Working Paper and Preprint

DRAFT

WATER EROSION ASSESSMENT

using reference soils of the ISIS database

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October 1995

ISRIC

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

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USING REFERENCE SOILS OF THE ISIS DATABASE

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1 INTRODUCTION

The global assessment study of soil degradation (Oldeman et al., 1991) indicated that water erosion is by far the most important type of land degradation, followed by wind erosion. Around 920 respectively 454 million ha is affected by water and wind erosion; this is 47% respectively 23% of the total area affected by human induced soil degradation. Both types of erosion result in loss of top soil and consequently productivity, mostly in areas where potential productivity is already low.
Nowadays, human induced changes in land use and vegetation cover are occuring at an alarming rate. In Asia, Africa and South America, more than 1000 million ha of agricultural land is affected by loss of topsoil, of which more than 600 million ha is at a moderate to strong degree, which is generally beyond the means of local farmers to restore the soil productivity (Oldeman et al., 1991).
An erosion assessment of different land use options for a particular area of land, still under present land use or original vegetation cover, can help to enlarge the insight and knowledge of its vulnerability under the proposed land use options and predict under which option the soil is most seriously endangered. This information, incorporated in land use planning for future development, at various levels of management decision, should help to protect more effectively our soils and agricultural lands.

This study was aimed to assess the water erosion hazard using the reference soils of the ISIS database, to test the applicability of the SOTER Water Erosion Assessment Program (SWEAP) on the ISIS database and to evaluate the assessment results by expert knowledge.

2 METHODS AND MATERIALS

Erosion models

The erosion risk of selected reference profiles was assessed with SWEAP (SOTER Water Erosion Assessment Program), a computer program for the asssessment of the erosion hazard applied to the SOils and TERrain digital database (SOTER). The main feature of SWEAP is that it makes use of a digital database as its source of input. The results of the assessment of data from SOTER can be linked to GIS and erosion/land degradation maps produced. Both SWEAP and SOTER are programs developed by ISRIC (Van den Berg, 1992; van Engelen and Wen, 1993).
Besides SOTER, ISRIC developed the ISIS (ISRIC Soil Information System) database (van Waveren and Bos, 1988). This database stores data from reference soils which were collected from all over the world by ISRIC in close collaboration with national soil institutes. Because of differences in codes and classes, compared to SOTER, the computer program SWEAP had to be adapted to be applicable to the ISIS database (van den Berg and Tempel, 1995).
SWEAP contains currently two erosion risk assessment models: the Universal Soil Loss Equation (USLE; Wischmeier and Smith, 1978) and the Soil Loss Estimation Model for Southern Africa (SLEMSA; (Elwell and Stocking, 1982). Shield and Coote (1989) proposed to use the USLE model to assess the erosion hazard of soils in the SOTER database. Rademacher (1991) suggested to use, besides USLE, also the SLEMSA model, as being a promising model for tropical conditions. Despite their regional origin, USLE and SLEMSA were developed for the United States and Southern Africa respectively, both models were applied to the reference profiles, which have a mondial distribution.

The Universal Soil Loss Equation is an emperical model, estimating the soil loss over an extended period of time (Wischmeier and Smith, 1978).

The basic equation of the model is: $A= R*K*LS*C*P$
where

A = Computed soil loss per unit area, expressed in ton ha^{-1} $year^{-1}$
R = Rainfall and runoff factor, expressed in rainfall erosion index units, ru
K = Soil erodibility factor, i.e. the (long term average) rate of soil loss per erosion index unit for a specified soil as measured on a unit plot, expressed in ton ha^{-1} yr^{-1} ru^{-1}
LS = Slope length and steepness factor
C = Vegetation cover factor (and management factor)
P = Erosion control practice factor

SWEAP was developed to assess soil loss at a small scale e.g 1:1.000.000 and at this scale uniform slopes will hardly occur. Therefore the soil loss "A" should be interpreted as a relative indication of the erosion hazard, expressed in "erosion hazard units" (EHUs), as proposed by Stocking et al. (1988), rather than as quantified estimates of soil loss in ton ha^{-1} yr^{-1}. The soil loss estimates of the selected reference profiles from the ISIS database also comply with it.

The SLEMSA model was developed as an alternative for USLE in Southern Africa (Elwell and Stocking, 1982; Stocking et al., 1988).
The basic equation of the model is: $Z = K*C*X$,
where

Z = Estimated soil loss (ton ha^{-1} yr^{-1})
K = Mean annual soil loss (ton ha^{-1} yr^{-1}) from a standard weed-free bare fallow field plot with a length of 30 m and a slope gradient of 4.5%)
C = Crop ratio, i.e. the ratio of soil lost from a cropped plot to that lost from a bare fallow land.
X = Topographic ratio, i.e.the ratio of soil lost from plot of length L and slope S, to that lost from the standard plot

For the same reason as mentioned for USLE, it is more appropriate to interpret the soil loss "Z" in terms of a relative indication of the erosion hazard rather than as a quantitative soil loss estimate.
For detailed information on SWEAP, reference is made to van der Berg and Tempel (1995).

Reference profile data.
From the 500 reference soil profiles, currently available in the ISIS database, about 257 profiles were selected for an assessment of soil loss with SWEAP. This will be referred to as the "SWEAP selection" in this paper. Criteria used for selection were: the availability of a complete data set for the reference profiles and a good chance that erosion by water can be expected on the basis of gradient and precipitation.
Selected profiles originate from the following countries; Brasil, Colombia, Costa Rica, Cuba, Ecuador, Peru, Kenya, Mali, Mozambique, Nigeria, Zambia, Zimbabwe, China and Indonesia.

Input
The models use the following information about the topsoil.
For the USLE equation: gradient and slope length (kept constant), soil depth, surface stoniness and rockiness, drainage class, structure type, grade and size, total carbon, abundance of coarse fragments, textural class, percentage very fine sand, silt and clay, land use and natural vegetation.

For SLEMSA, besides some of above listed information, degree of soil development and certain diagnostic properties (based on FAO'74 and '88 classification), including depth to bedrock, sensitivity to capping, lower depth of horizon, distinctness of horizon transition and electrical conductivity are also necessary.

In addition to this data, the program requires a linkage between a reference profile and a climate station. The following climatological information is needed to calculate the rainfall erositivity and the growing period on a monthly basis: rainfall, minimum and maximum temperatures, potential evapotranspiration (Penman). If potential evaporation data are not available, then hours of bright sunshine, vapour pressure, average relative humididity and mean wind velocity are required instead.

Output.

Erosion risk is assessed for 4 land use scenarios, viz. present land use, original vegetation, bare soil and a scenario for a specific crop. In this last scenario, a 'standard' crop is selected according to the following relationship with the precipitation at the site: sorghum, 600 mm yr^{-1} or less; maize at a precipitation of 600 to 1800 mm yr^{-1} and cassave, more than 1800 mm yr^{-1}. One exception was made for the soils of Cuba, where all soils were assessed on erosion risk under sugar cane.

Initially, the erosion risk assessment was calculated for the reference soils per country; both models were employed and the assessment results, soil loss expressed in ton $ha^{-1}year^{-1}$.

The results of the erosion assessment with SWEAP were classified using "erosion hazard units" (EHUs), according to their estimated soil loss, as defined in the procedure manual (Van der Berg and Tempel, 1995). Beside the classes suggested, a distinction was made between results exceeding 300 ton.ha^{-1} $year^{-1}$ and those exceeding more than 1000 ton.$ha^{-1}year^{-1}$ (model output limit). The following EHU classes were used:

Classes	Soil loss (ton.$ha^{-1}year^{-1}$)
A	0 - 2
B	2 - 5
C	5 - 20
D	20 - 100
E	100 - 300
F	300 - 1000
F"	>1000

3 INFORMATION ON REFERENCE SOIL SELECTED FOR SWEAP

3.1 Distribution of reference soils over agro-ecological zones and major soil groups.

Some background information of reference soils of the SWEAP selection is given in this section, especially those attributes which are of importance for the erosion assessment.
For more detail information, reference is made to "Soils of Major Eco-regions" (in this volume).

Agro-ecological zones in SWEAP selection
The distribution of the reference profiles of the SWEAP selection over the major agro-ecological zones (AEZ) is given in table 1, together with a distribution over the three main regions in the tropics.
It shows that refence profiles of the SWEAP selection are not equally distributed and that a certain AEZ in a region can be over or under represented, e.g. compare the seasonally dry tropics and humid tropics in Africa.

Table 1. Frequency distribution of selected profiles per AEZ and region.

Agro Ecological Zone	S.& M. America	Africa	S-E Asia	All
Highlands	19	5	3	27
Humid tropics	50	6	39	95
Seasonally dry tropics	39	58	20	117
Dry tropics	5	5	-	10
Temperate	3	-	3	6
Total	116	74	67	255

Major soil groups of SWEAP selection
Five major soil groups (FAO, 1974) dominate in the SWEAP selection, viz. Cambisols, Acrisols, Ferralsols, Andosols and Luvisols with percentages between 9 and 19 %. Other major soil groups in the selection with minor extent (percentages from 1% to 4%) are; Gleysols, Phaeozems, Fluvisols, Nitisols, Arenosols, Podzols, Regosols and Vertisols.

The dominant major soil groups (FAO, 1974) are distributed over the different agro-ecological zones and deviate somewhat from the representation in the ISIS database.
For the humid tropics Cambisols (27%) are dominant in SWEAP selection, followed by Acrisols (19%), Ferralsols (18%), Andosols (16%) and Luvisols (5%).
In the seasonally dry (sub)tropics Acrisols and Ferralsols dominate, resp. 22% and 21%, followed by Cambisols (13%) and Luvisols (12%), while in the highlands Andosols (70%) are the most important.

3.2 Landform and landcover

Topographical classes per major agro-ecological zone

The overall percentages of topographical classes (FAO, 1988) of the reference profiles in the SWEAP selection are given in table 2.

Table 2. Frequency percentages of topographical classes (FAO '88) per AEZ.

Topography	Highlands n=26[1]	Humid tropics n=94	Seasonally dry tropics n=117	Dry tropics n=10	Temperate n=8	All n=255
Almost flat	19	29	29	60		28
Undulating	19	31	50	40	75	40
Rolling	19	15	6	-	13	11
Hilly	8	10	3	-	12	6
Steeply dis.	12	12	3	-	-	7
Mountainous	23	13	9	-	-	8

[1] n= number of reference profiles per agro-ecological zone

Undulating topography dominates the soil sites in the SWEAP selection for the seasonally dry tropics and humid tropics, respectively 50% and 31% of the cases. Flat and almost flat topography follow with 29% and smaller percentages for the other classes with higher gradients. The humid tropics have a more broken topography than the seasonally dry tropics and show higher percentages for the rolling and hilly classes.

It is remarkable that only 35% of the topograghy of the highlands is classified as mountainous and steeply dissected, while almost flat and undulating lands together accounts for 38% of the cases.

When the topographical classes are compared to the actual gradients used for the calculation of the soil loss with SWEAP, there is a slightly higher percentage in the almost flat and undulating classes of the seasonally dry tropics (almost flat + undulating = 86%) and humid tropics (almost flat + undulating = 61%)

For the highlands these percentages also deviate, slopes falling into rolling and hilly classes comprise 48% and mountainous and steeply dissected classes 22%. This means that the gradient at the site of the profile is lower than one might expect from the topographical classification of the landform.

Vegetation and present land use

The dominant (original) vegetation type in the humid tropics is closed forest 72%, followed by woodland and herbaceous vegetation, each with 10 %.

The seasonally dry tropics are dominated by woodland 44% and closed forest 21%, herbaceous and shrub vegetation are resp. 12% and 24 %.

Closed forest 41 % and herbaceous vegetation 47% dominate the highlands, while shrubs occur only in 12% of the cases.

The dominant, current land use for all agro-ecological zones is arable farming. Generally, arable farming (including all levels of input and fallow), account for about 50 % of the present land use in the humid tropics of the SWEAP selection and an equal percentage in the seasonally dry tropics. Fallow is twice as extensive in the humid tropics as in the seasonally dry tropics (12% against 5%), so that more land is actually occupied for crop production in the seasonally dry tropics.

In the highlands, arable farming comprises 1/3 of all land use types, (no fallow recorded), while the (semi) natural vegetation is still 30 % compared with 23% in the humid tropics and only 14 % in the seasonally dry tropics.

Grazing, including grazing on natural vegetation as well as on cultivated pasture, occurs in 22% of the cases and can be considered equal for the three major agro-ecological zones.

3.3 Erosion degree and erosion type

Erosion degree

About 45 reference profiles had no classification at all for erosion degree. Of the remaining number 47 % were classified as having no erosion or erosion not observed. Slight erosion occurs in about 40 % (mainly sheet) and 7 % have moderate erosion.

Table 3. Frequency distribution (percentages) of erosion degree recorded per major agro ecological zone

Erosion degree recorded	Humid tropics n=69 [1]	Seasonally dry tropics n=109	Highlands n=19	All n=210
No erosion	54	44	63	47
Slight erosion	39	42	11	40
Moderate erosion	4	8	11	7
Severe erosion	3	2	10	3
Combined degrees	-	4	5	3

[1] n= number of reference profiles per agro-ecological zone

The frequency distribution of the erosion degrees between the humid tropics and the seasonally dry tropics shows only slight differences. The most important difference is, that, on basis of this data set, more profiles of the SWEAP selection are effected by erosion in the seasonally dry tropics than in the humid tropics.

It is remarkable, that a high percentage of profiles in the highlands is recorded with no erosion. This might be the result of a rather high percentage of data from locations with low gradients (see 3.2). A possible other reason might be a high percentage of Andosols in this AEZ (see 3.1). However, moderate and severe erosion are as frequent as slight erosion, indicating the high erosion risk, as can be expected for this agro-ecological zone.

Erosion type

less than half of the reference profiles in the SWEAP selection have the erosion type recorded. From the dataset (table 4), it appears that sheet erosion is by far the most significant type of erosion in all major agro-ecological zones.

Table 4. Frequency distribution (percentages) of erosion type per major agro-ecological zone.

Erosion Type	Humid tropics n=30 [1]	Seasonally dry tropics n=61	Highlands n=7	All n=110
Sheet erosion	80	67	29	68
Sheet and rill	14	8	43	14
Sheet and gully	3	5	-	4
Rill	-	7	-	4
Rill and gully	-	3	-	2
Rill and sheet	-	2	-	1
Rill and wind	-	-	14	1
Gully	3	5	-	3
Wind	-	3	14	3

[1] n= number of refence profile per agro-ecological zones

The soils in the SWEAP selection for the seasonally dry tropics have more frequent rill and gully erosion, or a combination of both than the soils in the SWEAP selection for the humid tropics and highlands.

The selection for the highlands is too small to draw valid conclusions, but it seems that combined sheet and rill erosion is more extensive than sheet erosion.

4 EROSION ASSESSMENT RESULTS OF SWEAP

4.1 Erosion assessment, USLE versus SLEMSA

Both models in SWEAP, USLE and SLEMSA were applied to assess the soil loss for the selected reference profiles. The profile attributes were automatically read from the ISIS database into the SWEAP program. Only the vegetation coding was done manually.

An interresting question is, to what extent are the assessment results of the USLE model comparable to those of SLEMSA? So far, we have used the same scale to transfer the models soil loss results to "erosion hazard units" (EHUs), therefore the estimated EHUs can simply be compared.
The results of the erosion assessment for 4 land use scenarios, of the complete SWEAP selection is shown in table 5 where the frequency distribution of the classified erosion hazard units (EHUs) of both models can be compared. Although the models have about a similar distribution trend, the distribution pattern of the EHUs for the land use scenarios of both models is different.

Table 5. Frequency distribution (percentages) of erosion hazard estimated with USLE and SLEMSA models for four different scenarios

Erosion hazard unit[1] (EHU)	USLE				SLEMSA			
	Present land use n=209[2]	Original vegeta tion n=188	Bare soil n=248	Crop scena rio n=248	Present land use n=213	Original vegeta tion n=191	Bare soil n=252	Crop scena rio n=252
A	24	62	1	46	13	49	3	21
B	24	12	1	18	13	10	3	14
C	29	14	7	19	18	16	6	15
D	17	8	41	11	20	13	18	25
E	3	3	25	4	13	4	11	10
F	2	1	12	1	10	5	11	7
F"	1	-	13	1	13	3	48	8

[1] for class boundaries, see section 2, output; [2] n= number of reference soils assessed;

The erosion assessment with SLEMSA results in a higher erosion risk. Generally, with SLEMSA, a higher frequency occurs in the higher erosion hazard units (classes D,E and F) than compared to USLE.
Based on these results, it is concluded that the estimated soil loss expressed in EHUs for both models are too different to be comparable and can not be substituted.
However, a further analysis of the erosion assessment results of the SWEAP selection, by stepwise regression analysis of the actual estimated soil loss of both models and the variables of the model,

precipitation, slope and K- or F-factor, indicated a distinct difference in significance of these variables in explaining the obtained results.

For all land use scenarios tested, the slope was the dominant parameter in explaining the final assessment results with the USLE model. In the land use scenario bare soil, slope explained 77% of the predicted soil loss (precipitation was not significant). Of all scenarios, bare soil had the highest percentage, while the land use scenario original vegetation had the lowest percentage of significance for slope; it explained only 13 % of the predicted soil loss (other parameters, precipitation and K-factor, not significant).

In a similar analysis for the SLEMSA model, precipitation appeared to be the dominant variable, explaining 83% of the predicted soil loss under the land use scenario bare soil. For the land use scenario original vegetation, only a low percentage of the estimated soil loss could be explained by this parameter. Other factors, of which with no doubt vegetation (cover factor) dominate in this calculation.

From this analysis it seems that of the three variables mentioned, slope dominates in the USLE equation and precipitation in the SLEMSA equation.

Since SLEMSA was developed for Southern Africa, a region with moderate precipitation, a selection was made from the data set on basis of precipitation less than 1200 mm yr^{-1}.

Again frequencies were calculated and compared, as well as a stepwise linear regression of the three variables slope, precipitation and K- resp. F-factor versus the estimated soil loss with the USLE and SLEMSA models.

From this analysis it appeared that there is a much better correlation between frequency distribution and the erosion hazard classes for the different land use scenarios. In a stepwise linear regression analysis, slope appeared now also the variable with a high significance explaining the soil loss in the SLEMSA model, except for the scenario original vegetation. So that the conclusion is that SLEMSA and USLE are comparable only under conditions where precipitation is moderate (<1200 mm yr^{-1}).

4.2 Erosion assessment results per agro-ecological region

Erosion assessment results of the humid tropics

Because of the strong impact of high and very high precipitation on the soil loss assessment results with SLEMSA for the humid tropics, only the erosion assessment results with the USLE model is presented here.

In table 6 the results of this assessment are given for four land use scenarios .

The first land use scenario, present land use is the current land use, as recorded in the ISIS database, while in the last land use scenario, a crop, considered significant for that region, is planted; cassave for the humid tropics (or maize dependent on the precipitation) and residue management is practised. This means that in this scenario crop residues are left on the fields and ploughing/land preparation is done just before planting. No other erosion control measures are incorporated in the scenario.

As can be expected for the humid tropics, the best protection against erosion is the original vegetation, which dominantly is closed (evergreen) forest. In this land use scenario 80 % of the sites are estimated to have no or very slight erosion (EHU class A). The land use scenario with cassave/maize is second best and scores better than the scenario present land use and bare soil. The land use scenario bare soil gives the EHUs, as found for bare land, recently prepared for planting and without any protection by vegetation. The trends are as expected.

The erosion assessment results for bare soil is also an indication of the erosion susceptability, it has about 65% of the estimated EHUs in a high or extremely high erosion hazard classes (E,F and F").

Table 6. Frequency percentages of erosion hazard for soils of the humid tropics assessed with USLE for four land use scenarios

Erosion hazard unit (EHUs) [1]	Land use scenarios			
	Present land use n=80[2]	Original vegetation n=77	Bare soil n=93	Cassave/ maize [3] n=94
A	25	80	1	51
B	18	3	2	20
C	31	8	2	16
D	19	6	29	11
E	4	3	36	2
F	3	-	16	-
F"	-	-	14	-

[1] for class boundaries, see section 2, output; [2] n= number of reference soils assessed; [3]depends on precipitation; <1800 mm yr^{-1} maize, >1800 mm yr^{-1} cassave, includes crop residue management.

It is remarkable is that the land use scenario cassave/maize seems to protect the soil much better than the scenario present land use. Evidently, the extra model inputs on residue management, besides differences of crops, appear effective in protecting the soil, as about 70% of the sites fall in the low EHU classes A and B.

Table 7. Frequency percentages of erosion hazard assessed with USLE for present land use matched with field observations on erosion degree.

Erosion assessment (EHUs) [1]	Field observation on actual erosion degree under present land use.	
	No erosion n=28 [2]	Slight erosion n=22
A	21	18
B	28	14
C	34	27
D	14	36
E	-	5
F	3	-

[1] for class boundaries, see section 2, output;[2] n= number of reference soils assessed

The model's results, the estimated EHUs classes are not validated. The only possible way to get some insight in the relevance of the soil loss estimates is to compare the EHUs classes of the erosion assessment and actual observed and recorded erosion degrees of the ISIS database. This is done in table 7.

The results of the the erosion assessment of the land use scenario present land use are cross tabulated with the field observations on actual observed erosion degrees, 'no erosion and slight erosion'. Moderate and severe degrees of erosion are not considered here, as they cover an insignificant part in SWEAP selection of the humid tropics (table 3).
As can be seen from the table there is a poor correlation between the EHUs and the field observation on erosion degree. Of the sites with field observation, "no erosion", barely 50% fall in the EHU classes A and B. This signifies that 50% of the sites are assessed to have slight to moderate erosion risk under present land use.
A similar poor correlation occurs between the EHUs and a slight degree of erosion, although in the latter case there is a clear shift to "moderate and high risks" of erosion (EHUs C and D). For both cases one might tentatively conclude that the model over estimate the soil loss and as a consequence also the erosion risk of these soils. It is evident that further field observation and "expert knowledge" are necessary to evaluate the outcome of the models in SWEAP.

Erosion assessment in the seasonally dry tropics
Also for the seasonal dry tropics a water erosion assessment of the reference profiles was made with SWEAP and erosion hazard units (EHUs) were estimated for 4 land use scenarios.
Based on a better correlation between the erosion assessment with SLEMSA under moderate precipitations and USLE, both models are compared for the seasonally dry tropics. The result of the assessment are presented in table 8.
A quick comparison of the frequency distribution of EHUs for USLE and SLEMSA reveals that a similar trend is observed, although it is evident that SLEMSA estimates are higher than those for USLE. This is most probably due to a relatively high precipitation for a number of selected profiles from the seasonally dry tropics, as it had a distinct impact on the assessment results (section 4.1).

The assessment reveals that the frequency distribution of EHUs estimated with USLE for the original vegetation is only slightly more favourable than those of the scenario with maize/sorghum. Both scenarios have almost 50% frequencies in the EHU class A. Even up to "moderate" EHU classes there is hardly any difference. The same comparison for SLEMSA show a similar trend.
Compared to the humid tropics, the land use scenario original vegetation in the seasonally dry tropics has a substancially lower frequency in EHU class A. This can be attributed to the different vegetation types dominating in both agro-ecological zones. Since woodland is the dominant vegetation type for the seasonally dry tropics, it is apparent that this is less effective in protecting the soil against erosion than closed forest.
The fact that the land use scenario maize/sorghum scores much better than the scenario present land use can probably be attributed to the residue management practises incorporated in the scenario, viz. the effects of the remaining crop residues on the soil untill ploughing is effected just before planting.

Table 8. Frequency percentages of erosion risk for soils of the seasonally dry tropics assessed with USLE and SLEMSA for four land use scenarios

Erosion hazard units [1] (EHUs)	Scenarios							
	Present land use n=98 [2]		Original vegetation n=88		Bare soil n=115		Maize/ sorghum [3] n=115	
	USL[4]	SLE[4]	USL	SLE	USL	SLE	USL	SLE
A	22	18	49	44	-	1	48	30
B	32	16	21	12	1	4	19	24
C	30	27	16	19	10	11	21	20
D	13	27	8	14	54	33	6	14
E	1	6	4	3	19	17	4	6
F	1	4	2	6	7	15	1	1
F"	1	2	-	2	9	18	1	5

[1] for class boundaries, see section 2, output; [2] n= number of reference soils assessed; [3] depends on precipitation, < 600 mm yr^{-1} sorghum, > 600 mm yr^{-1} maize; [4] USL = USLE model and SLE = SLEMSA model

The frequency distribution for the scenario bare soil is high for the EHUs D and E (including F and F" for SLEMSA). On the present scale of erosion risk (for the USLE model) this might be moderately severe and severe, with a relative low frequency in extremely high EHUs.

When the scenarios bare soil of the seasonally dry tropics are compared to the humid tropics there appeared to be a lower erosion risk for the seasonally dry tropics. This can probably be explained by a difference in ecological conditions. In the SWEAP selection, soils of the seasonally dry tropics are found on lower gradients (table 2) and probably there can be an effect of moderate (seasonally) precipitations.

The model's results, the EHUs classes, are not validated. In table 9 the EHUs classes of the erosion assessment with the USLE model are compared to the actual observed and recorded field conditions. The results of the erosion assessment for the scenario present land use are cross tabulated with field observations for the erosion degrees "no and slight erosion". Moderate and severe erosion are not considered here, as they occur in rather low frequencies in the seasonally dry (sub)tropics (table 3).

Table 9. Frequency percentages of erosion hazard assessed with USLE for present land use matched with field observations on erosion degree.

Erosion risk assessment (EHUs) [1]	Field observations on actual erosion degree under present land use	
	No erosion n=40 [2]	Slight erosion n=40
A	20	30
B	30	35
C	38	20
D	7	13
E	3	-
F	2	-
F"	-	2

[1] for class boundaries, see section 2, output; [2] n= number of reference soils assessed;

As can be seen from the table there is a poor correlation between the EHUs and the field observation of erosion degree. Where slight erosion is indicated a lower erosion risk exist than where no erosion is observed, so that there is reason to doubt the model estimates and/or field observations on erosion degree. It seems that the model does not estimate soil loss very well. Further field observation are necessary to evaluate and calibrate the outcome of the models in SWEAP.

4.3 Erosion assessment results per dominant major soil group

Erosion assessment results for the dominant major soil groups (FAO,1974) are presented in table 10. It gives the frequency distribution in percentages of a particular EHU class of each dominant soil group for two scenarios.

Generally, there is a similar distribution of the EHUs for the major soil groups. However, a carefull examination of the table, indicates that the percentage of Ferralsols under the present land use scenario with a low EHU class is higher than for all other soil groups, followed by the Acrisols.

Luvisols, Cambisols, Andosols and "other major soil group" are about equal when the EHUs are compared.

Table 10. Frequency percentages of erosion assessment results (USLE) expressed in EHUs per dominant major soil group for the scenarios present land use and bare soil.

E H U Clas[1]	Acrisols[2]		Cambisols		Ferralsols		Luvisols		Andosols		Others	
	n=31	46	n=35	46	n=28	44	n=19	21	n=15	33	n=45	58
	Pres LU	Bare[3]	Pres LU	Bare	Pres LU	Bare	Pres LU	Bare	Pres LU	Bare	Pres LU	Bare
A	32	0	17	0	43	2	5	0	20	0	16	0
B	29	0	29	2	25	5	32	0	13	0	31	0
C	26	6	17	2	29	18	32	5	27	0	35	9
D	7	52	20	30	3	48	26	38	40	9	18	54
E	3	20	6	22	0	16	5	43	0	39	0	24
F	0	7	8	17	0	9	0	5	0	24	0	10
F"	3	15	3	26	0	2	0	9	0	27	0	3

[1] for class boundaries, see section 2, output; [2] n= number of reference soils assessed; [3] Pres LU = scenario present land use, bare = scenario bare soil

This result, together with the results of the land use scenario "bare soil", which probably is a better indication of the susceptability for erosion, leads to a following sequence of susceptability; Ferralsols, Acrisols, "Others", which is a residual group of various major soil groups, Luvisols, Cambisols and Andosols.

4.4 Soil erodibility factors

The "soil erodibilty" factor, or K-factor for the USLE model, is calculated according to the equation of Wischmeier and Smith, (1978). It takes into account the various soil caracteristics mentioned in (section 2).

The equivalent for SLEMSA is the F-factor, a soil erodibility rating, that may vary from 1 (extremely erodible) to 10 (extremely resistant). The factor is a rating given to a certain soil type/major soil group by expert judgement and corrected for deviating soil characteristics.

The results of the mean and median K- and F-factors for the dominant major soil groups (FAO, 1974) of the SWEAP selection are given in table 11.

Table 11. Soil erodibility factors of major soil groups extracted from calculations with SWEAP.

Major soil group	K- factor				F-factor			
	mean	median	1st quart.	3rd quart.	mean	median	1st quart.	3rd quart.
Acrisol	0.400	0.285	0.165	0.638	4.65	5.00	3.50	5.50
Cambisol	0.446	0.412	0.285	0.626	4.50	4.50	4.00	5.00
Ferralsol	0.214	0.182	0.096	0.297	5.86	6.00	5.50	6.50
Luvisol	0.375	0.298	0.226	0.443	4.31	4.43	3.50	5.50
Andosol	0.669	0.705	0.442	0.801	4.20	4.00	4.00	5.00
Others	0.480	0.411	0.217	0.718	4.70	4.70	4.00	5.59
All	0.430	0.356	0.199	0.638	4.75	4.75	4.00	5.50

On basis of the above calculated K-factors, cautiously one can conclude that, under identical conditions, the Ferralsols are least susceptable to water erosion, followed by the Acrisols and Luvisols. Cambisols follow as a middle group, while the Andosols appears to be most susceptable, having a high K-factor.

The susceptibility for erosion expressed in the F-factor, has similar trend. Ferralsols are most resistent to erosion, followed by the Acrisols, with Andosols much more susceptable. On basis of the F-factor are Cambisols more resistant than Luvisols.

5 CONCLUSSIONS

Based on the water erosion hazard assessment of a selection of reference profiles from different agro-ecological zones with SWEAP some tentative conclusions can be drawn.

- In general, the assessment results of both models in SWEAP, USLE and SLEMSA, deviate too much to be comparable and they can not be substituted.
-The soil losses estimated with the SLEMSA model are higher than those of the USLE model.
-More or less comparable results were found for the SLEMSA model under moderate, less than 1200 mm yr^{-1}, precipitation, such as encountered in the region of Southern Africa.
- It appeared that the USLE and SLEMSA models had different variables, which dominated the assessment results. For the USLE model the slope variable appeared most significant and for the SLEMSA model, precipitation.
- Field observations on erosion, indicate that less erosion occurs in the humid tropics under natural vegetation compared to the seasonally dry tropics. A similar trend is found in the erosion assessment results with SWEAP (USLE) for the land use scenario original vegetation. Apparently the vegetation in the humid tropics is more effective in protecting the soil than in the seasonally dry tropics.
However, that more erosion occurs in the seasonally dry tropics is not confirmed by the assessment results for the scenario present land use. A possible explanation is that, in the SWEAP selection, there is a higher percentage sloping land in the humid tropics than in the seasonally dry tropics (table 2).
- The erosion assessments indicate more erosion in the humid tropics for bare soil conditions.
As already mentioned this can be the effect of more sloping land and/or the combination with much higher precipitations or the influence of differences in erosion susceptability of soils occurring in both agro-ecological zones (section 3.1).
- A comparison of the erosion assessment per major soil group (FAO, 1974) reveals that Ferralsols are less susceptable to erosion, followed by Acrisols, Luvisols and Cambisols. Most susceptable are the Andosols, under bare soil conditions. This sequence is confirmed by the estimated K-factors (table 11).

- As the water erosion hazard assessments for the profiles from the SWEAP selection are based on soil loss estimates by USLE and SLEMSA models, it is of interest to assess, if results are comparable to real field conditions.
Questions which require answers:
- Do the assessment results of a certain land use scenario have similarity with actual field erosion under the same land use conditions?
- Is there correlation between the models output and the erosion observations in the field?
Therefore, there is a need for further evaluation and calibration of the models based on the reference profiles.

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