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Editorial

Geoinformatics and water-erosion processes

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ABSTRACT

Geomorphologists have commonly published conclusions about soil erosion and water movement based on experimental data obtained at the catchment scale. The underlying assumptions were that there exists little spatial variation in conditions at the hillslope scale (the fundamental unit) and that the catchments are representative of other catchments in the same region. These assumptions are unlikely to be tenable in practice. Indeed, we suggest that there is substantial spatial variation in geomorphological properties even at small distances when observed at fine spatial resolution and that modern geoinformatics approaches can be used to quantify and characterize this variation. This introduction reviews the ten papers that comprise this Special Issue on Studying Water-Erosion Processes with Geoinformatics, drawn from across the geomorphological sciences. The water erosion processes studied in these papers include sediment transport, fluvial processes, slope denudation, landsliding, bank erosion and bank line migration. The findings suggest that innovative measurement and modeling approaches such as GPS measurements, geostatistics, image processing techniques, and physically-based models deliver new data with which to study water erosion processes. These findings involve domains that are associated with fundamental aspects of geomorphology. Hence, there are strong grounds for claiming that geoinformatics can contribute to greater understanding of water erosion processes through characterization of space–time dynamics. We suggest that geomorphologists need to use more geoinformatics to collect more data relating to the outcomes of water erosion processes, to seek out and apply innovative processing methods and, finally, model the data to provide greater understanding of processes and to forecast and explore future scenarios.

1. Introduction

Water erosion represents a large threat worldwide, potentially diminishing ecological functionality and food production capability and causing repetitive damage to built infrastructure (Boardman, 1998; Trimble and Crosson, 2000; Valentin et al., 2005). Factors such as climatic changes, anthropogenic land-use changes and intensification of agro technology may increase the damage caused by water erosion. However, we have yet to fully understand to what extent, where, when and how (Vanmaercke et al., 2011).

The increasing utility of geoinformatics for modeling and mapping Earth surface properties (e.g., detailed terrain data — Wilson, 2012) provides an excellent opportunity to help answer the aforementioned questions by providing high quality data at a wide range of spatial resolutions from millimeters to the continental scale. Spatially explicit datasets may increase the representativeness and accuracy of process modeling, increase model parameter space, add process-based model parameters that could not be accounted for before and improve calibration and validation approaches. Furthermore, Church (2010) pointed to enhancing the multi-scale possibilities embedded in computational methods and the ability to explore novel problems for prediction and model confirmation as most important for the emergence of geomorphology as a 'system science'.

The number of research papers in the peer reviewed literature on the use of remote sensing and GIS to study erosion has increased greatly during the last 20 years (Fig. 1). Publications on the use of geoinformatics for erosion modeling reveal that although much progress has been achieved, the potential of geoinformatics has not been fulfilled and several research avenues are still open and awaiting answers. For example, there are questions over the extent to which hyperspectral data can be used to provide maps of soil properties to more accurately predict soil resistance to erosion and how LiDAR data can be used within models of river erosion and deposition. A crucial question is how GIS can be merged into process-based models to create meaningful spatially and temporally explicit modeling of soil erosion in order to explain the formation of geopatterns such as river and gully networks. Another factor that hampers the use of geoinformatics for studying erosion processes is the error that propagates within system layers and increases prediction uncertainty and limits the representation of reality.

The aim of this Special Issue is to demonstrate that geoinformatics has an important role to play, over a wide range of spatial scales, in

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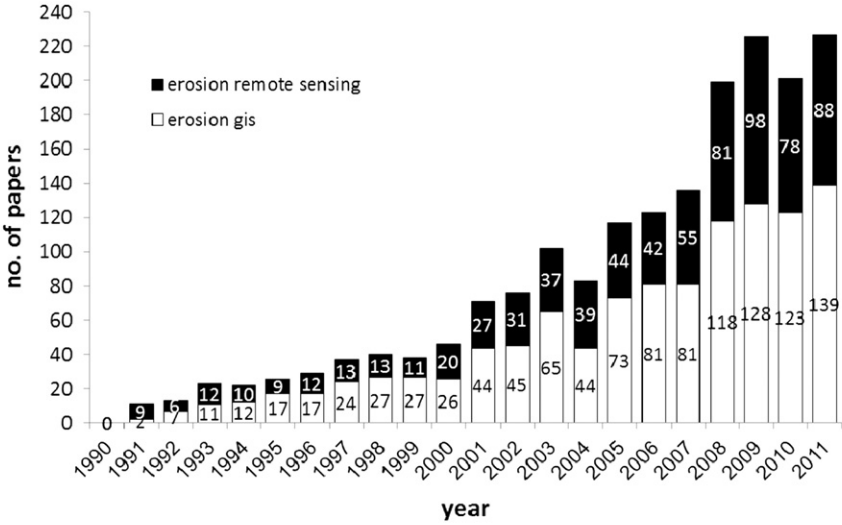

Fig. 1. A plot representing the number of research papers (journal articles only) on erosion and geoinformatics published each year from 1990 to 2011. The plot was created based on a search of the key words "remote sensing and erosion" (black bin) and "GIS and erosion" (white bin) in the ISI Web of Knowledge between the years 1990–2011. The results show a large increase in the number of papers during these 20 years in both fields of geoinformatics.

the study of water erosion. We invited papers that would provide new insights on runoff and erosion processes. Although not all the aforementioned subjects were covered in the Special Issue, it includes representation of a wide variety of approaches and topics within the broad field.

2. Overview of papers

The ten papers in this Special Issue demonstrate the use of geoinformatics tools and methodologies to study the processes at the heart of water and sediment flow over slopes and rivers (Table 1). These processes include sediment transport, fluvial processes, slope denudation, landslides, bank erosion and bank line migration. The research studies gathered in this Special Issue were applied to different parts of the world from France, Italy, Austria and Poland to Bangladesh, Australia, the US and even a study applied to the Martian environment. Based on the geoinformatics methods applied, we divided the set of papers into three groups: field measurement, image processing and spatially explicit modeling.

2.1. Field measurement

Devices such as differential GPS are usually applied in the field when the scale of observation (i.e., spatial resolution) is fine, for example, when 3D analysis of soil movement is the target. These studies usually include point measurements in the field that are assigned map coordinates and interpolated or processed using geostatistics or related approaches. As an example from this Special Issue, Wiegand et al. studied shallow landslides in the small-scale structure of a regolith body on an Alpine slope in the Tyrol, Austria. To quantify the 3D characteristics of the regolith body, they used a 3D volumetric lattice model. In addition, the patterns and variation in the penetration resistance were interpolated using the regularized spline with tension method. These analyses allowed description of the surface and bedrock morphology and the detection of discontinuities in the regolith. In addition, they were able to establish a distinct spatial relation between the derived geotechnical parameters and slope failure.

In another example of 3D analysis, Vergari et al. used differential GPS to perform volumetric estimation of eroded material and to calculate the average erosion rate for large timespans. In addition, an analysis of rainfall time-series facilitated evaluation of the role of critical rainfall events on denudation intensity. Their results show that cropland abandonment increased the erosion rate compared with natural areas characterized by similar conditions. The authors found that, after the abandonment of its cropland, the study site evolved in a manner that was driven by intrinsic thresholds to a greater extent than it was affected by climatic changes.

David et al. investigated the influence on flow resistance of flow structure and turbulence in a mountain channel using 3D velocity measurements and geostatistical analysis. The increase in flow resistance at low flows in a plane-bed reach was not fully explained by grain resistance. Therefore, detailed 3D velocity measurements were made to characterize the spatial variability in velocity and turbulence, and potential controls on flow resistance. One plane-bed reach was surveyed over two stages using a combination of a total station, LiDAR, and a SonTek Flowtracker handheld acoustic Doppler velocimeter. LiDAR data were used to capture bank and channel geometry at low flows, whereas the water surface and bed data were collected with the total station at all flows.

Hancock et al. examined soil organic carbon concentration along pasture transects in a catchment located in southern Western Australia. An erosion assessment using ^{137}Cs and also a numerical soil erosion and landscape evolution model found low and comparable erosion rates at the site. The results demonstrate that organic carbon concentration in this specific site is relatively uniform and that a transect scale assessment can provide a measure of hillslope and catchment scale soil organic carbon in this environment.

In the last paper of this group, Tomczyk & Ewertowski applied a new method to quantify short-term dynamics in recreational trails. The trails measured were located in different environments and types of use. The use of high resolution DEM provided by electronic theodolite allowed to assess sediment budget of surface changes. The short-term dynamics were high and several test fields had a predominance of deposition in one period and predominance of soil loss in another. Local geomorphic conditions, morphology of the trail tread and soil properties seemed to be the most important factors contributing to the relief transformation. The authors did not find connection between the number of visitors or type of use and the amount of soil loss or deposition.

2.2. Image processing

Remotely sensed data have been used for water erosion assessment through a variety of approaches as the review paper of Vrieling (2006) illustrates. In this Special Issue, we received contributions on