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# SOIL EROSION MODELLING IN THE MBULUZI RIVER CATCHMENT (SWAZILAND, SOUTH AFRICA)

## PART II
## SEDIMENT YIELD ANALYSES

**ABSTRACT:** MÄRKER M., DLAMINI D., MATONDO J., RODOLFI G. & SCHULZE R., *Soil Erosion Modelling in the Mbuluzi River Catchment (Swaziland, South Africa). Part II: Sediment Yeld analyses.* (IT ISSN 0391-9838, 2001).

As stated by many authors in the recent past, soil erosion is one of the major environmental problems in Southern Africa and will in future become even more severe owing to population growth and potential climatic changes. This study regards the application of the Universal Soil Loss Equation in the Mbuluzi-river catchment in Swaziland. It has been carried out within the framework of an interdisciplinary EU-funded Project aimed at developing an Integrated Water Resources Management System (IWRMS) for water resources analyses and prognostic scenario planning in semi-arid catchments of southern Africa. In this more general framework two methods of spatial discrimination of erosion processes at catchment scale have been tested. On one hand the Erosion Response Units (ERUs) concept (see Märker & *alii*, 2001) has been used for sediment source area identification and as a distributed modelling structure for the subsequent soil erosion modelling based on the Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978) as well as on gully erosion models (Sidorchuk, 1999). On the other hand, the *ACRU* Agrohydrological Modelling System (Schulze, 1995; Smithers & Schulze, 1995) was used to simulate the erosion dynamics at a catchment scale using a semi-distributed method. This case study from southern Africa shows that the erosion processes active in the catchment can be described only partly with the traditional USLE applications whereas the more detailed distributed modelling structure of the ERU concept is able to deliver more information about the individual erosion processes and their location. Especially the gully erosion processes, which are widely distributed all over Swaziland, can be identified and subsequently modelled in order to estimate the quality and quantity of these erosion processes.

## INTRODUCTION

Soil erosion is one of the major environmental problems in southern Africa and is likely to become severe owing to possible population growth and potential climatic changes. *In situ* damage caused by soil erosion includes the loss of crop production media, reduction of soil productivity as a result of lowered soil fertility, which may indirectly be perceived through decreased harvests. On the other hand, the products of soil erosion, *viz.* sediments, have a bearing on water quality in a river network. Apart from direct impacts such as reservoir sedimentation, the sediments are a storage medium and a catalyst for chemical, physical and biological pollution. Consequently, some aspects of water quality degradation may be viewed as being indirect impacts of soil erosion. These mechanisms may intensify problems associated with water shortage in affected regions such as southern Africa. This creates a need for the identification and adoption of suitable meth-

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*This paper follow in parts the methodological approach regarding the identification of erosion forms and processes based on the Erosion Response Units (ERU) concept published in the last issue of this journal (Märker & alii, 2001).*

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ods of land use management that can lead to a reduction of soil erosion and, subsequently, sediment yield in runoff. However, before remediation and prevention of excessive soil erosion can be undertaken, the extent of the problem has to be established. This is the objective of this study. After an evaluation of several existing methods of assessing soil erosion in a drainage network, it was concluded that a modelling approach provides a useful and powerful tool for identifying, qualifying and quantifying the soil erosion processes and dynamics in a catchment.

This study focussed on the suitability and hence the application of the Universal Soil Loss Equation (USLE) developed by Wischmeier & Smith (1978), in the Mbuluzi-river catchment, Swaziland. This was carried out within the framework of an interdisciplinary EU-funded Project aimed at developing an Integrated Water Resources Management System (IWRMS) for water resources analyses and prognostic scenario planning in semiarid catchments of southern Africa. In this more general framework, two methods of spatial discrimination of erosion processes at the catchment scale were tested. On one hand, the *ACRU* agrohydrological modelling system (Schulze, 1995), which incorporates the modified USLE (MUSLE) (Williams, 1975; Williams & Berndt, 1977), was used to simulate the magnitude and spatial extents of sediment yields in the catchment in a semi-distributed manner. On the other hand, an Erosion Response Units (ERUs) concept was employed in the identification of sediment source areas. This is a distributed modelling approach which makes it possible to undertake more detailed soil erosion modelling based on the Universal Soil Loss Equation (USLE) (Wischmeier & Smith, 1978). The second method was complemented with gully erosion models (Sidorchuk, 1999; Sidorchuk & *alii*, 2001b).

The primary objective of this study was to compare the applicability, merits, limitations of, and results from, the *ACRU*/MUSLE and a mixed spatial distributed modelling method in the Mbuluzi catchment.

## GEOGRAPHICAL LOCATION AND CLIMATE

The Mbuluzi river originates from Ngwenya hills in the north western part of Swaziland and drains an average of 372 $Mm^3$ of runoff per annum from an area of 2958.9 $km^2$ before crossing into Mozambique in the east. The Swaziland part of catchment area stretches latitudinally from 25°54' to 26°30' S and longitudinally from 31°02' to 32°06' E (fig. 1). Swaziland may be divided into four physiographic regions with roughly north-south boundaries, namely the Highveld, Middleveld, Lowveld and Lubombo Plateau (fig. 2), all of which are found in the Mbuluzi catchment. Altitude ranges from 125 m in the Lowveld to more than 1500 m in the Highveld.

Except for the semi-arid lowveld, most of the catchment has a sub-humid temperate climate. The catchment receives most of its rainfall during the summer season from October to March. These rains are mainly from convective storms in the higher altitudes of the highveld and from more maritime air mass regimes in the east. Mean

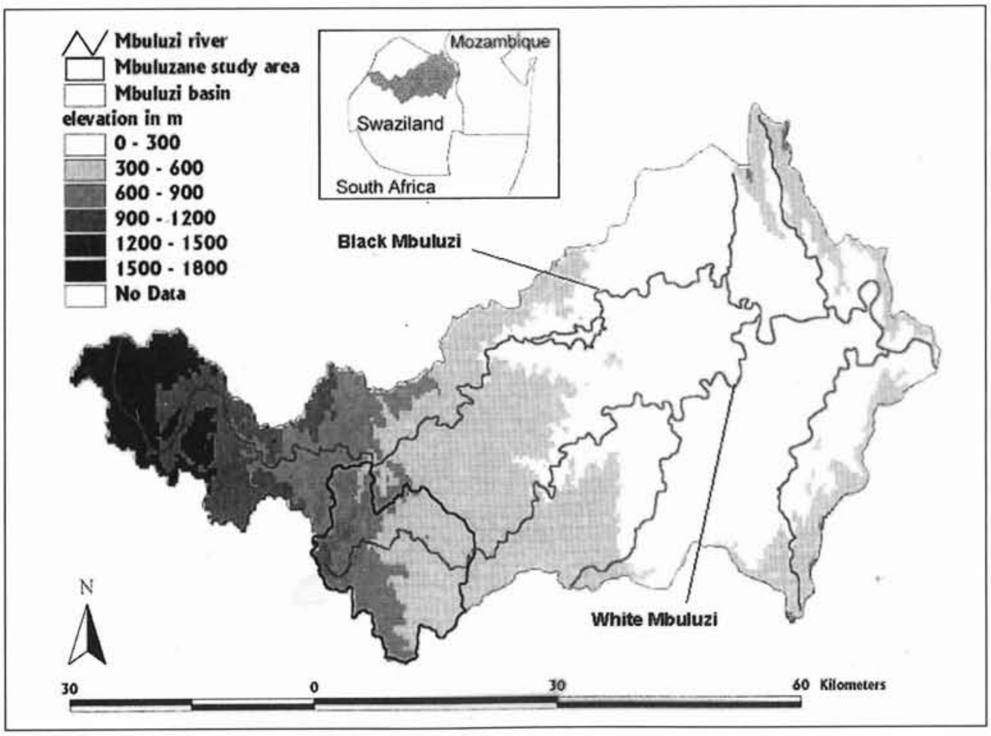


FIG. 1 - Mbuluzi catchment in Swaziland with the distribution of elevation zones and the location of study sites.

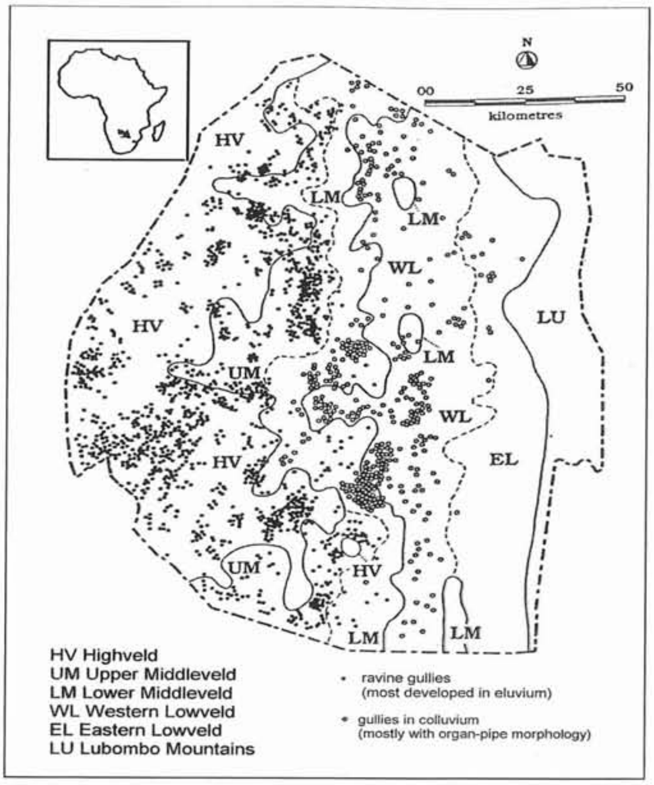


FIG. 2 - Distribution of gully erosion in Swaziland (after WMS Associates, 1988).

Annual Precipitation (MAP) rarely exceeds 700 mm in the lowveld, while it may be in excess of 1200 mm in some parts of the highveld. Temperatures vary by altitude. The lowveld is the hottest region in the catchment with monthly means of daily minima and maxima respectively exceeding 11 °C and 26 °C in winter (July) and 22 °C and 33 °C in summer (January). With mean temperatures ranging between 16 °C and 23 °C in summer and 6 °C and 20 °C in winter, the Highveld is the coolest part of the catchment. Owing to high temperatures, especially in summer, the Lowveld has the highest potential evaporative demand with January A-pan equivalent values in excess of 200 mm, while the values in the cooler Highveld barely exceed 180 mm in January. Potential evaporation is at its lowest in June, when the mean monthly A-pan values are less than 100 mm throughout the catchment (Schulze, 1997).

The geology of the upper Mbuluzi catchment is dominated by granites, and some areas by precambrian sediments and volcanic outcrops. Granite and granitic gneisses with outcrops of dolerite and gabbro are found in the Middleveld while the Lowveld area is underling by sedimentary and volcanic rocks of the Karroo period.

The main soil types in the Highveld and Middleveld part of the catchment are deep, acid and freely drained red and yellow ferrisolic and ferralitic soils, often with stone lines. In the lower Middleveld generally grey or red, light textured soils from granite and gneiss were found. The Lowveld is characterised by weathered red, brown and black clays from basalts (Murdoch, 1970; Fränzle, 1984; Mushala, 2000).

According to interpretations of the 1996 LANDSAT TM image (Thompson, 1996), major land covers and land uses consist of a combination of grassvelds and bushvelds which are either under communal grazing or converted to subsistence agriculture in the upper and middle section of the Mbuluzi river basin. The lower parts are dominated by large-scale intensive irrigated sugarcane plantations with all activities associated with the sugar industry such as milling, while the plateau is covered mainly by bushvelds.

The Mbuluzi river basin is a major source of water for agricultural activities as well as rural and urban water supplies. The Hawane dam is located along the Mbuluzi river and supplies water to Mbabane city. Water from the river is also used in various ways by communities along its course. This river is of critical importance in the economy of the entire country as it provides water supplies to Ngomane, Tambankulu and Simunye sugar cane irrigation schemes and various urban areas through the Mnjoli dam.

## METHODOLOGY

The *ACRU* agrohydrological modelling system (Schulze, 1995; Smithers & Schulze, 1995) shown in fig. 3, was selected for this study. *ACRU* is a physical-conceptual, daily time step, multi-layer soil water budgeting and multi-purpose model. *ACRU* was configured for the Mbuluzi catchment upstream of border with Mozambique to simulate sediment yields from 40 subcatchments (SC) (fig. 4) over a 46-year period from 1950 to 1995. In *ACRU* sediment yields are modelled by activating the Modified Universal Soil Loss Equation (Williams, 1975). This version of the equation, which is imbedded in *ACRU,* overcomes the incapability of the USLE equation to directly determine soil loss estimates for individual storm events, and eventually eliminates the need to determine sediment delivery ratios which were used to estimate the proportion of eroded soil which leaves the catchment (Williams & Berndt, 1977).

The *ACRU*/MUSLE sediment yield module uses factors (discussed in following section) that characterise physical conditions on the surface of a catchment as input information. Each of these factors was averaged for entire individual subcatchments. Hence the location of the sediment sources within each subcatchment could not be distinguished.

Flügel & *alii* (1999) and Märker & *alii* (1999, 2001) introduce an innovative approach, *viz.* Erosion Response Unit (ERU), to characterise erosion processes caused by water and other related dynamics. This concept is based on regionalisation methods used in hydrological modelling (Flügel, 2000; Märker & *alii*, 2001). The ERU concept represents a fully distributed modelling approach taking into account three dimensional physiographic

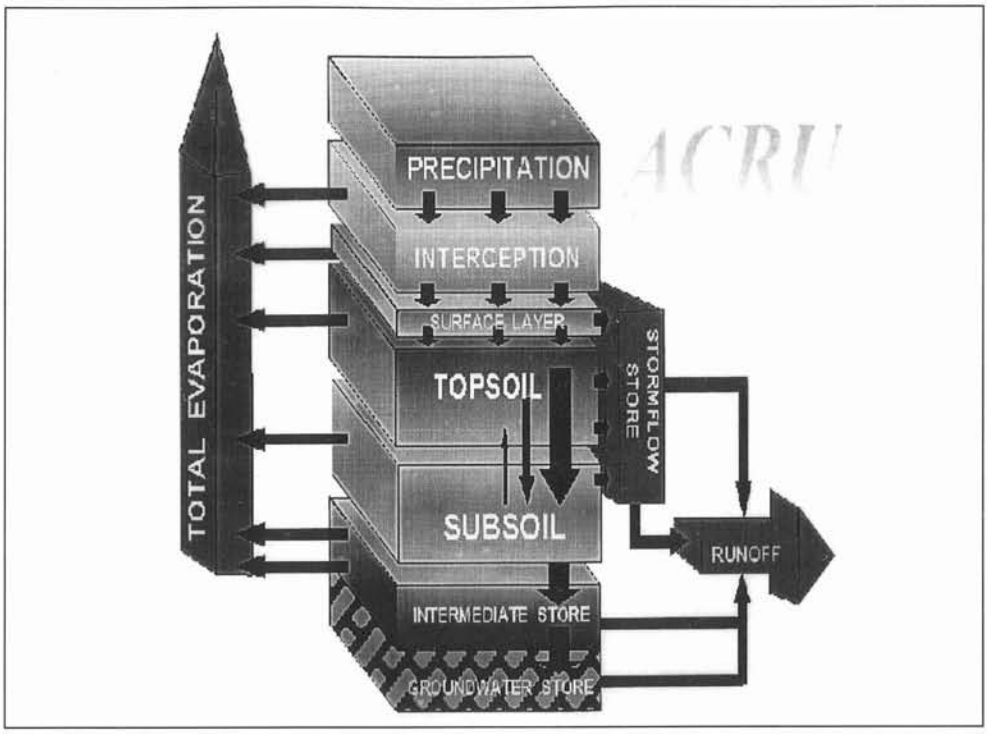


FIG. 3 - *ACRU* Agrohydrological Modelling System Structure.

characteristics of heterogeneousely structured terrain entities which have homogeneous erosion process dynamics characterised by a slight variance within a single unit, if compared to neighbouring ones. The units are controlled by their physiographic properties and the management of their natural and human environment (Märker & *alii*, 2001). Based on the finite element concept, the process related definition of the ERUs allows to catch up erosion processes at various temporal and spatial scales such as rill- interrill erosion, gully erosion or suffusion processes. In this study the ERUs are used to identify areas subject to different erosion processes and dynamics and as mod-

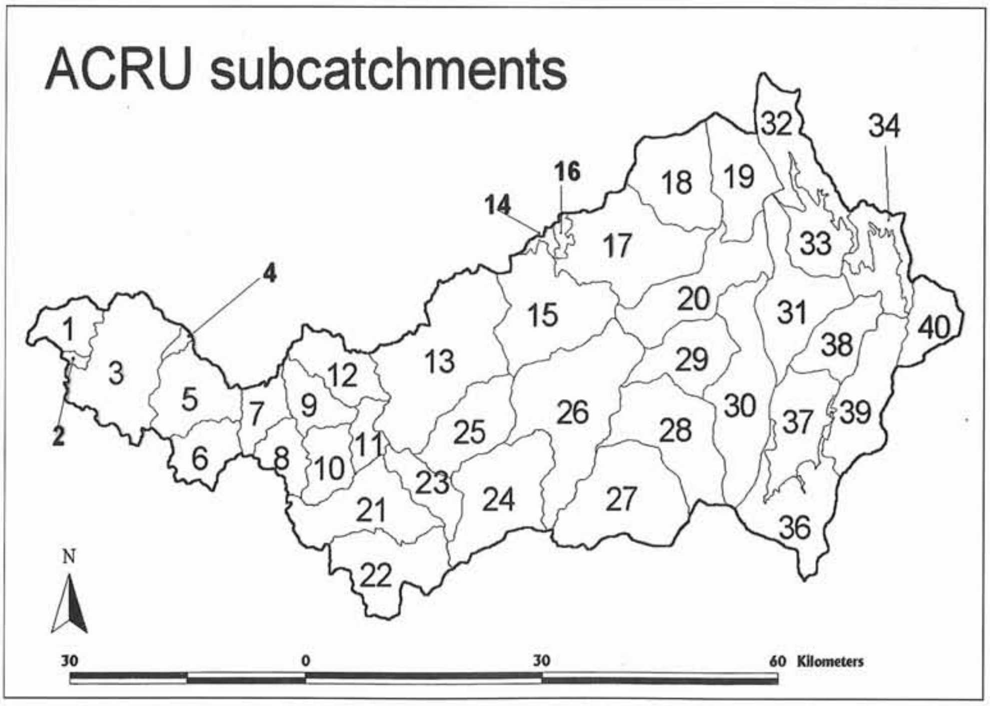


FIG. 4 - Subcatchments of the Mbuluzi River (Swaziland) and their numbering system.

elling entities for erosion simulations. Moreover, the application of different models for different erosion types is feasible and therefore the concept can be utilised in the regionalisation of erosion processes and dynamics. This finally leads to more exact information on the total amount of erosion within a catchment.

The Mhlambanyoni area (SC10) was selected for a more detailed study whereby the ERU concept was employed to assess the prevalent soil erosion processes. The ERU delineation was carried out by analysing stereo-aerial-photographs and orthophoto maps and by manipulating DEMs using GIS. For the classification of the erosion features and the subsequent delineation of erosion units, the erosion type, the degree and extent of erosion, as well as the density of the erosion features was mapped based on 1996 aerial photographs at a scale of 1:30.000. For the analyses a method adopted from Van Zuidam (1985) was applied. The results of these analyses are terrain entities subject to different levels (6 classes) of erosion processes (tab. 2). In the following delineation of ERUs, these entities are used as reference units (ERefUs). These ERefUs are characterised by similar erosion intensity and/ or frequency. They consist in a particular type or a combination of types of erosion (cf. Märker & *alii*, 2001 and tab. 1).

The main erosion processes identified in the Mbuluzi catchment are gully erosion and rill- interrill erosion. In this study the volume of sediments produced by gully erosion processes was calculated for a representative gully system using the dynamic gully model that accounts for the gully evolution dynamics (see Sidorchuk & *alii*, 2001b). From studies of Zorina (1979) it is well known that during the period of gully initiation the gully channel formation, following the drainage network, is very intensive and consequently the morphological characteristics are far from stable. This stage comprises only about 5% of the entire gully lifetime, but already more than 90% of gully length, 60% of its area and 35% of the gully's volume are formed in this period. In the remaining 90% of the gully's lifetime the morphological conditions are nearly stable (Sidorchuk, 1999; Sidorchuk & Sidorchuk, 1998; Sidorchuk & *alii*, 2001a). Consequently, the dynamic gully erosion model was applied to simulate the first stage of gully development, and run over a period of 150 years to approach also the stable final morphology of the gully (Sidorchuk & *alii*, 2001b). The model is physically based and adapted to the special conditions in the catchments.

TABLE 1 - Erosion intensities and features of the ErefUs

| ErefU Class | Erosion intensity and features |
|---|---|
| 1 | No erosion |
| 2 | Slight rill-interrill erosion |
| 3 | Rill-interrill; shallow deep gully erosion |
| 4 | Rills; medium-deep gully erosion |
| 5 | Rills; medium-deep to, deep gully erosion, shallow landslides |
| 6 | Rills; deep gully erosion; badlands; severe mass movements |

For the rill- interrill erosion the Revised Universal Soil Loss Equation (RUSLE) was chosen. These models were run for each single ERU on a 25m x 25m pixel basis. The sediments produced in an ERU then have to be routed down the catchment or be used as input for ERUs further downslope (Märker & *alii*, 2001).

## PREPARATION OF INPUT INFORMATION FOR EROSION MODELLING

The *ACRU*/MUSLE sediment yield module uses stormflow volume, peak discharge calculated by the ACRU-model (see results), a soil erodibility factor, slope length and steepness factor, an index of vegetation cover, a conservation practices factor as well as location specific MUSLE coefficients as input information. Each of these factors was averaged for entire individual subcatchments. Sources and methods of preparing the input information are described below.

### *Soil erodibility*

For the entire Mbuluzi the soil erodibility factor was estimated using mapped information of soil erosion classes (Mushala, 2000). For the detailed study of the *Mhlambanyoni* river catchment, the soil erodibility has been estimated using detailed soil texture and lithologic information obtained from the Swaziland Soil Map (Murdoch, 1968).

### *Morphology*

Field measurements of slope lengths and gradients were not conducted. The *ACRU* model internally computes the average slope length and gradient factor from average slope (%) using algorithms developed by Schulze (1979). The coverage of the Mbuluzi catchment with its subcatchment delineation was overlaid on a 200 m x 200 m Digital Elevation Model (DEM) (Hughes, 1997) and the average slope for each pixel was calculated using GIS. This value was input into *ACRU* and the slope length and steepness factor was computed internally in the model. For the detailed study of the Mhlambanyoni a DEM was derived form the topographic map 1: 50.000 scale with a 25 m x 25 m resolution.

### *Land cover and management*

The calculation of cover factors requires detailed vegetation information such as canopy cover, height of canopy and mulch cover. However, since such data were not available for the entire Mbuluzi catchment, a combination of information collected during reconnaissance-type survey and derived from the national land cover classification (Thompson, 1996) was used to estimate monthly cover factors for the dominant land cover classes in the Mbuluzi catchment, using methods described by Schulze (1995).

TABLE 2 - Conservation practices values for contour tilled lands and lands with contour banks (after Wischmeier & Smith, 1978)

| Land Use | Land Slope (%) | Contour Tilled |
|---|---|---|
| Cultivated lands (subsistence and large-scale irrigated agriculture) | 1 - 2 | 0.6 |
| | 3 - 8 | 0.5 |
| | 9 - 12 | 0.6 |
| | 13 - 16 | 0.7 |
| | 17 - 20 | 0.8 |
| | 21 - 25 | 0.9 |
| Pastures and communal rangelands | all | 1 |

### *Conservation practices*

Conservation practices have a reduction effect on overall soil loss. Factors representing the effects of support practices were estimated from table 2 in conjunction with slope and farming practices that are found in the Mbuluzi catchment.

## RESULTS

### *Sediment producing areas in the Mbuluzi catchment*

The *ACRU* model was used to simulate daily sediment loads for each of the 40 subcatchment (cf. fig. 4) for the period 1945-1995. From the daily values, monthly and annual average sediment yields were computed for each subcatchment. Catchment sediment yields in tonnes for each catchment were converted to a unit yield in t.ha$^{-1}$ for comparative purposes.

Mean annual sediment yield values are presented in fig. 5. For the 40 *ACRU* subcatchments (SC), they ranged from 0.59 to 96 t.ha$^{-1}$. The highest (greater than 50 t.ha$^{-1}$) values of sediment yields were simulated in SC32 in the north-eastern part of the catchment. This subcatchment has the highest average slope, at 16%, and is occupied by rural communities with more than 20% of the land under subsistence agriculture, the remainder being grazed and browsed bushlands and forests. Other high sediment yields were simulated in the upper-middle parts such as the catchment of the Mhlambanyoni tributary (SC10) with 17.09 t.ha$^{-1}$ annum$^{-1}$. This region also is predominantly rural with subsistence agriculture being the main farming activity, while all the unimproved grasslands (which cover more than 70% of the land) are used as communal pastures. During fieldwork, lands with relatively steep slopes were found to be cultivated. Bare patches of land, badlands (gullies) and livestock and human pathways, which are sources of sediments, were also observed in the rangelands.

Moderate to high sediment yields were generated in the subcatchments with MAP greater than 1000 mm in the higher altitude areas (e.g. SC1). Subcatchments such as SC24 in the middle and lower-middle sections exhibit the lowest mean annual simulated sediment yields, with values less than 2.5 t.ha$^{-1}$. These subcatchments have low average slopes (< 4%) and the land use is mainly well-managed privately-owned and government-owned demonstration cattle ranches. Moderately low mean annual sediment yields between 2.5 and 5 t.ha$^{-1}$ were simulated in the subcatchments with large-scale irrigated sugarcane estates (e.g. SC29). Besides these areas having low slopes, the land is covered by good crop canopy for most part of the year, especially during the rainy season.

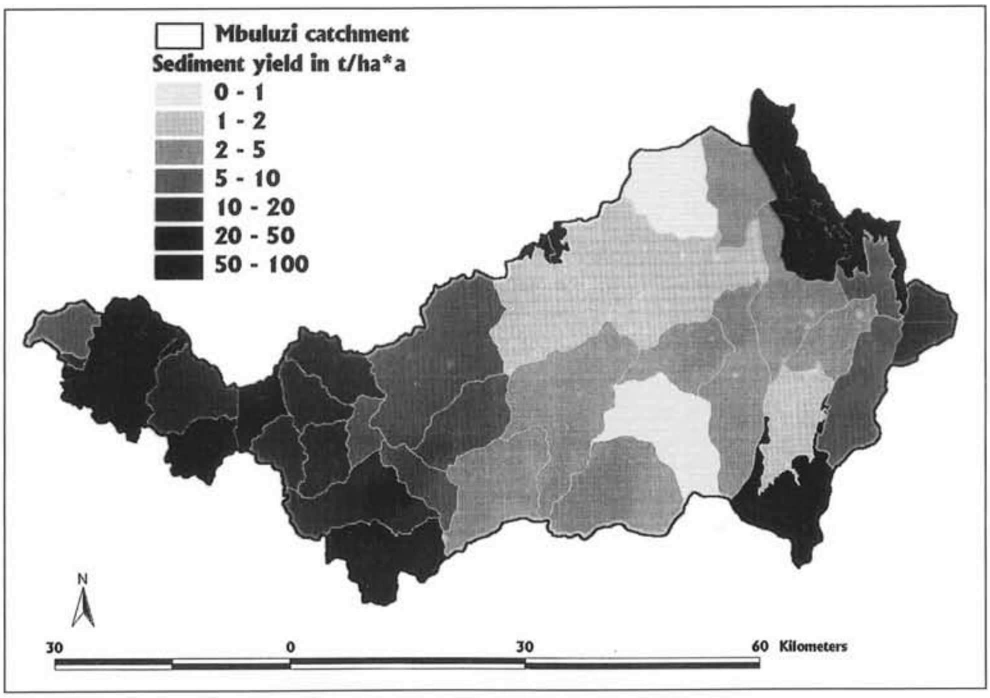
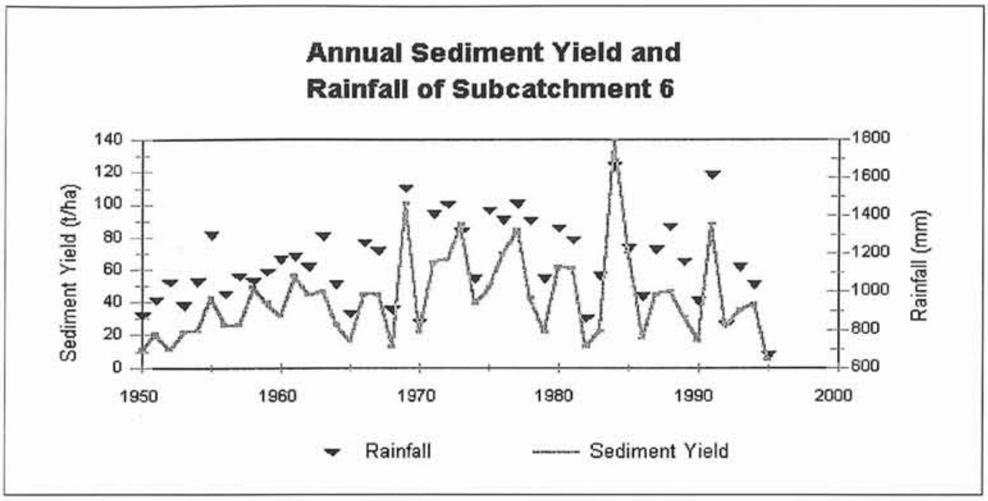


FIG. 5 - Mean annual simulated sediment yield for the 40 ACRU subcatchments with the ACRU/MUSLE.

FIG. 6 - Times series plot of Mean Annual Precipitation and mean annual sediment yield in subcatchment 6.



*Influence of storm events of different magnitudes on sediment yield*

Fig. 6 shows that a strong relationship between rainfall and sediment yield generally exists. Years of high sediment yields generally correspond with wet years, while the converse is also true. Not all wet years show corresponding high sediment yields though. For example, during 1990-91 hydrological year, SC6 received 1614 mm of rainfall, an amount that is comparable to the 1659 mm which was received in the 1983-84 season, while the sediment yield simulated for 1990-91 was only 63% of the amount simulated for 1983-84. Closer examination of the sediment generating events in fig. 7, on a daily basis, shows that most of the sediments in 1990/91 came from several storm events spread across the summer season. On the other hand, 70% of the 1983-84's yield was derived from a single storm event on January 29. This observation indicates that in any one catchment, one value of annual rainfall may result in different sediment yields in different years, depending on the magnitude of the individual storm events that contribute to the annual rainfall and antecedent catchment conditions, even if all the other catchment characteristics remain the same.

*Sediment analyses in the Mhlambanyoni catchment*

The distribution of the different erosion types and their intensity is shown in fig. 8.

Rill-interrill erosion and deep linear erosion (gully erosion) are predominant in the Mbuluzi catchment. Severe gully erosion was identified mainly in the upper part of the Mbuluzane River catchment and in the Mhlambanyoni catchment (fig. 8). In the latter, the Mbothoma gullies are classified in the highest erosion class and they are clearly visible at this scale (1:30 000).

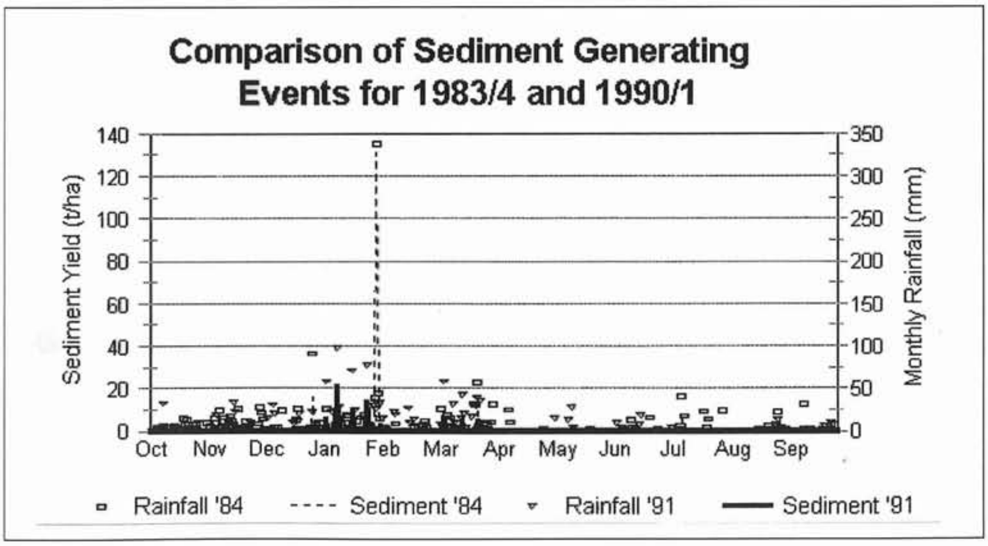


FIG. 7 - Comparison between rainfall and sediment discharge during the 1990-91 and 1983-84 hydrological years.

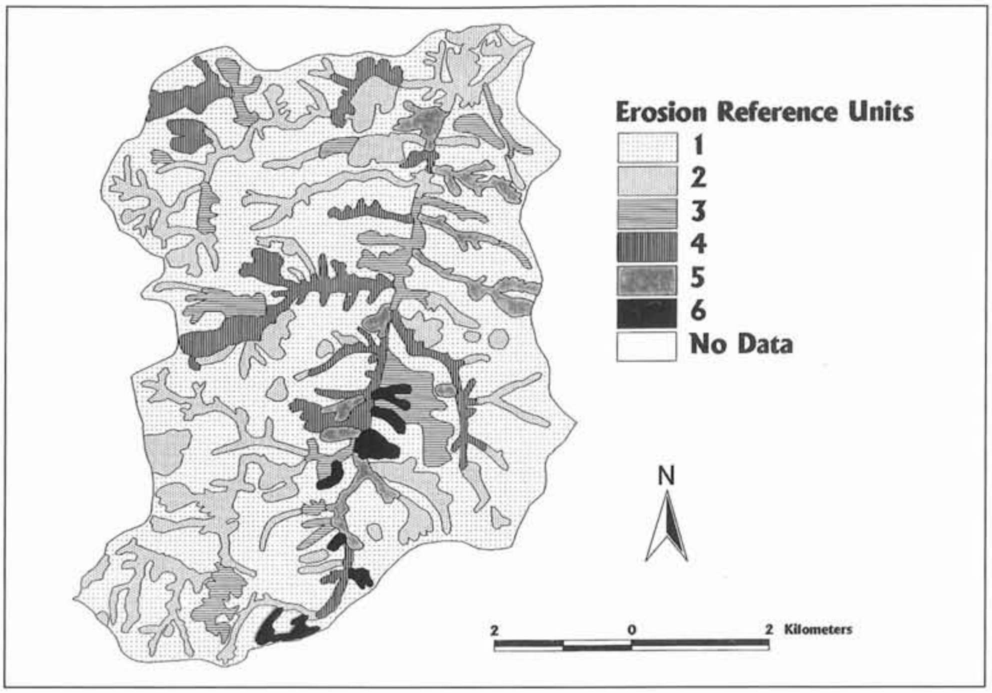


FIG. 8 - Map of Erosion Reference Units of the Mhlambanyoni catchment (SC 10).

About 8% of the Mhlambanyoni catchment is directly affected by severe deep gully erosion (classes 4, 5 and 6) as shown in fig. 8, whereas 40% of the area shows signs of erosion. It should be noted that the zone of intensive erosion is situated along a north-south running system of amphibolite/serpentine and dolerite/granophyre dykes. The main lithology consists of highly erodible saprolites (Mushala & *alii,* 1994; Scholten & *alii,* 1995). It is a densely populated area with a high livestock concentration. Consequently overgrazing occurs, especially on communal land such as the Mbothoma area. Livestock tracks and pathways are visible on the aerial photographs and analyses of different time series show that gullies often develop along these pathways and tracks (cf. WMS Associates, 1988).

The ERUs have been derived by overlay analysis of the reclassified physiographic layers and the ERefUs, according to Märker & *alii* (2001). Subsequently the ERUs have been used as modelling entities. For the rill-interrill erosion processes, the Revised USLE (RUSLE) (Renard & *alii,* 1991) has been applied.

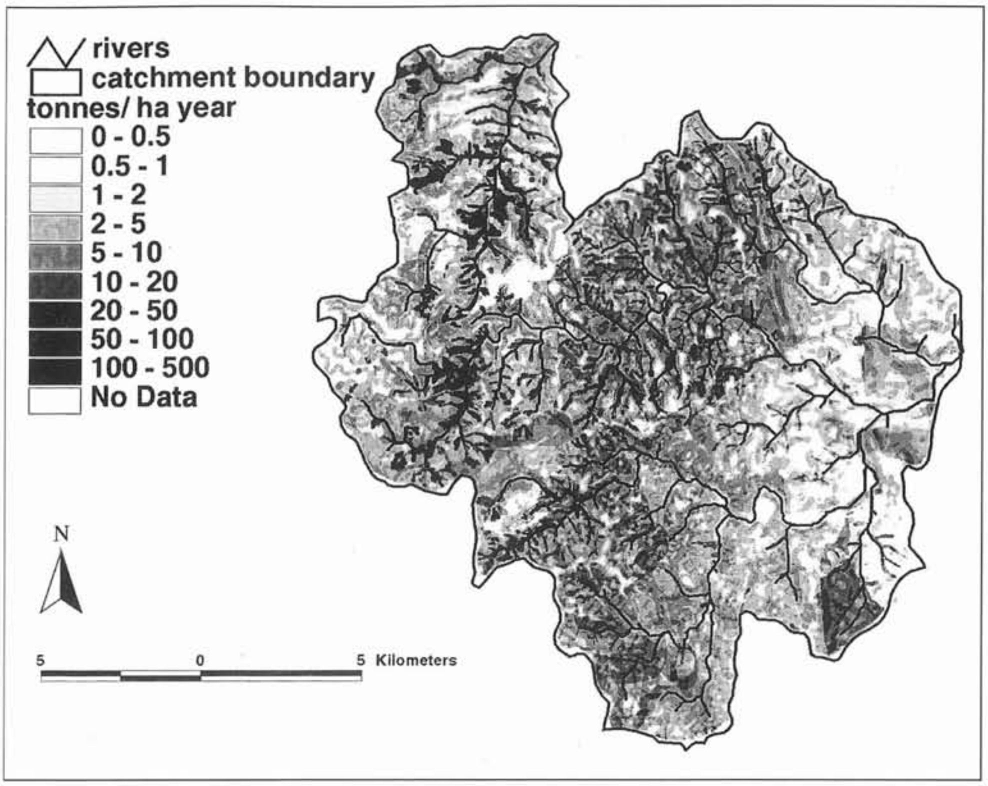
Fig. 9 shows the absolute values of eroded sediments in t.ha$^{-1}$ annum$^{-1}$ for the subcatchments 10, 21, 22 and 23. The single pixel values range from less than 0.5 t.ha$^{-1}$-annum$^{-1}$ in SC23 to 395 t.ha$^{-1}$ annum$^{-1}$ in the Mbothoma area (SC10). The mean value is about 10 t.ha$^{-1}$ annum$^{-1}$. In the subsequent step, the sediments of the single RUSLE cells have been routed down to the catchment outlet following the flow path of the overland flow. For this purpose, a simple *ARCInfo* flow accumulation procedure was used. This does not take into consideration the underlying sedimentation processes. This implies that all the sediments produced within the catchment exit the catchment. The sediment yield calculated by the technique described above results in 55153.5 t.annum$^{-1}$ for the Mhlambanyoni catchment (SC10) of 4208 ha. This is an averaged soil loss of about 13 t.ha$^{-1}$ annum$^{-1}$. Compared with the values of the *ACRU*/MUSLE calculations for the same catchment it can be stated that the amount of calculated sediments with the ERU method (13 t.ha$^{-1}$ annum$^{-1}$) is lower than the *ACRU*/MUSLE values of 17 t.ha$^{-1}$ annum$^{-1}$. Nevertheless, results from the two compare well when calculating the amount of sediments produced by rill-interill erosion.

In the Mhlambanyoni and upper Mbuluzane catchments, a high density of gullies has been identified using the ERU method. This was the reason for the more detailed research on gully erosion processes and dynamics in this area. Focussing on the Mbothoma subcatchment, the results obtained with the RUSLE modelling and the subsequent sediment routing for the gully catchment area of 426300 m$^2$ results in a soil loss of approximately 1434 t.annum$^{-1}$ which is equivalent to 34 t.ha$^{-1}$ annum$^{-1}$.

The RUSLE does not consider gully erosion processes. Consequently gully erosion processes require a separate modelling procedure. Therefore the dynamic gully erosion model (Sidorchuk 1998, 1999; Sidorchuk & *alii,* 2001b), developed for similar environmental conditions, was used.

The dynamic gully model (Sidorchuk & *alii,* 2001b), when applied for the Mbothoma gully system predicted an eroded volume of 1040000 m$^3$ for a gully catchment of 426300 m$^2$ which contained an active gully area of 250025 m$^2$. The dynamics of gully growth are characterised by a rapid growth rate of gully's maximum length followed by growth in gully area, mean gully depth and, finally, the growth rate of gully volume. Assuming a soil density of 1.2 g.m$^{-3}$, the averaged soil loss for the estimated entire

FIG. 9 - Values of eroded sediments in tons per hectare and year for the upper Mbuluzane and Mhlambanyoni catchments (SC10; 21; 22; 23) calculated with the RUSLE.



gully lifespan of 150 years was calculated for the active gully area to be 8320 t.annum$^{-1}$ i.e. 190 t.ha$^{-1}$ annum$^{-1}$ for the entire gully catchment and 332.8 t.ha$^{-1}$ annum$^{-1}$ for the active gully area.

To include the soil and substrate loss produced by gully erosion, the gully erosion rates have to be regionalised. Therefore, the active gully erosion features are of major importance. In this study, the areas of active gully erosion have been determined by overlaying the ERU information with a TSAVI index (Baret & Guyot, 1991) derived from a Landsat TM image (1990). In this case similar litho-pedologic conditions in the Mhlambanyoni area facilitates regionalisation of the gully erosion rates calculated by the model averaging the erosion rates over the surface that is affected by active gully erosion. This area was estimated to be 89.125 ha, which is only 2% of the entire Mhlambanyoni catchment area (SC10). Consequently, the amount of sediments produced by active gully erosion was calculated to be 29 669.8 t.annum$^{-1}$ which is more than 53% of the total sediment yield predicted by the RUSLE without considering deposition. Integrating the amount of sediments derived from both erosion processes (gully, rill-interrill) leads to a total sediment yield of 84 813,8 t.annum$^{-1}$, or 20.05 t.ha$^{-1}$ annum$^{-1}$ for the Mhlambanyoni catchment.

## DISCUSSION AND CONCLUSIONS

The *ACRU*/MUSLE model produces outputs of sediment yield on a daily basis. These were aggregated to monthly and annual averages. Furthermore, it is possible to simulate the dynamics of single storm events, as shown for the hydrological years 1983-84 and 1990-91. Nevertheless, by this modelling approach, the processes within the subcatchments remain unknown (black box model). Therefore, the semi-distributed modelling approach can deliver information only to a certain degree of spatial and temporal accuracy. To analyse the processes and dynamics which are active within the subcatchments, a more detailed distributed process based modelling approach has to be used. Areas subject to different erosion processes and intensities can be identified using the *Erosion Response Units* concept. Furthermore the ERU concept offers a fully distributed modelling structure. Thus, the ERU concept was applied to one of these subcatchments.

The Mhlambanyoni river basin was identified as having a high erosion risk and therefore it was chosen for a detailed study. The ERU approach show that there are lithologies that are highly vulnerable to erosion (saprolites) and that there are different erosion processes and features contributing to the erosion dynamics of the catchment. As already stated in the work of Morgan & *alii* (1997) especially the sediments derived from gully erosion can not be simulated by RUSLE/MUSLE models. This was the reason for using a differentiated modelling approach to simulate the erosion processes and dynamics in the Mhlambanyoni catchment.

The erosion dynamics were calculated based on the distributed ERUs identifying with high accuracy areas affected by different erosion processes. Subsequently these processes were modelled with specific models. Here the

USLE for the rill-interrill erosion processes and a model able to simulate the dynamics of gully erosion (Sidorchuk 1998, 1999, Sidorchuk & *alii*, 2001b) were applied on a yearly basis. As a next step the sediments obtained with the specific models for the individual ERUs have been regionalized and routed down the river network following the overland flow paths to obtain the catchment's sediment yield.

The comparison of estimated values of soil loss in tons per ha and year calculated with the RUSLE for the small Mbothoma test gully catchment (area 426 300 $m^2$) show that the soil loss is underestimated by a factor of 5 to 6 compared with the calculated values of the gully model averaged over the entire lifespan of the gully. Naturally these average values do not take into account the dynamics of the gully evolution.

For the entire Mhlambanyoni catchment, it was estimated that active gully erosion deliver more than 1/3 of the total sediment yield, while covering only 2% of the entire catchment area. The ratio for gully erosion might be even higher when deposition processes are integrated into the modelling.

The erosion modelling clearly shows that for a detailed study of the erosion dynamics within a subcatchment a fully distributed modelling structure has to be applied. In this case the ERU concept allows the identification of erosion processes and their location on time and spatial scale. Furthermore, it was clearly shown that gully erosion processes have to be included into a fully integrated erosion modelling at catchment level.

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