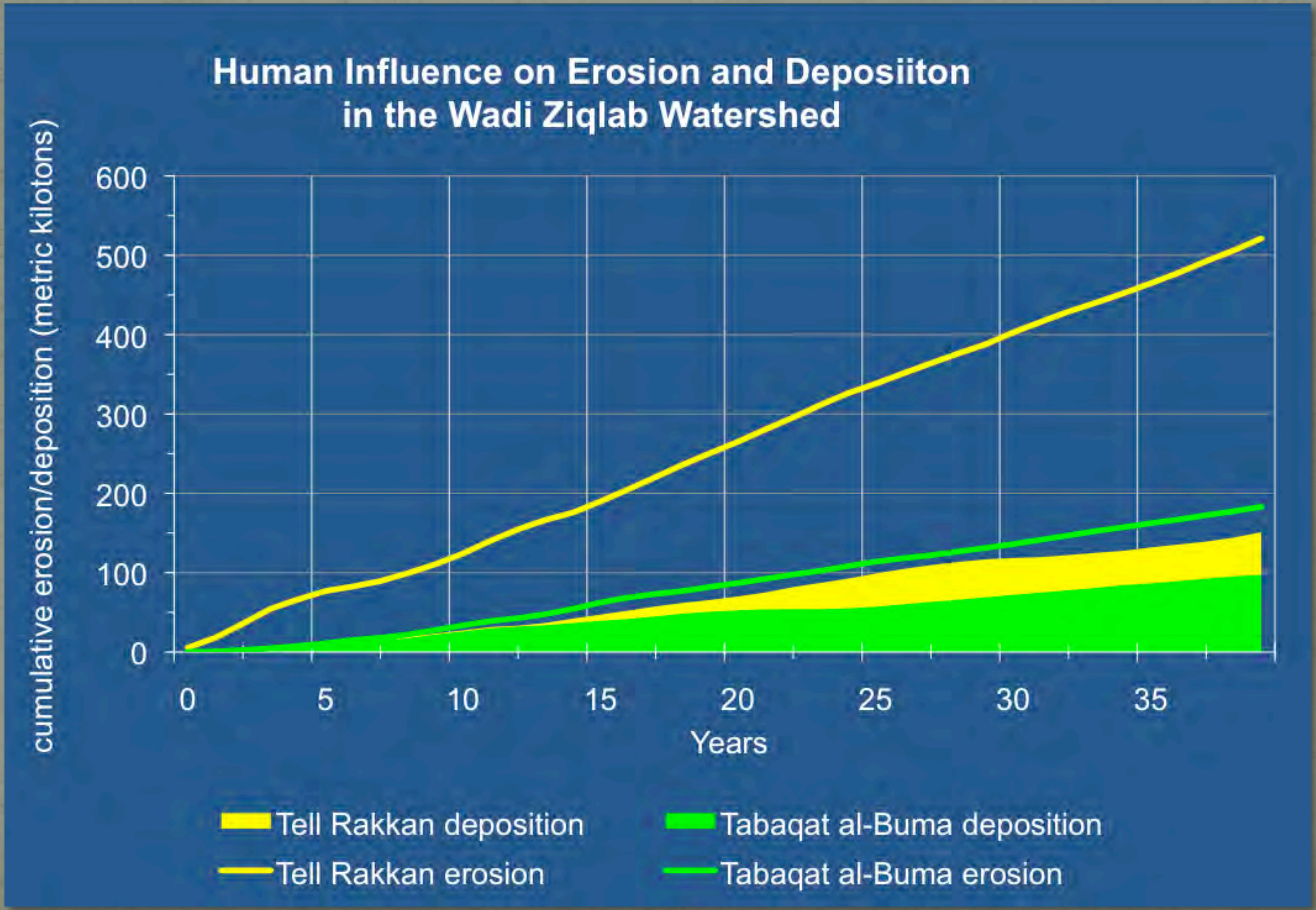
Neolithic Socioecology in N. Jordan

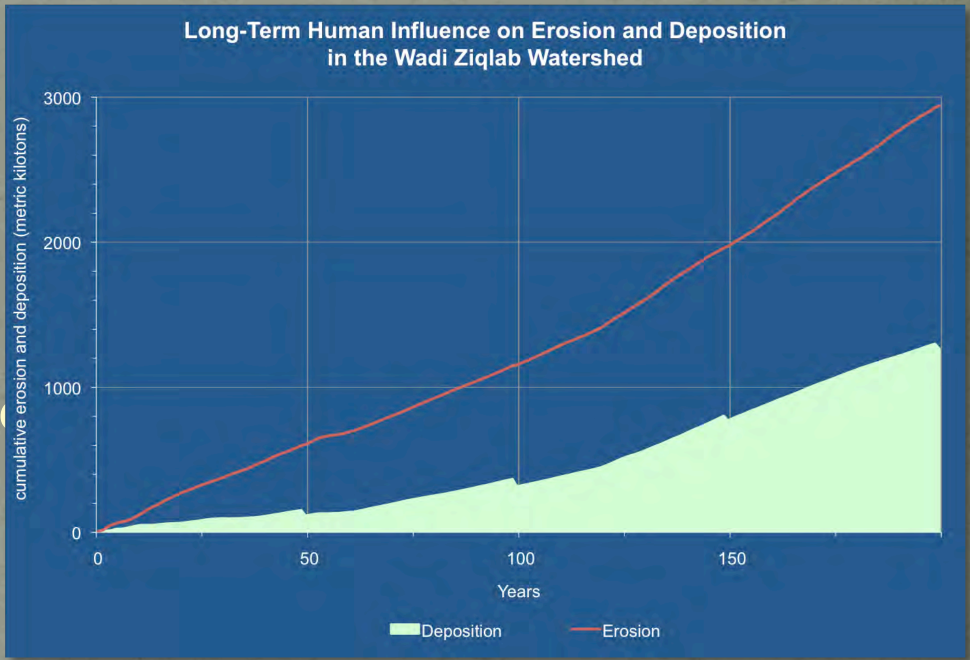
- Hamlet
  - Cultivation limited to wadi bottoms
  - Grazing causes most erosion
  - Erosion primarily in uncultivated uplands
  - Redeposited sediment in cultivated zones is 53% of erosion
- Village
  - Cultivation in uplands; more extensive grazing
  - Cultivation causes most erosion
  - Erosion in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

Neolithic Socioecology in N. Jordan



Neolithic Socioecology in N. Jordan

- Long-term outcomes
- 200 years of land-use around village
  - Erosion continues for 200 years
  - Rate of erosion increase
  - Ratio of redeposited sediment to erosion continues to decline



Neolithic Socioecology in N. Jordan

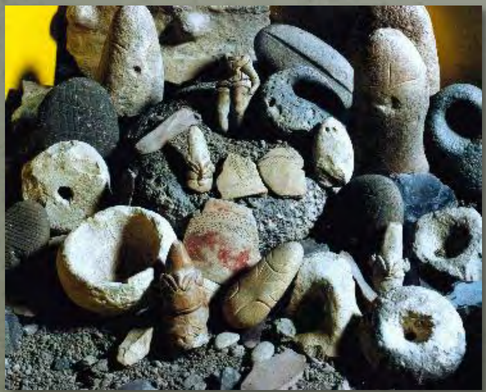
- Comparisons with the archaeological record
  - Growth of Neolithic communities through the PPN
  - Villages to larger “megasites” by end of PPNB
  - Subsequent disappearance of large communities
    - Prevalence of smaller communities
    - Initial appearance of pastoralism
    - Initial appearance of significant socioeconomic differentials

Long-Term Socioecological Dynamics

- Indirect interactions of society and water
  - Have had great impact
  - But may only be visible in hindsight
  - Difficult to trace causation or predict consequences due to complex interactions in SES
- Need time depth to understand Mediterranean SES

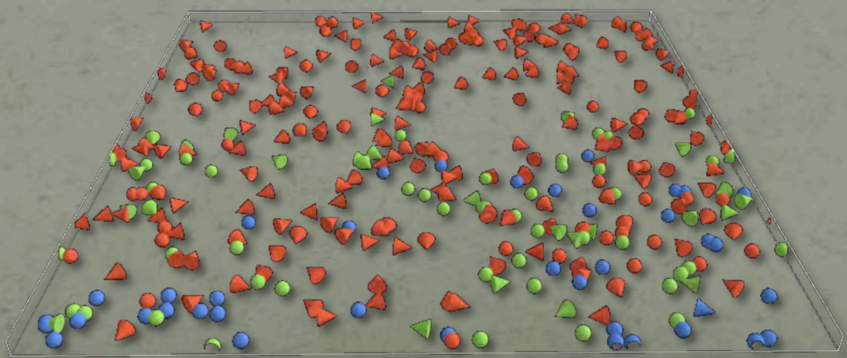
Archaeology & Socioecological Dynamics

- Potential for understanding long-term change
- But archaeological record problematic for studying SES
  - Static, fragmentary, mostly missing
  - Archaeological data recovery sophisticated
  - But still leaves enormous gaps filled with stories



Archaeology & Socioecological Dynamics

- Computational modeling offers
  - New tools to study dynamics of human societies
  - Experimental protocols needed for testing ideas about SES
- Can compare model outcomes against empirical record
- Modeling provides platform to build cumulative understanding



Archaeology & Socioecological Dynamics

- Changing archaeological practice
  - Create theory-driven models of human action
  - Translate into computational models of social dynamics
  - Test outcomes against archaeological record

Interdisciplinary & International Collaboration

- 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