SEMI-DETERMINISTIC ESTIMATION OF EROSION WITH REMOTE SENSING DATA

Mathias Leidig and Richard Gloaguen

TU Bergakademie Freiberg, Remote Sensing Group, Institute of Geology
Bernhard-v.-Cotta Str. 2, 09599 Freiberg, Germany
Corresponding author email: mathias.leidig@gmail.com

1. INTRODUCTION

Earth's changing surface reflects a dynamic linkage between various internal and surface processes. The aim of this ongoing project is to quantify erosion based on morphology. Aiming at this we focus on precipitation as an important climate factor in a tectonically and climatologically very active area. As a consequence of good results in previous works, using both: first, the Revised Universal Soil Loss Equation (RUSLE) with its ability to operate on various - from catchment to area - scales [1]. That approach delivers a good idea about soil erosion, especially when focusing at the sensitivity of soil loss, but not taking big mass transports like in landslides into account. Furthermore, there is the issue of considering support practices of erosion when calculating with RUSLE for a large area. Second, there is the river profile analysis for various streams individually. This attempt is detachment limited and will not give an accurate idea about what is going on beyond the considered catchment. We want to combine both attempts in one equation to use the strengths of each approach and improve our previous results for a very large study area but with fine-resolution. This study should make a contribution to the understanding of the correlation between climatic factors, tectonics, soil erosion and river incision. In contrast to former researches we want to create a comprehensive model describing all these relationships only on the basis of remote sensing data. Our model is not limited to the presented study area but applicable anywhere where erosion takes place.

2. STUDY AREA

Our study area is located between 70^o E to 100^o E and 25^o N to 40^o N including the Himalayas, the main part of the Quinghai Tibet Plateau, Nepal, Bhutan, the Northern parts of India, Pakistan and Myanmar as well as a part of Pamirs. Tibet and the Himalayas are among a tectonically very active area, where faulting and rock uplift are responsible for a rugged topography and a worldwide unique relief. The investigation area covers about 5.25 million km^2. The Tibet Plateau and Pamirs have an average altitude of 4500 meters above sea level. The observed region is characterized by ongoing tectonism and the creation of huge relief contrasts. Relief reflects the interplay between tectonics and erosion. The coupling of crustal deformation and erosion results in the kinematics of mountain building. Erosion influences tectonic processes by controlling boundary conditions at the Earth's surface through denudation and deposition. Consequently erosion is very closely related to climate and with this to precipitation, especially in a region where monsoon is active. Soil erosion sensitivity could be defined as a response of the regional environment to changes of impact factors like precipitation, soil texture, topography, vegetation and cultivation management. The complex interrelationship between all the components (natural factors and human activities), the large area with its unique geomorphological features and the lack of available long term data sets are an outstanding challenge for the investigation of the Tibet Plateau and the surrounding area. For this purpose we need and apply modern remote sensing methods and optimized models. Furthermore, this area is a source of many rivers. The entire area has a major influence on the environment and climate - not only of the Tibet Plateau and the region but also of Asia and even on a global scale.

3. METHODS AND DATA

The main purpose of this project is to estimate and calculate incision and the related erosion, based on interactions of the morphology with precipitation in a tectonically and climatologically very active area. Compared to former attempts with GIS and ground based data, this study focuses on an area where hardly any long term precipitation data is available and where precipitation differs a lot due to the relief. The whole study area is strongly influenced by monsoon, which is highly variable in its time scale starting from seasonal (monsoon vs. non-monsoon) to yearly, decadal, millennial and finishing in geological variations. The understanding of the spatial structure in precipitation regime shape (seasonal variability) and size (magnitude) may help to understand and estimate the amount of incision and related erosion in extreme physical environments where climatological patterns are complex and consequently hardly known. Precipitation displays small-scale variability that requires frequent, closely spaced observations for an adequate representation [2]. To access the precipitation, we depend on a variety of satellites to estimate precipitation on a global basis. Data sets based on the Tropical Rainfall Measuring Mission (TRMM), which provide a calibration-based scheme for combining precipitation estimates from multiple satellites at fine scales (0.25^ox0.25^o 3-hourly), seem to fulfill all these requirements [2]. We use these information along with RUSLE and a power law function describing erosion through river incision (equation 1). With that we will have a tool to control, validate and compare erosion rates received by applying results from calculations done only by means of remote sensing data. A detachment-limited incision into bedrock is often modeled as a power-law function for the river profile evolution [3]. River Profile evolution can be expressed as:

$$E = KA^mS^n \tag{1}$$

where E is the erosion rate (relative to a fixed base level), A is the (upstream) drainage area, S the local channel gradient, K a dimensional coefficient (so called erodibility) that represents the channel bed's resistance to lowering. The exponents m and n are constants, depending on local parameters. Furthermore we use data sets obtained e.g. from the Moderate-resolution Imaging Spectroradiometer (MODIS) and using SRTM (Shuttle Radar Topography Mission) data. While the incision model is detachment limited, RUSLE has the problem of verification and acquisition of all required data. This issue appears especially when considering the support practices factor. Due to that RUSLE lags in accuracy of the calculations in high mountain regions, far away from ideal erosion plots of flat farming land in the United States. On the other hand our modified RUSLE approach performs well in the field of qualitative approaches to access sensitivity to soil erosion [1]. Beside that river incision performs well on small (catchment) scales and with known uplift rates [4]. Our final equation, combining our experiences from applying RUSLE and river profile analysis individually, can be written as:

$$E = A \cdot K \cdot S^2 \cdot \frac{R}{R_{max}} \cdot \frac{C}{C_{max}}, \tag{2}$$

where E the erosion, R is the precipitation erosivity in the observed periode of time (3-hourly, daily, monthly,...) and R_{max} equals the maximal local erosivity. Parameter C is the crop-management factor as described in RUSLE. All the parameters required for our model are obtained only by remote sensing.

4. CONCLUSION

While factors for relief change include weathering, erosion, and mass transfer (e.g. landslides or floods), these factors themselves are governed by several complex geological and climatological feedbacks on different spatial and temporal scales. The efficiency of the underlying processes, their variability, rates, timescales and interaction can only be validated by innovative research that are focused on determining the thresholds for climatic and tectonic forces. A hardly accessible study area of more than 5.25 million km^2 can only be examined sufficiently by applying remote sensing methods. The results from previous studies using equations derived from RUSLE are promising but need comparison, revision and validation. The presented attempt directs towards these aims. It is a step in the direction of combining river profile analysis with RUSLE and other models for a large area with little trustful ground truth data available. While our approach is carried out in Asia, the basic idea can be applied everywhere in the world.

5. REFERENCES

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