GULLY EROSION IN SEMI-ARID LANDSCAPES - MONITORING OF PROCESSES AND DEVELOPMENT

Ries, J.B.[1*], Marzolff, I.[2], Seeger, M.[1]

[1]Department of Physical Geography, University of Trier, D-54286 Trier, Germany. *riesj@uni-trier.de
[2]Department of Physical Geography, Johann Wolfgang Goethe University, Altenhöferallee 1, D-60438 Frankfurt am Main, Germany.

1. Introduction

The research project MoGul (Large-scale Monitoring of Gully Erosion in Semi-Arid Landscapes) at Trier and Frankfurt University investigates the various types, development and dependencies of gullies as well as geomorphological processes involved in gullying. The investigations are carried out at different sites following a transect from the semi-arid Ebro Basin in Northeast Spain, via the sub-humid Baza and Guadalentín Basins in Southeast Spain and the arid Drâa Valley in South Morocco to the semi-arid Oudalan in Sahelian Burkina Faso.

Investigations on short-term gully change are mostly realised using field methods for quantification of linear headcut retreat rates. The lack of image resolutions corresponding to the magnitude and dynamics of gully erosion usually prevents the use of remote sensing data, which in contrast to field measurements allow for the rapid and spatially continuous coverage of a site (Marzolff, 1999; Ries and Marzolff, 2003). The objective of this paper is to present an overview of the first results of the MoGul project on gully monitoring which employs large-scale aerial photography taken from remote-controlled platforms (hot air blimp and kites).

2. Methods

The research methods include large-scale aerial photographic surveys, mapping of the regional surroundings and experimental measurements of surface runoff and infiltration capacity, with strong emphasis on monitoring and modelling of gully development with photogrammetry and GIS.

The large-scale aerial photographies were taken with a frequency of between 6 months and 2 years. The resulting high-resolution images (pixel sizes <10 cm) are employed for photogrammetric and GIS analysis in order to quantify gully development with linear, areal and volumetric measures.

The mapping of the surroundings focused on the catchments of the gully-headcuts and described amongst others soil surface characteristics and geomorphodynamic units.

Runoff and erosion data were collected by different experiments within the gully catchments. Infiltration rates were measured by a single ring infiltrometer. Runoff coefficient and erosion rate were determined by plot scale rainfall simulations (Seeger, 2007).

GIS-analysis of the spatial data combined with the experimental point data was performed to characterise the catchments runoff and erosion behaviour.

3. Results

Maximum linear headcut retreat rates for 12 gullies were analysed in order to investigate their relation to patterns of runoff and infiltration behaviour in the gully headcut surroundings.

Table 1. Experimental data on erosion rates (from rainfall simulations, summarised after 30 min experiment) and monitored headcut retreat rates.

Study region	erosion rate [g m^{-2}] min	max	headcut retreat Rmax [m a^{-1}]
Northeast Spain	0.1	94.3	0.07 – 0.50
Southeast Spain	4.5	93.6	0.13 – 0.51
South Morocco	2.7	29.2	0 – 0.31
Burkina Faso	0.0	312.0	3.16 – 9.85

Retreat rates for South Moroccan sites (0-0.31 m a^{-1}) were found to be lower than those obtained for Spanish gullies (0.07-0.51 m a^{-1}); however, by far the highest maximum retreat was observed in the West-African Sahel (3.16-9.85 m a^{-1}) (see Table 1). Infiltration measurements, runoff coefficients and erosion rates show differing ranges but always high variability within the gully catchments (Table 2).

Table 2. Summarised experimental data on infiltration (by single ring infiltrometer) and on runoff behaviour from rainfall experiments.

Study region	I/RS n	inf. rate [mm h^{-1}] min	max	runoff start [min] min	max	runoff coefficient min	max
Northeast Spain	25/48	24	159	00:38	29:30	0.01	0.76
Southeast Spain	10/7	14	60	01:25	06:33	0.44	0.80
South Morocco	8/5	33	67	02:21	06:02	0.16	0.52
Burkina Faso	13/13	16	120	01:00	24:00	0.01	1.00

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Ranges of minimum and maximum values for the soil erosion parameters result in the same ranking of study regions as ranges for maximum linear headcut retreat. This indicates a clear association between runoff behaviour and gully headcut retreat with respect to their spatio-temporal variability.

2D change quantification with detailed maps derived from the large-scale aerial photography provide additional information about the differences in headcut retreat behaviour which cannot be described by linear measures, illustrating the benefits of high-resolution aerial photography for monitoring and understanding gully erosion processes. An example for this quantification technique, the change analysis from Gully Gorom-Gorom, Burkina Faso, is given in Fig. 1.

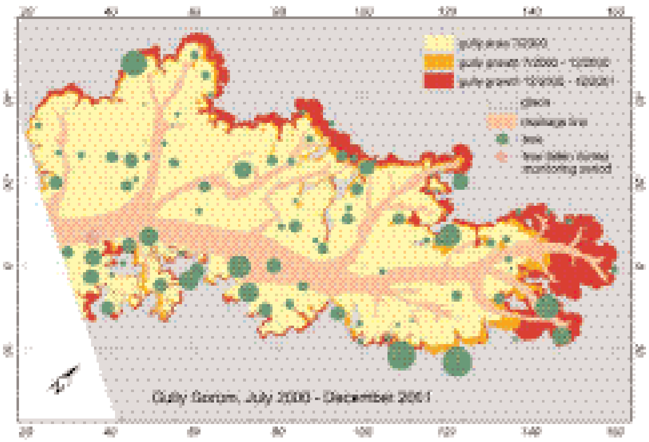

Fig. 1. 2D change analysis of Gully Gorom-Gorom, Burkina Faso, quantifying gully growth during the rainy seasons 2000 and 2001.

4. Conclusions

Like other measurement methods sampling the appearance of a changing object, the technique of large-scale aerial photographic survey also provides snap-shots of an ongoing process, and the development being monitored is described only incompletely depending on the temporal resolution. However, more than other measurement methods, photographic capture of a transient situation allows for retrospective interpretation of the spatial process leading to the actual gully form, and new parameters of interest may be derived years after the survey owing to the spatial continuity and sample density of the camera's "measurements".

Furthermore, the spatially continuous survey of the entire form offers the possibility of distinguishing different zones of activity both at the gully rim and within the gully interior, identifying patterns of erosion and deposition which prove the limited use of linear headcut retreat rates for the assessment of sediment production on a short-term basis.

The combination of this monitoring method with mapping of surface characteristics and the experimental quantification of runoff and erosion processes reveals that the spatial and temporal distribution of runoff generation and sediment production is important for gully development.

References

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