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The Agricultural Terraces Model (AgrTerrModel): Exploring Human-Environment Interactions in Terraced Landscapes

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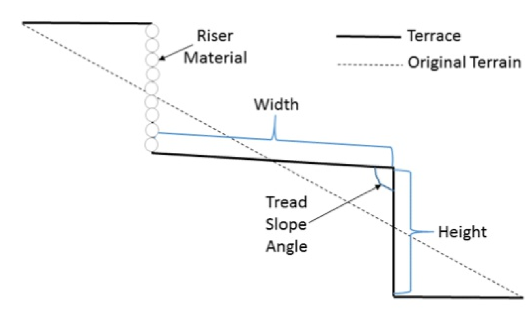
1. Introduction

Agricultural terraces are anthropogenic landforms that have been constructed for centuries in many parts of the world. Despite their widespread distribution and well-known reduction of sediment transport, terraces have rarely been implemented in LEMs (cf. Lesschen et al. 2009). Recent research on agricultural terraces has revealed that terrace abandonment often increases soil erosion and landscape degradation, reversing landscape evolution patterns modified by terrace construction (Tarolli et al. 2014; Arnáez et al. 2015). We present the Agricultural Terraces Model (AgrTerrModel), which is a coupled LEM-ABM system for analyzing long-term human-environment interactions in terraced landscapes.

Agricultural terraces in olive grove, Messenia, Greece.

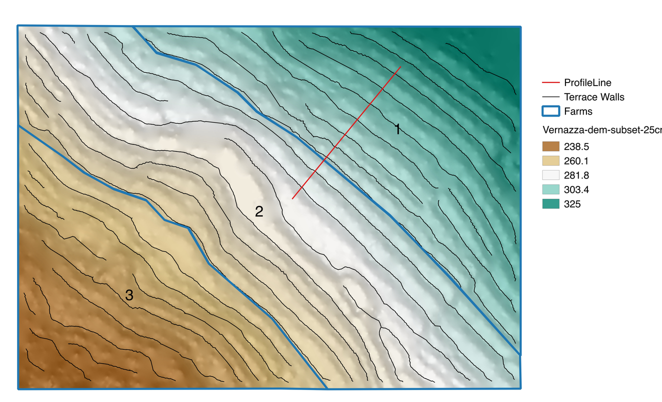


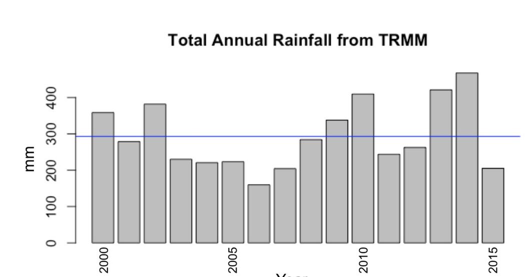
Landscape modification through terrace construction.

2. Study Area

Vernazza catchment, Liguria, Italy

The Vernazza catchment, located in Liguria, Italy, is part of the Cinque Terre World Heritage Site. The hillslopes have been terraced for around 1000 years, although some land has been abandoned in the past century. The area has a Mediterranean climate with seasonal variations in precipitation.

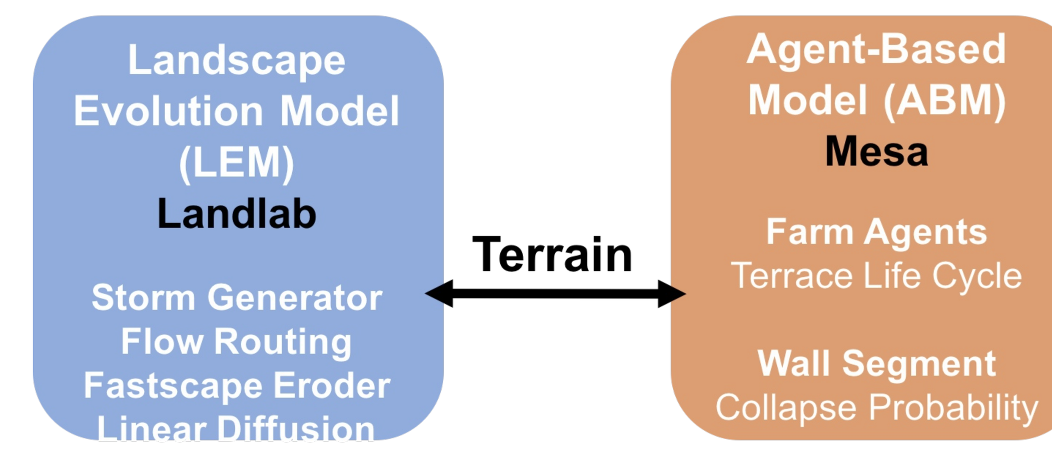




Mean interstorm duration: 101.733384 hr
Mean storm duration: 4.3035252 hr
Mean storm depth: 11.2 mm

3. AgrTerrModel

The LEM component is implemented using the Landlab library and features adjustments to governing landscape evolution equations to reflect changes to geomorphic processes after terrace construction, such as the impact of stone terrace walls that block sediment movement downslope. The ABM component is implemented using the Mesa ABM framework and includes mechanisms for terrace wall collapse and rebuilding.



Stream Power Equation:

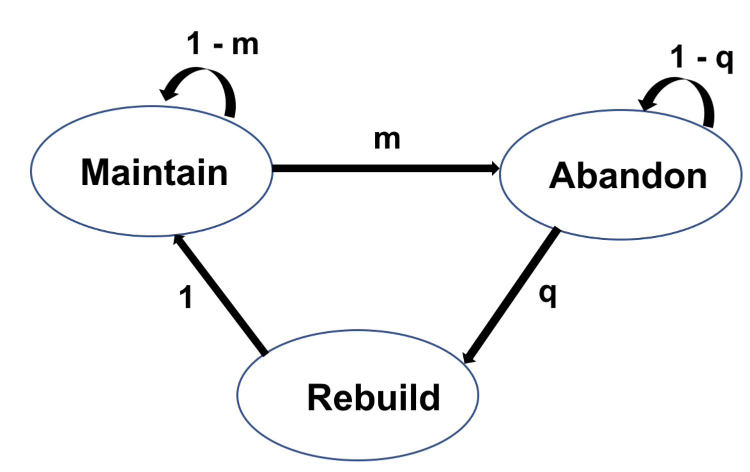
$$E = K_{sp} \times (\text{rainfall\_intensity} \times A)^m \times S^n - \text{threshold\_sp}$$

E is amount of sediment eroded, K_sp is soil erodibility, A is contributing area, S is slope, m and n are coefficients on slope and area.

Linear Diffusion Equation:

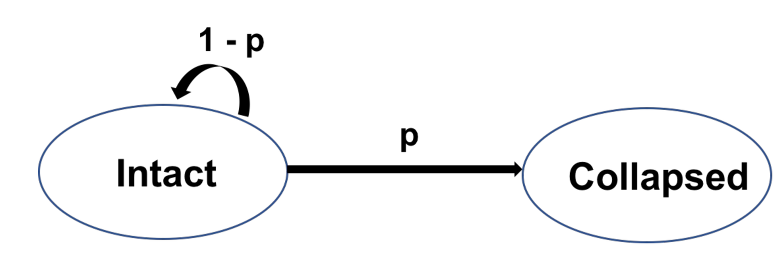
$$q = kd \times \partial z / \partial x$$

q is amount of sediment transported by gravity, kd is the diffusion transport coefficient, z is elevation and x is horizontal distance.



Markov Chain State Diagram for Terrace Life Cycle Stage

m is probability of abandonment
q is probability of rebuilding



Markov Chain State Diagram for Probability of Wall Segment Collapse
$F(t) \approx 1 - (1-p)^t$
Where p is the probability of collapse and t is time since wall segment was last maintained.

p = 0.00959 calculated from Agnoletti Et Al 2011 for Italy with F(t) = 0.4 and t = 53 years

4. Methods

Scenarios:

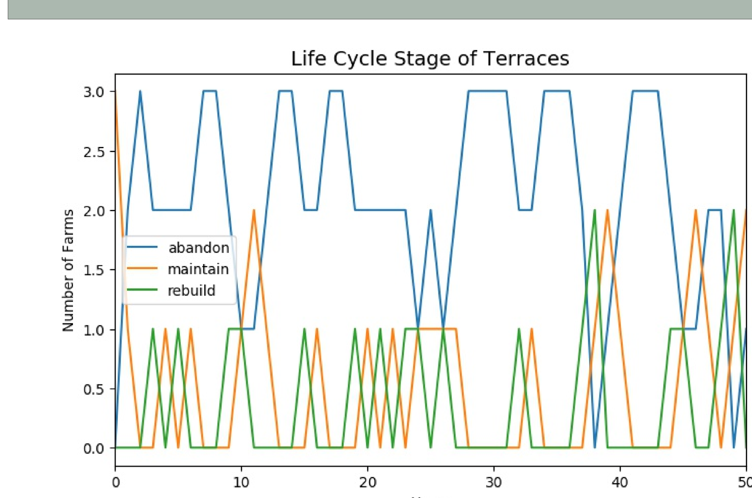
1. LEM-only, no walls
2. LEM-only, walls
3. LEM-ABM

50 simulations per scenario.

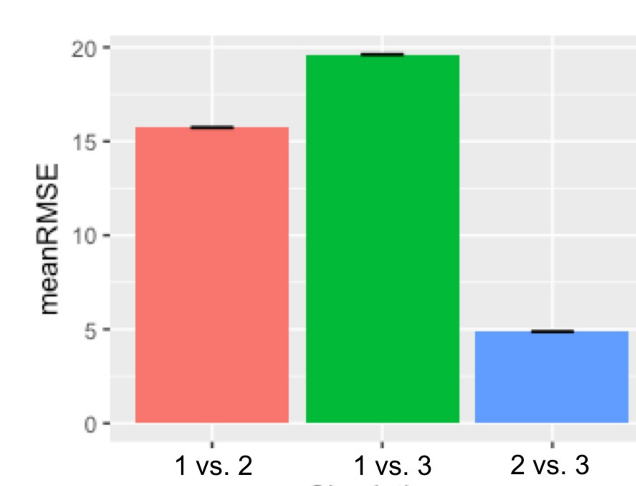
Simulation time extent is 500 years.

Parameter	Value
Mean Interstorm Duration	0.0116134 (year)
Mean Storm Duration	0.00049127 (year)
Mean Storm Depth	0.0112 (m)
K_sp: default	0.3
K_sp: wall	0.1
kd: default	0.5
kd: wall	0.02
m (abandonment)	0.8
q (rebuilding)	0.2
p (wall segment collapse)	0.00959

5. Results

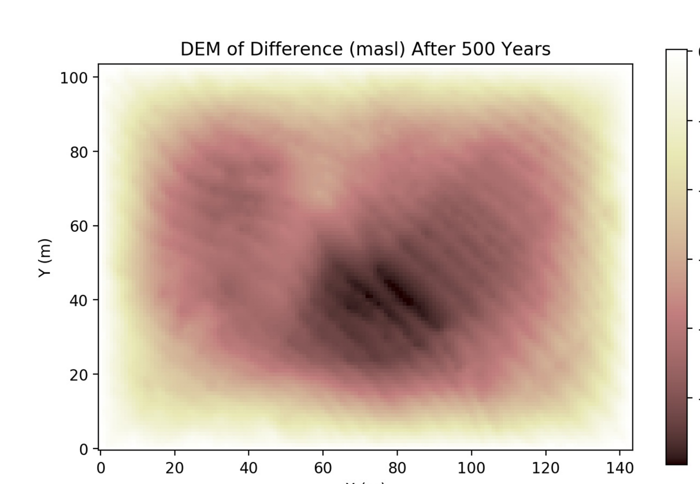


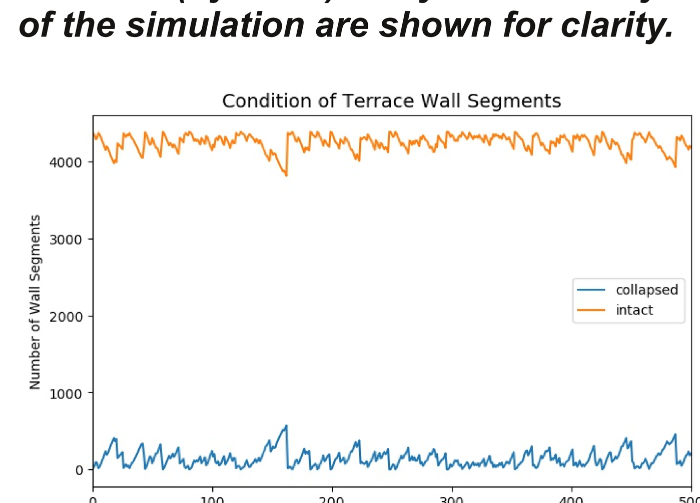
Example plot of Life Cycle Stage of Terraces (by Farm). Only the first 50 years of the simulation are shown for clarity.



Comparison of DEM of Difference between scenarios.

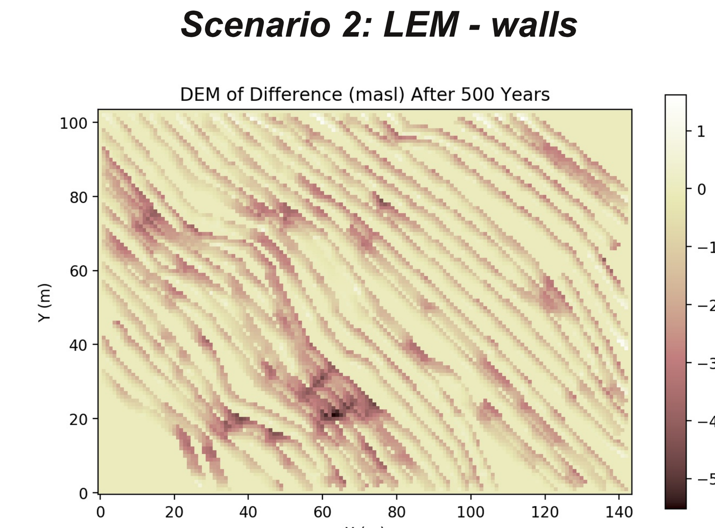
Scenario 1: LEM - no walls



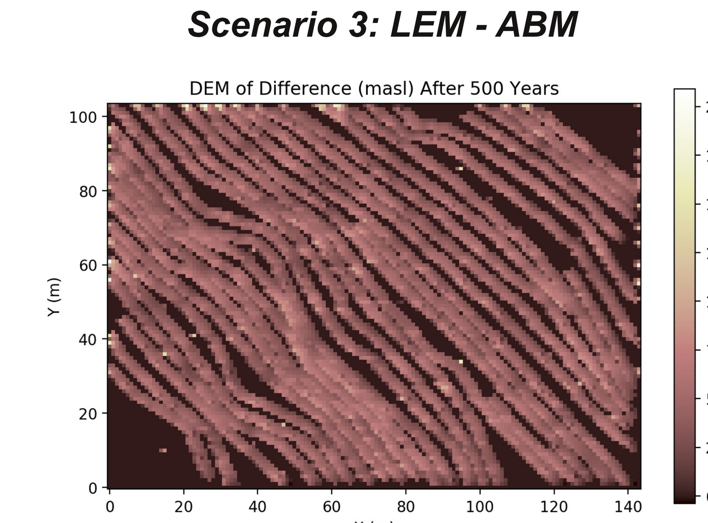


Example plot of Terrace Wall Segments Condition.

Scenario 2: LEM - walls



Scenario 3: LEM - ABM



6. Discussion

Incorporation of terrace walls in the model changes the quantity and spatial patterning of sediment transported. When modeling terraced landscapes, terrace wall locations should be included. And if the simulations cover long periods when terraces would have been abandoned and possibly rebuilt, the coupled LEM-ABM simulates wall collapses and rebuilding.

Future additions to the model include Farm agent decision-making based on environmental conditions (esp. precipitation) and erosion rates. Other issues, such as the role of seasonal precipitation will also be analyzed.

7. Acknowledgements

We acknowledge computing time on the CU-CSDMS High-Performance Computing Cluster.

TRMM precipitation data was obtained via Google Earth Engine script written by James Coll.

8. References

Landlab: https://github.com/landlab
Mesa: https://github.com/projectmesa

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