The effectiveness of soil conservation structures in steep cultivated mountain regions of the Philippines

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Abstract Three soil conservation measures were evaluated in terms of their effectiveness in reducing surface runoff and soil loss as well as their acceptability to the upland farmers. These measures are terraces, rock barriers and hedgerows. Control plots were monitored to serve as basis for determining the effectiveness of the various measures. The area has steep slopes ranging from 30% to 60% and is being used for agroforestry. Bench terraces and rock barriers proved to be more effective in the first year. The effectiveness of hedgerows, however, improved in the second year. Terraces, rock barriers and hedgerows reduced soil loss by 80, 78 and 68% respectively. Hedgerows were found to be less expensive and more acceptable to the farmers.

INTRODUCTION

The importance of hilly areas in the Philippines can be demonstrated by two simple statistics. Firstly, hilly areas comprise 30% of the total land area of 30 million ha and, secondly, of these 9 million ha, about 4 million ha are currently under cultivation by poor upland farmers (Paningbatan, 1991). These cultivated hilly areas are the most severely eroded and the most marginally productive farming systems in the country. The soil erosion problem is further aggravated by the country's rugged physiography, high rainfall intensities and long rainfall durations. Bayotlang (1986) examined rainfall depth-duration data from 41 weather stations located throughout the country and found that the annual rainfall erosivities range from 448 t m^{-2} ha^{-1} $year^{-1}$ in the south to 1857 t m^{-2} ha^{-1} $year^{-1}$ in the mountain provinces of the northern Philippines.

In 1982, soil erosion prevention was finally recognized as a national goal. The problem of erosion has been compounded by the influx of people into the uplands. It is estimated that at present, some 12-14 million people live in the highlands. The immediate effect of this is increased cultivation of the hilly areas, resulting in extremely high rates of soil erosion. This in turn affects agricultural productivity. Agroforestry has been introduced and is currently being practised as the major management strategy in these areas. Due to the steep slopes, erosion control structures were found to be necessary, because vegetation manipulation and conservation cropping practices were often not effective in reducing erosion.

In view of these problems, the research and development activities of several agencies were geared to support soil conservation programmes. Research projects have been established to determine the most appropriate soil and water conservation technologies in various areas of the country. The results of one study are presented here.

DESCRIPTION OF THE STUDY AREA

The study was conducted in Region VIII, one of the most eroded areas in the Philippines. Kaingin or shifting cultivation has long been a problem in the upland areas. The study area has slopes ranging from 30% to 60%. Mean air temperature and soil temperature were 26.7°C and 30.7°C respectively. The total annual rainfall in the area is 2200 mm. Maximum rainfall occurs in November and the mean number of rain days is 64. The soil is clay to clay loam and slightly acidic (pH 5.0-5.45). Chemical analysis of soil samples did not identify a limiting chemical property other than the low fertility levels commonly found in the tropics. The study area is one of the recipients of the Upland Development Programme of the Philippine government and the Rainfed Resources and Development Project which promotes agroforestry as an alternative land use in the area.

MATERIALS AND METHODS

The study was established in accordance with Randomized Complete Block Design (RCBD) with four replications. Four plots measuring 8 m × 20 m, with 2.0 m isolation strips between the plots, were established in each block. These plots supported the following treatments:

(a) *Terrace*: a reverse-slope terrace (1.5 m wide) built across the slope in order to break up the long slopes.

(b) *Rock barrier*: an embankment made of stones to trap or retain eroded soil resulting from farm cultivation.

(c) *Hedgerows*: vegetation strips of kakawate planted across the slope.

(d) *Control*: no conservation structures.

All plots were planted with *Acacia auricoliformis* spaced at 6 × 6 m, with corn-peanuts as a cash crop during the first year and pineapple in the second year.

Surface runoff plots measuring 6 × 8 m were established within the treated plots. The runoff plots were bounded by steel sheet buried to a depth of 15-20 cm. Runoff from individual plots was measured in the storage drums at about 8:00 a.m. each day. Water samples were collected from the storage drums after measurement of the total runoff. Soil movement and accretion were measured using erosion gauges installed at the upper, middle and lower portions of the plots.

RESULTS AND DISCUSSION

Tables 1 and 2 show the mean surface runoff from the various treatments during the first and second years of the study. Surface runoff during the first year ranged from 57.1 mm with terracing to 170.40 mm from the control plot. Rock barriers had the second lowest surface runoff (66.26 mm) followed by hedgerows (113.81 mm). Comparison of the mean runoff volumes indicated that the three treatments, namely, terraces, rock barriers and hedgerows differ significantly from the control plot in terms of surface runoff yield.

Table 1 Surface runoff (mm) produced from various plots during the first year of observation.

Block	Treatment: Terrace	Rock barrier	Hedgerows	Control
I	55.80	64.01	105.47	166.28
II	66.78	80.20	137.67	196.32
III	60.80	71.40	113.43	174.82
IV	45.05	49.41	98.66	144.23
Mean	57.10[a]	66.26[a]	113.81[b]	170.40[c]
% reduction from control plot	66.5	61.1	33.2	-

Means with the same superscripts are not significantly different ($P = 0.05$).

Table 2 Surface runoff (mm) produced from the various plots during the second year of observation.

Block	Treatment: Terrace	Rock barrier	Hedgerows	Control
I	111.23	120.11	131.95	256.05
II	121.04	135.67	171.64	318.43
III	110.00	114.67	140.22	297.27
IV	94.86	102.79	114.49	231.06
Mean	109.28[a]	118.31[a]	139.58[b]	275.7[c]
% reduction from control plot	60.4	57.1	49.4	-

Means with the same superscripts are not significantly different ($P = 0.05$).

There was a marked increase in surface runoff during the second year. The terraced plot had the lowest runoff, 109.28 mm, followed by the rock barrier plot, with 118.31 mm of runoff. The increase in surface runoff during the second year could be attributed to larger rainfall events and differences in vegetation cover. During the second year, pineapples were planted in the area whereas during the first year, the main crops were corn interplanted with peanuts. The lack of protection of the surface soil from the kinetic energy of raindrops afforded by the poor vegetation cover could have also caused the increase in surface runoff. Continuous rainbeat may have compacted and sealed the pore spaces of the surface soil, causing higher runoff (Kirkby & Morgan, 1980).

Based on these results, it appears that any of the three treatments can produce a significant reduction in surface runoff. The terraces and rock barriers proved more effective during the first year. The effectiveness of the hedgerows, however, seemed to improve during the second year. This is attributable to the growth of the kakawate hedgerows. In the longer-term, when the kakawate hedgerows are fully developed, they may equal the effectiveness of the two other treatments.

Terraces and rock barriers were found to reduce surface runoff by 66.5% and 61.1% respectively. The effectiveness of these two structures, however, were reduced to 60.4% and 57.1% during the second year. Regular maintenance was required to maintain the performance of these two structures. Hedgerows, on the other hand, were found to reduce surface runoff by 33.2% during the first year, and by 49.4% during the second year. The trimmed kakawate branches placed at the base of the hedgerows improved their ability to retard runoff, thereby enhancing infiltration. Colting (1987) reported that the use of Alnus buffer hedgerows on land with a 55% slope reduced runoff by 88%.

SOIL LOSS

Soil loss from the various treatments plots is shown in Tables 3 and 4. Terraces produced the lowest amount of sediment (4.73 t ha^{-1}) followed in increasing order by rock barriers (5.31 t ha^{-1}), hedgerows (11.77 t ha^{-1}) and control plots (28.45 t ha^{-1}). Analysis of variance indicated significant variations between the different treatments. A marked reduction in soil loss from the plots with hedgerows relative to the control plot was noted during the second year. This was attributed to the growth of the kakawate and the placing of the cut branches at the base of the hedgerow which trapped and filtered the sediment from the runoff. Over the two years the reduction in soil loss from the hedgerow plots relative to the control plots increased from 59% to 68%, and Paningbatan (1990) noted that after about three years of continuous cultivation cropping, the alleyways generally level off, producing a series of natural terraces with the hedgerows serving as risers. The trend of the soil loss results is similar to that

Table 3 Soil loss (t ha^{-1}) from the various plots during the first year of observation.

Block	Treatment: Terrace	Rock barrier	Hedgerows	Control
I	4.54	4.89	12.19	31.01
II	5.63	6.56	19.54	40.02
III	5.02	5.88	8.78	27.30
IV	3.73	3.89	6.58	15.47
Mean	4.73^{a}	5.31^{a}	11.77^{b}	28.45^{c}
% reduction from control plot	83.4	81.3	58.6	-

Means with the same superscripts are not significantly different (P = 0.05).

Table 4 Soil loss (t ha^{-1}) from the various plots during the second year of observation.

Block	Treatment: Terrace	Rock barrier	Hedgerows	Control
I	8.75	9.11	15.24	38.95
II	11.07	12.53	21.64	67.02
III	10.20	10.86	13.80	52.11
IV	6.30	8.27	8.09	22.73
Mean	9.08^{a}	10.19^{a}	14.69^{a}	45.20^{b}
% reduction from control plot	79.9	77.5	67.5	-

Means with the same superscripts are not significantly different ($P = 0.05$).

for surface runoff. This was expected as soil loss is a function of surface runoff. As mentioned previously, the greater rainfall total during the second year resulted in higher runoff values during this period.

SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS

The soils of the four blocks range from clays to clay loams. Covariance analysis shows a non-significant difference for most of the soil properties. Initially, the soils in the area were slightly acidic with pH ranging from 5.0 to 5.45. Soil pH was observed to decrease or become more acidic with time on all treated plots. The hedgerow plots, however, were observed to have a minimal decrease (from 5.44 to 5.35). Other soil constituents (% OM, N, K, Ca and Mg) were also observed to decrease after two years under cultivation. The decline in these important soil constituents could be due to uptake by the crops or loss by erosion. None of the treatments showed significant results in terms of maintaining the productivity of the soil during the two year observation period. In the hedgerow experiments undertaken in the Southern Philippines by Watson & Laquihon (1985) corn was continuously planted for 10 consecutive croppings on the same piece of land using ipil-ipil leaves from the hedgerows as fertilizers. The yields tended to stabilize at about 2 t ha^{-1} from the third to the tenth croppings. This means that plant litter from hedgerows improved the soil characteristics only after more than two years of continuous addition of hedgerow trimmings (leaves, twigs and branches). A double ipil-ipil hedgerow occupying about 20% of the land, when cut periodically, could yield about 5 t dry herbage per year. The fertilizer equivalent is about 145 kg N, 15 kg P and 75 kg K per ha, which could be enough to supply the fertilizer needs of the food crops (Paningbatan, 1990).

COST INVOLVED

The costs involved in constructing the different conservation measures on the plots are presented in Table 5. The most expensive treatment was terracing following by rock barriers and hedgerows. The cost incurred in replanting the kakawate hedgerows was not included, because it forms part of the regular maintenance activities of the field labourers. The higher cost associated with rock barriers was due to the greater amount of work involved, such as hauling of big rocks for the foundation of the structure and the stone filling. Terraces have a higher maintenance cost due to the earth moving activities required after storms to maintain the terrace structure.

Table 5 Construction and maintenance costs (Pesos) for the individual treatments applied to the plots (1$(US) = 26 Pesos).

Treatment	Construction:			
	Planting material	Labour	Maintenance	Total
Terrace	-	430.00	645.00	1075.00
Rock barrier	-	645.00	360.00	1005.00
Hedgerows	50.00	43.00	43.00	136.00
Control	-	-		

THE SOCIAL ACCEPTABILITY OF THE VARIOUS SOIL CONSERVATION MEASURES

Of the four treatments, hedgerows were found to be the most acceptable to the farmers. Of the ten cooperating farmers, nine have adopted this technology on their respective farms. These farmers believe that hedgerows are a good source of green manure which serves as an organic fertilizer. Furthermore, they were economical to install and were not labour-intensive.

The negative attitude of the cooperating farmers to terraces and rock barriers reflected the labour and time involved in their construction and the need for frequent repairs and maintenance. Rock barriers also harboured snakes and rats which greatly affected the yield of the crops.

Two farms were used by the Rainfed Resources and Development Program (RRDP) as demonstration areas for terrace construction, but as yet, no farmer has introduced this method, again emphasizing the reluctance of the farmers to adopt this technology.

CONCLUSIONS

Terraces, rock barriers and hedgerows were effective in reducing surface runoff and soil loss. Surface runoff was reduced to 67%, 61% and 33% of the control plot values during the first year and 60%, 57% and 49% in the second year, respectively. Soil loss was reduced to 83%, 81% and 59% of the control plot values in the first year and 80%, 78% and 68% in the second year. The effectiveness of hedgerows increased with time, whereas the effectiveness of terraces and rock barriers depends largely on the continued maintenance of the structures. Hedgerows were more acceptable to the farmers, because they were less expensive and because of the farmers' perception that they provide a source of organic fertilizer to the food crops.

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