DEVELOPMENT OF METHODS TO MEASURE SOIL LOSS AND RUNOFF IN FIELD EXPERIMENTS INVOLVING VETIVER GRASS

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Abstract

Methods to measure soil loss are numerous, most involving the use of two or three tanks to collect runoff and sediment, with a divisor attached between any two of them. These methods have been used for field experiments, including the use of vetiver grass for soil conservation. Recently, there have been attempts to measure soil loss by collecting most or all sediment and weigh it as such at intervals or after harvest. These methods have made trials where normal research facilities are lacking possible, with the added value of high precision, hardly obtainable by conventional procedures. A number of vetiver experiments have been conducted in Thailand using the so-called total sediment methods.

However, in order to overcome one main disadvantage of these methods, i.e. the amount of runoff not being known, an experiment involving vetiver grass is being conducted at the Chaipattana development project in Hua Hin, where each plot is equipped with a concrete pond of fixed dimension at the lower end. Runoff amount is obtained by calculating the volume of water in the pond minus that which evaporated from it. At the end of the first year, a number of shortcomings of this method would be identified for further improvement.

Introduction

On sloping land there is a serious problem of soil erosion after the forest is cut down for crop cultivation. Measuring the loss of soil from such areas is useful in order to monitor the use of land to conform to the land-use plan. However, using the conventional method – employing a number of collecting tanks with a divisor between any two of them – would require much cost and manpower, which normally are not available. The first author therefore has devised a plan to use a simple method to measure important criteria which may indicate the degree of soil and land degradation. This would result in a better chance to learn about the amount of soil lost from any one area after one year. The method was developed partly from a South American trial and the rest was derived from pure common sense as well as by a trial-error approach.

The method mentioned so far involves the use of a plastic sheet to line a pond out of which the runoff and sediment from a runoff plot flow. It has so far provided a satisfactory result of annual soil loss with one significant shortcoming, i.e. the amount of water loss cannot be accounted for. The second author has therefore attempted to solve this problem by using a cement pond of fixed dimensions in order to get the best estimate of water loss. This paper describes mainly the development of the plastic method with resultant experimental data, which may be useful for other researchers or practitioners to choose methods to use in their work.

Literature Review

Measurement of soil loss from a specified plot has been done for more than half a century, mostly using long plots located up and down slope, where the sediment-laden runoff escapes each plot on the lower side and runs into certain devises in order to measure the volume of sediment flux and the amount of soil carried with it. Hudson (1993) made a comprehensive review of most available methods to measure soil loss and runoff from catchments and from plots.

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The conventional method of measuring soil loss and runoff from fixed-size plots involves a series of tanks and a divisor between any two of them. Constant care has to be exercised and much work needs to be done after each sizeable storm. Normal practice in running these plots includes measuring the height of water in each tank, heavy swirling and sampling of sediment flux, weighing sediment and calculating the losses of soil and water from one plot after one storm. Though this conventional method looks straightforward, the cost to run it is high and a number of well-trained persons have to be stationed nearby for the whole rainy season. These requirements have thus limited the use of the conventional method mainly to experimental stations. Moreover, recent findings indicate that the accuracy of the conventional method is doubtful. Zoebisch et al. (1995) found that, in a sampling trial where five Kenyan technicians tested their skill in sampling a standard flux, only two of them could do close to the real concentration while the others got a result very far from that, making the mean square sampling error to be as high as 41.3 % (range = 4.7-83.2 %).

In another trial, Lang (1990) found that sampling sediment flux with a 300 ml flask after the content was well agitated yielded only 67 % of concentration of soil particles. Using a 50 ml pipette to sample further from the flask yielded only 34 % of the total sediment concentration.

Subsequently, researchers tried to use simpler methods to find soil loss. Humphreys and Wayi (1990) in Papua New Guinea used one half of a 200 L oil drum (long section) to capture sediment from small plots. When collecting sediment only heavy particles could settle at the bottom of the tank; those that got carried away with runoff were simply ignored.

On the Andes mountains in South America, and later in Thailand and in other countries in Southeast Asia, Howeler (1987) used a trench with a cross section of 40 x 40 cm, with its length going along the contour line, to capture heavy sediment, allowing excessive particles to be carried away when spillage occurred. Soil material deposited in the trench (separated by plastic lining) was taken up once a month for weighing and analysis. The volume in m^3 vs. area of plot in m^2 was 2.4:150 (or 1.6:100 = 1.6%).

After having experienced various difficulties in working on the highlands in Northern Thailand, the first author has devised a method to collect the whole sediment in order to measure soil loss only once a year. The “trench” in Howeler’s method was expanded into an earth pond, lined with a flexible black plastic sheet, with the volume-area ratio increased to 5:100 or 5 %. The result from the first-ever trial was reported at the sixth ISCO conference in Ethiopia in 1989 (Sombatpanit et al. 1992).

In the present paper a further trial in order to improve the efficiency of the so-called plastic-sheet method in collecting sediment, compared with the conventional method, is described.

Development of the Plastic-sheet Method for Measuring Annual Soil Loss

General Considerations

Opinions are generally held that, in studying soil and water conservation, the most frequently used figure is the amount of soil loss per year or one crop duration. The loss of water is probably the second figure needed. The amount of soil loss according to each storm will be required only when we study the processes of soil erosion. Many soil and water conservation studies therefore mention only soil erosion loss per year, and less so per crop.

It is therefore considered sufficient if a method can give the amount of soil loss when studying various conservation measures in agricultural areas. A method using plastic sheets to line the sediment pond, with sufficient precaution for the spillage of sediment flux, would thus be an answer.

Determination of the Size of a Sediment Pond

First, considering that the runoff from a plot due to each storm would be in the range of 10-30 %, using a figure of 40-% runoff coefficient would be well on the safe side. Second, the highest amount of rain for each storm would be about 100 mm; in one year, very few storms would exceed that level. Therefore a maximum rainfall figure of 125 mm would suffice.

In the case of a 100 m^2 runoff plot, the runoff generated from each storm would be well in the level of equal to [proportion of runoff to rainfall x maximum rainfall in metre x area in m^2], which is equal to:

$$\frac{40}{100} \times \frac{125}{1000} \times 100 = 5\ m^3$$

In short it can be said that for each 100 m^2 of catchment area, a pond with a capacity of about 5 m^3 would be sufficient. A simple volume-area ratio of 5:100 may be used generally, and can be adjusted to suit local conditions.

Construction of a Sediment Pond

When determining an experiment plot using the total-sediment method, the width of the plot should be the same as the width of the pond, allowing its other two dimensions to vary according to the texture of the soil, slope, and land availability.

The earth excavated from the pond should form the berm on three sides, except the side which receives sediment flux from the plot. The slope of each side of the pond should not be steeper than 1:1 to avoid slipping. The outer slope on the three sides of the pond should be as appropriate. When sediment ponds of two plots are constructed together, they can share a berm.

Use large black plastic sheets to cover the pond up to the berms, with the side attaching with the plot running 0.5 m upslope and the plastic rim dug into the ground for not less than 10 cm. This kind of surface coverage will facilitate the smooth flow of sediment into the pond without any soil and water coming from outside the plot and the pond.

It should be mentioned at his stage that for most kinds of experiment the plot boundary is sufficiently secure by constructing a low earth bund on three sides, 15 cm high and 30-40 cm wide. This will ensure its practicality; most of the cost in doing so goes to pay the labourers.

Control of Sediment During a Trial

In theory, a pond of such size will ensure receiving sediment flux from one big rainfall event. But if several events are put together there is a chance that spillage may occur, resulting in losing some soil particles. In order to avoid that, the water level in the pond should be lowered. There are three ways to do so:

1. Natural evaporation into the air.
2. Seepage into the ground along the seam line between plastic sheets which are sewn together. Seepage can be accelerated further by making holes on the sheet by knife.
3. Siphoning the clear water off occasionally. If water is still turbid, use alum [$KAl(SO_4)_2$] to deposit clay particles first.

It is therefore worthwhile to assign someone to observe the water level in the pond frequently, especially during a high rainfall period, so that no spillage may occur.

Measuring Soil Loss

The sediment will dry after the rainy season. Simply weigh the sediment in the pond by using a commercial scale with acceptable accuracy. Deduct the moisture content to get the exact figure of moisture-free soil loss per plot, without any factors to multiply or divide.

With proper plot and pond construction and careful sampling of sediment for measuring moisture content, this plastic-sheet method is expected to give an accurate figure of annual soil loss.

Results from Trials

There are two trials to report in this paper. The first one is from the original plots since 1988-1991 (Sombatpanit et al. 1992) and the second one is from the verification trial in 1993.

Original Trial

This trial was done in Chiang Khong reddish-brown lateritic soil in the highlands of Chiang Rai province. The elevation is about 700-800 m, with 1400-1500 mm precipitation. An area with 41-% slope was constructed into two plots, 5 m wide each, 71 m long, up- and downhill. At the lower end of each plot there was one plastic-lined sediment pond of approximate volume of 16 m^3. One plot was grown to upland rice and designated as farmers' practice; the other plot was put to strip cropping with several food and cash crops (rice, corn, red kidney bean and soybean), to be divided by strips of setaria grass which act as a soil and water conservation measure. The latter treatment was done according to the recommendations of the Thai-German Highland Development Program.

After four years of this trial, the soil loss results for the two plots are as shown in Table 1.

Table 1. Soil loss from the original trial plots

Year	Rainfall (mm)	Soil loss (t/ha)	
		Plots with farmers' practice	Plots with grass strips
1	1490	71.0	2.1
2	1490	111.4	0.0
3	1391	25.0	0.2
4	1504	201.8	0.2
Average	1469	102.3	0.6

The data in Table 1 show that this kind of sediment pond is usable, and there was no evidence of spillage of sediment flux over the berms.

Verification Trial

When the results from the first trial were disclosed, there was a not-so-certain attitude from members of the public. The first author was therefore urged to undertake another trial to verify the claim. The special features present in this trial were that:

- It is a comparison of methods to collect sediment, i.e. plastic-sheet method and conventional cement ring sediment tank method, with the same upslope and down-slope cultivation, four replications altogether.
- For the plastic-sheet method there was an assurance that there would not be any spillage to outside, since a smaller plastic-lined pond, or safety pond, was built alongside. Any spillage, if it occurred, would directly flow from the main pond into this pond.

The trial was conducted on Chiang Kan sandy loam soil, 3-% slope, at the Uttaradit Land Development Station from 1993 to 1996. Only the result from the first year (rainfall = 721.5 mm) is available to report here.

The trial plots were grown to mung bean in the first part of the rainy season (June-August) and corn in the second part (August-November). The practice for both plots in each pair, for altogether four pairs, was the same, i.e. upslope and down-slope cultivation, which is generally farmers' practice. The results from this trial are shown in Table 2. That the average amount of soil loss detected by the conventional method was only 40 % of the plastic-sheet method speaks by itself of the overall superior performance of the latter.

The Use of the Plastic Sheet Method in Thailand and Elsewhere

Since the original trial was conducted in 1988 in Chiang Rai province, there have been close to 30 experiments done in this way in the provinces of Chiang Rai, Chiang Mai, Tak, Nakhon Rachasima, Sakon Nakhon, Khon Kaen, Maha Sarakham, Uttaradit and Rayong. A number of these trials concern the use of vetiver grass in erosion control on sloping land. Apart from that, there have been two trials outside Thailand, one each in Vanuatu and Sri Lanka.

Table 2. Soil loss from the verification trial plots

Replication	Soil loss measurement method employed		
	Plastic-lined sediment pond (t/ha)	Conventional cement ring sediment tank	
		t/ha	% of plastic-lined method
1	29.12	12.63	43
2	50.97	17.00	33
3	73.73	27.69	38
4	52.97	23.44	44
Average	51.70	20.19	40

Correlation = 0.936
Source: Sombatpanit et al. (1999)

There are in fact several points which may cause the result of experiments using the plastic-sheet technique to differ somewhat. Selection of site, calculation of pond size, excavation of pond and how the berm is formed, how to attach and lay down plastic sheets in the pond, how to weigh the sediment and how to take samples for moisture content determination: these are the main items to consider if the researcher wants the result to be precise as intended.

Improvement of the Plastic-sheet Method to Measure Soil Loss and Runoff

With the need to know the amount of runoff, especially with some categories of investigations, the second author has initiated an experiment using a method which may reveal how much runoff can occur and how much water percolates into the ground. In the experiment "Vetiver grass plantation for degraded land and environmental reclamation" conducted at the Chaipattana Foundation project in Hua Hin, a concrete pond, 2-m wide, 3 m long, 0.8-m deep, has been constructed at the lower end of each vetiver plot, which is 4-m wide and 12-m long. The ratio of the volume of the pond to the area of the plot is 4.8:48 or 10 %, which would suffice to receive runoff over a long period, though the siphoning device is always at hand. This impermeable concrete pond of fixed dimension would give a good estimate of runoff in certain periods or on an annual basis. However, due to the long period of time that water stands in the pond, much of it would evaporate. Therefore the measured figure of runoff would have to be adjusted by adding the evaporated amount.

For the amount of soil loss per annum in this case, the way to measure would be the same as with the plastic-sheet method. The efficiency for collecting sediment would be similar for both methods, except that the structure of the latter is more durable and does not need changing material like the plastic-sheet method does.

Discussion and Conclusion

It has been argued that collecting sediment using plastic sheets may cause too much error and may not be acceptable in the circle of soil and water conservation researchers. The statement has been made many times that the invention of this method is to answer needs, not to advocate it as the best method for soil erosion and conservation studies. For example, if one is interested in comparing a number of soil and water conservation measures in reducing soil loss on an annual basis or how much soil in a certain geographical area, of specific characteristics, is lost in one year, the plastic-sheet method can give an answer.

The plastic-sheet method is much more accurate than the conventional cement ring sediment tank method (Table 2) in that it gives a precise measurement.

A major shortcoming of the plastic-sheet method is being entertained: the concrete-pond method executed by the second author at Hua Hin will provide an answer about annual loss of water from the plot. It would require a few more years for this point to be well verified.

Apart from this, it can be said that to know the rates of runoff and soil loss would not be possible by employing these methods. These days, soil erosion studies using data logger and computer technologies have been developed in many places.

However, in developing countries where accurate soil-loss data are very much needed in order to formulate a work plan to correspond with natural soil and land degradation, agencies dealing with soil and land should find accurate methods to measure soil loss. Otherwise, in the case of Thailand, if we take the conventional method as a standard and overlook its flaws, we will not know the real extent of land degradation. Wrong work plans would be formulated and one day the deterioration of this important natural resource might have gone too far to make corrections, or it would be too expensive to do so.

For the time being, while accurate methods which would enable researchers to study various other components of soil and water losses are not available, it would not be a bad idea to use this plastic-lined sediment pond method as a "check" plot, which can be constructed along with any experiment to be done in the future.

A manual is being developed to assist researchers and practitioners in handling soil erosion trials or demonstration plots effectively.

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