The Qualitative Assessment of Water Erosion Risk in the Moist Savanna of Benin

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Abstract: Soil erosion and land degradation are severe problems in Africa. Quantitative information on the magnitude of soil erosion for different soils and eco-regions is generally not available in Benin. The aim of this study is to give qualitative estimation of erosion risks under farmers conditions. The study makes use of two different erosion hazard models (USLE, SLEMSA).

The calculation are facilitated by the SWEAP application which extracts basic input data from the SOTER database. In the present version of the program only one climatic station can be linked to each SOTER Terrain unit. However, in the case of the BENIN-SOTER most Terrain units are related to more than one climatic station. Thus the calculation was run on the SOTER terrain sub-component level.

According to the cropping systems in the study area the following scenarios are studied: annual crop rotation with two crops, maize in the first rainy season (April-June), and cotton in the second rainy season (July-October). The soil conservation management options were minimum tillage with no erosion control, strip cropping or contouring.

The SLEMSA model in general shows lower erosion hazard indices than USLE for the same terrain sub-component. It is that the SLEMSA model has a better applicability under the given tropical conditions because the SLEMSA results are similar to plot results.
Keywords: assessment of erosion, SOTER database, savanna Benin

1 Introduction

Soil erosion and land degradation are severe problems in Africa (Lal, 1995). Quantitative information on the magnitude of soil erosion for different soils and ecoregions is rarely available in Benin. Some quantitative data of erosion effects on crop yield under different systems of management can be found for the Terre de Barre Plateau in southern Benin (Verney and Volkoff, 1967, Verney *et al*., 1969, Azontondé, 1979). On the crystalline basement only one document was found for the Parakou region (Van Campen, 1977), 200 km north of our study area.

The aim of this study is to estimate erosion under farmers conditions in the Central Benin on the basis of a nearly developed environment information system. The study makes use of two different erosion hazard models (USLE, SLEMSA, Van den Berg and Tempel, 1995).

2 Materials and methods

The environmental information Database was made for Central Benin on basis of the SOTER approach (van Engelen, 1993) with a slight modification (Weller and Stahr, 1995).

The concept is based on the identification of areas (land units) with distinctive, often repetitive patterns of geomorphological, or geological elements characterised by a certain soil pattern (Shield and Coote, 1988 ; Brabant, 1992). The mapping units are stored in two different data sections: the geometry in a Geographic Information System (GIS), and attribute information (i.e. slope) in a separate database.

In Central Benin the uppermost spatial level are seven Terrain units (TUs), which have been distinguished by overall slope gradient and relief intensity. Terrain Units are subdivided at a second level into 26 terrain components (TCs) and 45 terrain subcomponents (TsCs) based on petrography. The Soil and Terrain Database of Central Benin contains 445 soil profiles which are grouped in 26 profile sets (Igué, 2000).

For the calculations of the erosion hazard index (EHI) the computer program SOTER Water Erosion

Assessment Program (SWEAP) is used **(**van den Berg, and Tempel 1995). This program was developed as application programme of the SOTER database. It contains modules for USLE, the Universaly Soil Loss Equation **(**Wishmeier and Smith, 1978) and SLEMSA, the Soil Loss Estimation Model for Southern Africa (Elwell and Stocking, 1982; Stocking *et al.*, 1988).

SWEAP consists of two parts: (1) the menu and (2) the model. This parts must be linked with the SOTER package parts: (a) a database and (b) a GIS.

SLEMSA, the Soil Loss Estimation Model for Southern Africa (Elwell and Stocking, 1982; Stocking *et al.*, 1988) has been developed as an alternative for the USLE in the region. SLEMSA uses seasonal rainfall energy, (EJ • m^{-2} • yr^{-1}), a soil erodibility factor, (F as a rating), and the percentage rainfall energy intercepted by crop, (I in %). The basic equation of the model is (Figure 1).

Stocking (1988) suggest to express the results in terms of abstract Erosion Hazard Units (EHU) rather than as quantitative soil loss estimates.

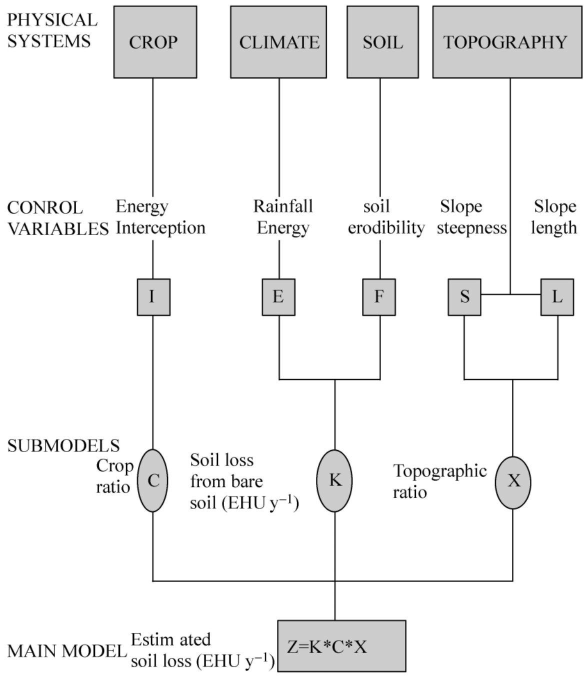

Fig. 1 The framework of SLEMSA (Stocking *et al.*, 1988)

SWEAP utilises data from four different kind of input files (Van den Berg and Tempel 1995):

(1) Terrain and soil characteristics, actual land use/vegetation and climate are extracted from the SOTER database;

(2) Scenario data regarding hypothetical combinations of land use, management and erosion control practices are provided interactively by the user through the SWEAP menu system;

(3) Conversion tables are used to derive erosion factors from scenario data and SOTER data;

(4) Configuration data control the working and output of the program.

All input files are plain ASCII files that can be viewed and edited with any ASCII editor.

3 Results and discussion

One of the main advantages of storing soil and terrain information in a digital database (SOTER), is that tailor-made thematic maps can be derived on request, using the data as a basic source. The derivation of water erosion risk maps is one possible application.

According to the cropping systems in the study area the following scenarios are studied: annual crop rotation with two crops, maize in the first rainy season (April-June), and cotton in the second rainy season (July-October). The soil conservation management options were minimum tillage with no erosion control, strip cropping or contouring.

SWEAP calculates the erosion hazard for every soil component within a terrain component. Subsequently the results may be classified and sorted in various ways, and written in a table format (Table 1). These output files are used by a GIS (e.i. ARCINFO) to create erosion hazard maps. For example the terrain subcomponent Lgn1 consists of seven soil components respectively with the following percentage of occurrence and degree of erosion hazard (t • ha^{-1} • yr^{-1}, scenario maize/cotton: minimum tillage, no erosion control) :

Table 1 Erosion hazard index (EHU y^{-1}) of soil components within terrain subcomponent high peneplain on gneiss basement (Lgn1)

Soil component	Coverage (%)	Erosion index	Profile sets	Experim. Plot
Lgn1/1	45	64	Ferric Luvisols	20 (t • ha^{-1} • yr^{-1})
Lgn1/2	14	80.8	Ferric Alisols	nd
Lgn1/3	14	44.6	Eutric Regosols	nd
Lgn1/4	7	98.7	Humic Alisols	nd
Lgn1/5	8	119.3	Eutric Plinthosols	nd
Lgn1/6	7	117.3	Gleyic Luvisols	nd
Lgn1/7	5	37.3	Cambic Arenosols	nd

L = High peneplain , gn = gneiss, 1 = migmatitic, nd = no determined

For each scenario an erosion hazard index (EHI) map will be produced by using the USLE equation. The maps (Figure 2) were created from the predicted values in erosion hazard units (EHU) per year. Because the model is not yet calibrated for the area, there is no reliability for quantitative values.

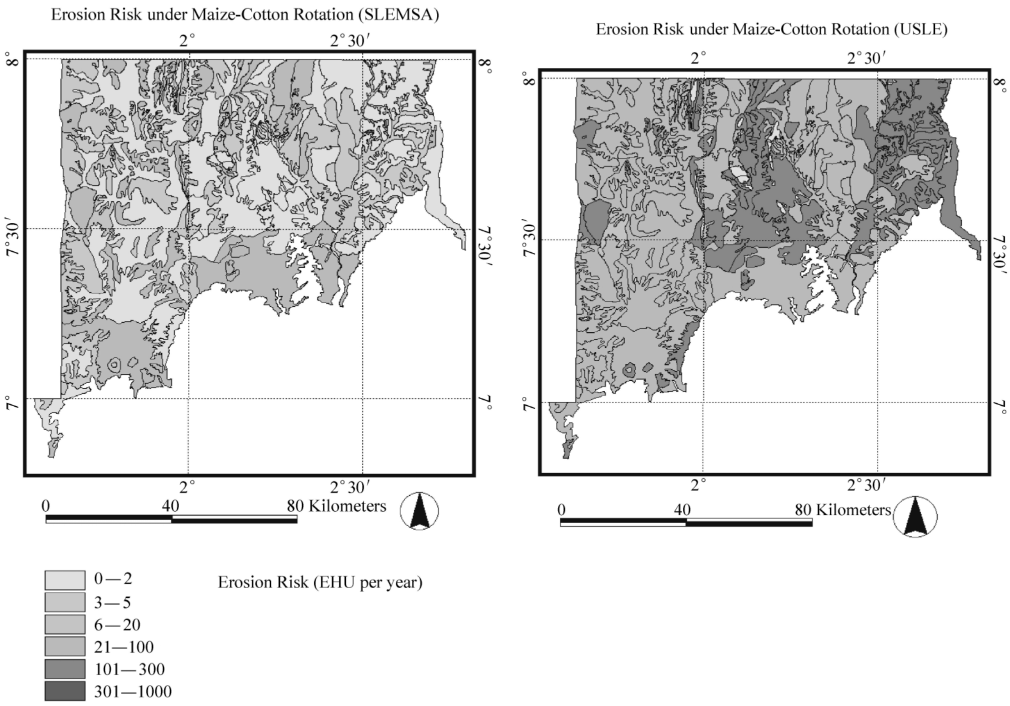

Fig.2 Erosion hazard map under maize-cotton rotation in most Savanna of Benin

The results indicated in Table 2 (SLEMSA) shows that erosion hazard indices (EHI) are low (2—4) for terrain sub-component Pgn1) (maize-cotton rotation) in the two options *strip cropping* and *contouring* compared to the option *no erosion control* where EHI is moderately high (34). These results show that *strip cropping* and *contouring may* reduce erosion of 88%—94% in maize-cotton land use field compared to the option *No erosion control*.

Table 2 Erosion hazard index in EHU y^{-1} of selected TCs (SLEMSA or USLE, maize/cotton, minimum tillage)

TsCs	SLEMSA			USLE			Percent coverage
	No erosion control	Strip cropping	Contouring	No erosion control	Strip cropping	Contouring	
Plateaus							
Pgn1	34	2	4	63	51	23	34
Pgn2	7	–1	–1	14	11	5	49
Pg1	67	–1	–1	128	88	38	51
Footslopes							
Fgn1	9	7	12	158	106	47	39
Fgn2	6	4	8	140	94	41	70
Fgn3	13	10	19	280	183	81	77
Fb1	6	5	9	95	63	28	66
Fg1	67	–1	–1	126	84	37	71
Fq1	72	–1	–1	119	79	35	33
Fr-b	62	–1	–1	232	159	69	82
Fr1	2	2	3	102	68	30	43
Fcr	5	4	8	83	57	24	76
High peneplains							
Lgn1	3	2	4	63	42	19	45
Lgn2	48	–1	–1	81	54	24	37
Lgn3	2	1	3	74	59	26	100
Lgn4	29	–1	–1	47	31	14	60
Lgn5	40	–1	–1	72	48	21	36
Lgn6	2	2	4	73	49	21	76
Lgn7	1	1	2	132	88	39	36
Lg1	52	–1	–1	113	74	33	41
Ls1	3	3	5	104	69	31	82
Lr1	2	1	3	117	78	34	100
Lm1	5	4	7	159	106	47	68
Lm2	4	3	6	123	83	37	45
Low peneplains							
Vgn1	2	1	3	110	88	39	58
Vgn2	1	1	2	40	32	14	40
Vgn3	2	2	3	54	43	19	55
Vgn4	2	1	3	75	60	26	72
Vgn5	3	2	4	113	91	40	90
Vgn6	7	6	11	103	69	30	42
Vgn7	34	–1	–1	38	30	13	100
Vgn8	2	2	3	54	43	19	29
Vgn9	37	–1	–1	79	61	27	31
Vga1	3	2	3	78	62	28	64
Vga2	2	1	3	33	26	12	83
Vm1	33	–1	–1	127	102	45	55
Vc1	22	–1	–1	40	32	14	100
Floodplains							
Va1	37	–1	–1	175	140	62	100

P = plateaus, F = footslope, L = high peneplains, V = low peneplains; gn = gneiss, b = balsalt, g = granite, q = quqrtzite, r-b = rhyolite-basalte, r = rhyolite, cr = cretaceous sediment, s = sandystone, m = mylonite, ga = gabbro, c = colluvium deposits, a = alluvium deposits

The results after running USLE show another Figure. USLE indicates values higher than SLEMSA (normal case). In Mozambique SLEMSA shows higher values than USLE (Westerink 1999).

The USLE method gives good results (Table 2) and shows that without erosion control EHI is moderate (14, Pgn2) to high (128, Pgn1) on the plateaus. On the other hand, on the footslopes and some high peneplains and floodplains EHI is comprised between 102 and 280 (high EHI). On gneiss-migmatite high peneplains and most of low peneplain and floodplains, EHI are moderate.

The use of *contouring* under maize-cotton land use decreases 3 times or more erosion risk on all landscapes compared to *no erosion control* (Figure 3, 64%—70% on plateaus, 70%—79% on footslopes, 60%—73% on high peneplains and 64%—74% on low peneplains and floodplains). On the other hand, the option *strip cropping* reduces erosion of 20%—31% (plateaus), 30%—35% (footslopes), 20%—33% (high, low peneplains and floodplains).

Likewise, contouring is considerably reducing erosion risk more than strip cropping under maize-cotton.Erosion risk index is more higher on floodplains than other landscapes and lower on Plateaus (Figures 3)

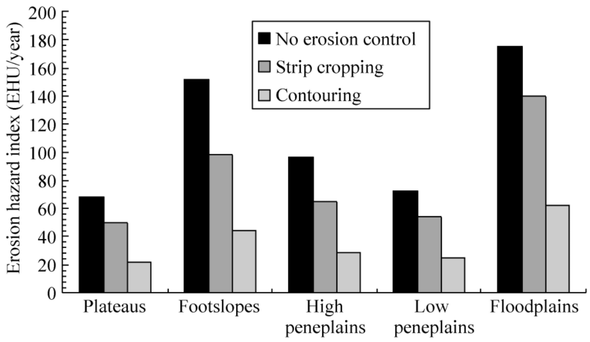

Fig. 3 Erosion hazard index on different landscapes under maize-cotton with minimum tillage and three soil conservation management (USLE)

Accelerated soil erosion by water is a serious problem on agricultural land in several regions of Africa (Dregne, 1990, Lal, 1993). Estimated current erosion rates are in excess of 75 t • ha^{-1} • yr^{-1} for the Maghreb region in the northwestern parts of Africa, 25 t • ha^{-1} • yr^{-1} to 50 t • ha^{-1} • yr^{-1} and 10 t • ha^{-1} • yr^{-1} to 25 t • ha^{-1} • yr^{-1} for southern and eastern respectively and less than 10 t • ha^{-1} • yr^{-1} for most of West Africa (Lal, 1995).

The data obtained by running SWEAP in the study area are higher than the mean in West Africa. However, the results with SLEMSA (34 EHU yr^{-1} option no erosion control) obtained on Plateaus with Ferric Luvisol correspond to those obtained on Plateaus with Acrisols (35 t • ha^{-1} • yr^{-1}) in southern Benin but higher than of those obtained on Ferric Luvisols (20 t • ha^{-1} • yr^{-1}) in the north.

4 Conclusions

The erosion hazard index (EHI) pattern resulting from SLEMSA and USLE runs show that SLEMSA resulted in lower EHU values compared to USLE for the same terrain component (Table 2). In respect of this reason that Stocking *et al*. (1988) concluded that the SLEMSA model claims better applicability in tropic conditions. However, the model needs to be improved.

The SOTER Water Erosion Assessment Program (SWEAP) is designed to facilitate the use of the SOTER database for erosion hazard prediction at scale 1∶100.000 to 1∶200.000. SWEAP units are supposed to be presented at a mapping unit level which covers large areas. Therefore SWEAP results are interpreted such that the output is an abstract indication of erosion hazard, expressed in erosion units rather than quantified estimates of a soil loss model in t • ha^{-1} • yr^{-1}.

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