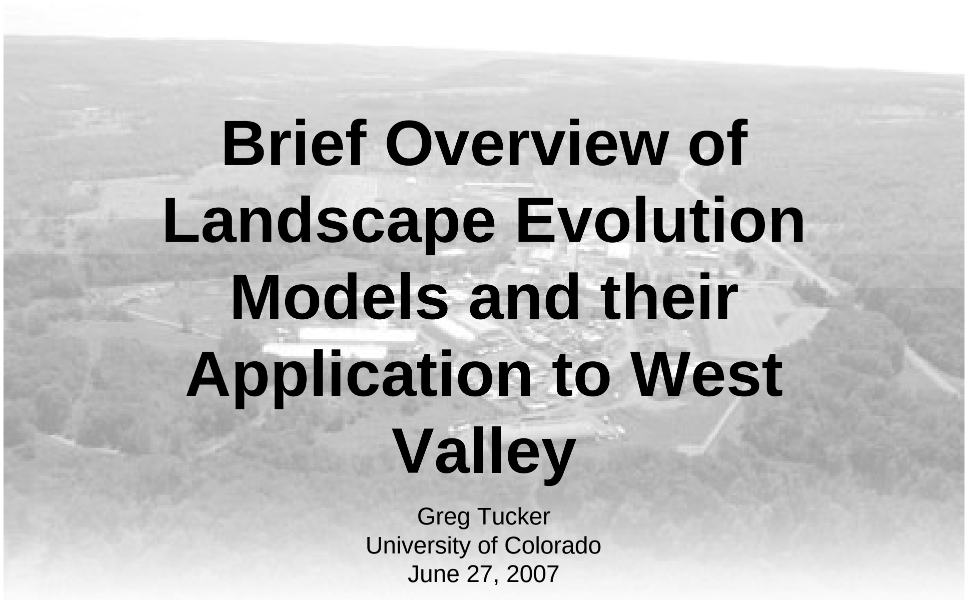

Brief Overview of Landscape Evolution Models and their Application to West Valley

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June 27, 2007

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Outline

1. Overview of landscape evolution models (LEMs)
2. Perspectives on erosion modeling at West Valley
3. Summary

Brief History

- 1940s and 50s: birth of quantitative landform analysis
- 1960s: USLE introduced. First geomorphic transport functions. *Example:* $q_s = D\,S$
- 1970s: first computer models of 3D landform evolution
- 1990s: modern generation of models

Some Current Models

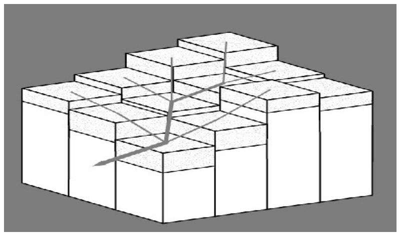
Table 1: Partial list of numerical landscape evolution models published between 1991 and 2005

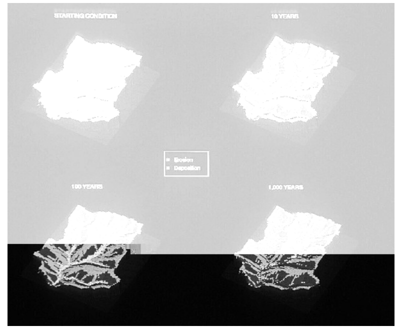
Model	Example reference[1]	Notes
SIBERIA	Willgoose et al. (1991)	Transport-limited; introduces channel activator function
DRAINAL	Beaumont et al. (1992)	Fluvial transport based on "undercapacity" concept
GILBERT	Chase (1992)	Cellular automaton
DELIM	Howard (1994)	Detachment-limited
GOLEM	Tucker and Slingerland (1994)	Introduces algorithms for regolith generation and landsliding
CASCADE	Braun and Sambridge (1997)	Introduces irregular discretization method
CAESAR	Coulthard et al. (1997)	Cellular automaton algorithm for 2D flow field
ZSCAPE	Densmore et al. (1998)	Introduces stochastic bedrock landsliding algorithm
CHILD	Tucker and Bras (2000)	Introduces stochastic treatment of rainfall and runoff
€ROS	Crave and Davy (2001)	Modified precipiton algorithm

Notes:
1. First reference in mainstream literature.

(source: Tucker and Hancock, in review)

Ingredients of a LEM





- Grid of cells
- Hydrology model
- Geomorphic transport functions for:
  - Water-driven sediment transport processes
  - Gravity-driven transport processes (hillslopes)
  - Other processes (e.g., weathering, vegetation)
- Initial and boundary conditions

Example of a Landscape Evolution Model

(quicktime movie)

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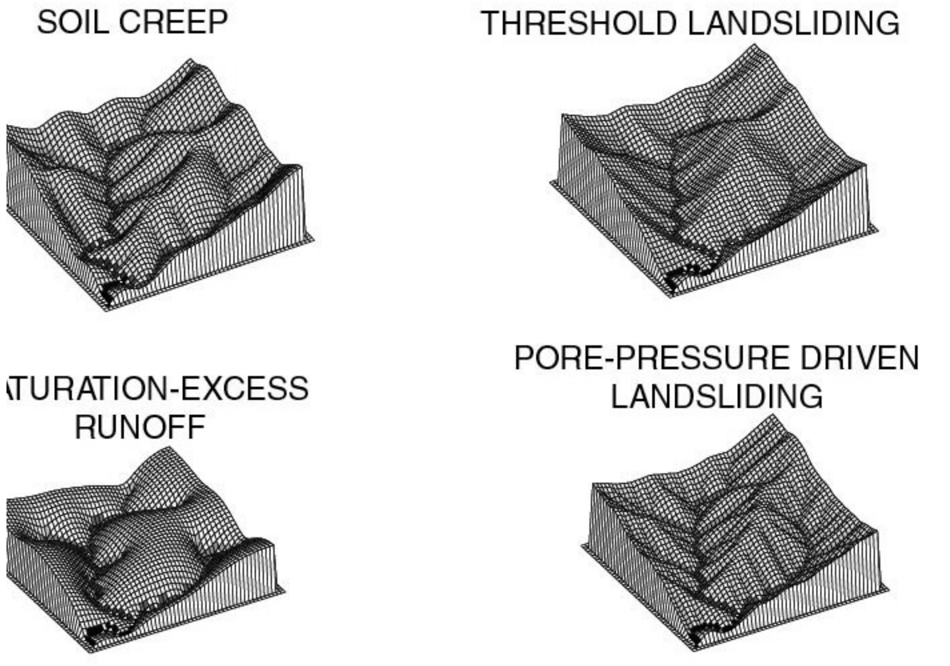
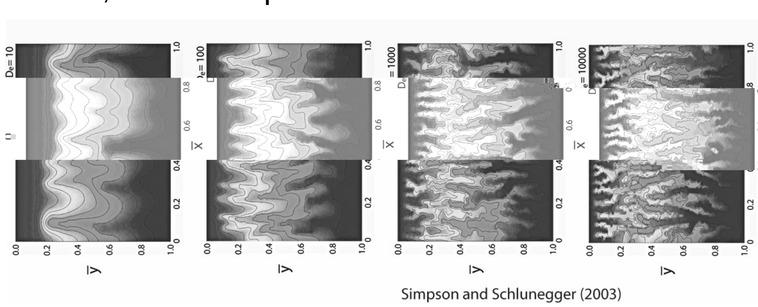


Smooth and rough landscapes

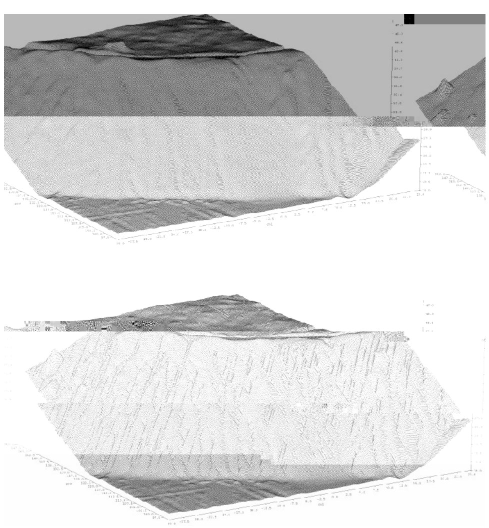
- Roughening: growth of rills and gullies
  - Less vegetation, more runoff, more erodible soils
- Smoothing: soil creep
  - Rapid soil mixing by plants and animals, ice growth in soil, and other processes



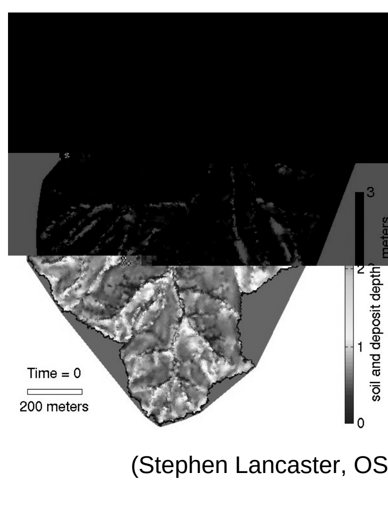
Applications of Landscape Evolution Models

- Better understanding of surface processes and dynamics
- Design and decision-making for mine spoil engineering and reclamation
- Gully erosion analysis to support land management
- Fate and transport of heavy metals in sediments
- Sediment flux and storage in forested mountain drainage basins

Two examples



(Hancock et al., 2006)



(Stephen Lancaster, OSU)

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Testing and Calibration

- Measured water and sediment yield
- Laboratory scale models
- Rapid landforms
- Natural experiments
- Field and lab tests of individual components (for example, soil creep)

Buttermilk Creek

- Evolution from reasonably well known initial condition following last glacial retreat
- Similar time scale to 10,000-year forecast window
- Sources of uncertainty include boundary conditions (past and future climate), initial conditions, materials, and constitutive laws

Perspectives on LEM application at West Valley

- *"…SIBERIA predictions are so vastly different from the current topography, that … results should be rejected."*

- Excessive smoothness reflects choice of very large soil creep coefficient
- Recommendation: use nonlinear slope transport model to better capture rapid mass movement on steep slopes

Perspectives on LEM application at West Valley

- *"… core issue of whether there is any defensible technical basis for conducting quantitative long-term erosion predictions with a certainty that would allow these predictions to be used in a License Termination Rule (LTR) compliance demonstration."*
- Ability of LEMs to model long-term landscape development can be tested by running forward-in-time simulations from post-glacial topography

How climate enters landscape evolution models

- Rainfall and runoff
- Soil creep rate
- Other factors (bedrock weathering, vegetation cover effects)

Perspectives on LEM application at West Valley

- *"… model does not change properties as the stream channels reach elevations where they would intersect different geological materials."*
- CHILD has this capability
- To some extent, the importance of this issue will be tested by paleo-erosion modeling
- Seek to understand simple models first

Summary

- A LEM applies transport functions that iteratively shape a gridded representation of topography
- History of landscape evolution models dates back to 1960s (and conceptually to late 19th century)
- LEMs are being used to support environmental decision making in a variety of contexts
- Confirmation and testing derives from flux measurements, scale models, rapid landforms, and natural experiments
- Buttermilk Creek is a type of natural experiment; comparing predicted and observed post-glacial landform evolution might help reduce uncertainty