**ASSESSMENT OF GULLY EROSION USING PHOTOGRAMMETRIC TECNIQUES.
A CASE STUDY OF THE UPPER MBULUZI RIVER, SWAZILAND**

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1. Introduction

Swaziland is severely affected by gully erosion contributing to a sediment budget up to 250,000 m^3 y^{-1} (WMS Associates, 1988). This type is more important than inter-rill and rill erosion. Severe gully erosion is mainly in the Middleveld especially on communal land highly populated (43.65 inhabitants km^{-2}) and with high livestock concentrations. Here, the calculated carrying capacities are 0.27 LSU ha^{-1} (Livestock Units) vs. stocking rates 0.87 LSU ha^{-1}.

In general, to assess gully erosion, numerous investigators have made use of aerial photos and GIS to predict the morphometric conditions that favoured gulling (Nachtergaele and Poesen, 1999).

In Swaziland, from 1947 to 1987, the WMS Associates (1988) established gully erosion rates from aerial stereo photos. Subsequently, Mushala et al., 1994 analyzed the gullies distribution and their relationship to lithology and land tenure.

In the present research long terms rates of gully erosion have been measured by aerial photos taken from 1947 to 1996. Particular attention was focused on two dendritic gully systems. One of them is dynamically evolving, whereas the other one is in a static phase (Sidorchuk, 1999). The objectives of this research were to calculate the historical development of the morphology of gully as input data to the *gully erosion model* (Sidorchuk et al., 2001) and to predict hillslope area susceptible to gulling. A High Digital Terrain Models (HDTMs) with 1-m resolution were devised for this purpose.

2. Materials and methods

2.1. Study area

The study site “Fig. 1” is located in Mbothoma, 15 km north of Manzini (26°20’S; 31°23’E). This area is in the Mhalambanyoni river basin (42 km^2) a tributary of the Upper Mbuluzi river, Swaziland. Mbothoma district is a densely populated area with widespread overgrazing. The altitude ranges from 610 to 760 m a.s.l. and the mean slope is about 12%. The lithology consists of a thick granodioritic saprolite layer and a system of amphibolite and serpentite dykes (Hunter et al., 1984; Mushala et al., 1994). The mean annual rainfall ranges from 700 to 1,200 mm. Kiggundu (1986) has calculated a rainfall erosivity (EI_{30}; Wischmeier and Smith, 1978) of 450 KJ mm m^{-2} h^{-1}.

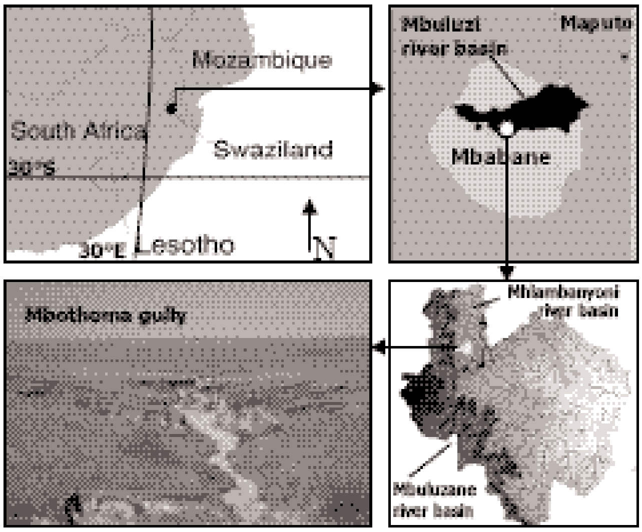

Fig. 1. Location of the study area, Mbothoma, Swaziland.

2.2. DTM analyses

To determine the historical development of gullies, aerial stereo photos were analyzed using a photogrammetric stereoanalyser (Planicomp P33, Carl Zeiss, Jena). To obtain HDTMs “Fig.2”, gully breaklines, borderlines and surface points were digitized from 1940s, 1960s, 1970s, 1980s and 1990s aerial photo series. The georeferencing was done with 1:5,000 scale orthophoto maps.

The stereo photo analysis was repeated using an automatic digital procedure to cover a bigger surface. This approach was taken because gully erosion is often caused by the hydraulic saturation overland flow. These HDTMs were utilized to calculate the flow lines (MDD8-combined flow; Schäuble, 2003) and to predict hillslope areas susceptible to gulling by Topographic Wetness Index (TWI; Moore et al., 1988). For the areas affected by footpaths and tracks the headcut was predicted using a ratio of flow length to flow accumulation (MDD8-combined flow; Schäuble, 2003).

3. Results

A quantitative assessment of gully dynamics was conducted by comparing the elevation of gully mouth for different time steps of aerial photos. The results show that the mean lowering rate of the gully bed was of 0.25 m y^{-1} during the 1960 decade and of 0.93 m y^{-1} for the two

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following decades. Selective erosion affected the river bed from 1960 to 1990. The erosion of granodioritic saprolite was more intensive, with 0.77 m y^{-1}, than the amphibolite dykes with 0.59 m y^{-1}, so new steps of a longitudinal profile were formed. Furthemore, a field observation in the 1999 showed a collapse of an amphibolite dyke, crossing the river downstream the gully study site. It is hypothesized that the Tropical Cyclone named Domoina in January 1984 (242 mm d^{-1} in Mbothoma area) caused the removal of the blocking dikes and consequently the erosional base was lowered instantaneously.

In the 1947 photos the dynamic gully investigated was absent, but the surface was cut by a cattle trail. In 1960 it was about 180 m long and 5 m deep, presently the cutting has continued above the gully head. In the 1998 it was 490 m long and 14 m deep. Hence, in the first 11 years the average growth rate was 2 m y^{-1} along the axial part. It deepened of 0.64 m y^{-1} while it widened of 0.36 m y^{-1}. From 1971 to 1998 the gully length increased of 10 to 11 m y^{-1}; its depth increased at the rate of 0.14 m y^{-1} while the width rate was 0.4 m y^{-1}.

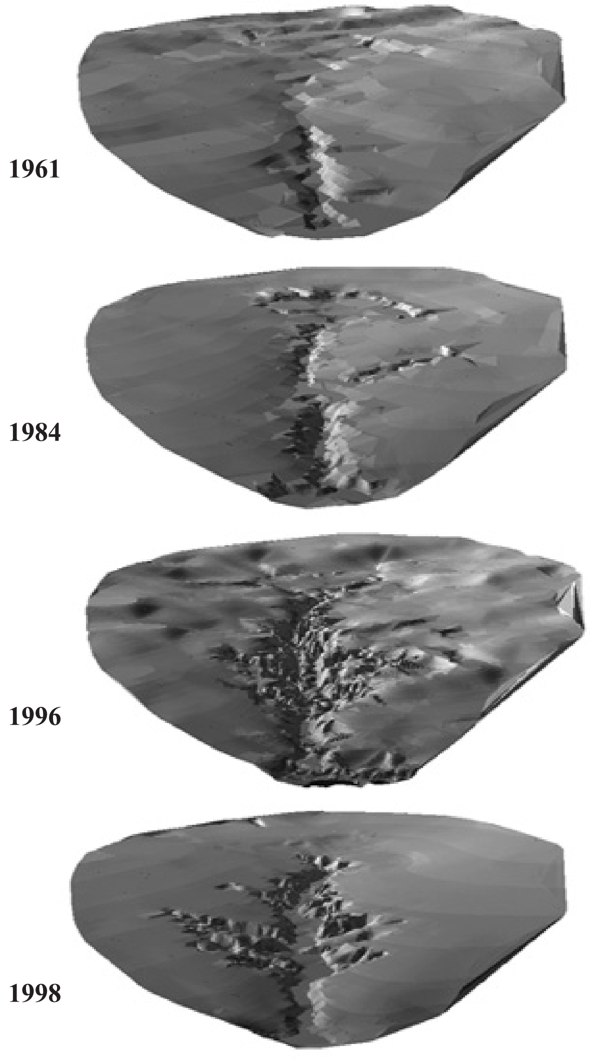

Fig. 2. Time series of the Mbothoma gully (Manzini, Swaziland). High resolution DTMs (1mx1m) derived from photogrammetric stereoanalyser and survey (1998).

Hillslope areas susceptible to gulling were predicted based on TWI and by using a ratio of flow length to flow accumulation. This analysis will be used in a subsequent step to assess the regional potential for gulling.

4. Conclusions

The results show that gully erosion are associated with footpaths and tracks. The mean lowering rate of the gully bed increased from 0.25 m y^{-1} during the 60s to 0.93 m y^{-1} during the next two decades. The bedrock plays a role in affecting the temporary base level. A catastrophic event due to a Tropical Cyclone caused the removal of the dikes with consequent lowering of the stream base level.

This study shows that the use of remote sensing is particularly suitable in area lacking of monitoring structures; it can provide important information on erosion. In this specific research the use of aerial photos and GIS techniques was able to predict the development of the gully pattern and the areas susceptible to gully formation. In addition it was possible to quantify the gully erosion from the time aerial photos were available.

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References

Hunter , D.R., Baker, F., and Millard, H.T., 1984. Geochemical investigation of archean bimodal and dwalidle metamorphic suites, Ancient Gneiss Complex, Swaziland. *Precambrian Res., 24*:131-155.

Kiggundu, L., 1986. Distribution of rainfall erosivity in Swaziland. *Research paper 22*. Kwaluzeni Campus, University of Swaziland.

Moore, I.D., Burch, G.I., and MacKenzie, D.H. 1988. Topographic effects on the distribution of surface soil water and the location of ephemeral gullies. *Transactions of the American Society of Agricultural Engineers*, *31*:1098-1107.

Mushala, H.M., Scholten, T., Felix-Henningsen, P., Morgan, R.C.P., and Rickson, R.J. 1994. Soil erosion and river sedimentation in Swaziland. *Final report to the EU*, Contract number TS2-CT90-0324.

Nachtergaele, J., and Poesen, J., 1999. Assessment of soil loss by ephemeral gully erosion using high-altitude (stereo) aerial photographs. *Earth Surface Processes and Landforms, 24*:693-706.

Shäuble, P., 2003. HydroTool 1.0 for ArcView 3.x. Hydrological analyses with single-flow and multiple-flow algorithms. *http//www.terracs.de*.

Sidorchuk, A. 1999. Dynamic and static models of gully erosion. *Catena*, *37*:401-414.

Sidorchuk, A., Märker, M., Moretti, S., and Rodolfi, G., 2001. Soil erosion in the Mbuluzi river catchment (Swaziland, South Africa). Modelling the dynamic evolution of gullies. *Geografia Fisica e Dinamica Quaternaria, 24:*177-187.

Wishmeier, W.H., and Smith, D.D., 1978. Predicting rainfall erosion losses – a guide to conservation planning. *Agricultural handbook,537*. USDA, Washington DC.

WMS Associates 1988. Gully erosion in Swaziland. *Final report*. Fredericton, N.B., Canada.