Rain erosion hazard evaluated from microtopographic erosion features on arable fields and forest – a case study in Nepal.

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ABSTRACT

Erosion hazard has been studied under the existing conditions in 12 sites, representative of physiographic landscape units in the Likhu Khola watershed, which is located 50 km. northwest of Kathmandu, Nepal. For this purpose the accumulated effect of erosion has been recorded as expressed by microtopographic erosion features formed in a rainy period. Seven types of microtopographic features are used: resistant clods, eroding clods, flow paths, prerills, rills, depressions and basal plant cover.

As a measure of erosion hazard, the observed erosion intensity was expressed by an indicator using the percentage of shallow flow features and the more heavily weighted features of incision.

Soil erosion hazard on the maize-wheat sites was found to be various, partly due to different soil surface texture of the sites. The hazard was lower on sites of dense Sal forest. Crown canopy, a seasonal litter layer and a good permeability limit the erosion. The erosion hazard is lower still on sites with degraded Sal forest. These sites have a substantial basal plant cover.

The erosion intensity derived from microtopographic features did not correlate with results of the Bouyoucos test, but had a good correlation with the Crusting index.

Foreword.

In this article, the data and much of their interpretation are derived from Kunwar (1995). His MSc study showed great promise for Kunwar to contribute to work on erosion problems and soil conservation in his country. A traffic accident was the cause of Mr.Kunwar's death in 1997. The present article is written by two staff members who were his closest colleagues at the time of his studies at ITC.

In his MSc thesis, Kunwar used a new field method for the determination of comparative rain erosion hazard, which uses microtopographic erosion features.

1. The need for the study of rain erosion hazard.

Rain erosion hazard is often required information in planning of alternative types of land use. Soil loss is used as a measure of the rain erosion hazard under a certain land use. Models and approaches exist to indicate the amount of soil loss that is expected to occur. The models need calibration for areas other than their area of establishment. Though the types of erosion factors are always the same, locally the importance of certain of their components may vary strongly.

For instance precipitation as snowfall does not cause splash, but after thawing it causes overland flow to increase more than proportional to rainfall. In addition, rain may occur in conditions of frozen impermeable subsoil. Other examples of strong local effects on erosion rate are hill and mountain slopes of different exposition that frequently receive very different precipitation even on short distances. Lateral subsurface flow may cause semi-saturation of the topsoil in specific parts of the topography. This will prevent rain to infiltrate and thus give rise to overland flow occurrence in these parts: the concept of the partial area or variable source area of peak flow in streams (for instance Ward, 1975). Rainfall and structural stability of the surface soil have complex interactions (Zaslavsky & Sinai, 1981). Soil management in many countries does not leave a uniform soil surface such as a model may assume.

Because of the difficulty of determining the individual local erosion factors and the subsequent difficulty of combining them in a conclusion about erosion hazard or the expected soil loss, a method has been designed at ITC to evaluate the erosion hazard directly in the field on the basis of the effect that erosion has had in a rainy period up to the moment of observation. (Bergsma 1992, 1997, 1999, Bergsma & Kwaad 1992).

A record is made of various erosion features of microtopography. The practical use of the method is that without the need to determine soil loss in ton/ha/y, a comparison can be made between cropping systems, land use practices and conservation systems for their resistance to erosion in locally operating conditions. This would answer by observed erosion intensity a question that is of practical relevance for conservation advice: which system of cultivation in an area protects best against erosion. An example of application is used in de Bie (2000, Chapter 11). In applying the method for comparison, care has to be taken that other erosion conditions than the one investigated do not vary too much. But the method is simple and can be readily applied anew in areas where erosion conditions are different from the first area of investigation.

2.The study area

The case study is located in the Middle Mountain region of Nepal, in the watershed of the river Likhu Khola (Shrestha 1997) that is about 60 km north of the Kathmandu valley. The watershed occupies about 160 sq. km. (Figure 1). Large elevation differences, from 700m to 2100m of valley floor to mountain summits, lead to bioclimatic diversity. Also the area is characterised by east-west oriented mountain ridges. They have sharp crests, and are on Precambrian mixtures of mica schist, phyllite and gneiss. The climate varies from subtropical in the main valley and footslopes through warm temperate at mid-elevations to cold temperate in the higher mountains. The average summer temperature is 19° C and the

Figure "Major physiographic regions of Nepal and the location of the study area in the watershed of Likhu Khola river, north of Kathmandu (Shrestha, 2000).

Average winter temperature is 11° C, with extreme values of -4° C in December. The annual precipitation varies from 1000 mm in the lowlands to 2800 mm at higher elevations. Most rain falls during the months of May to September. Cultivation is possible on steeper slopes by means of terraces. Sal trees (*Shorea robusta*) dominate at lower elevations. Crops grown are rained maize and millet, and rice which is irrigated.

3. The sites of the rain erosion hazard study.

Characteristics of the 12 locations chosen for the study of soil erosion hazard are summarised in Table 1 (Shrestha 2000). They represent physiographic landscape units. Several sites were located on cultivation terraces, because these are the parts where rain erosion is most important. The CEC of the clay indicates that illite types of clay dominate.

Table 1: Environmental characteristics of the 12 observation sites.

Site	Location	Elevation a.s.l.	Steepness of site	Aspect	Land use/ management	Soil name
1	Geragaon	800 m	10%	North	Maize-millet/mustard 3-4 times contour ploughing 2 times hoeing and weeding	Fine loamy, acidic, thermic, deep to very deep, Ultic Haplustalf
2	Mahadev Khola	750 m	35%	South	Degraded sal forest (Shorea sp.)	Fine loamy, acidic, thermic, very deep, Ultic Paleustalf
3	Baseri	780 m	16%	South	Maize-millet/mustard 3-4 times contour ploughing, 2 times hoeing and weeding	Coarse loamy, thermic, shallow, Typic Ustochrept
4	Rachandanda	910 m	10%	North	Maize-millet/mustard 3-4 times contour ploughing 2 times hoeing and weeding	Coarse loamy, thermic, deep, Ultic Haplustalf; red colour phase
5	Furkesalla	770 m	35%	South	Dense sal forest (Shorea sp.).	Coarse loamy, thermic, shallow, Lithic Ustochrept
6	Furkesalla	960 m	20%	South	Maize-millet/mustard 3-4 times contour ploughing 2 times hoeing and weeding	Fine loamy, non acidic, thermic, moderately deep, Typic Ustochrept
7	Geragaon, office building	790 m	20%	North	Degraded sal forest (Shorea sp.).	Fine loamy, acidic, thermic moderately deep, Typic Haplustult
8.	Budisera	770 m	35%	North	Dense sal forest (Shorea sp.)	Coarse loamy, acidic, thermic, moderately deep, Typic Haplustult.
9	Kothwok	1150 m	20%	North	Maize-millet/mustard 3-4 times contour ploughing 2 times hoeing and weeding	Coarse loamy, thermic, shallow, Typic Ustochrept
10	Jaisigaon	1150 m	20%	South	Maize-millet/mustard 3-4 times contour ploughing 2 times hoeing and weeding	Coarse loamy, thermic, very shallow, Typic Ustochrept
11	Chanpaboat	1270 m	20%	North	Maize-millet/mustard 3-4 times contour ploughing 2 times hoeing and weeding	Coarse loamy, thermic, deep, Dystric Ustochrept
12	Gurunggaon	1600 m	20%	North	Maize-millet/mustard 3-4 times contour ploughing 2 times hoeing and weeding	not sampled

Soil analytical data that were obtained by Kunwar (1995) for the sites of the erosion hazard study are extracted to summarise the topsoil characteristics (Table 2).

Table 2: <u>Topsoil characteristics related to the erodibility of the observation sites.</u>

Site / Profile code	Percentage			Soil texture class	Organic matter %	Bulk density	CEC m.e.		pH	Base sat. %
	sand	silt	clay				soil	clay		
1 / DP-10	68	21	16	sandy loam	1.6	1.1	8	48	4.8	49
2 / DP-15	41	32	27	loam	2.3	--	--	--	5.3	--
3 / DP-9	66	23	12	sandy loam	1.5	1.2	8	72	5.7	65
4 / DP-11	50	29	21	loam	2.0	1.1	7	34	5.3	79
5	no soil profile data									
6 / DP-6	52	22	25	sandy clay loam	1.9	1.3	9	36	5.8	>100
7 / DP-7	55	31	14	sandy loam	2.0	--	8	59	4.8	10
8 / DP-12	61	22	17	sandy loam	2.1	1.0	7	41	5.1	16
9 / DP-8	74	19	8	sandy loam	1.9	1.0	7	86	6.1	75
10 / DP-7	64	32	5	sandy loam	1.2	--	8	68	5.6	61
11 / DP-14	67	24	9	sandy loam	2.0	--	--	--	--	--
12	no soil profile data									
--	= no analytical data available									
CEC	= cation exchange capacity in milli-equivalents/100 gram									

At the time of observation the areal cover by maize is low. A few rills had formed (Photo).

4. Materials and methods

Topographic information and soil data are derived from Kunwar (1995), Shrestha (1999) and Bergsma (field visit 1994). Soil analyses were done by Kunwar, using the following methods: particle size distribution after dispersion by sodium pyrophosphate and hydrometer method; pH in 1:1 soil-water suspension; organic matter by the Walkley-Black method; total nitrogen by the Kjeldahl method; available phosphorus by the Olsen bicarbonate method at pH 8.5 in 1:20 dilution; available potassium extracted with neutral ammonium-acetate and determined in 1:5 dilution by flame photometry.

5. The method of evaluation of rain erosion hazard.

The method of evaluation of rain erosion hazard has been used in several research studies (Bergsma 1992, 1997, 1999, Bergsma & Kwaad 1992). The method uses the accumulated effect of the rain erosion of an erosive period previous to observation, as expressed in the presence of microtopographic erosion features. The erosion period is for instance the time from seeding till the closure of a crop. Recording the presence of different types of

microtopographic erosion features allows determining an indicator of erosion intensity. Thus the intensity of the erosion can be judged in a comparative way for different types of land use. In other words, the erosion hazard of cultivation systems can be compared. The method can be used equally well for sites of annual or perennial crops, forests, plantations and grazing land. The seven types of microtopographic erosion features are described in Table 3.

In a field that is to be studied, the most eroded part represents the place of highest erosion hazard. There a measuring tape (of for instance 2.5 meters length) is stretched along the contour, so that during recording the features made by flow will be met across the tape. The tape has alternating coloured intervals of 25 cm. For each interval the dominant one of the seven microtopographic features (Table 3) is recorded. The record covers 50 intervals, following a contour line, each tape interval represents 2 % of the area. The percentage distribution of the seven features is determined. The feature distribution reflects the erosion intensity that existed in the field. An indicator of erosion intensity is calculated as the percentage flow area + two times the percentage prerill and rill area.   This indicator based on microtopographic erosion features showed correlation with soil loss in previous research cases (Bergsma 1997, 1999).

Two repetitions of the feature record are made, each in the contour direction, at one or two meters above the first observation line. The repetitions permit to avoid extreme errors, and give an impression of the range of variation in features that results from variation in the crop and soil management. The recording of the microtopographic erosion features has an accuracy of 4 percent in a feature percentage that is obtained from observation of 50 tape intervals. More numerous intervals have been used in other cases of research. It is then not immediately clear that better distinction between cultivation systems would be obtained, but further research is necessary in this respect.

For monitoring purposes, the microtopographic erosion features may be recorded after each heavy rainstorm.

Table 3: Types of microtopographic erosion features.

Type	General description	Characteristics
Resistant or recently made clods	original forms that generally were created by tillage and either resist degradation or have been newly formed.	* sharp edges * overhanging sides * former soil surface may be present on a side ...of the clod * rocks and stones are included under this ...heading
Eroded clods	formed by splash and disaggregation (wetting, drying, etc.), not by flow.	* dominantly convex surface * micro-pedestals of coarse sand, gravel and ...vegetal matter may be present on the upper ...clod surface * are situated above the areas of flow
Flow surfaces	formed by shallow unconcentrated flow	* developed on deposits that smoothed the pre- ...existing micro-relief, or on parts that have ...been smoothed by erosion * often have parallel linear flow patterns of ...lag sediment
Prerills	Shallow micro-channels of concentrations of flow, up to about 3-5 cm deep	* shallow channel, slightly concave ...cross-section * may have small scarps at the sides * mostly discontinuous, not integrated in the ...micro-drainage system of the field.
Rills	Micro-channels, incised deeper than the prerills of 3-5 cm depth	* formed by incision into the soil, or formed ...originally by collapse of seepage tunnels * may reach the ploughpan or B-horizon * in case of a resistant subsoil have a distinct ...rill-bottom and U-shaped cross section * clear lateral micro-scarps occur at the sides ...when flow was recent * function mostly as part of the micro-drainage ...system of the field * occur often below a knickpoint in the ...gradient of flow
Depressions	Areas without immediate drainage outlet, where ponding occurs and material can accumulate. Tillage as in land preparation leads to small depressions. Eventually these areas may be filled by deposits, or be removed by incision and headward erosion of micro-channel flow.	* no immediate outlet * site for surface ponding and in-field ...deposition of eroded material.
Vegetative matter	Basal cover of living or dead residue, close to the surface and resistant against wash	* low folial and other vegetal matter that ...cannot be removed easily, either because of ...intensive plant rooting, partly ploughed-in ...residues or otherwise stable in position.

6. Results and discussion.

6.1. Erosion hazard of the sites derived from microtopographic erosion features.

Microtopographic erosion features were recorded on 12 sites that had various land uses and geographic and topographic position, but were characteristic of certain landscape units. The features were recorded after each rain shower in the period of May 31 - June 16, 1994. The field record of observations of the microtopographic erosion features is given in Table 4.

Table 4. <u>Field record of the microtopographic erosion features</u>.

Site	Date	Percentages of the microtopographic features							Indicator of erosion intensity*
		resistant clods	eroding parts	flow paths	pre-rills	rills	depres-sions	basal cover	
1	31-5	-	64	18	-	-	18	-	18
	5-6	-	52	18	2	16	12	-	54
	14-6	-	24	38	0	34	4	-	106
	16-6	-	18	42	4	34	2	-	118
2	31-5	-	0	54	2	4	-	40	66
	5-6	-	5	49	2	4	-	40	61
	14-6	-	6	46	2	6	-	40	62
	16-6	-	9	41	4	6	-	40	61
3	31-5	-	44	34	-	16	6	-	66
	5-6	-	44	22	6	10	16	-	54
	14-6	-	48	18	-	30	4	-	78
	16-6	-	34	38	-	28	-	-	94
4	31-5	-	46	10	2	42	-	-	98
	7-6	-	34	22	2	42	-	-	110
	14-6	-	25	45	-	30	-	-	105
	16-6	-	22	50	-	28	-	-	106
5	31-5	-	20	60	18	-	2	-	96
	14-6	-	32	48	16	4	-	-	88
	16-6	-	24	54	16	6	-	-	98
6	31-5	-	36	38	7	22	-	-	96
	5-6	-	30	22	12	30	6	-	106
	7-6	-	30	22	12	30	6	-	106
	14-6	-	24	41	7	28	-	-	111
	16-6	-	24	47	-	30	-	-	107
7	5-6	-	18	52	2	-	-	28	56
	14-6	-	14	56	2	1	-	27	62
	16-6	-	13	57	2	1	-	27	63
8	5-6	-	8	82	-	-	-	10	82
	14-6	-	18	70	2	-	-	10	74
	16-6	-	22	65	4	-	-	9	73
9	7-6	-	24	16	-	46	14	-	108
	16-6	-	22	50	-	22	6	-	94
10	7-6	-	34	22	2	42	-	-	110
	14-6	-	28	30	-	40	2	-	110
	16-6	-	28	32	-	40	-	-	112
11	16-6	-	30	34	-	34	2	-	102
12	16-6	-	32	36	-	28	4	-	92
- = the feature was absent									
* = indicator of erosion intensity: % flow + 2 (% prerill + % rill)									

The resisting and original clods had disappeared already at the beginning of the observation period. During this period prerills and rills are replacing eroding clods, and depressions tend to disappear. Basal cover occurs on sites 2 and 7 in degraded Sal forest, where shrubs grow

between the trees. The sites 5 and 8 of dense Sal forest have a basal cover of respectively zero and 10%. Surface wash disposes of the litter there.

The Sal forest sites show the dominance of the effect of soil cover over slope steepness (Table 3 and 5), on the relatively steep sites the erosion intensity is lower. On these sites there is little development of the erosion intensity during this period.

By observation of the microtopographic erosion features after heavy showers, monitoring of the erosion development can be done. This is a valuable suggestion for other researchers as it will probably lead to more insight in the development of erosion and its description in dynamic models. From the data in Table 4 one can see that different stages exist: rapid change, a rather constant situation, and gradual increase in intensity.

For a conclusion about the relative rain erosion hazard, a ranking of increasing erosion intensity of the observation points is made. This is done on the basis of the indicator of the erosion intensity that uses the most serious erosion features, which are rills, prerills and flow paths. The indicator is calculated as: the percentage flow area + two times the percentage prerill and rill area. In contrast to Kunwar (1995) who gives equal weight to all types of features, in the present study the ranking of erosion intensity uses a weight of the prerills and rills that is twice that of the flow areas. This unequal weight represents better the relative importance of the features in the erosion process that causes soil loss. The indicator appeared to correlate with measured soil loss in previous research cases (Bergsma 1997, 1999; Bergsma & Kwaad 1992).

The results of the relative ordering of the sites, following the indicator value for the last observation date, are presented in Table 5.

For some sites, the value of the indicator of erosion intensity is very similar. These cases have received the average of their rank values.

Site 5 has an exceptionally high amount of prerills. It is the only soil profile that has a lithic contact within 50 cm. This will have limited incision and increased overland flow. Otherwise, hydrologic depth does not show a strong influence on erosion intensity. Points 2, 10 and 11 have a relative great hydrologic depth, but not all have low erosion intensity

What is the explanation of the difference between Sal forest and the annuals? In the Sal forest there will be less exposure to splash, because there is protection by undergrowth and leaf litter on the forest floor. The sites of degraded Sal forest have the lowest erosion hazard. There is more sunlight on the soil surface and this allows a more dense basal plant cover. An

additional explanation is that in the Sal forest there is no loose topsoil structure with available erodable material, such as is produced by the soil tillage for the annuals.

Table 5: Sites ordered from high to low erosion intensity, observed on 16-6-94.

Site	Percentages of microtopographic features							Erosion intensity indicator	Land use	Slope aspect
	resistant clods	eroding parts	flow paths	pre-rills	rills	depres-sions	basal cover			
1	-	18	42	4	34	2	-	118	maize	N
10	-	28	32	-	40	-	-	112	maize	S
6	-	24	47	-	30	-	-	107	maize	S
4	-	22	50	-	28	-	-	106	maize	N
11	-	30	34	-	34	2	-	102	maize	N
5	-	24	54	16	6	-	-	98	Sal	S
3	-	34	38	-	28	-	-	94	maize	N
9	-	22	50	-	22	6	-	94	maize	N
12	-	32	36	-	28	4	-	92	maize	N
8	-	22	65	4	-	-	9	73	Sal	N
7	-	13	57	2	1	-	27	63	degS	N
2	-	9	41	4	6	-	40	61	degS	S
Sal = Sal forest; degS=degraded Sal forest; N = north; S = south										

There does not appear a dominant effect of slope exposition, or surface texture. The number of sites does not allow detection of interactions between these factors of erosion hazard.

Aspects of soil erodibility have been compared with the erosion feature intensity recorded on the last observation of the fieldwork period. Table 6 shows the ranking of the Bouyoucos test results, the Crusting index and other site aspects expected to relate to erosion intensity, from the highest expected erosion to the lowest. The Bouyoucos test (Bouyoucos 1935) gives an index of soil detachability and is calculated as percentage sand and silt divided by the percentage clay. The Crusting Index (FAO 1983) is calculated as:

1.5 * fine silt fraction + 0.75 * coarse silt fraction

percentage clay + 10 * percentage organic matter

Table 6. <u>Indicator of erosion intensity ranked from high to low erosion and some soil erodibility aspects of the sites.</u>

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-----+-----------+-----------+-----------+------+-----------+----------------+
Site | Bouy.     | Crust.    | O.M.   r  | Top  | Indicator | Indicator 1,2,3|
     | index   r | index   r |          | text.| value   r | value        r |
-----+-----------+-----------+-----------+------+-----------+----------------+
 1   | 5.6     7 | 0.99   10 | 1.6   10  | SL   | 118    12 | 152       11.5 |
10   | 21.2   12 | 2.52   12 | 1.2   12  | SL   | 112    11 | 152       11.5 |
 6   | 2.9   1.5 | 0.61    1 | 1.9   8.5 | SCL  | 107   9.5 | 137        9   |
 4   | 3.4     3 | 0.98  8.5 | 2.0    4  | L    | 106   9.5 | 134        9   |
11   | 9.9    10 | --      6 | 2.0    4  | SL   | 102     8 | 136        9   |
 5   | 5     4.5 | 0.98  8.5 | --    6.5 | LS   | 98      7 | 104        4   |
 3   | 7.6     9 | 1.10   11 | 1.5   11  | SL   | 94      5 | 122        6.5 |
 9   | 12.1   11 | 0.89    4 | 1.9   8.5 | SL   | 94      5 | 116        5   |
12   | --    6.5 | --      6 | --    6.5 | --   | 92      5 | 120        6.5 |
 8   | 4.9   4.5 | 0.79    2 | 2.1    2  | SL   | 73      3 | 73         3   |
 7   | 6.1     8 | 0.81    3 | 2.0    4  | SL   | 63    1.5 | 64       1.5   |
 2   | 2.8   1.5 | --      6 | 2.3    1  | L    | 61    1.5 | 61       1.5   |
-----+-----------+-----------+-----------+------+-----------+----------------+
Bouy. index    = Bouyoucos index; high values indicate more sand and silt, less clay |
Crust.index    = Crusting index; high values indicate more silt, less binding agents|
O.M.           = Organic matter content of the topsoil                              |
Top text.      = Topsoil texture                                                    |
--             = not determined; rank given is average rank                         |
Hazard indic.  = Indicator of the erosion hazard: %flo+2(%pre+%ril)                 |
Hazard 1,2,3   = Indicator of the erosion hazard: %flo+2%pre+3%ril                  |
r              = rank of low to high expected erosion hazard                        |
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The order of observation sites in the table is that of the erosion intensity indicator.

The erosion intensity at the end of the observation period is expressed by the indicator %flo+2(%pre+%ril) In addition an indicator is used that gives more weight to the occurrence of rills.

Spearman rank correlation gave the following results (Table 7).

Table 7. <u>Indicators of erodibility correlated with the erosion intensity indicator.</u>

			Bouyoucos index	Crusting index	Organic matter
Indicator of erosion intensity	all 12 points	R t Prob.	0.16	0.48* 1.78 95%	-0.61* -2.41 98%
	excl. point 6, 9	R t Prob.	0.28	0.71** 3.03 99%	
Indicator of erosion intensity, with more weight on rills	all 12 points	R t Prob.		0.50* 1.82 96%	-0.65* -2.67 98%
	excl. point 6	R t Prob.		0.71** 3.00 99%	

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R    = Spearman rank correlation coefficient
*,** = significant at 95%, 99%
t    = Student's t-value
Prob.= the probability of the correlation indicated by R.
excl.= excluding
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As can be expected, the organic matter content shows a negative correlation with the observed erosion intensity.

The erosion intensity derived from microtopographic features shows some correlation with the crusting index of soil erodibility. This is remarkable, because land use through its plant cover and management practices is usually by far the most important influence on erosion intensity. In this case study however, many other erosion conditions for the cropped sites were similar. The steepness of the cropped sites is similar, being cultivation terraces, Slope shape was rather similar on cropped sites, and the erosion down slope length is short. Differences in slope exposure also did not have a dominant effect on erosion intensity (Table 5). , So the influence of crusting could become apparent.

The correlation indicates that crusting of the sandy loam soils was important for the erosion development.

Among individual sites that showed relatively poor correlation was frequently site 6. It has a heavier texture, sandy clayloam. This may explain the lack of correlation between its crusting test result and the observed erosion intensity amidst the many ranks of sandy loams. Here is a disadvantage of the ranking system when there is such an unequal distribution of soil surface textures over the sites. The many ranks of sandy loams "push" the rank of the sandy clay loam to an unrepresentative position.

The lack of correlation of observed erosion intensity and the results of the Bouyoucos test might be caused by the test's independence of organic matter content. On the contrary, in the Crusting index this property is included. The two indices have a poor correlation between them: R = 0.38, at a significance level of about 11%.

7. Conclusions.

1) Soil erosion hazard was found to be various on the maize-millet sites. Under Sal forest the development of the erosion was slow (Table 4) and erosion intensities were low (Table 6, column 6 and 7). In the dense forest this was due to the canopy cover and litter, in the degraded Sal forest it was mostly due to the basal cover of shrubs, favoured by the open stand of the forest.

2) The organic matter content shows a negative correlation with the observed erosion intensity. The Bouyoucos test results do not show a correlation, but the Crusting Index, which includes the influence of organic matter, shows a correlation with the observed

erosion intensity. The correlation indicates that crusting of the sandy loam soils was important for the erosion development.

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