# Simpler is better: lessons from modeling coupled human and natural systems in the MedLanD Project

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## MedLanD Project History

- 2004/2005 - Project initiated
- 2007 - First simple models constructed (stochastic landuse), initial experimentation
- 2008 - First experiment conducted, Wadi Ziqlab
- 2009 - First MedLanD publication, integration of ABM landuse: "AP-SiM" routine
- 2010 - First AP-SiM experiments conducted in the Penaguila Valley project area, results published, further model refinement
- 2011 - Final refinement of model, project nears completion

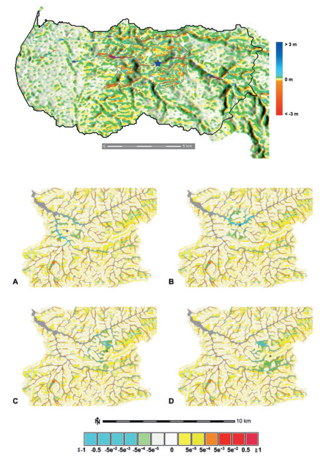


Figure 1: Cumulative elevation change maps from some previous MedLanD research experiments. Wadi Ziqlab, Jordan (top), Penaguila Valley, Spain (bottom).

## Lesson 1: The Benefits of Explicit Computational Modeling

- **Traditional Modeling Approaches**

  *Inferential Models*

  Formal models ("Middle-range theories")

  Simple modeling protocol (Data → interpretation)

  Work well for understanding specific events

  Do not work well for understanding higher level systems

  *Narrative Models*

  Desciptions of systems and processes ("Big picture")

  Informal, descriptive modeling protocol

  Mental synthesis of data, not testable

  Interesting, but not really useful for real-world application

- **A New Approach: Explicit Computational Models**

  Better understanding of complex systems and interacting processes

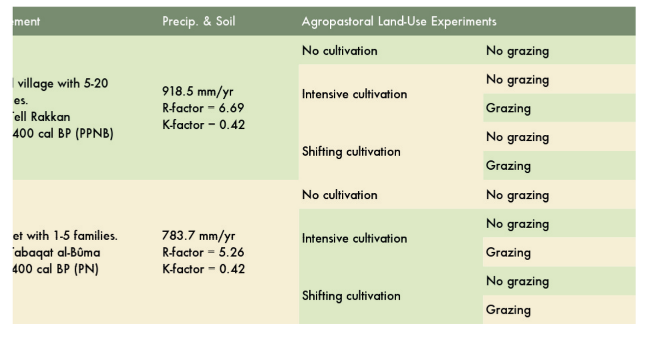
  Formal modeling protocols

  Generate testable hypotheses

  Potential application of archaeologically-derived models to non-archaeological problem domains

## Lesson 2: The Experimental Approach

- **Formulate explicit and specific research questions**
- **Use the models to generate hypotheses about the real world**
- **Understand the effect of different variables in the model**
- **Control models and multi-model comparisons (i.e., "contrafactual" prehistories)**



| ment | Precip. & Soil | Agropastoral Land-Use Experiments | |
|---|---|---|---|
| village with 5-20 es. ell Rakkan 400 cal BP (PPNB) | 918.5 mm/yr R-factor = 6.69 K-factor = 0.42 | No cultivation | No grazing |
| | | Intensive cultivation | No grazing |
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| | | Shifting cultivation | No grazing |
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| et with 1-5 families. abaqat al-Bûma 400 cal BP (PN) | 783.7 mm/yr R-factor = 5.26 K-factor = 0.42 | No cultivation | No grazing |
| | | Intensive cultivation | No grazing |
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| | | Shifting cultivation | No grazing |
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Figure 2: The experiment design for a past MedLanD simualtion experiment.

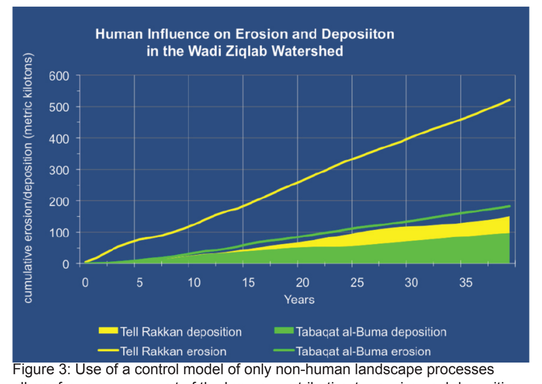


Figure 3: Use of a control model of only non-human landscape processes allows for an assessment of the human contribution to erosion and deposition rates in model experiments.

## Lesson 3: Keep it Simple!

- **Balance the "Real" with the "Analytical" in a research design**
- **Start with very simple models and only add complication as/when needed to answer specific research questions**
- **Restrict the number of manipulated variables in an experiment**

Figure 4: A simplified digtial landscape in Wadi Ziqlab (above) and a photograph of the real location (below).

## Lesson 4: Choose the right programming environment

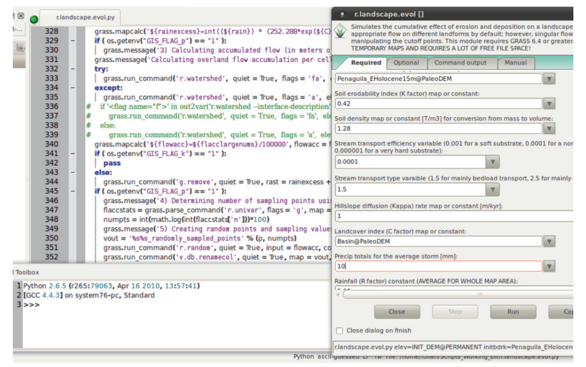

Figure 5: An example of a MedLanD script written in the Python scripting language.

- **Cross-platform scripting language vs. compiled language**
- **Extensibility/power of scripting language (e.g., Python vs. Bash)**
- **Take advantage of the nature of Open-Source software**
- **Use as many "off the shelf" components as possible**

## Lesson 5: Model Validation

- **Stochastic variability is introduced in *every* model run**
- **It is vital to repeat the model multiple times**
- **Sensitivity Analysis**

  Analyze central tendendencies across the repeated runs

  Analyze the variablitly across the repeated runs

  Measure the effects of changing the values of model variables

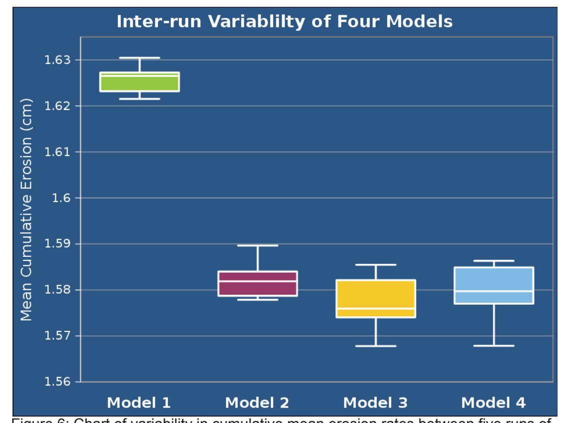


Figure 6: Chart of variability in cumulative mean erosion rates between five runs of the same four model experiments. This chart makes clear the need for multiple runs before trends can be believed.

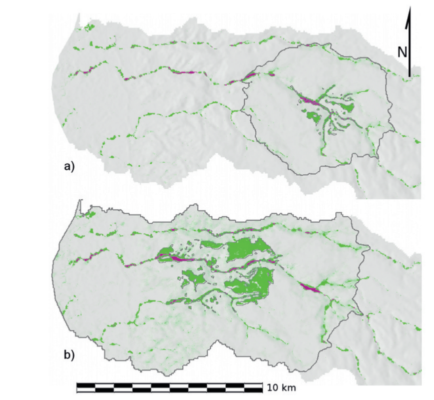


Figure 7: Maps of areas with high inter-run variablity (magenta) and low inter-run variability (green). Certain areas of the landscape are more sensitive to stochastic variation between model runs.

## Lesson 6: Modular Models

- **Modular vs. Monolithic**

  Monolithic models have traditionally been most common

  Modular models are easier to modify and improve

  Modular modeling is facilitated by use of Open-Source tools

- **Coupling**

  Loose coupling (sequential models, manual parameter passing)

  Tight coupling (automatic parameter passing, faster, more difficult to implement)

  Tight coupling is the goal of future models

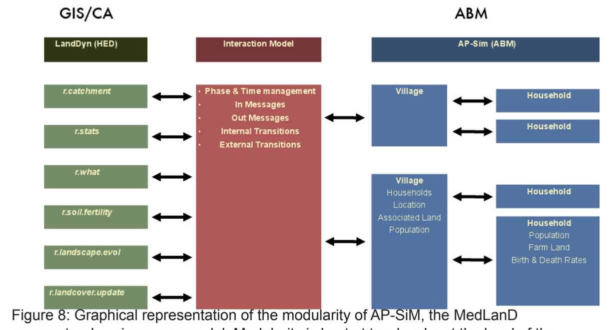


Figure 8: Graphical representation of the modularity of AP-SiM, the MedLanD agropastoral socioecoogy model. Modularity is kept at two levels: at the level of the "Model" (i.e., the Agent Based Model, Interaction Model, and GIS model, see Figure 10), and at the level of the "Module" (i.e., the individual scripts).

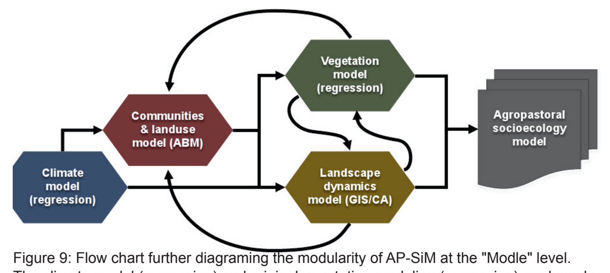


Figure 9: Flow chart further diagraming the modularity of AP-SiM at the "Modle" level. The climate model (regression) and original vegetation modeling (regression) are loosely coupled to the other AP-SiM components. The Communities and Landuse model (ABM), and the Landscape Dynamics model (GIS) are tightly coupled together (via the Interaction Model shown in Figure 8).

## Lesson 7: Training Personel

- **No one "already knows" how to do this type of modeling**
- **Modeling ideas must first be invented and then taught**
- **The project PI *must* know enough about the entire process in order to build the right team**

Figure 10: MedLanD team members hard at work!

## Select MedLanD Publications

Mitasova, Helena, Harmon, R. S.; Barton, C. Michael; and Ullah, Isaac I.
n.d. Geospatial Information Science-based Erosion Modeling. In: Treatise in Geomorphology: Vol. 3 Remote Sensing and GI Science. Manuscript submitted to Elsevier, Amsterdam, February, 2011.

Ullah, Isaac I., and Sean M. Bergin
n.d Modeling the Consequences of Village Site Location: Least Cost Path Modeling in a Coupled GIS and Agent-Based Model of Village Agropastoralism in Eastern Spain. In Least Cost Analysis of Social Landscapes: Archaeological Case Studies for Beginners and Experts Alike, edited by Devin White and Sarah Surface-Evans. Manuscript submitted to University of Utah Press, Salt Lake City, January 2011.

Ullah, Isaac I.
2011 A GIS method for assessing the zone of human-environmental impact around archaeological sites: a test case from the Late Neolithic of Wadi Ziqlâb, Jordan. Journal of Archaeological Science 38(3): 623-632.

Barton, C. Michael, Isaac I. Ullah, and Sean M. Bergin
2010 Land use, water and Mediterranean landscapes: modelling long-term dynamics of complex socio-ecological systems. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 368(1931): 5275 -5297.

Barton, C. Michael, Isaac I. Ullah, and Helena Mitasova
2010 Computational modeling and Neolithic socioecological dynamics: A case study from Southwest Asia. American Antiquity 75(2): 364-386.

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More information about the MedLand project can be found online at **ttp://medland.asu.edu** h