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Estimating Soil Erodibility From Microtopographic Features of Erosion By Rain Under Selected Cropping Systems and Management Practices In Mhong Chun Yen Village, Northern Thailand

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ABSTRACT

Protection of soil resources on farm lands is an important issue especially where rain erosion has led to decreasing soil productivity and rural income. For several decades this has been the case with a majority of the farmers in Mhong Chun Yen Village in Northern Thailand, where the hilly relief makes the land naturally prone to erosion by heavy tropical precipitations. This study investigated the erodibility of the soils as one of the possible causes of the observable differences in resistance to erosion presented by different cropping systems and management practices common in the area. The objective was to obtain adequate information necessary for conservation advice on how to prevent further land degradation and improve the livelihoods of the rural farming population. An easy to use, cheap, rapid and efficient methodology was employed to estimate the erodibiltiy of the soils under the most common cropping systems and management practices. The procedure recognizes and uses seven features of microtopography that result from erosion by rain, namely, *resisting clods, eroding clods, flow paths, prerills, rills, depressions, and vegetal matter*. Several tests on the physical properties of these features were carried out to provide reliable estimates of the erodibility of the soils: *shear vane test*, to determine the soil shear strength; *penetrometer test*, to evaluate the soil strength; *and particle and bulk density* measurement, to evaluate the rainfall acceptance of the soil surface. Results obtained showed that erodibility of the soils varied among the different cropping systems and management practices. Erodibility was highest where presence of cover was poorest, and was least with cropping systems and management practices that provided more vegetative cover and surface roughness. Also, contour cultivation was shown to be a more sustainable practice than along- slope tillage operations, while farming on steep slopes invariably increased the erodibility of the soils.

Key words: Soil, erodibility, microtopograhic features, erosion by rain, cropping systems, management practices.

Introduction

Land degradation resulting from rain- induced soil erosion has become a major environmental issue posing a serious threat to sustainability of livelihood of the farming population in Mhong Chun Yen Village, Northern Thailand. Preventing further deterioration of the situation would demand an adequate understanding of the underlying principles of the erosion problem, especially with respect to the nature and characteristics of the soils.

One of such characteristics is soil erodibility, which has been generally defined as an estimate of the ability of a soil to resist erosion, based on its physical characteristics. It is a measure of the susceptibility of soil particles to detachment and transport by rainfall and run off.

Conventionally, soil erodibility is often calculated using the nomograph proposed by Wischemier and Smith (1978) or a modification of it when all the values of the soil erodibility index (k) are available. According to Morgan (1975), such calculation should be based on measured values wherever possible. However, this procedure has been criticized for the fact that data are often rare, and also that it is too time consuming and expensive for a situation where the erosion problem is urgent and demands a rapid and cheap solution (Bergsma, 1992). Such is the case with Thailand, a developing economy.

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Goldman *et al*., (1986) had earlier stated that several methods could be employed to estimate soil erodibility factor. This study uses one of such methods which was developed by Bergsma (1990,1992). This procedure recognizes seven features of soil surface microtopography which are normally created by rain erosion. The features are *resisting clods, eroding clods, flow paths, prerills, rills, depression, and vegetal matter.* The erodibility of the soils would be estimated from the physical properties of these features, using three tests, namely, the shear vane test, to determine soil shear strength; penetrometer test, to evaluate the soil strength; and erosion pin measurements, to determine soil detachment, transport, and deposition by raindrop splash and overland flow forces.

These tests would be carried out on each of the seven microtopographic features of erosion under five different cropping systems and management practices inorder to know how the latter contribute to the erodiblity of the soils.

Research on soil erosion mechanics has established a link between soil surface shear strength on one hand, and rill flow and splash detachment processes on the other (Brunori *et al*., 1989). Torri (1987) had earlier noted that surface soil shear strength can be proposed as a measure of soil strength, the reciprocal of soil detachability, which itself has been recognized as an important component of soil erodibility (Houghton and Charman, (1986).

Overall, the information derived from this study would be used to proffer conservation advice for sustainability and improvement of the livelihoods of the farming population in the study area.

Materials and Methods

The study area is located north of Mhong Chun Yen Village, about 7 km from Ban Mae Malai, west of the Mae Ping River, in the central part of Chiang Mai Province, Northern Thailand. It is situated within latitudes 19^0 05^1 to 19^0 10^1 N and longitudes 98^0 51^1 to 98^0 53^1 E. The climate of Northern Thailand is monsoonal, characterized by three distinct seasons, namely, the rainy season, the cool dry season and the hot dry season. The rainy season lasts from April to late October or early November during which period the south-west Monsoon brings rain-bearing clouds from the Indian Ocean. The climatic data from Chiang Mai Meteorobgical Station show that the mean annual average rainfall in the area is about 1,200mm/ yr, with about 90% of the total precipitation falling during mid- May to November and reaching peak rainfall intensities of between 120 to 180mm/ 24 hrs in August and September, the two wettest months. The soil moisture regime is usually **ustic**, although at higher elevations it can be udic. The soil temperature regime is 18^0C- hyperthermic, with the mean monthly temperature ranging from 27^0C in the wet season to 37^0C in the dry season.

The area is underlain by marble derived from the Ordovician era. They are metamorphic rock with white sugary texture (an equivalent of limestone). They outcrop in many places. Sometimes bedding planes with streaks and bands of other mineral impurities such as mica schists and quartzites are observed.

The landscape of the study area is hilland, with a mean altitude of over 500m above sea level. Three soil types cover the entire five sites, namely, Petrocalcic calciustoll, Pachic argiustoll and Typic kandiustalf. These soils were previously described and classified by Lopez and Van Sleen (1996) using appropriate procedures according to the FAO (1977) and Soil Survey Staff (1998). Five sites, representing different cropping systems and management practices were chosen for the study, as shown in Table 1.

The following tests were carried out on the seven Soil Surface Microtopographic Features (SSMF) of rain erosion at each site. All the tests were carried out on the last day of the study period, which lasted for five weeks.

Shear Vane Test:

This test is used to assess the shear strength of the seven soil surface microtopographic features of erosion as a measure of their detachability. Soil detachability has been defined as the susceptibility of a soil to the removal of transportable fragments by an erosive agent, such as rainfall and running water, and it is considered to be an important component of soil erodibility (Houghton and Charman,1986).

Soil shear strength has been defined as the ability of a soil to bear or withstand stress without collapsing or deforming excessively. According to Hillel (1990), it derives from the mutual bonding of interlocking particles and from their frictional resistance to deformation. Houghton and Charman (1986) define shear strength as the internal resistance of a soil to shear along a plane. They attribute the resistance to the inter-granular friction and cohesion of the soil.

In this study a torvane apparatus was used to carry out the shear vane test. The apparatus was pressed 1cm deep into a soil surface microtopographic feature, and then rotated. The torgue needed to shear the surface of the feature was read off a scale at the handle of the apparatus. The scale was moved back to zero mark, and the next reading was made. Fifty readings for each type of feature present at a study site were made in this way.

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Table 1: Site Specific Information.

Site No.	Slope (%)	Land use and management practice	Soil Name (Soil Taxonomy)	Remark
(1)	55	Arable: Maize, melon; slash and burn, tillage with hand hoes, weeding first with hand hoes and later with herbicide; stubble mulching.	Petrocalcic Calciustoll, fine loamy, carbonatic.	Land has been cultivated for twenty years now.
(2)	19	Like site 1, but Ploughing is by 4-wheel tractor up and down slope; Plus fertilizer use.	----do-----	----do----- Surface sealing.
(2)	21	Agroforestry: teak, banana, lemon grass; Grazing	Pachic Argustoll fine loamy, mixed, nonacid.	Old terrace, Grass cover (65%), earthworm caste.
(4)	20	Orchad: longan (1 yr old), inter-planted with ginger; mulching, fertilizer use, ploughing with 4-wheel tractor up and down slope.	Typic Kandiustalf, clayey, mixed, nonacid	Land cultivated to cotton for 13 yr. until 2007. & Surface sealing.
(5)	20	Orchard: longan (5yr old), litchi, mango; herbicide use, pesticide use.	----do------	Grass cover (70%), Earthworm caste, Surface gravel (5%), Green algae

Penetrometer Test:

A penetrometer test was carried out on each of the features inorder to assess their compactness or penetration resistance. The penetrometer was pressed into the surface of a feature with a steady pressure until the mark on the apparatus head was reached, and the pressure read off a scale on the handle. The scale was moved back and the next reading was taken. Fifty readings for each feature type were taken in this way in each plot.

Erosion Pin Level Recording:

This was aimed at determining soil detachment, transport, and deposition by raindrop splash and overland flow forces.

On each study site, the features were carefully distinguished at the beginning of the observation period. An observation line 12.5 meters long was then carefully selected to include all the features present on the site. Subsequently, feature recording was carried out along this line.

In order to avoid mislocating features for repeated recording, the line was permanently fixed using a rope fastened at each end to a stable peg. A 2.5 meters tape with alternate green and white 25cm bands was then spread five times along the observation line, thus giving a total of fifty (50) bands for the 12.5 meters long observation line. Each band represented an observation interval. The feature that dominated a square of 25cm at an observation interval was then distinguished and recorded. Thus there were fifty (50) observations along an observation line, each representing 2% of the surface area.

Fifty (50) erosion pins were then firmly installed along the observation line, each pin on a definite feature in an observation interval. A nick of 5cm was made at the aerial end of the pin to which a flag was glued, bearing an identification number for that observation interval. The initial level of each pin was then recorded using a mm metal tape, giving an accuracy of 1mm.

Subsequently, feature recordings and pin level readings were made after each erosive shower or tillage operation (weeding) to monitor the development of the features and the changes in the surface level (erosion, deposition, or a balance) at the pin.

Results and Discussion

The results of the shear vane test are summarized in Table 2. Table 3 shows the results of the penetrometer test while Table 4 summarizes change in level and percentage coverage of feature types as obtained from erosion pin level recording.

Table 2: Share Vane Test Values (kPa), moist condition.

		Features						
Site	Statistics	Res	Ero	Flo	Pre	Ril	Dep	Veg
	Mean		* 28	26	34	28	!	!
1.	S.D			2	3	5	4	
	C.o.V		8	11	16	14		
	Mean	18**	28	25	35	30	!	!
2.	S.D		3**	3	3	6	5	
	C.o.V.	15**	10	11	18	16		
	Mean	!	67	69	56	27	!	65
3.	S.D.			9	9	13	5	7
	C.o.V			13	13	23	18	11
	Mean	†	65	61	36	30	!	!
4.	S.D.			19	18	7	8	
	C.o.V		31	29	19	27		
	Mean	!	63	70	44	!	!	*
5.	S.D.			10	13	8		
	C.o.V		11	19	17			

Legend:
S.D = Standard deviation
C.o.V.= Coefficient of variation
! = feature not present
* = feature too small to permit use of instrument or shatters at introduction of same.
** = feature brought up by 1st weeding after land preparation
† = feature under much cover and therefore could not be assessed.

On sites 1 and 2, the prerills show the highest shear resistance. This is probably because most of them have reached the more compact bottom after the loose materials produced by tillage have been removed by the scouring action of flow in the channel. The eroding clods and rills show less shear resistance because the former have been reduced to very small size by tillage and so already shear almost completely even before the apparatus is rotated. The low shear resistance of the rills is due to the fact that they are still developing on materials loosened by tillage. Least in shear resistance are the flow areas mainly due to the loose sediments. There are no resistant clods in site 1 probably because the soil surface has been loosened by the long continuous cultivation, tillage with hand hoes, and slash and burn practice.

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Table 3: penetrometer reading (kPa), moist condition.

		Features						
Site No	Statistics	Res	Ero	Flo	Pre	Ril	Dep	Veg
	Mean	0.27	0.10	0.08	0.22	0.13	!	!
1.	S.D	0.06	0.04	0.03	0.02	0.04		
	C.o.V	23.25	39.39	39.99	11.40	28.12		
	Mean	0.25	0.17	0.15	0.19	0.17	!	!
2.	S.D	0.05	0.04	0.04	0.04	0.01		
	C.o.V.	22.21	23.19	25.69	22.83	7.31		
	Mean	!	0.26	0.26	0.31	0.16	!	0.36
3.	S.D.			0.05	0.05	0.07	0.04	0.04
	C.o.V			20.03	18.01	23.64	24.24	12.31
	Mean	0.14	0.28	0.28	0.23	0.20	!	!
4.	S.D.		0.05	0.09	0.09	0.04	0.05	
	C.o.V		35.94	30.72	30.85	18.05	22.34	
	Mean	!	0.26	0.41	0.22	!	!	0.37
5.	S.D.			0.11	0.08	0.05		0.04
	C.o.V			42.79	19.78	22.84		10.81

Legend:

S.D = Standard deviation
C.o.V.= Coefficient of variation
! = features not present.

Table 4: Summary of pin reading showing change in level and percent coverage of features on the last observation day.

		Features							
Site		Res	Ero	Flo	Pre	Ril	Dep	Veg	Net change in level of all the feature types (mm)
	(a)	2	36	34	8	20	/	/	-332
1.	(b)	-5	-170	+6	-32	-131	/	/	
	(c)	-2.5	-4.7	+0.8	-4.9	-6.6	/	/	
	(a)	6	52	26	6	10	/	/	
2.	(b)	-32	-83	+52	-16	-53	/	/	-132
	(c)	-5.3	-1.6	+2.0	-2.7	-5.3	/	/	
	(a)	/	58	22	2	6	/	12	
3.	(b)	/	-25	+23	0	+25	/	0	+23
	(c)	/	-0.4	+1.1	0	+4.2	/	0	
	(a)	/	36	26	12	26	/	/	
4.	(b)	/	-40	-30	-22	-88	/	/	-180
	(c)	/	-1.1	-1.2	-1.8	-3.4	/	/	
	(a)	/	64	28	4	/	/	4	
5.	(b)	/	+8	-20	-8	/	/	0	-20
	(c)	/	+0.1	-0.7	-2.0	/	/	0	

Legend:

(a) = percent coverage of a feature (%)
(b) = total change in level of a feature (mm)
(c) = average change in level of a feature (mm)
+ = deposition (soil gain)
- = erosion (soil loss)
/ = feature not present.

On site 3, the features show high shear strength, probably due to the dense network of grass roots. This has enhanced the structure and coherent of the surface soil, thereby increasing the shear strength of the features. The relatively low shear strength shown by the features in site 4 may be attributed to the non-conservative practice of ploughing along slope, more so, with a heavy machine, and also due to the long continuous cultivation which all have loosened the eroding surface soil. On site 5, the flow paths and eroding surface show the highest shear resistance, probably because they have close contact with the grass roots which enhanced the soil structure and hence increased their shear strength.

In a decreasing order of magnitude, the compactness, that is, the penetrometer resistance of the features in site 1 are as follows: res>pre>ril>ero>flo. The relatively high resistance of the pre-rills and rills may be attributed to the fact that the loose materials had been removed by the scouring action of flow in the channels and a more compact bottom had been reached. Pre-rills show twice the penetration resistance of rills, probably due to the differences in moisture content. It was observed that the rills remained moist for longer time than pre-rills after a shower. Hence, the antecedent moisture content of features is a factor to be considered in the erosion process.

The penetrometer resistance of features in site 2 are in this decreasing order: res>pre>ero>ril>flo. The eroding parts, flow areas, per-rills and rills show much similarity in compactness. It is not clear why the eroding clods show such a striking similarity with the other features rather than with the original chods from which they derived.

Compared to sites 1 and 2, features in site 3 show high penetrometer resistance. This clearly demonstrates the importance of vegetative cover, both basal and canopy, as provided by the dense grass and trees of the agro-forestry respectively, in preventing or reducing erosion.

The features on site 4 show relatively high resistance probably because of the dense mulch cover. A much lower resistance would have been expected considering the land use in place and the unconservative along-slope ploughing with a heavy machine.

There were no rills and original clods in site 5 because there was no tillage operation. The eroding features show comparable penetrometer resistance with those in sites 3 and 4, while the flow features show the highest resistance compared to all the other four sites. Again, this may be a clear demonstration of the effectiveness of vegetative cover in reducing the erodibility of soil.

Erosion pin level recordings were intended to characterize the seven micro topographic features of rain erosion. They provided a measure of soil detachability and soil movement. Influence of the land use types and management practices on soil erodibility could easily be seen. Whether there will be loss or gain of soil at a given point on a slope is determined by the interaction of erosion processes at that point (Hanns et al., 1982) under a particular land use and management. The interacting processes of soil erosion and sedimentation by water involve the detachment, transportation and deposition of soil material. These processes often recur intermittently as rainstorms progress. Detachment of soil particles is basically a function of the erosive forces of raindrop impact and the scour action of the overland flow. Transportation of detached soil particles or aggregates results from both raindrop splash and overland flow. Most soil moved by water for major distances is transported by surface runoff, although considerable soil may be moved short distances by raindrop splash from the interrill to rill areas. The quantity and size of material that can be transported are a function of overland flow characteristics, such as velocity and turbulence, which generally increase as the slope steepens and as the overland flow volume increases. Either detachment or transport capacity may limit erosion and sediment load at a location on the slope (Haans *et al.,* 1982). At a given location on a slope, if the amount of sediment made available for transport by the detachment processes is less than the transport capacity, then the sediment load moving on down slope will be the amount of detached sediment available for transport. But if the available detached sediment exceeds the transport capacity, deposition occurs and the transport capacity controls the sediment load.

Table 4 shows the results of the pin readings. Erosion, deposition or stability of soil surface level are clearly indicated. In brief, the feature types rank as follows, in decreasing contribution to the total soil surface level change: ril>pre>ero>res>flo>dep>veg. This observed comparison agrees with the expected. According to Bergsma (1992), rill erosion, indicated by pre-rills and rills, is the most serious indication of erosion hazard among the seven features. Before they disappeared by the third erosive shower, the depressions (at site 2) made a little contribution to the total surface level change. The vegetals show no level change probably because it is in close contact with the soil surface. No detachment occurs by raindrop impact where the soil surface is covered since there is no fall distance for drops to regain energy. Also materials in close contact with the soil surface such as grass, dead leaves and stubble and mulch, slow runoff and thereby increases flow depth. Increased flow depth decreases detachment by cushioning the impact of raindrops and reducing impact forces (Haans et al., 1982). This explains the observation in sites 3 and 5 which show the least surface level change, that is the least soil detachment when all the sites are compared. In addition, the roots of the dense grass cover at these two sites had improved the soil structure and its coherence thereby reducing the soil erodibility. Houghton and Charman (1986) have noted that soil detachability by water is an important component of soil erodibility and that it is largely dependent on soil texture and structure.

Also substantial amount of the raindrops was intercepted by the canopy of the trees at these two sites and this must have contributed to reduction of surface soil detachment.

Summary and Conclusion:

The study has shown that soil erodibility can be estimated from the properties of soil surface micro topographic features of erosion by rain.

The established relationship between soil detachability and soil erodibility have been clearly demonstrated. Soil detachability was evaluated from soil surface level change using erosion pin level recording during a rainy period.

Since this method is cheap, rapid, efficient and easy to learn, it is here proposed as a good procedure for the evaluation of the erodibility of soils under several competing land use and management options, in order to choose which one(s) support most, soil resources conservation for sustainable production and improved livelihoods of the farmers.

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