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Erosion Intensity Evaluated from Microtopographic Soil Erosion Features, its Correlation with Conservation Practice, Presence of Fertilizer, and Erosion Development between Alley Cropping Hedges

The Cases of Doi Thung and Nan, Northern Thailand

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ABSTRACT

Field observation of soil microtopography could distinguish seven features instead of a 'random' roughness of the eroded soil surface. The features are: resisting clods, eroding clods, flow surfaces, prerills, rills, depressions and basal vegetal cover. In each of fifty tape intervals of 25 cm along the contour, the dominant feature is recorded. From the distribution of the features the erosion intensity is derived. Application on soil loss plots finds a correlation between erosion intensity derived from microtopographic features and measured soil loss, for a period previous to observation. Exceptions in this correlation revealed errors in erosion intensity determination as well as errors in soil loss measurement; a mutual check is the result. An example is the case of Doi Thung.

The method is developed to compare the effect of conservation practices, rotations, or cultivation systems of one crop. Extrapolation of results should follow erosion conditions similar to those at the observation site, but the method is easy to learn, has practically no cost for equipment, and can be rapidly applied. In the same way soil loss data may be extrapolated.

The method detected the effect of fertilization (which causes a denser crop stand) by a low erosion intensity in certain replication plots at Nan (significance 99%). Another result obtained was the conclusion that an increase of erosion intensity within contour barrier intervals could be detected from feature observations in the upper and lower part of the intervals on erosion plots at Nan. From more of such data, criteria could be set for an acceptable erosion intensity versus spacing of contour barriers.

The seven microtopographic features are forms on which different erosion subprocesses act. In combination with the change in the distribution of the features with time, the monitoring of the features may contribute to an improvement in erosion modeling.

INTRODUCTION

An indicator of erosion intensity would be a useful to advise land users, to distinguish land use practices in research about erosion reduction and as an argument for policy of land management. Farmers in many cases experiment, adapt, and innovate, with the aim of making improvements to their farming systems (Richards, 1985; Chambers et al., 1989). The possibility of comparing the conservation function of various adaptations of farmer's practices may help to bring about practical advice to landusers on ways of cultivation of a crop or crops that reduces erosion most. The method serves the local comparison of land use effects on erosion. The extent of the area over which the comparison can be made is determined by the similarity of other erosion conditions than the land use, for instance soil differences.

New applications and refinement are presented here of a method (Bergsma, 1992; Bergsma and Kwaad 1995; Bergsma, 1997) which is based on field observation of the soil surface to compare sites for their erosion intensity. The paper emphasizes possibilities for use of the method in conservation advice, erosion research, and modeling.

The apparent chaos of microtopographic forms at the soil surface, which has been called "random roughness", does not exist in the sense that in all cases investigated so far, the soil surface which has been exposed to rain is made up completely by only a few main microtopographic forms.

Soil surface microtopography in this study is the distribution of forms with relief from about 1 cm to 50 cm for large clods or shallow gullies and a width of a few centimeters up to about 1 m (or several meters in the case of wide braids (Bergsma et al., 1996)). The surface forms may result from soil management such as plowing/weeding, activity of soil animals, cattle, by plant stem concentrations, and the subsequent influence of soil erosion.

Research on erosion processes and soil surface microtopography gives attention to soil surface roughness and infiltration behavior (Casenave and Valentin, 1992), porosity of microtopographic forms (Gascuel-Odoux et al., 1991), sedimentary crust formation, infiltration and random roughness of loess soils (Jetten and Boiffin, 1998), macroporosity of higher and lower parts of the microrelief (Dunne et al., 1991), microtopography as condition for infiltration and local flow paths (Dunne et al., 1991), soil moisture content and the breakdown of roughness by successive rains (Auerswald, 1993), shallow relatively impermeable layers, soil moisture content and erodibility (Bryan and Rockwell, 1998), antecedent moisture and rainfall acceptance (Luk, 1988), cloddiness, runoff distribution and flow paths (Helming et al., 1998). Huang

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and Bradford (1993) state that many transport processes are controlled by surface microtopography.

METHOD

After fieldwork in eight countries: the Netherlands (Zuid Limburg), Colombia, Thailand, Argentina, Nepal, Tanzania, Portugal and Switzerland, with different climates and soils, it appears possible to describe the microtopography of the soil surface at a site, at a moment in the erosive period of the year, by seven main forms (Bergsma, 1992):

ORIGINAL / RESISTANT clods, the original forms that were created by tillage. Characteristics are:

- Sharp edges
- Overhanging sides
- Former soil surface may be present on some side of the clod
- Rockiness and stoniness are counted under this heading

ERODED parts, formed by splash and disaggregation (wetting, drying, etc.).

Characteristics are:

- Dominantly convex form
- Micro-pedestals on the upper clod surfaces may be present
- Is situated above the level of flow
- The eroded clods are above the general level of flow and very slightly convex and rough surfaces occur, often with micropedestals, where very shallow and slow flow during rain starts to form on minor parts of the surface.

FLOW surfaces, used by shallow unconcentrated flow. Characteristics are:

- Developed on deposits that have smoothed the previous micro-relief, or developed on eroded parts, that have been smoothed by flow.
- Have often parallel linear flow patterns of lag sediment
- Long and narrow flow paths that are flat, smooth, and have a sediment cover that shows the lines of flow. Or they can be wider flow surfaces, less rough than the eroding surfaces and largely covered by a flow pattern of very fine sediment, micropedestals are generally absent.

PRERILLS, shallow concentrations of flow, up to about 3-5 cm deep. Characteristics are:

- Shallow channel, slightly concave cross-section
- May have small scarps at the sides
- May be discontinuous, not integrated in the micro-drainage system of the field,
- Can be the upslope beginning and downslope continuation of rills.

RILLS, micro-channels incised deeper than the prerills of 3-5 cm depth. Characteristics are:

- Formed by incision into the soil or by collapse of tunnel erosion
- May reach the plowpan or B-horizon
- In case of a resistant subsoil have a distinct rill-bottom and U-shaped cross section
- Clear lateral micro-scarps occur when flow was recent
- Function mostly as part of the micro-drainage system of the field
- Occur often below a knick point in the gradient of flow
- Fine to coarse bed deposits, related to peak flow and after flow.

DEPRESSIONS: areas where transported soil material can accumulate. Tillage, as in land preparation, leads to micro-depressions. Eventually these areas may be filled by deposits, or be removed by incision and headward erosion of micro-channel flow. Characteristics are:

- No low external outlet
- Site for surface ponding and in-field deposition of eroded material.

VEGETATIVE MATTER: basal cover of living or dead vegetal matter.

Characteristics are:

- filial and other vegetal matter that cannot be removed to inspect the soil surface, either because of intensive plant rooting, partly plowed-in residues or otherwise stable in position against flow

Some of these seven forms are produced early in a rain shower; others appear only after some consecutive rainstorms have occurred. Certain forms, such as eroding clods, indicate activity by splash only. Other forms, such as flow areas and prerills, indicate a more developed stage of erosion and a greater role of flow. These forms are shaped by scour and deposition

Recording the features is done along a tape with intervals of 25 cm, stretched in the direction of the contour. Thus features formed by flow will strike the observation line. In each of 50 intervals on the measuring tape the dominant one of the seven feature types is recorded, see Figure 1 for an example. The proportion of the different features that occur on a site forms the basis for judging the intensity of the erosion that has occurred.

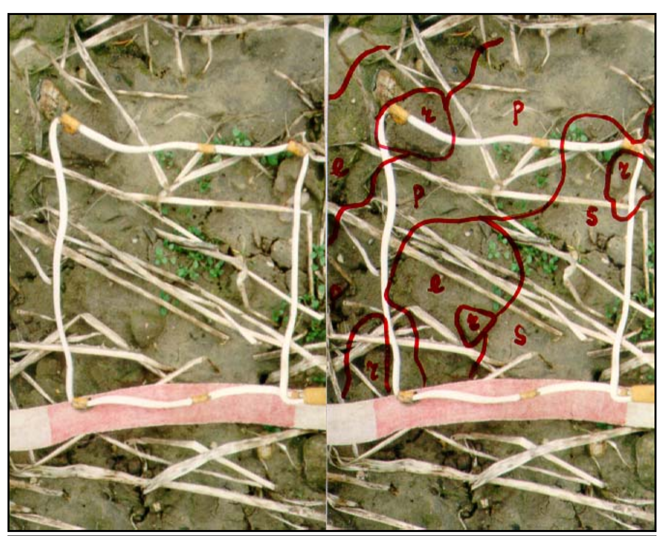

Figure 1. Vertical stereogram of erosion features on the soil surface.

Caption of the stereogram

Stereophoto-pair of a soil surface with microtopographic features. Photos taken in March 1994, in the loess area of South Limburg, the Netherlands. Visible is some residue of last year's maize. Topsoil texture is loam. The white-black tape has intervals of 25 cm and is 4 cm wide. The white frame, bent by use, indicates a square area with 25 cm sides, extending from the tape interval. Determination of the dominant feature is done at one side along the tape, per tape interval or per squared tape interval. Types of microtopographic features visible in the stereogram are:

r = resisting clod; e = eroding clod; s = flow surface; p = prerill

It is expected, and in some cases demonstrated (Bergsma and Kwaad, 1992; Bergsma, 1997), that the erosion intensity derived from the seven microtopographic features is related to the amount of erosion. However, it is not the amount of soil loss that is derived from the features but the erosion intensity. Huang and Bradford (1993) call this a "foot print" of the physical processes that have occurred. It is the accumulated effect of erosion of a period previous to observation, for instance the period since land preparation in the case of annual crops, up to the moment of observation before the maturing stage, when often a closed canopy exists..

The site for observation is chosen:

- In relation to slope form, that dominates the removal and deposition processes.
- In relation to slope steepness.
- In relation to criteria for the length of expected overland flow.
- On a part of the slope where the maximum expression of erosion is to be expected. This would serve as reference for the effect of later conservation practices.

The moment of observation is chosen:

- In relation to the development of annual erosion: at the end of the most erosive season. In that way the features represent the accumulated effect of erosion since the beginning of the rainy season.
- In relation to the plant growth stages: preferably before the complete closure of the plant cover, to allow more easy observation of the features at the soil surface.

A test of the reliability of the method to evaluate erosion intensity is comparison of the results using the seven features with measured soil loss. Soil loss measurements are not always a completely reliable reference however. As has appeared in previous studies (Bergsma and.Kwaad 1992; Bergsma 1997), the comparison between soil loss and erosion intensity derived from surface features has shown at times that some plots were not managed according to experiment specifications. In other cases, deposition inside erosion plots has been found after an excessive discrepancy was discovered between soil loss and erosion intensity of a plot. In some cases, the erosion intensity observed within contour barrier intervals on an irregular slope revealed the influence of slope shape and steepness and explained differences of soil loss between replicated plots. Though the comparison between erosion intensity derived from surface features and the measured soil loss may substantiate to a degree the reliability of the feature method, in turn the feature method proves to be a useful tool in checking the results of soil loss measurement.

Work is continuing on the reproducibility of the feature recording (provisional conclusion: maximum expected error in feature occurrence is 4% or 2 observations in 50), monitoring the features during a rainy season (sequence of feature development), relative moisture content of different features in different weather conditions and consequent feature-erodibility, physical characteristics of the features (shear strength, infiltration behavior, structural stability), the question of extrapolation of site data to larger areas; examples of handling the downscaling question are found in Bornand and Favrot (1998) and Beauchesne et al. (1998).

In future work it will be considered to include in the recording of surface features the headcuts and knickpoints in flow paths as they represent an active process of scour (Bryan 1990). This may improve the relation between the feature record and soil loss.

Doi Thung, relation between microtopographic features and soil loss.

The Doi Thung experimental station is located in the Mae Sai district of Chiang Rai, in northern Thailand. Information about rainfall, soil, erosion plots and the treatments is compiled in Vlassak et al. (1992). Microtopographic features were recorded on eight of the plots of the Doi Thung station. Primary tillage and two weeding operations had taken place. Conclusions about the erosion intensity derived from the record of surface features per plot were drawn (Table 1) before information about the measured soil loss was asked for and received.

The practices or conservation treatments at Doi Thung are running for 8 years, all plots are planted with upland rice. The treatments are:

- T1 Traditional farmer's practice (tillage and weeding by hoe), but tillage is along the contour.
- T2 Alley cropping
- T3 Bahia grass strips
- T4 Hillside ditch
- T5 Agro-forestry

The treatments have four repetitions. Repetition 1 and 4 received fertilizer; Repetition 2 and 3 did not.

A indicator of erosion intensity has been used which in previous research is shown to have a correlation with measured soil loss (Bergsma and Kwaad, 1992). The indicator uses features that indicate transport over the surface. It is calculated from the percentage flow features and gives weight to those where scour is important.

There is a difference in erosion intensity between repetition 1 and 2 in treatment T1 as well as in treatment T2. Repetitions 1 have not been fertilized, Repetition 2 have been fertilized. On the fertilized plots the crop and the weeds give a much denser vegetative cover and protect more against erosion.

By rank correlation a comparison is made between the result of the feature method on eight plots at Doi Thung and their measured soil loss suffered during the part of the rainy season, previous to the feature observation date (Table 2). In treatment T2 some plots had strong deposition of eroded material inside erosion plots. These cases showed a much higher observed erosion intensity than is in agreement with their low measured soil loss.

In earlier cases of the application of the feature method to soil loss plots (Bergsma and Kwaad, 1992; Bergsma, 1997) the correlation between erosion intensity derived from surface features and measured soil loss had often a medium high rank correlation coefficient, that was however highly significant. Comparison by treatment, combining the replications, gave higher correlation coefficients. Prediction may be then justified to a degree that is not lower than in the

Table 1. Erosion intensity derived from micro-topographic erosion features on eight plots at Doi Thung, observed on 30/7/1999 (after last rain on 28/7), ordered by increasing intensity.

Plot	Slope %	res	ero	flo	pre	ril	dep	veg	f+2(p+r) indicator	Rank
		Microtopographic features %								
Forest	25	-	-	-	-	-	-	100	0	1
T4R1	15	2	50	12	7	-	-	29	26	2
T5R1	38	18	47	14	9	-	-	13	32	3
T1R1	32	5	60	13	15	-	-	7	43	4
T3R1	22	5	42	26	10	-	-	19	46	5
T5R2	55	30	23	36	9	-	-	2	54	6
T2R1	25	-	48	31	14	-	-	7	59	7
T1R2	†	2	20	43	33	-	-	2	109	8

Explanation of symbols:
TxRx = code of treatment and replication.
Slope = steepness of the part of the plot where the record of features was made.
res = resisting clods
ero = eroding clods and surfaces
flo = flow paths and surfaces
pre = prerills
ril = rills
dep = depressions
veg = low basal
f+2(p+r)= percentage flow area + two times the sum of the percentages prerill area and rill area.
Rank = order of the indicator values.
† = slope steepness was not measured.

Table 2. Correlation of erosion intensity and measured soil loss for the period 28 March-28 July 1997, of eight plots at Doi Thung.

f+2(p+r) rank	soil loss March-July'97	soil loss rank/T	rank correlation R	Sig.	R^2
8 plots	x		0.55	<<95%	0.30
not T2R1	x		**0.93****	**>99%**	**0.83**
8 plots		x	0.62	<<95%	0.38
not T2		x	**0.94****	**>99%**	**0.88**

R = rank correlation coefficient.
rank/T = rank of soil losses per treatment in previous years.
Sig. = significance of the rank correlation coefficient.
not = plots excluded because of erroneous soil loss data.
x = soil loss data used in correlation.

Table 3. Correlations of erosion intensity derived from surface features and measured soil loss.

Location and date	Number of treatments x replications	Rank correlation coefficient		
		all individual plots	number of plots excluded †	plots grouped per treatment
South Limburg, the Netherlands, April 1991	8 x 3	0.44**	1: 0.52**	0.53 (93%)
Chiang Dao, Northern Thailand, August 1994	5 x 4 (= 2 x 2) and 2 x 1	0.39 (93%)	3: 0.76*** 4: 0.79***	0.86* (98%)
Doi Thung, Thailand, July 1977	5 x 4 (=2 x 2) and 3 x 1 of which 8 plots studied	0.55 (<<95%)	1: 0.93** 4: -	- 0.94**

* = significance level of 0.05 *** = significance level of 0.001
** = significance level of 0.01 ( ) = statistical significance.
† = exclusion of plots for reasons of faulty management, in-plot deposition, or otherwise unlikely extreme observed erosion intensity

case of recommendations based on soil loss measurement. An overview of other correlations that were made between erosion intensity by the feature method and measured soil loss gives Table 3.

In the cases of South Limburg and Chiang Dao (65 km north of Chiang Mai) the number of plots investigated was much larger than in the case of Doi Thung. High numbers of plots allowed to reach high significance levels of the correlation, but the strength of the correlation found was weaker than in Doi Thung.

In South Limburg observations were made several weeks after harvest and soil loss recording, when the soil surface had been flattened by subsequent rains, which made characterization of the features more difficult. A strong spread of mosses provided a biocrust in some plots and this was not recorded as basal cover at that time. One plot has been excluded from improved correlation, because it received a faulty management. This was discovered after its erosion intensity was found to differ very much from that of its replications. Three other plots that were excluded from final correlation also had an erosion intensity very different from what could be expected, but the cause remained unknown.

Microtopographic erosion features at Nan used as indicator of relative soil loss.

The feature method was also applied on fields of the experimental erosion station of Nan. The station Ban Thum Wiang Kae is located 80 km north west of the city of Nan, in Nan province, northern Thailand. The practices on the erosion plots on the station at Nan are:

T 1 Traditional practice
T 2 Vetiver hedgerows along contour
T 3 Thephrosia hedgerows (planted in two lines)
T 4 Hillside ditches (only 40 cm deep)
T 5 Hill side ditches plus Leuceana at upper bank
T 6 Bare fallow, weeded by hoe and hand
T 7 Natural vegetation (one plot, divided into three different parts)
T 8 Thrashlines (one plot)
T 9 Upland rice (one plot)

T1 - T6 all have three replications. More information on the station at Nan about rainfall, soil, erosion plots and the treatments is compiled in Vlassak et al. (1992). Microtopographic features have been recorded on the plots at Nan and the relative erosion intensity per plot has been derived from them (Table 4).

One notes that the replications of T6 all have a high percentage of rills. The last column of Table 4 shows the spread in the erosion intensity of the replications of the systems. Especially the replications of system T7, natural vegetation, show a wide spread. These plots have widely different densities of cover. T7R1 is densely covered by shrub of about two meter height mixed with small trees of about three meter height. There is much residue on the surface. Plot T7R3 has a medium dense cover, T7R2 a very poor cover.

During field observation in T7R1, new types of microtopographic features were identified: the drip surface and the algae surface. The drip surface is nearly level, and pocketed by drop impacts in a thin layer of loose splash sediment. Flow is absent. The algae surface is greenish or blackish in colour. It is nearly level, possibly developed on eroding surfaces and flow surfaces which are relatively moist. It borders flow paths and (pre)rills by a micro-scarp which is evidence of the relative resistance of the algae surface to splash and scour. The drip surface and the algae surface are most similar to the eroding surface and have been added to that percentage.

The sum of the ranks of the replications of a treatment in the order of the indicator f+2(p+r) is used to indicate the relative resistance to erosion provided by the conservation treatment as a whole (Table 5).

One can conclude on the basis of the data that the treatments T1 and T6, the traditional practice and the bare fallow, erode more than the treatments T3, T4 and T5. Treatment T2 reduces erosion more than T3, T4 and T5, but T3 does not distinguish itself significantly from T4 and T5. It is striking that these results, which are obtained by the feature method, are similar to conclusions from soil loss in previous years (data provided by research coordinator Suntorn Ratchadawong, 1997).

Table 4. Plots at Nan, listed in order of increasing rain erosion intensity, as evaluated from erosion features observed on 31/7 and 1/8 1997.

Plot	Steepness line o/o	Steepness plot o/o	Form at line	Microtopographic features % res	ero	flo	pre	ril	dep	veg	f+2(p+r) value	r	Relative position replication
T7R1	38	35	cx	3	35	-	-	-	-	62	0	1	<u>7</u>
Grass	38	35	cx	2	58	14	-	-	-	26	14	2	G
T1R3	36	40	ca	8	32	47	9	-	-	5	65	3	(1)
T2R1	43	43	/	7	36	25	21	-	3	8	67	4	<u>2</u>
T2R2	29	38	ca	2	26	38	28	-	-	3	94	5	2
T4R1	42	43	/	6	27	32	32	-	-	2	96	6	<u>4</u>
T3R3	25	30	ca	3	14	69	13	1	-	-	97	7	3
T3R1	37	42	ca	7	16	50	23	1	1	1	98	8	<u>3</u>
T2R3	26	26	cx	-	20	47	26	-	-	8	99	9	2
T7R3	35	40	ca	1	24	49	19	6	-	1	99	10	7
T5R1	33	45	ca	-	15	62	19	-	-	4	100	11	<u>5</u>
T5R3	22	30	ca	7	9	64	20	-	-	-	104	12	5
T5R2	28	38	ca	-	13	65	22	-	-	-	109	13	5
T1R1	43	42	/	6	22	29	40	-	3	-	109	14	<u>1</u>
T4R2	35	39	ca	2	11	45	33	-	-	9	111	15	4
T6R1	38	35	cx	-	17	54	14	15	-	-	112	16	<u>6</u>
T4R3	29	27	cx	1	10	61	27	-	-	-	115	17	4
T3R2	45	48	ca	1	17	48	34	-	-	-	116	18	3
T6R3	37	38	/	3	8	62	14	14	-	2	118	19	6
T9	33	45	ca	-	5	68	27	-	-	-	122	20	9
T6R2	42	44	ca	-	6	64	6	24	-	-	124	21	6
T7R2	32	42	ca	1	10	51	37	-	-	-	125	22	7
T1R2	40	45	ca	-	6	58	35	1	-	-	130	23	1

Explanation of abbreviations, see also Table 1.
cx = convex slope form, x = underlinings in last column: plots with fertilizer applied
ca = concave slope form, ( ) = probable error in data.
/ = straight slope form, | r | = rank
f+2(p+r)= indicator of erosion intensity: the percentage flow features plus two times the percentage prerills and rills
On T8 no record of features was made.

Table 5. Comparative resistance to erosion of treatments at Nan.

Treatments compared by sum of replication ranks	Significance level of difference (Kruskal-Wallis test)
(T1 + T6) x (T3 + T4 + T5)	slightly less than 99 o/o.
(T2) x (T3 + T4 + T5)	slightly less than 95 o/o.
(T3) x (T4 + T5)	<< 95 o/o.

Table 6. The microtopographic features of the plots at Nan, observed on 31/7 and 1/8 1997. Plots grouped per treatment.

Plot Nan	Steepness line o/o	Steepness plot o/o	Slope form at obs.line	Microtopographic features % res	ero	flo	pre	ril	dep	veg	indicator of erosion intensity
T1R3	36	40	ca	8	32	47	9	-	-	5	120(corr)
T1R1	43	42	=	6	22	29	40	-	3	-	109 fert
T1R2	40†	45	ca	-	6	58	35	1	-	-	130
T2R1	43	43	=	7	36	25	21	-	3	8	67 fert
T2R3	26	26	=	-	20	47	26	-	-	8	99
T2R2	29†	38	caca†	2	26	38	32	-	-	3	102
T3R3	25	30	ca	3	14	69	13	1	-	-	97
T3R1	37	42	ca	7	16	50	23	1	1	1	98 fert
T3R2	45†	48	ca	1	17	48	34	-	-	-	116
T4R1	42	43	ca†	6	27	32	32	-	-	2	96 fert
T4R2	35	39	ca†	-	11	45	33	-	-	9	111
T4R3	29	27	cx†	-	10	61	27	-	-	-	115
T5R1	33	45	caca	-	15	62	19	-	-	4	100 fert
T5R3	22†	30	caca†	7	9	64	20	-	-	-	104
T5R2	28†	38	caca†	-	13	65	22	-	-	-	109
T6R1	38	35	cx†	-	17	54	14	15	-	-	112 fert
T6R3	37	38	=	3	8	62	14	14	-	2	118
T6R2	42†	44	ca	-	6	64	6	24	-	-	124
T7R1	38	35	cx	3	35	-	-	-	-	62‡	0 fert
T7R3#	35	40	ca	1	24	49	19	6	-	1	99
T7R2#	32	42	caca	1	10	51	37	-	-	-	125

Explanation of symbols, see also table 1.

Fert = fertilizer applied, the dominant influence on the relative soil loss of the replication.

† = the dominant factor in explaining the erosion intensity of the plot relative to the other two replications.

‡ = low trees, shrub and their residue limit the development of erosion. No serious erosion features are observed. The erosion intensity is very low.

Indicator = value of o/o flo + 2 x o/o pre + 3 x o/o ril.

= low density or absent (burned) natural vegetation.

cx = steepness at observation line is ≤ 5 o/o higher than that of the plot as a whole: the slope form at the line of observation is convex.

ca = steepness at observation line is ≤ 5 o/o lower than that of the plot as a whole: the slope form at the line of observation is concave.

caca = steepness at observation line is > 5 o/o less than that of the plot as a whole: the slope form at the line of observation is strongly concave.

= = slope form is almost straight

corr. = erroneous value replaced by the average of the other replications.

Table 7. Erosion features within contour strips in alley cropping treatment of plot T2R2, Doi Thung, northern Thailand.

	res	ero	flo	pre	ril	dep	veg
strip 1, slope 4 o/o,	res	ero	flo	pre	ril	dep	veg
upper part	8	28	45	-	-	3	18
lower part	9	13	-	11	-	11	56
strip 2, slope 11 o/o,	res	ero	flo	pre	ril	dep	veg
upper part	10	31	33	7	-	2	17
lower part	-	11	20	11	-	-	57
strip 3, slope 17 o/o,	res	ero	flo	pre	ril	dep	veg
upper part	3	33	20	-	-	-	45
lower part	-	9	-	9	-	-	82
strip 4, slope 20 o/o,	res	ero	flo	pre	ril	dep	veg
upper part	2	45	29	10	-	-	12
lower part	-	28	4	17	-	-	55
strip 5, slope 26 o/o,	res	ero	flo	pre	ril	dep	veg
upper part	5	32	32	9	-	-	20
lower part	-	13	-	15	-	-	79
strip 6, slope 31 o/o,	res	ero	flo	pre	ril	dep	veg
upper part	5	31	43	14	-	-	10
lower part	-	13	2	17	-	-	69

res = resisting or original clods　　pre = prerills
ero = eroding clods and surfaces　　ril = rills
flo = flow paths and surfaces　　dep = depressions
veg = basal vegetative cover

Comment:

1) The o/o prerill increases from the upper to the lower part of a strip.
2) There is a weak tendency for the o/o prerill in the lower parts of the contour strips to increase with increasing steepness (Spearman rank correlation coefficient Rs = 0.71, significance <<0.95).
3) The vegetative cover in the lower parts of the strips is greater than in the upper parts. The difference in vegetation cover between the high and low part of the contour strips does not show a relation to slope steepness. The difference is caused mainly by tillage erosion, the downward displacement of soil during the land preparation by hoe, which shifts fertile topsoil downwards (see also Turkelboom et al.,1997).
4) It is somewhat surprising that the intensity of flow areas does not increase downslope within the contour barrier interval, as does the intensity of prerills. The explanation is the new vigorous growth of weeds and crop in the lower part, which together occupy areas that otherwise would have qualified for flow area. This explanation is supported by data (Bergsma 1997) about erosion intensity within contour strips at Chiang Dao. That case had no vegetative cover and the prerills and flow areas increase downwards within the contour intervals.

Separation of the fertilized plots at Nan by the indicator of erosion intensity

From analysis of the erosion intensity derived from surface features, it appeared that in 6 of the 7 conservation systems the fertilized plot happens to have the lowest erosion intensity (Table 6).

The presence of fertilizer causes a higher plant density of crops and weeds. This results in a greater protection against erosion. Other influences on the comparative soil loss of replications are the steepness of slope and the shape of slope. It appeared that the plot with the lowest erosion indicator of the three replications of a conservation treatment is very often the one that has received fertilizer. This occurs 5 times in the 7 cases. In one case the erosion intensity of the fertilized field is equal to the erosion intensity of another replication. The probability that this pattern occurs by chance is only 12% (Kolmogorov-Smirnov test). In combination with similar results obtained at Doi Thung, the probability is less than 1% that the fertilized fields have by chance the lowest erosion intensity derived from microtopographic features.

Erosion intensity at the upper and lower parts of alley cropping strips at Doi Thung

The six strips of the plot with alley cropping treatment, T2R2, at Doi Thung, have been numbered 1 - 6 from high to low position. A record of surface features has been made one meter below the upper contour hedge, and another is made one meter above the lower contour hedge (Table 7).

The recording of erosion features within contour strips may give information on the required interval between the contour barriers. Too serious features would indicate that (at that steepness) the spacing should be more narrow or an altogether different cultivation system would be needed to reduce erosion sufficiently.

Summary of the possibilities for application of the method

- Comparing cultivation systems or local adaptations of farmer's practices for their resistance to erosion
- Comparing cultivation systems and the extrapolation of results about resistance to erosion of cultivation systems is of course only allowed in so far as all other erosion factors are the same, such as rainfall, topography, soil. However, as the method is simple, rapid and cheap, the recordings of surface feature can be made wherever a comparison between cultivation systems is required.. Observations on 20 sites, close together, can be made in one day. Obviously other considerations may be critical for the final adoption of a practice aimed at good land husbandry. They include for instance labor requirements, increase in yield, social acceptance, administrative support, institutional structure and others.
- Developing criteria for design of conservation practices, for example criteria for the 'width' of the interval between contour hedges.
- Extrapolation of the information about soil loss obtained from soil loss plots.
- Improving erosion modeling by subdividing the soil surface into the seven features and determining groups of erosion subprocesses working on each. Change in the feature distribution with time would relate to a change in the dominant erosion subprocesses.

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