SADCC

SOIL AND WATER CONSERVATION

AND

LAND UTILIZATION PROGRAMME

EROSION HAZARD MAPPING:

MOZAMBIQUE

by

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REPORT No. XX

COORDINATION UNIT

etc.

Date

FOREWORD

This report is one of a series of SADCC country reports on the Erosion Hazard Mapping of the region. It arises from a project initiated in September 1985 in the first phase of the work programme of the SADCC Coordination Unit for Soil and Water Conservation and Land Utilization, based in Lesotho. The aims of the Erosion Hazard Mapping project are:

- define main danger areas for erosion and the principal processes contributing to the hazard;
- assist the design of appropriate conservation strategies;
- give guidance in regional planning, environmental monitoring and land utilization programmes;
- provide an action-learning exercise and training forum for SADCC participants.

Erosion hazard assessment is a technique to express the natural danger of soil erosion over large areas. As such it is an appropriate exercise for the SADCC Coordination Unit which is very much concerned with land degradation problems and the safe utilization of land resources, especially soil. Details of the technique have already been published in Report No.9, "A Methodology for Erosion Hazard Mapping of the SADCC Region", April 1987. Local staff members from SADCC countries have done all the data collection and processing necessary for the national maps.

All participants at the four Erosion Hazard Workshops -- Harare, September 1985; Maseru, March 1986; Mbabane, November 1986; Lusaka, April 1987 -- as well as their departmental heads and junior staff are warmly thanked for their enthusiasm and hard work. Several of the country teams have laboured under severe manpower constraints with competing demands on their time and resources. That this project is nearing completion is a tribute to SADCC cooperative spirit. This country report was compiled from draft reports submitted by the country team under the overall technical supervision of Dr Michael Stocking.

B. Leleka

ACKNOWLEDGEMENTS

This report is part of the work programme of the Departmento de Terra e Agua, Instituto Nacional de Investigacao Agronomica, Maputo, which is to assess the land productivity potential and population supporting capacity for agricultural development in Mozambique (Kassam et al, 1983). Technical assistance has been provided through the FAO/UNDP project "Natural Resources Survey and Land Evaluation".

The assistance of technical staff at INIA and the support of the Head of the Land and Water Department, Mario Ruy Marques, is gratefully acknowledged. Antipas Mate, Agronomist/Pedologist at INIA, also took part in the series of Erosion Hazard Mapping Workshops.

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INTRODUCTION

Soil erosion hazard is one aspect of the assessment of the productive potential of land. As such it needs to be considered alongside surveys of natural resources and the evaluation of the quality of land. The main objective of this study on erosion hazard is to indicate the extent and severity of soil erosion so that land use can be planned on a sustainable basis and that populations can be supported adequately from their own resources.

Erosion hazard as presented in this report is not a survey of actual erosion, but is a description of the natural propensity of the environment to allow soil erosion to happen. It should thus be seen as the potential for erosion rather than the historical amount of erosion that has already occurred.

In the Mozambique analysis of erosion hazard, we have not considered land use patterns and how this affects vegetation cover. The relevant data are extremely difficult to obtain. Nevertheless, in future work we anticipate the inclusion of land use characteristics so that the final erosion hazard map is broadly comparable with those of the other SADCC countries. Therefore, the erosion hazard map included here at Annex 4 presents erosion hazard classes for bare soil conditions, without the influence of vegetation and cropping.

THE DATA SET

In line with the SLEMSA methodology (Elwell, 1980) which is used to calculate erosion hazard in this exercise, the factors of erosion are taken to be (1) rainfall erosivity, (2) soil erodibility, and (3) slope gradient and length. Almost no pre-existing information on these factors was available in Mozambique prior to this study.

So that the work on erosion hazard mapping could be fully integrated with the survey of other natural resources and land evaluation, it was decided to utilise a Geographical Information System (GIS) data base upon which the individual factors could be quantified, and the calculations made for SLEMSA done automatically on computer and then plotted in map form. This considerably eased the burden of calculation and draft mapping. The package used was the commercially-available CRIES, Version 6.0, 1986. Maps showing the geographical distribution of rainfall erosivity, soil erodibility and slope gradient were digitized and then converted into raster files with a grid resolution of 5 x 5 km to cover the country. The data sources and input for each factor map are as follows:

Rainfall erosivity

Because of the paucity of information on rainfall erosivity in Mozambique, it was decided at the outset to adapt the original Zimbabwe data for SLEMSA relating mean annual rainfall to mean seasonal energy. After reviewing the literature and testing suggested relationships (e.g. van der Poel, 1980) from the analyses of rainfall charts for 13 meteorological stations widely dispersed over the country, an equation was developed for Mozambique which appears to reflect local rainfall conditions and the relationship between annual rainfall and its kinetic energy (Reddy & Mussage, 1985):

$$E \times 10^{-3} = 5.45 + 0.017\,P \qquad \text{(correlation, } r = 0.87\text{)}$$

where, E is the mean seasonal kinetic energy; and P is the mean annual rainfall. This equation, when plotted graphically, gives a line which lies slightly above the relationships deduced for Zimbabwe and Botswana, indicating a somewhat greater energy of Mozambican rainfall per millimetre of rainfall. Based on this equation, a country map of rainfall erosivity was constructed (Reddy & Mussage 1985) and used for this study. The map was digitized using the CRIES system running the COLORDIG subroutine, and presents classes of rainfall erosivity with a resolution of 5 x 5 km on the ground (Annex 2).

Soil erodibility

No information on the erodibility of Mozambican soils was available prior to this study. A national soil inventory map at the scale of 1:2 million using the FAO classification existed. Mapping units are soil associations with one dominant soil (exceeding 50 percent of the unit) and associated soils. Additional information on texture (coarse, medium, fine) of the dominant soil also existed. The map and a comprehensive report on its compilation (Voortman, 1986) are used here.

Using the Zimbabwe experience on erodibility, Mozambican soils were correlated with their Zimbabwean equivalents, relating major characteristics and components important to erodibility. Some Mozambican soils do not occur in Zimbabwe, at least in FAO legend terms. In these cases, a value for erodibility was assigned that would place the soil in its correct position relative to known soils.

Table 1 lists the erodibility ratings, F_b, for Mozambican soils with modifiers according to topsoil texture, substrata type and lithic phases. These ratings have been incorporated into the National Soil Inventory according to the specific erodibility of the dominant soil in each association, its texture and depth. the soil map at 1:2 million was then digitized using te CRIES GIS package using the COLORDIG subroutine on a 5 x 5 km grid. A soil erodibility map was then constructed running the GROUP subroutine and the result is presented at Annex 1.

Slope gradient and length

As a first stage, information on slope steepness was first gathered from the Soil Resources Inventory map which included steepness classes in each mapping unit. However, two problems arose. Slope classes were divided into three: 0-8, 8-30 and >30%. These categories are too broad to be useful in assessing the danger of erosion. Furthermore, because soil mapping units were used, more than one class of slope often occurred in each unit, thus making slope estimates meaningless in this exercise.

Instead, slope steepness classes have been directly mapped from available topographic maps through the analysis of contour intervals. The 1:250,000 topographic map series (Edition 1, Army

Table 1. Soil erodibility ratings, F_b, for sheet erosion for the soils of Mozambique with modifiers according to substrata and lithic phases.

FAO Soil Unit	Topsoil texture			Substrata type (*)			Lithic phase
	Coarse	Medium	Fine	Coarse	medium	fine	
Ferric Acrisol	4.5	5.5	6.0	–	–0.5	–0.5	– 1.5
Gleyic Acrisol	4.0	4.5	5.0	–	–0.5	–0.5	– 1.5
Humic Acrisol	–	5.5	6.0	–	–	–0.5	– 1.5
Chromic Cambisol	–	3.5	4.0	–	–	–0.5	– 1.5
Eutric Cambisol	–	4.0	4.5	–	–	–0.5	– 1.5
Orthic Ferralsol	–	5.0	6.5	–	–	–0.5	– 1.5
Xanthic Ferralsol	5.5	–	–	–	–1.0	–1.5	– 1.5
Rhodic Ferralsol	–	5.0	6.0	–	–	–0.5	– 1.5
Humic Ferralsol	–	5.5	–	–	–	–0.5	– 1.0
Lithosol	–	2.5	4.0	Not applicable			
Orthic Luvisol	4.5	5.0	5.5	–	–0.5	–0.5	– 1.5
Chromic Luvisol	4.5	5.0	5.5	–	–0.5	–0.5	– 1.5
Ferric Luvisol	5.0	5.5	6.0	–	–0.5	–0.5	– 1.5
Gleyic Luvisol	4.5	5.0	5.5	–	–0.5	–0.5	– 1.5
Albic Luvisol	4.0	5.0	–	–	–0.5	–0.5	– 1.5
Haplic Phaeozem	–	5.5	6.0	–	–	–0.5	– 1.5
Gleyic Phaeozem	–	4.5	5.0	–	–	–0.5	– 1.5
Luvic Phaeozem	–	5.0	5.5	–	–	–0.5	– 1.5
Eutric Nitosol	–	5.5	5.5	–	–	–	– 1.5
Dystric Nitosol	–	5.5	5.5	–	–	–	– 1.5
Humic Nitosol	–	6.0	6.5	–	–	–	– 1.0
Cambic Arenosol	6.0	–	–	–	–1.0	–	– 1.5
Luvic Arenosol	6.0	–	–	–	–1.0	–	– 1.5
Ferralic Arenosol	6.5	–	–	–	–1.0	–	– 1.5
Albic Arenosol	6.0	–	–	–	–1.0	–	– 1.5
Eutric Regosol	6.0	–	–	–	–0.5	–	– 1.5
Pellic Vertisol	–	–	5.0	–	–	–	– 1.5
Eutric Planosol	3.5	4.5	–	Not applicable			– 1.0
Solodic Planosol	3.0	4.0	–	Not applicable			– 1.5
Orthic Solonetz	2.0	2.5	2.5	Not applicable			– 0.5
Orthic Solonchak	2.5	3.0	3.0	Not applicable			– 0.5
Gleyic Solonchak	2.5	3.0	3.0	Not applicable			– 0.5

(*): Only applicable when topsoil and substrata texture classes are different. In addition substract 0.5 for clear textural changes (< 8 cm) and/or compact subsoil.

Map Services, Washington DC, 1969) which covers all but about 15% of the country was employed. This is the most up-to-date and accurate series available. Contour intervals are mainly at 100 metre spacing but some sheets use 20, 40, 60 and 75 m spacings. Average distances between contours were then calculated for the following slope classes: 0-2, 2-6, 6-10, 10-14, 14-20 and >20 %.

A 10 x 10 km grid was drawn on transparent film corresponding to the same size grid on the 1:250,000 topographic maps. Slope classes were then directly mapped and boundaries drawn onto the transparent film along with three fixed control points. Boundaries were then transferred by hand onto the same grid square pattern on a 1:2 million base with the control points serving to align the map correctly.

The exercise was repeated for all 65 map sheets and gave a country-wide slope class map. The map has then been digitized using the CRIES GIS package running the MONODIG subroutine and then processed into a raster file with a 5 x 5 km grid base. The resultant map is at Annex 3.

THE MAPPING

Approach

Since virtually no information on erosion existed in Mozambique before this exercise, it was recognized that predictive modelling techniques would have to be employed. Various models and techniques were examined:

- Soil Loss Estimation Model for Southern Africa (SLEMSA)
- Universal Soil Loss Equation (USLE)

- FAO Soil Loss Assessment Methodology as outlined in FAO (1984)
- Soil loss degradation module of the Land Evaluation Computer System (LECS)

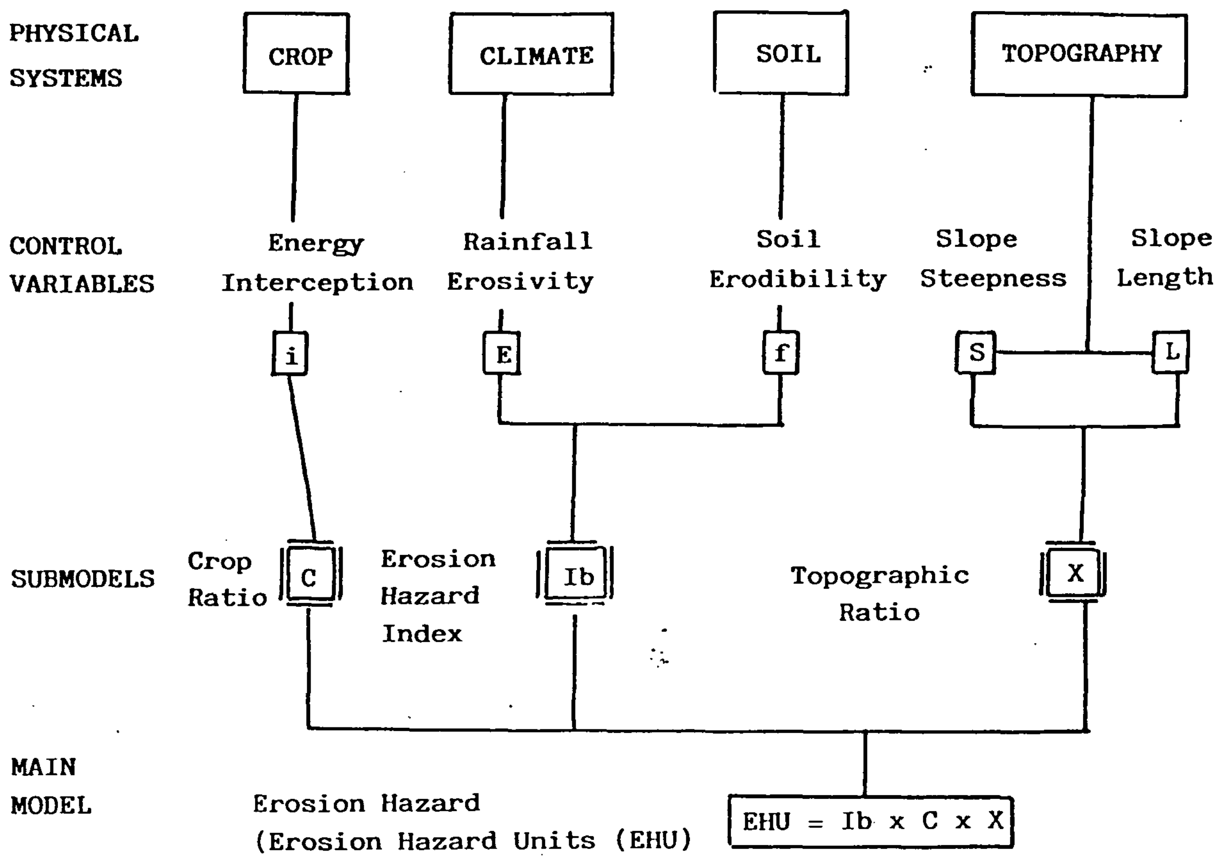
Paying special attention to basic data input requirements and the availability of information that will provide reasonably accurate assessments, the SLEMSA technique was adopted as used in Zimbabwe (Elwell, 1980). The selection of SLEMSA was based primarily on its low data input requirement and relative simplicity. Although SLEMSA was originally intended to estimate mean annual soil loss by sheet erosion from lands which are protected by contour ridges, the present study used it to assemble the factors of erosion to measure the relative susceptibility of large areas to erode. This adaptation of SLEMSA for erosion hazard mapping (Stocking, 1987; see also Figure 1) was the subject of a series of Workshops held by the SADCC Soil and Water Conservation and Land Utilization Programme.

Method

Fortunately, at the time of this exercise the Land and Water Department of the Instituto Nacional de Investigacao Agronomica in Maputo was installing a computerized data bank as described earlier. This poweful software permits the manipulation of maps including their overlapping, grouping and matching of grid-based attributes.

The intention is to analyse four factors, namely rainfall erosivity, soil erodibility, slope steepness and land use/vegetation, on a grid basis for the whole country, and

Figure 1. The SLEMSA framework.



Symbol	Explanation	Units
Control Variables		
E	Seasonal rainfall energy	J/m2
f	Soil erodibility	Index
i	Rainfall energy intercepted by crop	%
S	Slope Steepness	%
L	Slppe length	m
Submodels		
Ib	Erosion hazard index	Index
C	Crop canopy	–
X	Topography	–
Output		
EHU	Erosion Hazard Units	–

the mechanism of calculation. On a 10 x 10 km grid for a country the size of Mozambique, this would entail individual analysis of more than 7800 squares -- an impossibly large number to do with the lack of trained Mozambican personnel and without the use of computerisatiom.

To date three factors of erosion have been considered, and the data prepared, digitized and output in the form of computer printed maps at a scale of 1:4 million. The grid cell base that has been defined is 5 x 5 km for the whole country. Through a series of computer operations as shown diagrammatically in Figure 2, erosion hazard has been mapped in Mozambique for bare soil conditions (Annex 4).

The last step will consist of the incorporation of land use characteristics and the completion of sensitivity tests to analyse for the potential effect of errors in the final calculation of Erosion Hazard Units.

CONCLUSION

Although the map at Annex 4 depicts erosion hazard for bare soil only, the information will have use in the following capacities:

* afforestation programmes in Mozambique; to guide plantation operations to zones where erosion hazard is naturally high and forestry would be the safest option of land use;
* land evaluation at national and regional level; especially the consideration of erosion hazard as a separate land

Figure 2. The sequence of operations using the CRIES GIS for erosion hazard mapping.

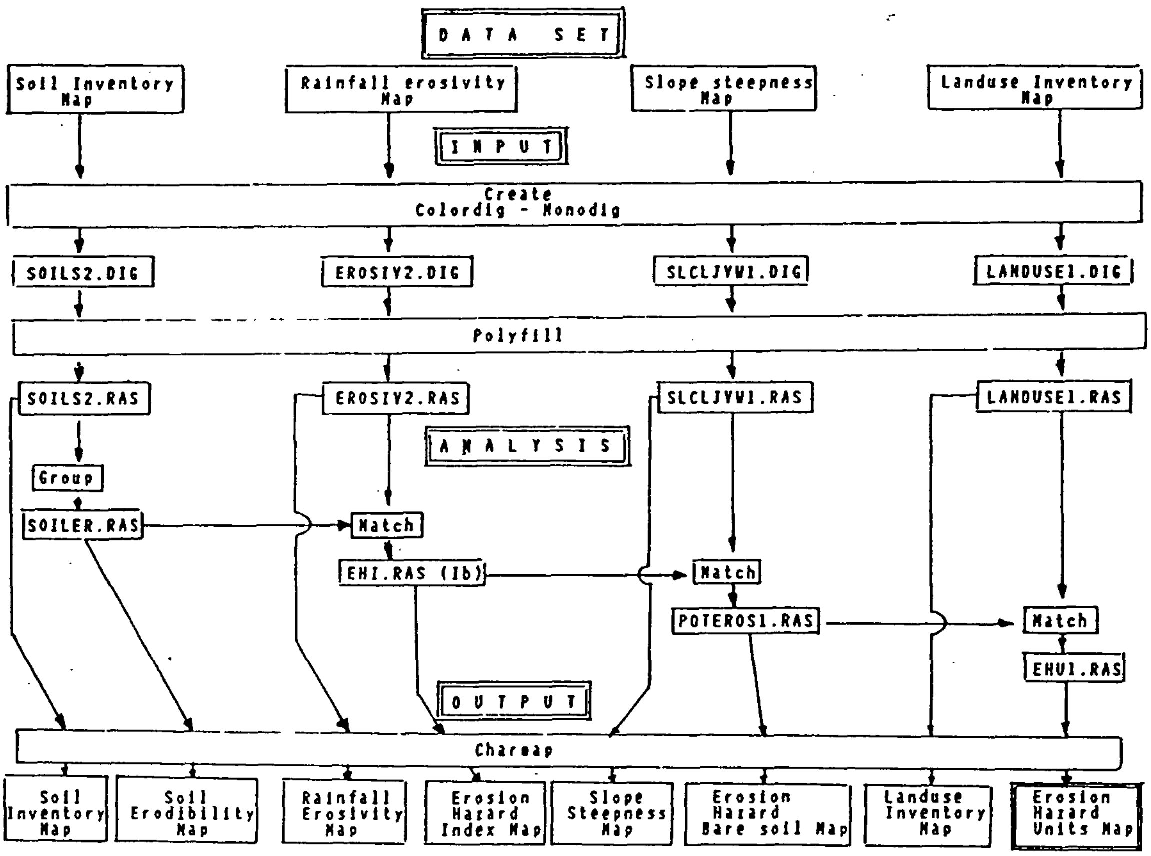


FIGURE 2: Sequence of operations using the CRIES GIS for erosion hazard mapping.

* background information for soil conservation and resource allocation;
* formulation of land use plans for specific areas, in particular for areas prone to high erosion hazard where alternative cropping and land uses could be tested in their role to minimize actual erosion.

This exercise in erosion hazard mapping has succeeded in raising awareness of erosion as a constraint in Mozambique development, and in bringing professionals from several different fields to work on a common problem.

REFERENCES & BIBLIOGRAPHY

Carvalho, de M. 1969. Agricultura tradicional de Mocambique. 1. Distribuicao Geografica das Culturas e sua Relacao com o meio. Missao de Inquerito Agricola de Mocambique, Lourenco Marques.

Elwell, H.A. 1980. Design of Safe Rotational Systems. Department of Conservation and Extension, Harare, Zimbabwe

FAO 1984. Provisional Methodology for Soil Degradation Assessment. Food and Agriculture Organization, Rome.

Flora Zambesiaca 1967. Vegetation Map of the Flora Zambesiaca Area. Edited by H. Wild & A. Fernandez. M.O. Collins (Pvt) Ltd., Salisbury.

Kassam, A.H., van Veldhuizen, H.T., Shah, M.M. & Conze, E. 1983. Land Productivity Potential and Population Supporting Capacity Assessment for Agricultural Development in Mozambique. Inception Report, FAO-MOZ/81/015, Maputo.

Reddy, S.J. & Mussage, R. 1985. The Rainfall Erosive Capacity in Mozambique. Communicacao No.24, Instituto Nacional de Investigacao Agronomica, Maputo.

Schultink, G., Zusmansis, A., Buckley, B., Brown, D., Nair, S., & Chen, S. 1986. Comprehensive Resource Inventory and Evaluation System (CRIES) - Geographic Information System - Version 6.0. Michigan State University, East Lansing, USA.

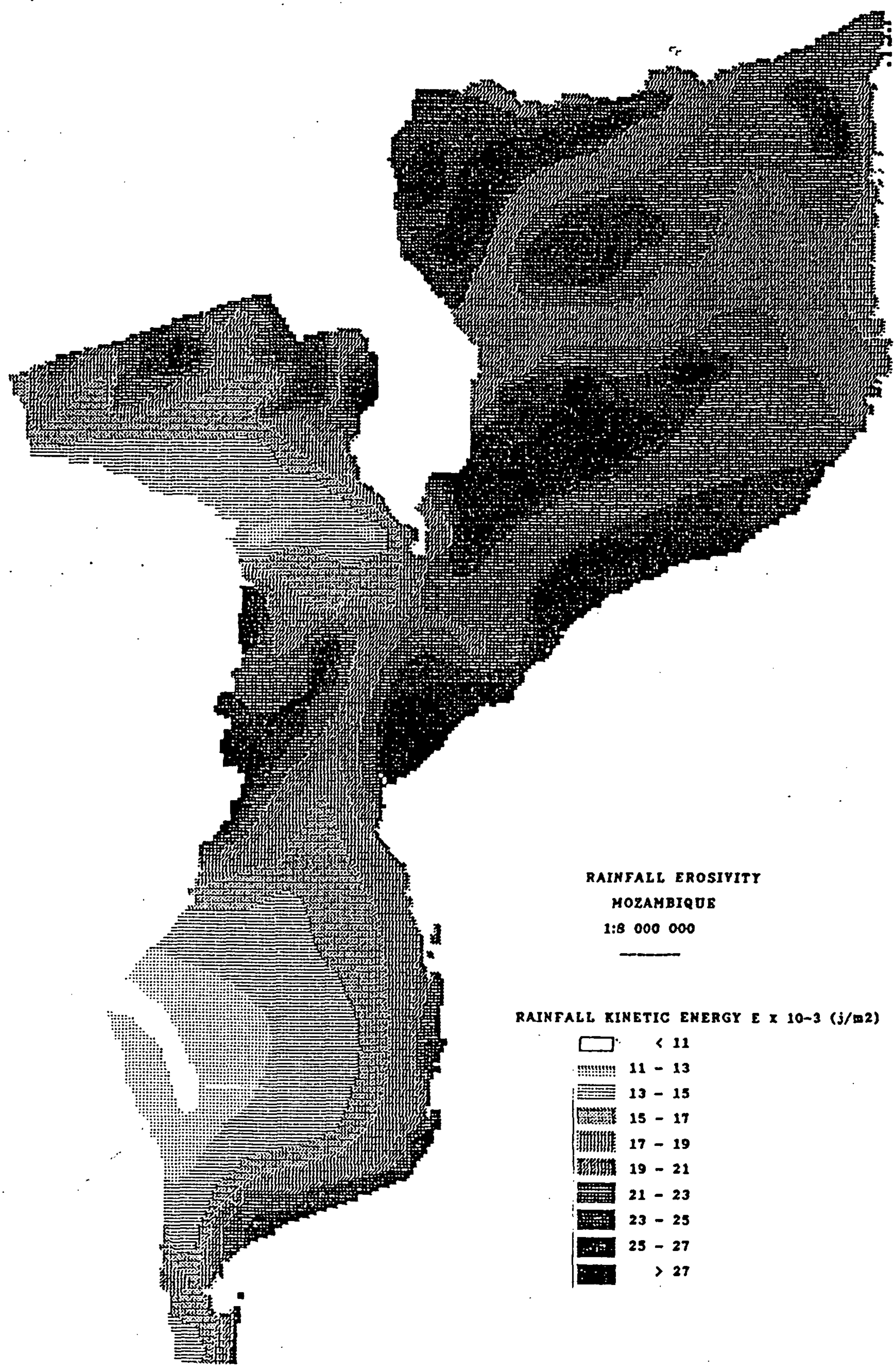
Snijders, F.L., 1985. Land Use Inventory of Mozambique. Communicacao No.43, Instituto Nacional de Investigacao Agronomica, Maputo.

Stocking, M.A. 1987. A Methodology for Erosion Hazard Mapping of the SADCC Region. SADCC Soil & Water Conservation and Land Utilization Programme, Maseru, Lesotho.

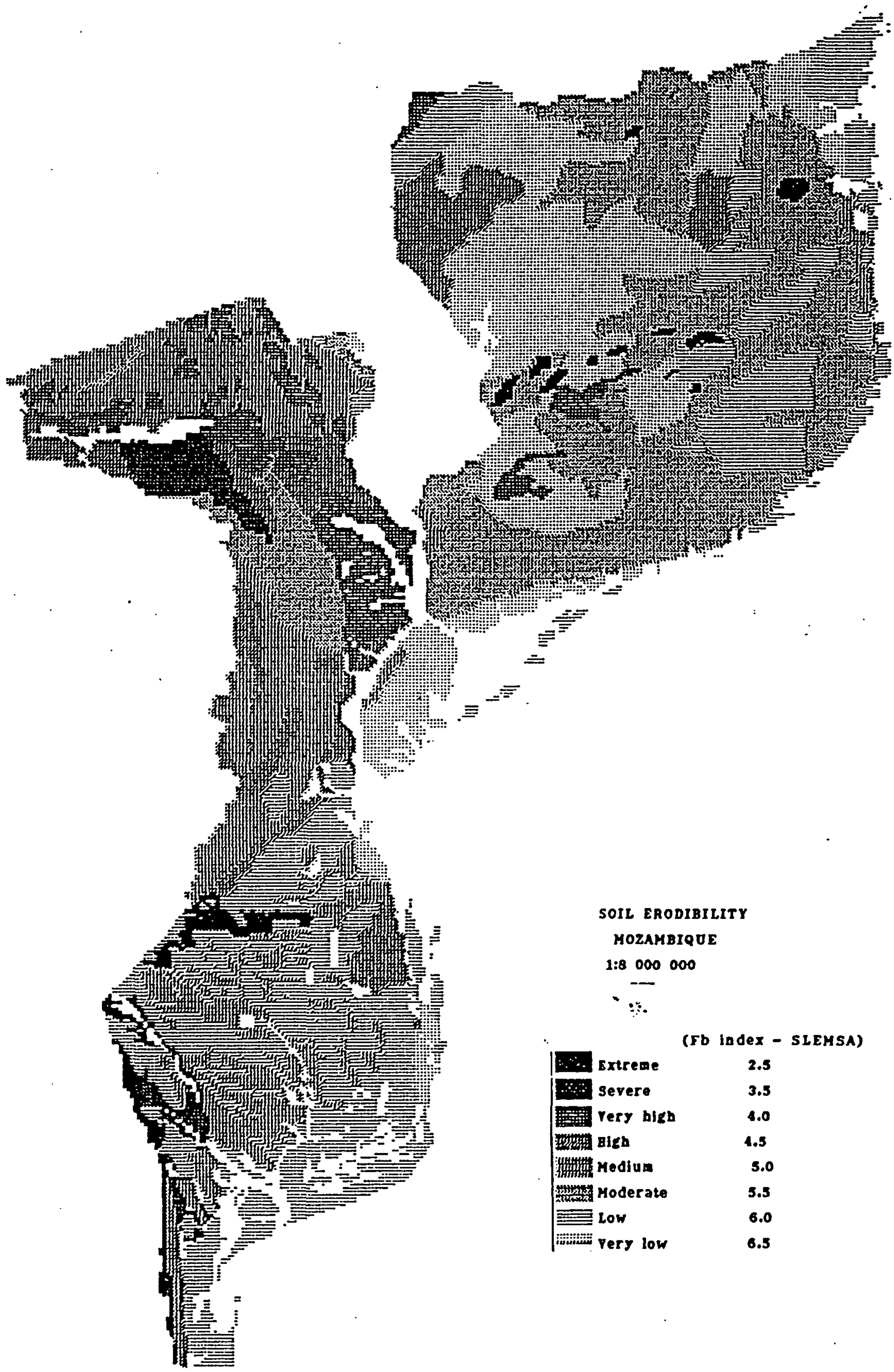
Van der Poel, P. 1980. Rainfall Erosivity and its Use for Soil Loss Estimation. Division of Land Utilization, Ministry of Agriculture, Gaborone, Botswana.

Voortman, R.L. 1986. Soil Resources of Mozambique. Communicacoes No.21, Instituto Nacional de Investigacao Agronomica, Maputo.

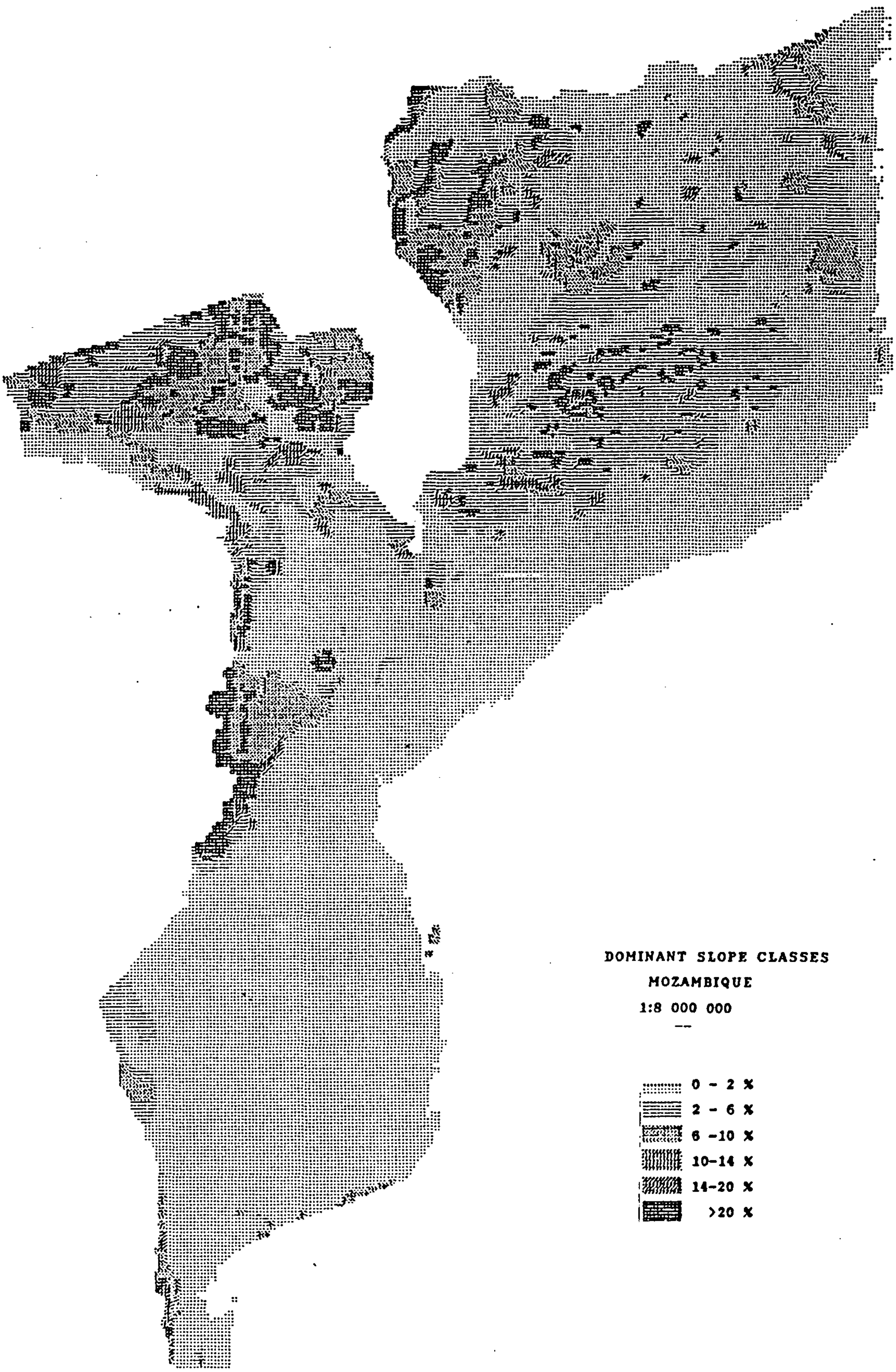
Map 1


RAINFALL EROSIVITY
MOZAMBIQUE
1:8 000 000
RAINFALL KINETIC ENERGY E x 10-3 (j/m2)
< 11
11 - 13
13 - 15
15 - 17
17 - 19
19 - 21
21 - 23
23 - 25
25 - 27
> 27

Map 2


SOIL ERODIBILITY
MOZAMBIQUE
1:8 000 000
(Fb index - SLEMSA)
Extreme 2.5
Severe 3.5
Very high 4.0
High 4.5
Medium 5.0
Moderate 5.5
Low 6.0
Very low 6.5

Map 3


DOMINANT SLOPE CLASSES
MOZAMBIQUE
1:8 000 000
0 - 2 %
2 - 6 %
6 -10 %
10-14 %
14-20 %
>20 %

.f.

Map *k*

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!j

11

		(EHU*)
	Very Low	(o - 50)
§ 3	LOW	(51-250)
	Moderate	(251-500)
	High	(501-1000)
	Severe	(1001-1500)
	Extreme	(> 1500)

(*) Eroslon Hazard Units - SLEMSA

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