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Geodynamic processes in the Himalayas. Inverse calibration of Remote Sensing data by in-situ determination, numerical- and analog modelling

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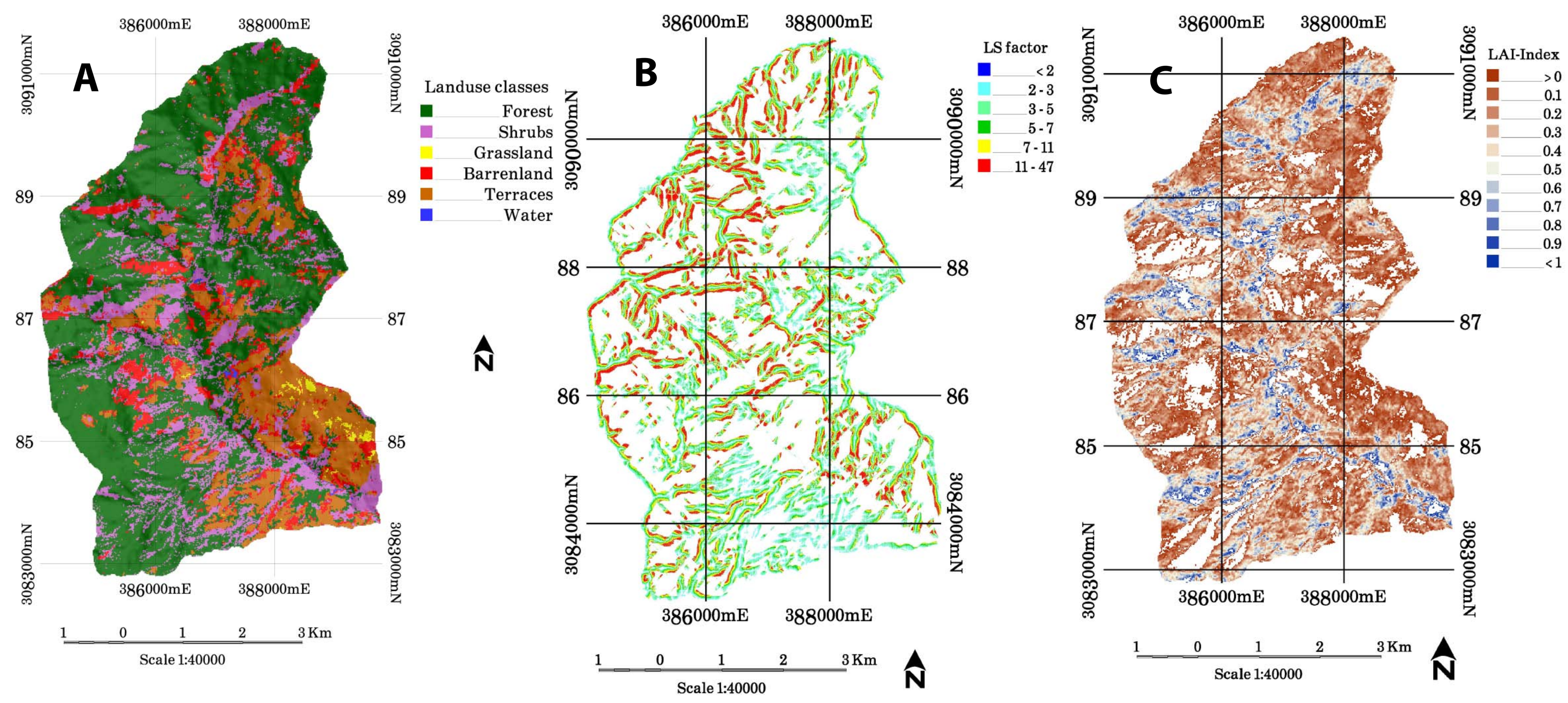
Abstract

Extreme and hardly accessible terrain in the High Himalayas make field studies on a large scale impossible. Yet, an integrative approach of several remote sensing techniques in combination with field studies, task oriented experimental simulation and numeric modelling provides the necessary tools to understand the coupling between climate, landscape, erosion and tectonic processes. Climate, tectonic uplift, erosion and landscape morphology are key issues for the global understanding of environmental processes. New remote sensing technologies have the capability of measuring physical parameters, such as precipitation, landuse, vegetation coverage, soil moisture and tectonic uplift within a wide area and with a high spatial resolution. Integrated experimental simulations can provide insights on relationships between erosional processes and landscape morphologies and on landscape dynamics related to climate and tectonics. These information can be used to validate and calibrate numerical models, that are mainly based on intuitive assumptions concerning geomorphological processes. Together, numerical and experimental modellings provide complementary data to interpret natural data acquired through remote sensing techniques and to understand erosional processes in the Himalayas.

Remote Sensing Approach



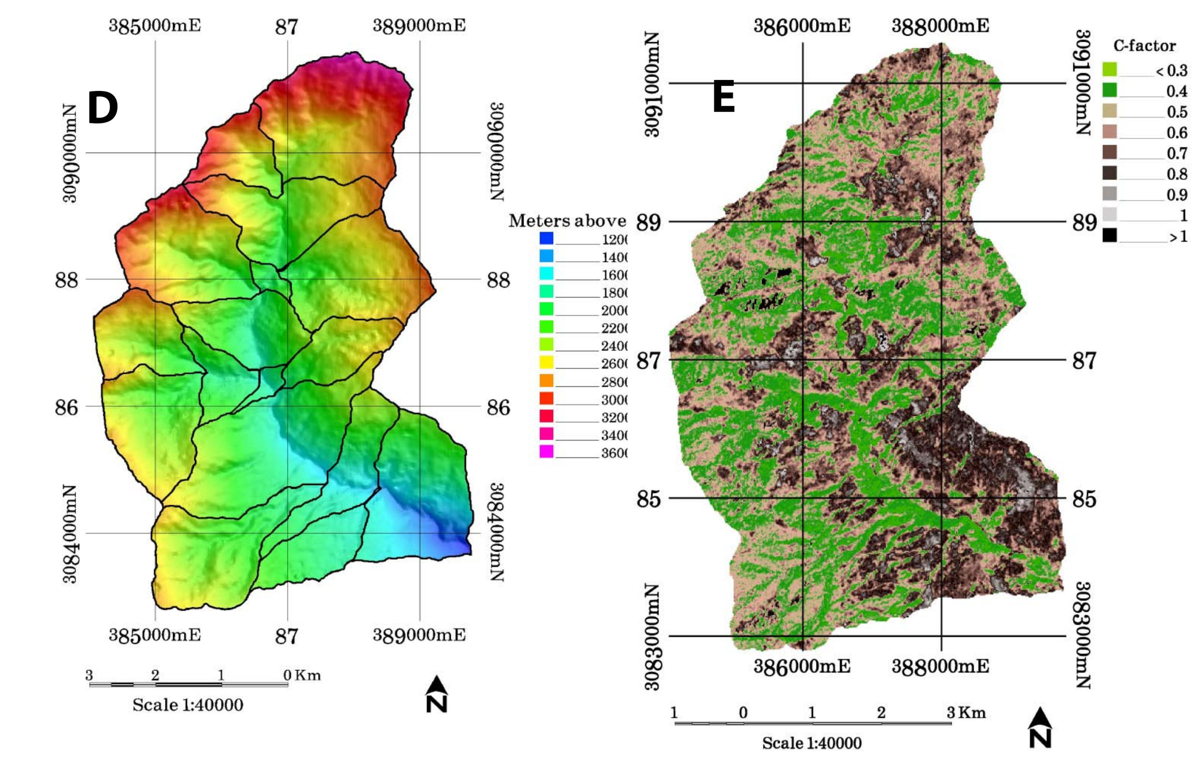


Figure 2: Examples for parameter modelling with remote sensing techniques, from a small catchment in the Himalayas: A) Landuse classification with SVM, B) Slope length factor LS, C) Vegetation cover from NDVI, D) DEM 5m resolution, E) Leave area index LAI

E.g. using a modified RUSLE "Revised Universal Soil Loss Equation" [Renard et al., 1994]

$$A = R * K * L * S * C * P \quad \textbf{(Eq. 1)}$$

- **R: rainfall erosivity** ⟶ **TRMM- Data, Tropical Rainfall Measurement Mission**
- **K: soil erodibility** ⟶ **Nonlinear classification analysis of optical Remote Sensing data for soil type mapping**
- **S: slope steepness** ⟶ **High resolution DEM, TerraSAR-X data**
- **C: vegetation cover** ⟶ **Band ratio operation (LAI etc.) of optical Remote Sensing data**
- **P: conservation practices** ⟶ **Changes in landuse, e.g. Terrassing from optical image time series**

A: computed spatial and temporal average soil loss per unit and year

Ground Truthing

(1) Training- and test sites will be measured in the field with GPS.
(2) Sediment load and discharge volumes of rivers from local authorities.
(3) High resolution testsite data from the PARDYP program (figure 1).
(4) Cosmogenic nuclides (e.g. 10Be and 26Al) [Von Blanckenburg, 2005].

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Area of Interest

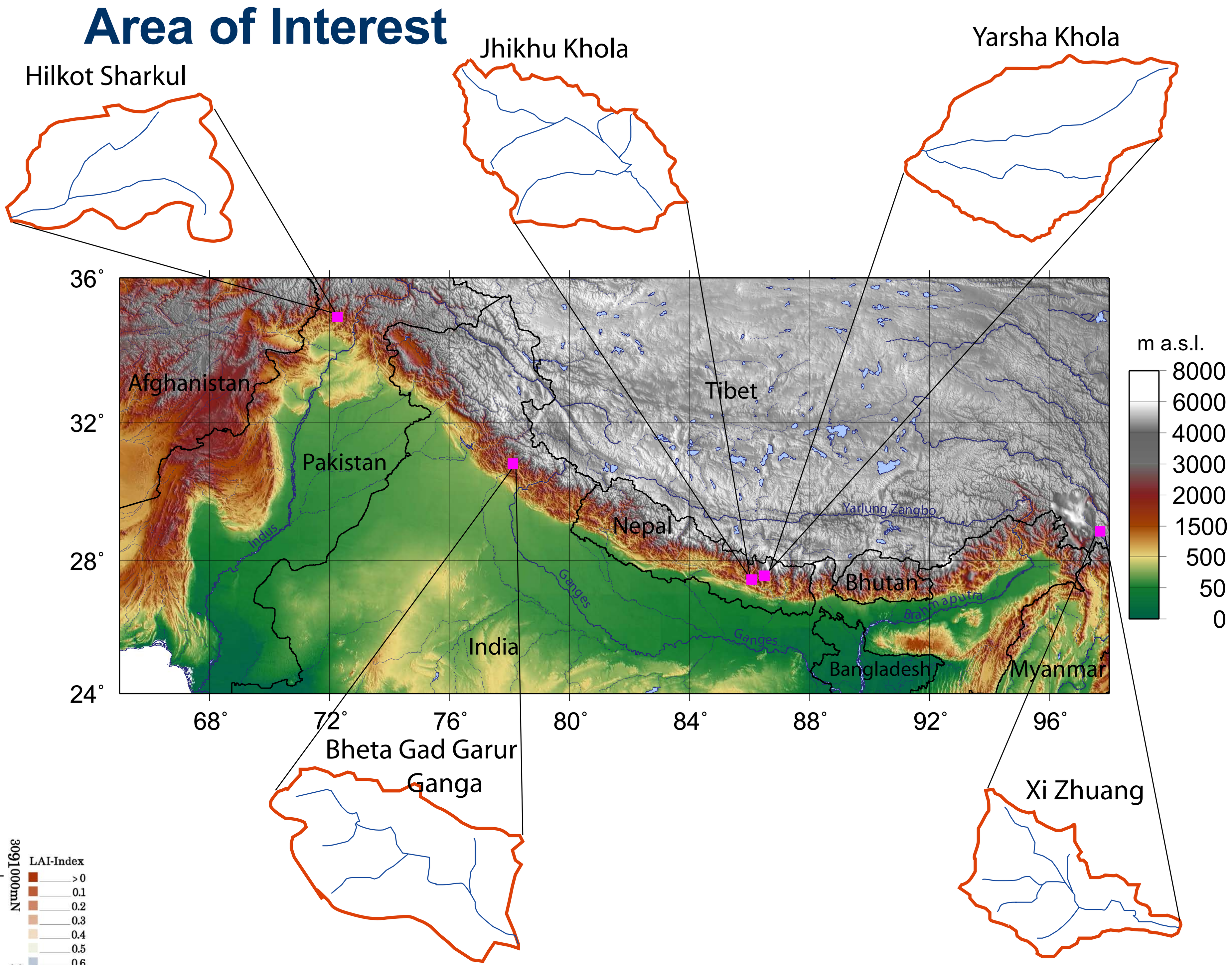
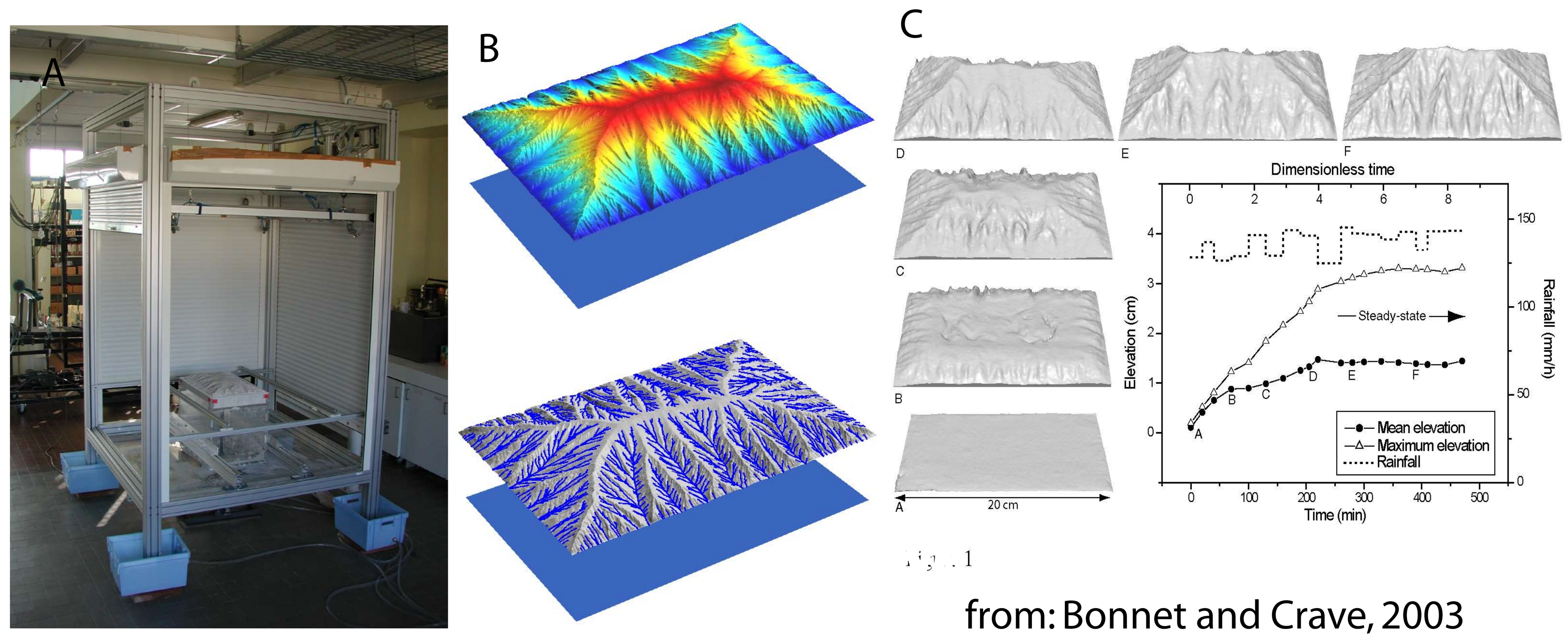


Figure 1: **Overview of the study area with country boundaries and the shaded relief from GTOPO30 data, Red squares: PARTYP watershed where detailed field data over the last 5 to 10 years exists**

The whole Himalayan range is still highly active, rising every year approximately 5-10 mm [Lave and Avouac, 2001]. The high altitude differences on a relative short distance and the rugged terrain are responsible for a diverse climatic mosaic. The People and Resources Dynamics Project (PARDYP) in mountain catchment's of the Hindu Kush- Himalayas maintains five target watersheds to study the environmental processes. The five watersheds are situated in the four countries: Parkistan, China, India and Nepal (figure 1). Within this program elaborate erosion studies on the single landuse classes have been carried out.

Experimental and numerical simulation

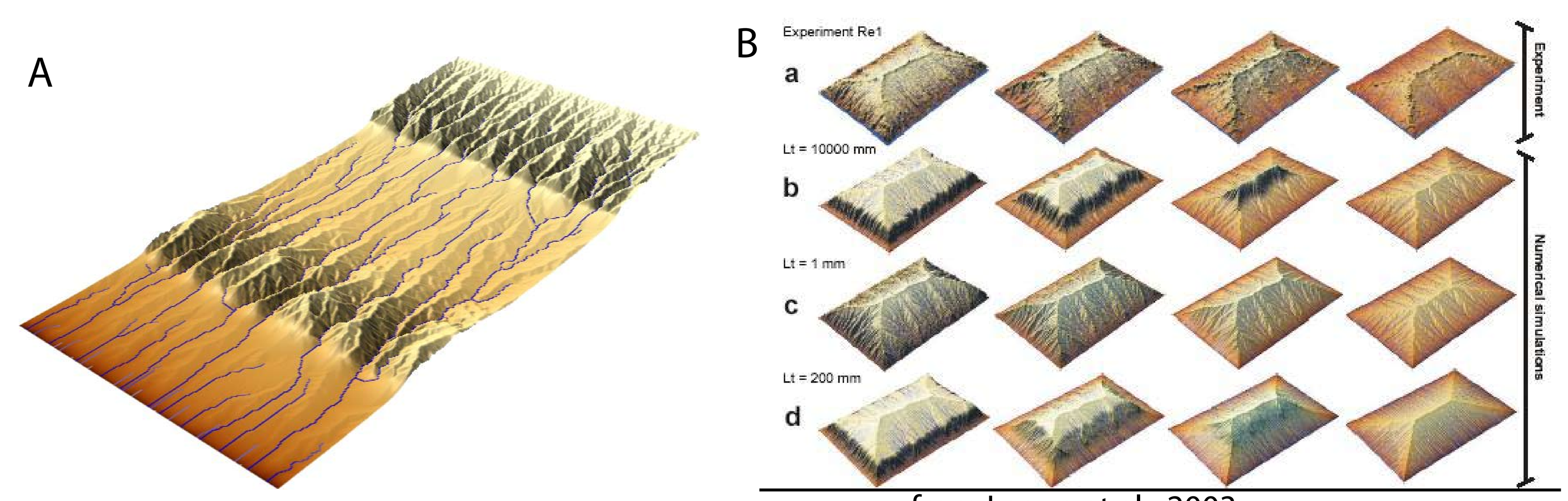


from: Bonnet and Crave, 2003

Figure 3: **Experimental simulation of geodynamic processes: A) experimental device "rainfall simulator" (also called "fog box"), B high-resolution DEM's (0.5 mm) relive and drainage network, C evolution of mean and maximum elevation**

To test the evolution of landscapes under:

1. **Varying rainfall intensity**
2. **Varying precipitation variability**
3. **Conservable impact of vegetation cover**
4. **Constant and varying uplift motion**



from Lague et al., 2003

Figure 4: **Numerical simulation of geodynamic processes: A) numerical simulation of landscape evolution and the deployment of two tectonic boundaries. B) DEM of numerical and experimental produced landscapes; a) experimental produced reference land scape, b-d) numerical simulated landscapes with different Sediment Transport Length (Lt) [Lague et al., 2003]**

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