WHAT IS THE OPTIMUM SPACING OF VEGETATIVE BUFFER STRIPS IN TROPICAL SMALLHOLDER CONSERVATION SYSTEMS?

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ABSTRACT

Natural vegetative filter strips (NVS) are attractive contour barrier systems compared with other alternatives because they are simple to establish and maintain, they control erosion effectively, and they compete less with associated annual crops. The recommended practice has been to space hedgerows so that there is a one-meter drop in elevation between them. This results in very close hedgerow spacing (3-6m apart) on sloping lands, which removes considerable area from crop production. We hypothesized that acceptable soil loss may be possible with fewer hedgerows, and tested the effect of hedgerow density on soil loss in an experiment on a field with 50 meters slope length and 45% slope. A single NVS across the middle of the field reduced soil loss by 60% compared with the open-field control. As hedgerow density increased (4m, 2m, and 1m drop in elevation between hedgerows) soil loss further declined, but at a decreasing rate. Erosion did not differ significantly between the 2m and 1m elevation drops, although the number hedgerows doubled in number. Maize yield declined with increasing number of hedgerows due to an increase in the cropped area. We conclude that it is most practical to space hedgerows at a distance corresponding to a 2m to 4m elevation drop. We conclude that even a single hedgerow across the middle of a field provides a reasonable starting point for a farmer to tackle erosion with minimal investment and without significant loss of cropped area.

1. INTRODUCTION

Soil erosion is one of the major problems endangering the sustainability of agricultural systems in sloping tropical uplands. Erosion causes rapid soil quality degradation, nutrient depletion, and a decline in crop productivity (El-Swaify 1993, Lal 1984, Stocking and Peake 1986, Turkelboom et al 1993). It is recognized as a major constrain to agriculture in the uplands of Southeast Asia (Cruz, Francisco and Conway 1988; Fujisaka et al 1994; Garrity, 1993, Garrity et al, 1995). Contour hedgerow systems using nitrogen fixing trees have been widely promoted to minimize soil erosion, restore soil fertility, and improve crop productivity (Huxley 1986, Kang and Wilson 1987, Young 1986, 1987). They have been recommended as a common feature of extension programs for sustainable agriculture in Asia (Garrity, 1996). But this innovation has not been widely adopted by upland farmers (Fujisaka, 1994) despite the positive results reported in a number of experimental and demonstration sites.

The constraints that limit the effectiveness and adoption of pruned-tree hedgerows have become more apparent to researchers and extensionists in recent years. They include the tendency for the perennials to compete for growth resources and reduce the yield of associated crops planted in adjacent rows, and the inadequate amount of phosphorus that is recycled to the crop from the tree-leaf prunings (Garrity 1996). However, the major problem is the large amount of labor needed to prune and maintain woody hedgerows. ICRAF (1996) estimated that the amount of labor required to prune leguminous-tree hedgerows was about 31 days per hectare, or 124 days annual labor for four prunings in the Philippines. There is a great need for simpler, less labor intensive but effective contour hedgerow systems

The use of natural vegetative strips (NVS) has proven to be an attractive alternative because they are so simple to establish and maintain. NVS are laid out along the contour lines by leaving unplowed strips 40-50 cm wide across the field on the contour. These strips are spaced at desired intervals down the slope. The recommended practice for spacing contour buffer strips has been to place them at every one meter drop in elevation. The contour lines are determined by using an A-frame. The natural vegetation that is naturally growing in the strips filters the eroded soils, slows down rate of water flow, and enhances water infiltration, making them very effective for soil and water conservation. Researchers found that these natural vegetative contour strips have many desirable qualities (Garrity, 1993). They needed much less pruning maintenance compared with fodder grasses or tree hedgerows, and offered little competition to the adjacent annual crops compared to the introduced species (Ramiaramanana 1993). They are efficient in minimizing soil loss (Agus, 1993), and do not show a tendency to cause greater weed problems for the associated annual crops (Moody, 1992 as cited in Garrity, 1996). Natural vegetative strips (NVS) were found to be an indigenous in practice on a very limited scale in other localities, including in Batangas (Garrity 1996) and in Leyte Provinces between 1944 to 1977 (Fujisaka, 1993). ICRAF has been working with a number of agencies to refine and expand the use of this conservation farming practice to much wider areas where it may be suited.

One of major concerns of farmers contemplating the adoption of any contour hedgerow practice is the loss of cropped area to provide space for the hedgerows. The more strips installed in a given field the greater the loss of area for crop production. The general rule of thumb has been to recommend spacing the hedges at a 1-meter vertical drop (Watson and Laquihon 1986). This translates into alleyways between hedgerows that are approximately 6 meters wide on a 20% slope. Such a spacing reduces the cropped area by 15%. Crop yields in the alleyways would have to be more than 15% greater to compensate for this cropped area loss and for any competitive effects of the hedgerow plants for growth resources such as soil moisture and nutrients.

We therefore have a serious tradeoff. A fairly dense spacing of hedgerows may be more effective in minimizing soil loss, but as spacing decreases the negative effects on crop production increase. The attractiveness of contour hedgerows as a widely adoptable soil conservation technology depends upon a better understanding of this erosion-production tradeoff, and the development of more flexible recommendations for hedgerow spacing to accommodate the wide spectrum of farm circumstances in the uplands. Hence, this research was aimed at determining the relationship between hedgerow spacing, soil loss, and crop yields.

Our experimental hypothesis was soil loss declines as the spacing between hedgerows is reduced, but that the relationship follows an asymptotic curve, showing a much smaller reduction in marginal soil loss as the spacing decreases. The hypothesis was based on experience with the Modified Universal Soil Loss Equation (MUSLE) which predicts that the soil loss does not increase proportionally relative to increases in slope length. Thus, an decrease in the spacing between hedgerows to 1/2 or 1/4 the spacing normally recommended will be associated with an increase in off-field soil loss that is much less than double or quadruple that predicted if the two factors were proportionally related. The experiment provides data on the functional relationship between hedgerow spacing and the concomitant soil loss expected. This indicates a basis for new, more flexible guidelines for extension recommendations in future. This may enable the development of management recommendations for wider hedgerow spacing that are more consistent with practical farming demands to reduce the aggregate area lost from cropping to 5 to 10%

2. METHODS

The experiment was conducted on a field of 45% slope with 50-m slope length from top to bottom. The field is owned and managed by the Misamis Oriental State College of Agriculture and Technology (MOSCAT), in the village of Anei, municipality of Claveria, Misamis Oriental, Philippines. The soil is classified as an Ultic Haplorthox with a pH of 4.7.

Five treatments were compared: T1- no NVS (control), T2- one NVS at the middle of the field (8 m elevation drop between the contour strip and the upper and lower field borders), T3- three NVS spaced 12.5 m apart (4 meters vertical drop), T4- seven NVS spaced 6 meters apart (2 meters vertical drop), and T5- fifteen NVS spaced 3 meters apart (1-meter vertical drop). These 5 treatments were replicated three times in a randomized complete block design (RCBD). The experiment was initiated in March, 1995. Trenches 6-meters long, 50-cm deep, and 50-cm wide lined with bamboo splits were installed at the bottom of each treatment to collect all eroded soil from each of the 15 plots. Galvanized iron sheeting was inserted in the ground around the circumference of every plot to provide a barrier to run-on from outside the plot. These erosion plots 48 meters long and 6 meters wide. The eroded soil was collected whenever sediment was observed in the trenches. The sediments were weighed and subsamples were oven-dried to determine their moisture content. Erosion estimates were calculated in metrice tons per hectare of oven-dried soil.

During the onset of rainfall and after thorough land preparation (2-3 plowings and 1-2 harrowings), the field was furrowed with rows approximately 70 centimeters apart. Recommended rates of NPK were applied as a combination of organic and inorganic fertilizers. Lime was applied before the last plowing and harrowing at the rate of 2 tons per hectare. Maize (Pioneer hybrid #3014) was planted at approximately 30 cm between hills. Inter-row cultivation was done 7 days after emergence (DAE), off-barring at 15 DAE, and hilling-up at 30 DAE. The maize was harvested approximately 110 DAE by cutting the plants at ground level. Samples were processed and weighed row-by-row. Sub-samples were taken to determine moisture content. Cobs were shelled and the grain was dried and weighed, with moisture content adjusted to 14%.

3. SOIL LOSS IN RELATION TO HEDGEROW SPACING

Annual average soil loss in the open-field control treatment was 27.5 tons per hectare (Figure 1). A single contour strip across the middle of this steeply sloping field (45% slope) reduced soil loss to 11.0 tons per hectare, a reduction of 60%. There were further reductions in soil loss as the spacing further declined from 25 m to 12.5 m (9 t/ha), 6 m (6 t/ha), and 3 m (2.5 t/ha). However, none of the differences between the treatments with hedgerows were statistically significant.

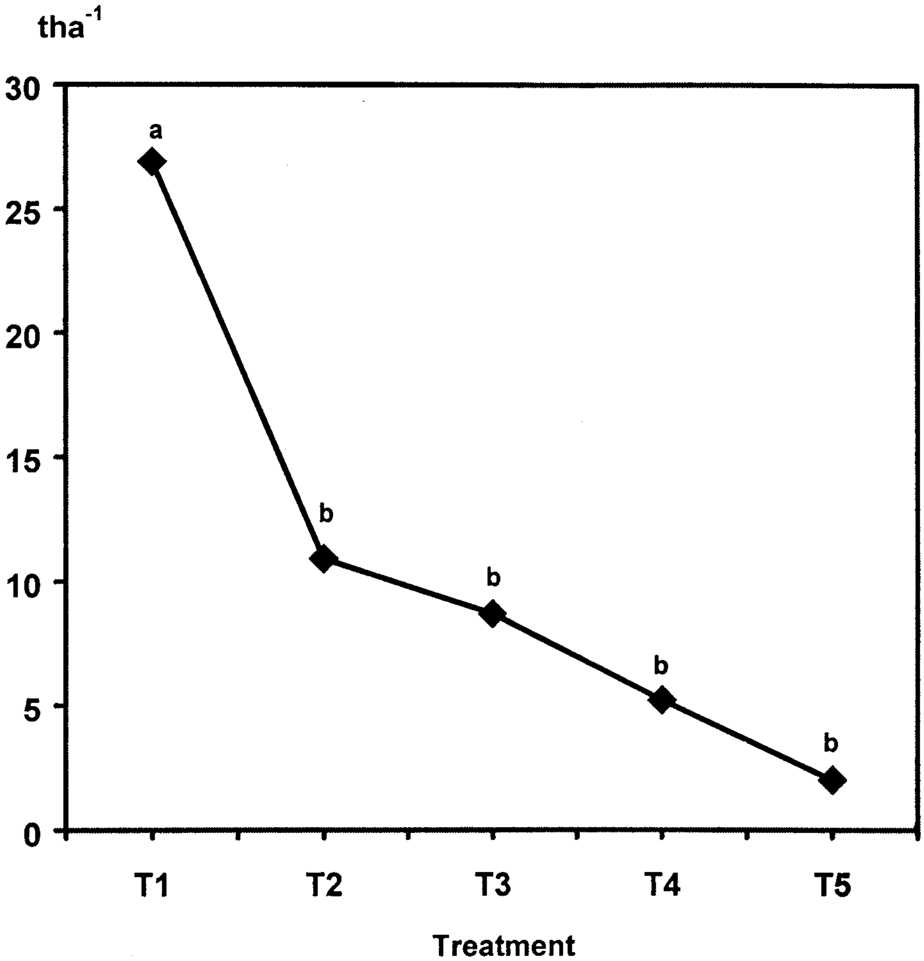

Figure 1. Annual soil loss as affected by different natural vegetative filter strips (NVS) density in an acid upland soil. Claveria, Misamis Oriental, Philippines. (mean of 3 years)

The treatment with the densest spacing between hedgerows (T5- one meter drop) reduced soil loss 86% during the first year, and 96% during the second year, compared to the control. Thus, the effectiveness of the hedgerow treatments tended to improve with time as the natural vegetation established itself in the strips and provided a more effective barrier. When the spacing between hedgerows was doubled (T4- two-meter drop) the efficiency of the strips in preventing soil loss was reduced only slightly: Soil loss was decreased 77% in the first year and 84% in the 2nd year. Soil loss in T4 (4-m drop) and T5 (8-m drop) were still acceptable in terms of soil loss, assuming a threshold soil loss tolerance rate of 12 tons per hectare per year (El-Swaify 1993). Having one NVS across the middle of the reduced soil erosion by more than 67% during the first year, and 59% in the 2nd year.

4. CROP YIELDS AND HEDGEROW SPACING

During the 3 successive cropping cycles the rainfall distribution was favorable. Table 1 showed the grain yield and total dry matter yield. There were no significant treatment effects during the first two crops (Table 1), but significant differences were observed during the 3rd crop. The treatments with more densely-spaced hedgerows produced lower yields compared with the treatments with fewer hedgerows. The mean yield from the three crops in T5 (2.73 t/ha, 3-m between hedgerows) was reduced 21% compared to the yield of the open-field control (3.46 t/ha). The crop area lost in this treatment due to the presence of the contour strips was 22%. The yield in T5 was also significantly lower than that in T4, which had 6 meters between hedgerows.

Table 1. Grain yield and total dry matter yield of maize (Pioneer hybrid #3014) as influenced by different spacing of natural vegetative strips (NVS) on an acid upland soil. Claveria, Misamis Oriental, Philippines.

	------ Grain yield (tha-1) -----				Total dry matter yield (tha^{-1})			
Treatments	1st Crop	2nd Crop	3rd Crop	Mean	1st Crop	2nd Crop	3rd Crop	Mean
T1	3.97 a	2.79 a	3.62 a	3. 46 a	9.62 a	5.75 a	7.13 a	7.50 a
T2	3.50 a	2.60 a	3.22 b	3.11 ab	8.52 a	5.31 a	6.28 b	6.70 ab
T3	3.62 a	2.49 a	3.34 ab	3.15 ab	8.41 a	5.05 a	6.48 ab	6.64 ab
T4	3.78 a	2.40 a	2.90 c	3. 02 b	8.45 a	4.76 a	5.32 c	6.18 b
T5	3.20 a	2.34 a	2.65 c	2.73 c	7.76 a	5.43 a	5.12 c	6.10 b
Mean	3.62	2.52	3.15	3.10	8.55	5.71	6.07	6.78
CV %	13.71	10.03	5.33	9.69	14.21	7.78	5.96	9.32
LSD	0.93	0.48	0.32	0.58	2.29	0.84	0.68	1.27

In a column, means having a common letter are not significantly different at 5% level by DMRT.

Total dry matter yields showed the same pattern as with grain yield. The reduction in grain yield and total dry matter yield were most probably due the reduction in cropped-area as the spacing between hedgerows declined. The net number of crop rows were less in treatments with more densely-spaced hedgerows. Plant height did not show significant differences among treatments but the mean height in the control treatments was numerically higher.

The crop-area loss, alley width, and pruning labor were all influenced by different natural vegetative strips spacing density (Table 2). The pruning labor required was directly related to the number of hedgerows. Twenty-nine mandays are required to prune a hectare of NVS spaced at a one-meter drop (T5). This is a very significant amount of labor considering the total labor required to produce the entire maize crop. A hedgerow spacing density of 2-meters requires one-half as much labor; a density of 4-meters requires a quarter the labor (7 days/ha). There were 2 pruning opêrations in each cropping period. The major plant species occupying the natural vegetative strips were *Chromolaena odorata, Imperata cylindrica, Ageratum conyzoides,* and *Roetboella cochinchinensis.*

Table 2. Hedgerow spacing, and pruning labor required as influenced by different natural vegetative filter strips (NVS) density in an acid upland soil. Claveria, Misamis Oriental, Philippines.

Treatments	Crop area loss (%)	Alley width (m)	Vertical drop (m)	Pruning labor (mandays ha^{-1} $cropping^{-1}$)
T1 - no NVS		-	-	-
T2 - one NVS at the middle of the slope	5.80	23.92	8	3.5
T3 -Three NVS	8.69	11.92	4	107
T4 - Seven NVS	11.59	5.98	2	15
T5 - Fifteen NVS	17.39	3.00	1	29

5. CONCLUSIONS

Natural vegetative contour strips are a practical and attractive option to leguminous trees for contour hedgerow systems. We observe that they typically provide a foundation for establishing fruit and timber trees that enables farmers to diversify the economic species on their farm, leading to a productive agroforestry system that is more environmentally sustainable than annual cropping. However, many farmers are not attracted to the establishment of contour strips if it means withdrawing a substantial amount of their limited crop land from food production. A flexible systems of recommendations are needed for the spacing of contour hedgerows that takes these concerns into consideration. Such recommendations must be built upon an understanding of the tradeoff between soil loss and cropland loss. This study aimed to address these issues.

Annual soil loss (39 ton $ha^{-1}yr^{-1}$) was highest in the open-field control treatment (T1), but maize yields were also highest in the treatment. The lack of any evident yield reduction due to erosion was probably due to the application of fertilizers and the greater cropped area. Barbers (1990) reported that on deep soils erosion may have a negligible effect over a short time period. He observed that erosion rates of 150 to 200 t/ha/yr in eastern Java did not significantly affect crop yields. Lal (1990) suggested that on soils with favorable subsoil properties, nutrient losses through erosion may be replaced using fertilizers so that crop production levels can be maintained. However, few tropical soils have favorable sub-soil characteristics drastic declines in crop productivity may occur as the depth of the soil surface declines (Lal 1984). Doolette and Smyle (1990) estimated that yield declined 60 percent with the first 5 cm of top soil lost, 65 percent after the loss of 10 cm, and 80 percent following the loss of 20 cm.

Upland farmers recognize soil erosion and nutrient depletion as major problems in sustaining crop production in sloping upland soils (Fujisaka 1993, Garrity 1993). They are aware of the need to control soil erosion, and are interested to adopt suitable soil conservation measures. But farmers usually evaluate the appropriateness of the innovations or the new technology specifically for their own particular situation. This involves thinking about how the new technology might affect the farming operations or the family (Follet and Stewart 1985). Although NVS are simple to establish, a spacing that is too close (eg 1-meter drop) significantly affects farmers field operations in terms of convenience and labor requirements. Such recommendations for good soil conservation are counterproductive in that the may completely inhibit farmers to adopt. The results of this study indicate that very densely spaced hedgerows do not provide a proportionally greater benefit in terms of soil conservation, but may reduce crop yields significantly in the shorter term. They also require much greater amounts of pruning labor than more widely spaced strips.

The amount of labor required to prune and maintain the NVS was shown to be directly proportional to the hedgerow spacing density: Thus a halving of the spacing between hedgerows doubles the maintenance labor, doubles the cropped area lost, but doesn't add much value in terms of soil conserved.

The results of the study indicate that one single hedgerow reduced soil loss by more than one-half compared with open-field cultivation. As hedgerow spacing decreased soil loss declined further, but at decreasing rate.

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