Appropriate Spacing of Natural Vegetative Filter Strips in Upland Conservation Farming Systems[1]

Agustin R. Mercado, Jr.[2], Dennis P. Garrity[3], Nestor Sanchez[4] and Luciano Laput[5]

Abstract

Natural vegetative filter strips (NVS) are attractive contour hedgerow system because they are simple to establish and maintain, control erosion effectively, and compete less with associated annual crops than other alternatives. The recommended practice has been to space the hedgerows every 1 meter drop in elevation. This results in close hedgerow spacing (3-6m apart) which removes considerable area from crop production. A collaborative study between the International Centre for Research in Agroforestry (ICRAF) and Misamis Oriental State College of Agriculture and Technology (MOSCAT) to determine the effect of NVS density on crop production and soil loss. 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 reduced soil loss by one half compared with the open-field control. As hedgerow density increased (4m, 2m, 1m) soil loss declined, but at a decreasing rate. Erosion did not differ significantly from the 2m and 1m drop, although the number hedgerows doubled. Maize yield declined with increasing number of hedgerows. We conclude that it is most practical to establish hedgerows at a 2m or 4m elevation distance. Even a single hedgerow is a good start for a farmer to tackle erosion with minimal investment and without significant loss of crop area.

---

[1]Paper presented during the 15th Annual Scientific Conference of the Federation of Crop Science Societies of the Philippines on April 10-15, 1999 at the Family Country Home, General Santos City.

[2]Research Associate, International Centre for Research in Agroforestry (ICRAF), Claveria Research Site, MOSCAT Campus, Claveria, Misamis Oriental, Philippines.

[3]Principal Scientist and Regional Coordinator, Southeast Asian Regional Research Programme, International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia.

[4] Field Assistant, International Centre for Research in Agroforestry, Claveria, Misamis Oriental 9004, Philippines.

[5]Instructor and Farm Manager, Misamis Oriental State College of Agriculture and Technology (MOSCAT), Claveria, Misamis Oriental, Philippines.

Introduction

Soil erosion is one of the major problems besetting the uplands that caused rapid soil quality degradation, nutrient depletion and decline in crop productivity (El-Swaify 1993, Lal 1984, Stocking and Peake 1986, Turkelboom et al 1993,), and is recognized as major problem in cultivated sloping uplands in Southeast Asia (Cruz, Francisco and Conway 1988, Fujisaka, et al 1944, Garrity 1993, Garrity et al 1995). Contour hedgerow systems using nitrogen fixing trees have been promoted to minimize soil erosion, restore soil fertility, and subsequently improve crop productivity (Huxley 1986, Kang and Wilson 1987, Young 1986, 1987), and has been a common feature of extension programs for sustainable agriculture on the sloping uplands in Southeast Asia (Garrity 1996). This innovation has not been widely adopted by the upland farmers (Fujisaka 1994) despite of positive results have been observed and reported in number of experimental and demonstration sites. Constraints that limit the effectiveness and adoption of pruned-tree hedgerows include the tendency for the perennials to compete for growth resources and hence yields of associated crops planted in adjacent rows, and the inadequate amount of phosphorus recycled to the crop in the prunings (Garrity 1996). But the major problem is the enormous amount of labor needed to prune and maintain them. Farmer's labor investment to prune their leguminous-tree hedgerows was about 31 days per hectare, or 124 days annual labor for four prunings (ICRAF, 1996). There is a dearth need for simple, less labor intensive but effective contour hedgerow system.

The use of natural vegetative strips (NVS) is proven to be an attractive alternative because of its simplicity in establishment and maintenance. NVS is laid out along the contour lines by leaving 40-50 cm of unplowed strips spaced at desired intervals usually 6 to 10 meters apart. 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 the water lateral flow and enhances water infiltration that makes it very effective for soil and water conservation. Researchers found that these natural vegetative contour strips have many desirable qualities (Garrity 1993). They needed very 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)

Despite of the benefits of natural vegetative contour strips, farmers are still concerned about the cropped area loss (field area allocated for hedgerows), and the consequence of eventual scouring of the upper alleyways (Garrity 1996, Garrity and van Noorwijk 1995, Tulkelboom et al 1993). The more number of strips always correspond to a more reduction of cropped area loss and the scouring of the upper alleyways. The rule of thumb has been to space the hedges at 1meter vertical drop (Watson and Laquihon 1986) which translate into approximately 6 meters wide alleyways at 20% slope. This is translated into 15% cropped area loss due to hedgerows. The crops in the alley must increase up to 15% at least to compensate for this cropped area loss.

It is logical to assume that a fairly dense pattern of hedgerows is useful in minimizing soil loss. But dense hedgerow pattern does remove a larger portion of the field area from crop production, thus reducing the attractiveness of this soil conservation technology in terms of adoptability. Hence, this experiment was aimed at determining the relationship between hedgerow density and soil loss. If this question can be answered satisfactorily it is possible to determine with greater precision the implications of starting with less pattern of strips.

Our experimental hypothesis was soil loss is negatively correlated with hedgerows density, but follow an asymptotic curve that indicates a much smaller reduction in marginal soil loss as the density of strips increases. Our hypothesis is based on our experience with the Modified Universal Soil Loss Equation (MUSLE), is that the soil loss will not increase proportionally relative to the slope length. Thus, a reduction in hedgerow density to 1/2 or 1/4 the density normally recommended will be associated with the increase in off-field soil loss much less than double or quadruple that indicated if the two factors were proportionally related. This experiment will provide a data to calibrate the MUSLE for tropical acid upland soils with natural vegetative filter strips installed at variable distances. The data will also provide clear guidance as to the functional relationship between hedgerows density (alley width) and the concomitant soil loss expected. Better tradeoff may enable the development of management recommendations for wider hedgerow spacing more consistent with practical farming demands for less than 5 to 10% reduction aggregate crop area.

One further issue to be explored is whether wider alleyways (i.e. greater elevation drop between hedgerows) will exacerbate the development of upper alley scouring effects. This might be expressed as the depth of soil removed from the upper alley will be greater as the terraces flatten out.

Materials and Methods

This experiment was conducted in a sloping land of about 45% slope owned and managed by the Misamis Oriental State College of Agriculture and Technology (MOSCAT), as an institutional collaborator of this research. The soil is classified as Ultic Haplorthox with pH ranges from 4.2 to 5.1, with an average value of 4.7. The site is part of the college corn production income generating project. This experimental site is located at Lupoc, Ani-e, Claveria, Misamis Oriental, Philippines. The land preparation, crop establishment, maintenance, and protection were borned by the college. These different field operations were uniformly applied throughout the experimental field. The NVS or the different treatments were laid out before these land preparations were done in March 1995.

There were five treatments compared: T1 - no NVS (control), T2 - one NVS at the middle of about 50 meters long, T3 - three NVS spaced at about 4 meters vertical drop, T4 - seven NVS spaced at about 6 meters apart or 2 meters vertical drop, and T5 - fifteen NVS spaced at about 3 meters apart or 1 meter vertical drop of this 45% slope. These 5 treatments were replicated 3 times in a randomized complete block design (RCBD).

Trenches of 6 meters long, 50 cm deep, and 50 cm wide lined with bamboo splits were installed at the bottom of each treatment to collect eroded soils. Galvanized iron sheets outlined the erosion plot which extends to the whole length of the plot (48 meters long average) and 6 meters wide. The eroded soils were collected once or twice a month or as soon as we observed soil in the trenches. The soil samples were weighed and subsamples were taken and oven dried to determine the moisture content.

During the onset of rainfall and after the thorough land preparation which means having 2-3 plowings and 1-2 harrowings, the field was furrowed at approximately 70 centimeters apart. Three bags of diammonium phosphate (18-46-0), 1 bag of potash (0-0-60), 20 bags of chicken manure, and 1 bag of furadan 3G per hectare were applied in the furrow as basal. Lime was applied before the last plowing and harrowing at the rate of 2 tons per hectare. Maize (Pioneer hybrid #3014) was used and planted at approximately 30 cm apart between hills in 70 cm apart between furrows. Interrow cultivation was done at 7 days after emergence (DAE), off-baring at 15 DAE, and hilling-up at 30 DAE. Right before the hilling up 3 bags of urea (46-0-0) were applied as sidedressing. Followed up by handweeding at 40-45 DAE. The maize was ready for harvest approximately 110 DAE. Maize was harvested by cutting the plants at ground level row by row from the bottom of the plot to the top. Samples were processed and weighed row by row. Subsamples were taken to determine moisture content. Cobs were shelled and grains were dried and weighed, and moisture content was adjusted to 14% row by row.

Collected data on grain yield, total dry matter yield, plant height, soil loss, productive plants, harvest index, pruning parameters were analyzed by ANOVA in RCB design using Statistical Analyses Systems (SAS Institute version 9.0, 1996)

Results

Crop productivity

During the 5 successive croppings, rainfall distributions were good and able to produce good harvest, except during the El Niño period which run from October 1997 to May 1998 (Figure 1). During this long dry spells crop suffered drought stress but was able to produce grain.. Table 1 showed the grain yield and total dry matter yield. There were no significant treatments effect during the first 2 croppings, but the differences were observed to be significant during the 3rd, 4th and 5th cropping periods. The treatments with more hedgerows had lower yields compared with no or fewer hedgerows. The total dry matter yield has the same pattern with grain yield. The reduction in grain yield and total dry matter yield were attributed to more cropped area loss. The net number of crop rows are smaller in treatments with denser hedgerows compared to fewer ones. Although, the plant height (table 2) is not showing significant differences but the control is numerically higher mean plant height. The plant height is the mean of all the rows from the bottom to the top of the plot in each treatment which is about 50 meters long.

Vertical drop, alley width, crop area loss, maize row spacing, pruning labor, change in slope and embankment as influenced by different natural vegetative strips spacing are presented in table 4. The average row spacing is computed based on the total length of the plot divided by the total number of rows in a given plot. The average row spacing in T1 (no hedgerow) is 69 cm while in T5 (fifteen hedgerows) is 81cm. The mean row spacing tended to be wider in denser hedgerows compared to less dense or no hedgerows. This relates to a more cropped area loss in dense hedgerows (17%) compared with less dense hedgerows. The alley width is a function of vertical drop. The higher the vertical drop the wider are the alleys. One meter drop gives an average 3 meters wide alley in an average slope of 45%. The pruning in mandays per hectare is directly related to the number of hedgerows but inversely related with the vertical drop. The more number of hedgerows require more mandays to prune. There were 2 pruning operations in each cropping: one before planting and middle of the growing season. The major NVS species were *Chromolaena odorata, Imperata cylindrica, Ageratum conyzoides, Roetboella cochinchinensis.* In one meter vertical drop of 3 meters wide between alleys, requires 29 mandays to prune a hectare while a less dense hedgerow requires about 10 percent only. The amount of labor required in pruning the NVS hedgerow is directly proportional to the number of hedgerows: the denser the hedgerows the higher the amount of labor required to prune.

Change in slope and embankment

Table 4 also shows the change in slope (in degrees) and embankment 4 years after the establishment of the NVS. In control plot has no change in slope gradient as expected. One single NVS has changed the slope gradient to 19 degrees which means 17% change. Fifteen NVS (1 m vertical drop) has dramatically changed the slope to 8 degrees or 65%. This indicates that the closer the spacing of hedgerows the faster the land to form into flat terrace. Embankment is a function of accumulation in the upper portion of the hedgerow and the scouring in the lower portion. Single NVS has the highest embankment after 4 years, while fifteen NVS has 30% lower in embankment. This indicates that wider-spaced hedgerows accumulate more soil and form high terraces.

Soil loss

The soil loss as affected by different natural vegetative strips density is presented in Figure 2. This figure shows annual soil loss for 3 years: Year 1 covers from May 14, 1995 to May 8, 1996 while year 2 covers from March 23, 1996 to March 31, 1997, and the third year covers from April 1, 1997 to March 1998. The slope length of the erosion plot is 48 meters long and 6 meters wide, and the mean slope is 45%. No hedgerow (T1) is significantly higher in soil loss in both years. During the first year soil loss was at 23.27 tons per hectare per year, and 53.83 during the second year. The difference in value was due to more rainfall during the second year. One hedgerow is effective in reducing soil loss which was about 67% during the first and 59% in the second year. Although there were numerical differences in soil loss in both years in with hedgerow treatments (T2 to T5) but there were no statistical differences. This can be attributed to high coefficient of variation of 82.92% and 78.32% in the first and second year, respectively. Dense hedgerows (T5- one meter drop) control erosion from 86% during the first year to 96% during the second year. When the number of hedgerows was reduce to half (T2 - two meters drop), the efficiency of the hedgerows reduce slightly to 84% in the 2nd year to 77% in the first year. Soil loss in T4 and T5 were still in acceptable rate of 12 tons per hectare per year under intensive agriculture in the USA, which is also accepted to the tropics despite the different environmental contexts (El-Swaify 1993). However, in the third year the amount of soil was significantly lower compared from the previous years because of unusually low amount of rainfall due to the effect of El Niño phenomenon where rainfall is much below normal.

Figure 2 shows the mean annual soil loss after 3 years. Open field control plot (T1) has 41.39 tons ha^{-1} $yr^{-1.}$ Single NVS (T2) has reduced soil loss by about one-half (47%). NVS spaced at 1 m vertical drop reduced soil loss to 3 tons or 93% reduction compared to open field control. When spacing was increased to 2 m vertical drop which means half of the total number of strips, soil loss has increased to 7.59 tons. Four meter vertical drop has mean soil loss of 16 tons annually per year.

Hedgerow pruning and biomass

The amount of labor involved in pruning and spreading the NVS was given in table 4. The number of mandays required to prune and maintain the NVS is directly proportional to the density. The most dense hedgerows at one meter vertical drop (T5) require 29 mandays to prune a hectare per cropping season. Increasing the vertical drop to 2 meters reduces the number of NVS by half, and there was a corresponding reduction of labor. Having one NVS at the middle of the slope require 3.5 mandays to prune the NVS per cropping, and having three NVS require 7 mandays. It was also observed that the denser the NVS the time required per unit length is getting a little smaller. This is something to do with the economy of scale.

The hedgerow biomass and nutrient content are given in table 5. There were 7 pruning schedules. The 4 major NVS species were *Chromolaena odorata, Imperata cylindrica, Rottboellia cochinchinensis, Ageratum conyzoides*, and combined minor species and collectively called as "others" which include: *Pennisetum polystachyon, Mukania cordata, Passiflora poetida, Elephantopus tomentosus, Setaria geniculata, Bidens pilosa, Borreria laevis, Paspalum conjugatum, Crassocephalum crepidiodes, Mimosa pudica, Centella asiatica, and Cleome rutidosperma.* Each pruning schedule was analyzed separately by ANOVA using SAS. NVS species weights were significant in each pruning schedule. The species composition is getting diverse as the cropping progressed. There were more annual weeds invading to the NVS. The danger of NVS may invade to the alleys is not feasible but the other way around because NVS are usually dominated by perennials species. The weeds that had invaded to the NVS may possibly be the source of weed seeds to the alley if the hedgerow is not prune regularly like *Rottboellia cochinchinensis.*

Chromolaena odorata has more NPK contents compared with other NVS species. The grasses (*Imperata, Rottboellia, and Ageratum*) have lower nutrients contents compared to broadleaves (e.g. *Chromolaena*).

The amount of biomass and the corresponding nutrients (NPK) contribution are directly proportional with the density of NVS i.e. the denser the NVS the higher the biomass. Having one NVS at the middle yielded (T2) 103.59 kgs. of total biomass per cropping thus contributing 2 kilograms of N, 8.30 grams of P, and 1.97 kilograms of K. Putting 15 NVS produced 679 kgs. of total biomass with NPK contribution of 14.63, 0.53, and 12.50 kilograms, respectively.

Discussion

Natural vegetative contour strips has been looked at as an option to leguminous-tree based contour hedgerow systems because of being simple, less cost in establishment and maintenance (Garrity, 1996), and less competitive to associated food crops (Ramianamanana 1993) but it is effective in controlling soil erosion (Agus 1993), and it is farmer's invented technology (Fujisaka 1994, Garrity 1996). NVS serves as a foundation for establishing fruit and timber trees that enables the farmers to diversify species on their farms, and will lead to a good and stable agroforestry system which is environment friendly.

However the intriguing issues of cropped area loss, pruning labor and scouring effect are still haunting in the minds of farmers, researchers and extension workers that slows down adoption rate by the sloping upland farmers. The study is aimed primarily on looking at the effect of the NVS density on crop production and soil loss. This is to address the above issues without compromising the soil loss and crop productivity.

The mean annual soil loss of 41.39 tons $ha^{-1}yr^{-1}$ in T1 (control) did not affect the crop productivity because of the following reasons: a.) application of fertilizers, such as: diammonium phosphate, Urea, lime and chicken manure, were high that enable to replenish the eroded soils and nutrients, b) the number of plants are high in no hedgerow treatments, c) no scouring of the upper alleyways and no hedgerows competition, and no cropped area loss. Barbers (1990) reported that on deeps soils, erosion may have a negligible effect for a short time. He also found out that erosion rates of around 150 to 200 t/ha/yr. in east Java have not significantly affected crop yields. Lal (1990) suggested that on soils with favorable subsoil properties, nutrient loss through erosion may be replaced using fertilizers so that crop production levels can be maintained. This maybe the general observation of few farmers in Claveria particularly the vegetable growers that they don't adopt soil conservation measures, and in fact vegetable crops rows are usually oriented up and down the slope. However, few tropical soils have favorable sub-soil characteristics and usually results in drastic declines in crop productivity as the depth of soil surface soil declines (Lal 1984). In general, yield declines 60 percent on average with first 5 cm of top soil lost, 65 percent after the loss of 10 cm and 80 percent following the loss of 20 cm (Doolette and Smyle 1990).

Upland farmers recognized 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 interested to adopt suitable soil conservation measures. But farmers usually evaluate how the new technology fits their socio-economic and bio-physical environments. This may simply involve thinking about how the new technology might affect their farming operations or family (Follet and Stewart 1985). Although NVS are simple to establish, but too dense (3 meters apart) may significantly affect farmers field operations in terms of convenience and labor requirement that may inhibit farmers to adopt. Having too dense hedgerows do not provide added benefit but they give additional burden on labor and farming inconveniences.

The amount of labor required to prune and maintain the NVS is directly proportional to the density: the denser the NVS the more labor required. Although the alter ego for upland farmers to adopt soil conservation is soil erosion control, allocating 29 mandays per cropping to maintain the hedgerow is unaffordable to most of the farmers.

The amount of biomass and nutrient contribution of NVS to the crop production is directly related to the density of NVS i.e. the denser the hedgerows the more biomass and nutrient contributions. However, the amount of nutrients contributed does not justify the amount of labor invested in dense NVS, and they are incapable of recycling phosphorus (Garrity 1996) which is the most limiting nutrient under acid upland soils (Garrote et al 1986, ICRAF 1996)

The NVS pruning biomass are declining as the croppings progress.. This frequency of pruning gives pressure to the perennial NVS that provides an opportunity to the annual weeds to colonize the hedgerow. It was also observed that more annual weeds were observed in the hedgerow as the NVS is frequently pruned. This may be the threat of NVS (hedgerow) to become the source of weed seeds to the alley thus requiring more frequent pruning to avoid the annual weeds to produce seeds for the alley. Frequent pruning is required when the NVS is dominated with annual weeds to avoid producing weed seeds to the alleys.

Conclusion

Upland farmers recognized soil erosion and nutrient depletion as major problems in sustaining crop production in sloping upland soils. They are aware of the need to control soil erosion, and willing to adopt suitable soil conservation technology, but usually they evaluate the appropriateness of the technology for their situation, and think about how the new technology fits the bio-physical and socio-economic conditions of the households.

The conventional leguminous-tree hedgerow systems, although showed good results in some areas, they are not widely adopted by farmers because of some constraints associated with them such as the tendency of the perennials hedgerows to compete for growth resources (both above and below ground), inadequate amount phosphorus recycled by the prunings, and require enormous amount of labor to establish and maintain.

NVS provide the alternative option because they are simple to establish and maintain, control erosion effectively, and compete less with the associated annual crops. However, close NVS (hedgerow) spacing will remove considerable area from crop production, and it will likely be rejected by the farmers.

One single hedgerow reduced soil loss by one-half compared with open-field control. As hedgerow density increased soil loss declined, but at decreasing rate. Maize yield declined with increasing number of hedgerows. The amount of labor required to maintain NVS is directly proportional with density. Pruning biomass and nutrient contribution from NVS are also directly associated with density. Too dense hedgerows (1 meter drop) which require more labor to maintain (29 mandays per cropping and 17% crop area loss) does not provide the added benefit to the soil conservation and crop production.

Frequent pruning on NVS dominated by broad-leaved perennial species (*Chromolaena odorata*, etc.) will likely be colonized by annual weeds which will later on require more pruning frequencies to avoid annual weeds to produce seeds for the alley. However, further study is needed to fully understand this phenomenon.

We further conclude it is more practical to establish hedgerows at a 2m - 4m elevation distance on steeper slopes. Even a single hedgerow is a good start for farmers to tackle soil erosion with minimal investment and without significant loss of crop area.

References

Agus, F. 1993. Soil processes and crop production under contour hedgerow systems on sloping Oxisols. PhD Thesis, North Carolina State University, Raliegh, North Carolina, USA.

Barbers, E.B. 1990. The farm-level economics of soil conservation: the uplands of Java, Land economics, 66:2 pp. 199-211.

Cruz, W., Francisco, H.A. and Conway, Z.T. 1988. The on-site and downstream costs of soil erosion, Working paper series, 88-11, Philippine Institute for Development Studies, Manila, Philippines.

Doolette, J.B. and Smyle, J.W. 1990. Soil moisture conservation techniques: review of literature. In: Doolette, J.B. and magrath, W.B. (Eds), Watershed development in Asia: strategies and technologies, World Bank technical paper no. 127. The World Bank, Washington DC, USA.

El-Swaify, S.A., 1993. Soil erosion and conservation in the humid tropics. In Pimentel, D (Ed), World soil erosion and conservation, Cambridge University Press, Cambridge.

Follet, R.F. and Stewart, B. A. 1985. Soil erosion and crop productivity. Soil Science Society of America. Madison, Wisconsin, USA.

Fujisaka, S. 1993. A case of farmer adaptation and adoption of contour hedgerows for soil conservation. Experimental Agriculture 29:97-105.

Fujisaka, S. And Cenas P.A. 1993. Contour hedgerow technology in the Philippines: not yet sustainable. Indigenous knowledge and development monitor. Volume 1/no.1.

Fujisaka, S., Jayson, E. and Dapusala, A. 1994. Trees, grasses, and weeds: species choice in farmer-developed contour hedgerows. Agroforestry Systems 25:13-24.

Garrity, D.P. 1993. Sustainable land-use systems for sloping uplands in southeast Asia. In Technologies for Sustainable Agriculture in the Tropics. American Society of Agronomy Special Publication 56 Madison, Wisconsin, USA

Garrity, D.P., Mercado, A. Jr., and Solera, C. 1995. The nature of species interference and soil changes in contour hedgerow systems on sloping acidic lands. In Kang, B.T. (ed) Proceedings of the International Conference on Alley Farming, IITA, Ibadan, Nigeria, 14-18 September 1992.

Garrity, D.P. and van Noordwijk, M. 1995. Research imperatives in conservation farming and environmental management of sloping lands: an ICRAF perspective. Paper presented at the IBSRAM workshop, Feb. 27 - March 2, 1995.

Garrity, D.P. 1996. Conservation tillage: a southeast Asian perspective. A paper presented during the Conservation Tillage Workshop held at PCARRD, Los Baños, Laguna on November, 1996.

Garrote, B.P., Mercado, A. and Garrity, D.P. 1986. Fertility management in acid upland environments. Phil. Jour. of Crop Sci. 11(2):113-123.

Huxley, P.A. 1986. Rationalising research on hedgerow intercropping: an overview. International Council for Research in Agroforestry. Nairobi, Kenya, Working Paper Series 40.

ICRAF. 1996. Annual Report for 1995. International Centre for Research in Agroforestry, Nairobi, Kenya.

Kang, B.T. and Wilson G.F., 1987. The development of alleycropping as a promising agroforestry technology. In: Steppler, H.A. and Nair, P.K.R (Eds), Agroforestry- a decade of development, International Council for Research in Agroforestry, Nairobi, Kenya.

Lal, R. 1984. Soil erosion from tropical arable lands and its control. Advances in Agronomy, 3., pp. 183-284.

Lal, R. 1990. Soil erosion in the tropics: principles and management. Mc-Graw Hill, New York.

Ramiaramanana, D. M. 1993. Crop-hedgerow interactions with natural vegetative filter strips on acidic land. Msc thesis, University of the Philippines, Los Baños, Laguna.

SAS Institute, Inc., SAS/STAT^R User's Guide, Release 9.0 Edition, SAS Institute, Inc., 1996, Cary, North Carolina, USA

Stocking, M. And Peake, L. 1986. Crop yield losses from the erosion of alfisols. Tropical Agriculture 63:1, pp. 41-45.

Turkelboom, F., Ongprasert, S., Taejajai, U. 1993. Alley cropping on steep slopes: Soil fertility gradients and sustainability. Paper presented at the International Workshop on Sustainable Agricultural Development: Concepts and measures, Asia Institute of Technology, Bangkok, Thailand, December 14-17, 1993.

Watson, H.R. and Laquihon, W.A. 1986. sloping agricultural land technology (SALT); a social forestry model in the Philippines. In: Rao, Y.S., Hoskins, M. W., Vergara, N.T. and Castro, C.P. (Eds), Community forestry: lessons from case studies in Asia and the pacific region. East-West Center, Honolulu, Hawaii.

Young, A. 1986. The potential of agroforestry for soil conservation. Part I. Erosion control. working Paper Series 42, International Council for Research in Agroforestry, Nairobi, Kenya.

Young, A. 1987. The potential of agroforestry for soil conservation. Part II. Maintenance of soil fertility. Working Paper Series 43. International Council for Research in Agroforestry, Nairobi, Kenya.

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

		Grain yield (tha-1)						Total dry matter yield (tha^{-1})					
Treatments		1st Crop	2nd Crop	3rd Crop	4th Crop	5th Crop	Mean	1st Crop	2nd Crop	3rd Crop	4th Crop	5th Crop	Mean
T1		3.97 a	2.79 a	3.62 a	2.12 a	2.44 a	2.98 a	9.62 a	5.75 a	7.13 a	5.49 a	5.51 a	6.70 a
T2		3.50 a	2.60 a	3.22 b	1.69 ab	2.16 ab	2.63 b	8.52 a	5.31 a	6.28 b	4.27 ab	4.79 ab	5.83 b
T3		3.62 a	2.49 a	3.34 ab	1.70 ab	2.09 b	2.65 b	8.41 a	5.05 a	6.48 ab	3.90 abc	4.38 b	5.64 b
T4		3.78 a	2.40 a	2.90 c	1.12 b	2.07 b	2.44 bc	8.45 a	4.76 a	5.32 c	2.75 bc	4.64 ab	5.18 b
T5		3.20 a	2.34 a	2.65 c	1.12 b	2.31 ab	2.34 c	7.76 a	5.43 a	5.12 c	2.45 c	4.83 ab	5.11 b
Mean		3.62	2.52	3.15	1.55	2.22	2.61	8.55	5.71	6.07	3.77	4.83	5.69
R2		0.58	0.48	0.90	0.90	0.66	0.82	0.44	0.72	0.89	0.87	0.61	0.82
CV %		13.71	10.03	5.33	20.75	6.77	5.52	14.21	7.78	5.96	25.21	11.81	6.99
LSD		0.93	0.48	0.32	0.61	0.28	0.27	2.29	0.84	0.68	1.79	1.07	0.75
SV	DF	F - Values											
Replication	2	3.49 ns	0.68 ns	5.43 *	25.51 **	1.46 ns	.16 ns	1.29 ns	1.71 ns	1.68 ns	15.74 **	3.09 ns	2.66 ns
Treatment	4	1.03 ns	1.49 ns	15.13 **	5.26 *	3.22 ns	8.80 **	0.92 ns	4.41 *	16.04 **	5.0 *	1.61 ns	7.73 **
Rep x Trt	8	1.85 ns	1.22 ns	11.90 **	12.01 **	2.63 ns	5.92 *	1.04 ns	3.51 ns	11.25 **	8.58 **	2.11 ns	6.04 *

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

** - Significant at 1%

* - Significant at 5%

ns - Not significant

Table 2. Plant height and productive plants of maize (Pioneer hybrid #3014) as influenced by different spacing of natural vegetative strips (NVS) in an acid upland soil. Claveria, Misamis Oriental.

Treatments	Plant height (cm)						Productive plants (ha^{-1})					
	1st Crop	2nd Crop	3rd Crop	4th Crop	5th Crop	Mean	1st Crop	2nd Crop	3rd Crop	4th Crop	5th Crop	Mean
T1	235.00 a	209.50 a	218.53 a	163.33 a	161.67 ab	198 a	18594 ab	24415 a	28931.0 a	39998 a	30066 a	28401 a
T2	224.13 b	220.50 a	204.03 bc	148.67 ab	154.0 bc	190 ab	18889 ab	24530 a	29382.3 a	36408 a	28834 a	27608 a
T3	224.40 b	216.23 a	208.17 b	155.33 ab	151.0 c	191 ab	18854 ab	23747 a	29314.0 a	36114 a	28710 a	27347 ab
T4	227.13 ab	204.50 a	201.50 c	132 b	153.0 bc	183.67 b	23082 a	23832 a	26246.3 b	27303 b	30385 a	26169 ab
T5	224.20 b	216.27 a	202.43 bc	135.33 b	165.67 a	188.67 ab	17533 b	23282 a	24088.0 c	29750 b	28613 a	24653 b
Mean	226.97	213.40	206.93	146.93	157.07	190.27	19390.47	23961.07	27592.33	33914.53	29321.66	26835.87
R2	0.67	0.50	0.87	0.89	0.72	0.73	0.54	0.07	0.90	0.92	0.29	0.77
CV %	2.39	4.50	1.62	8.92	3.58	2.79	15.18	10.03	3.79	9.54	7.39	5.75
LSD	10.22	18.07	6.33	24.68	10.59	9.99	5541.40	4525.7	1967.5	6094.6	4082.6	2903.80

SV	DF	F - Values											
Replication	2	3.86 ns	1.29 ns	0.70 ns	19.91 **	2.66 ns	0.32 ns	1.44 ns	0.01 ns	4.23 ns	31.38 **	.73 ns	8.25 *
Treatment	4	2.21 ns	1.31 ns	12.91 **	3.06 ns	3.74 **	1.87 ns	1.58 ns	0.14 ns	15.15 **	7.81 **	.45 ns	2.69 ns
Rep x Trt	8	2.76 ns	1.30 ns	8.84 **	8.67 **	3.38 *	1.35 ns	1.53 ns	0.10 ns	11.51 **	15.67 **	.54 ns	4.54 *

In a column, means having a common letter are not significantly different at 5% level by DMRT.
** - Significant at 1%
* - Significant at 5%
ns - Not significant

Table 3. Harvest index and number of unproductive plants of maize (Pioneer hybrid #3014)as influenced by the different spacing of natural vegetative strips (NVS) in an acid upland soil. Claveria, Misamis Oriental.

		Harvest index						Unproductive plants (ha^{-1})					
Treatments		1st Crop	2nd Crop	3rd Crop	4th Crop	5th Crop	Mean	1st Crop	2nd Crop	3rd Crop	4th Crop	5th Crop	Mean
T1		41.33 a	48.33 a	50.67 b	37.67 a	44.33 a	44.33 a	1389.3 a	1007.3 a	830.7 a	1878 a	556.3 a	1094.3 a
T2		41.33 a	49.00 a	51.00 ab	37.67 a	45.33 a	45.00 a	1773.7 a	1444.0 a	1338.0 a	2549 a	601.7 a	1541.0 a
T3		43.33 a	49.33 a	51.67 ab	54.00 a	48.00 a	49.33 a	1544.0 a	1454.3 a	590.0 a	2080 a	766.7 a	1287.3 a
T4		45.00 a	49.00 a	54.67 a	38.67 a	46.33 a	46.67 a	1296.7 a	1475.0 a	1093.0 a	4204 a	459.7 a	1705.7 a
T5		40.67 a	44.67 a	51.67 ab	45.67 a	48.00 a	46.33 a	1667.0 a	815.7 a	571.0 a	2434 a	320.0 a	1200.3 a
Mean		42.33	48.07	51.93	42.73	46.4	46.33	1534.13	1239.27	884.53	2629	540.86	1365.73
R^2		0.55	0.37	0.68	0.27	0.7	0.45	0.26	0.56	0.50	0.72	0.44	0.66
CV %		8.22	6.59	3.84	33.85	8.44	7.65	33.69	32.05	46.20	48.25	44.62	24.48
LSD		6.55	5.96	3.75	27.24	7.38	6.67	973.04	747.77	769.48	2388.2	454.44	629.53
SV	DF	F - Value											
Replication	2	3.37 ns	0.09 ns	4.66 *	0.03 ns	8.18 *	1.44 ns	0.54 ns	1.44 ns	0.08 ns	7.30 **	0.73 ns	8.25 *
Treatment	4	0.80 ns	1.12 ns	1.91 ns	0.73 ns	0.51 ns	0.89 ns	0.43 ns	1.79 ns	1.96 ns	1.58 ns	0.45 ns	2.69 ns
Rep x Trt		1.66 ns	0.78 ns	2.82 ns	0.50 ns	3.07 ns	1.07 ns	0.47 ns	1.68 ns	1.33 ns	3.49 *	0.54 ns	4.54 *

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

** - Significant at 1%

* - Significant at 5%

ns - Not significant

Table 4. Vertical drop, alley width, crop area loss, maize row spacing, pruning labor required, change in slope and embankment (accumulation + scouring)* as influenced by different natural vegetative filter strips (NVS) spacing in an acid upland soil. Claveria, Misamis Oriental, Philippines.

Treatments	Vertical drop (m)	Alley Width (m)	Crop area loss (%)	Maize row spacing (cm)	Pruning labor (madays ha^{-1} $cropping^{-1}$)	Slope (°)	Embankment (cm)
T1– no NVS	-	-	-	69	-	23	-
T2– one NVS at the middle of the slope	8	24	6	73	3.5	19	107
T3– Three NVS	4	12	9	75	7	18	103
T4– Seven NVS	2	6	12	77	15	13	89
T5– Fifteen NVS	1	3	17	81	29	8	75

- - Average in 4 years

Table 5. Hedgerow pruning parameters as influenced by different spacing of natural vegetative strip (NVS) in an acid upland soil. Claveria, Misamis Oriental, Philippines.

Hedgerow species	Nutrient content (gkg^{-1}) N	P	K
Chromolaena odorata	23.36	0.10	20.10
Imperata cylindrica	11.00	0.06	10.70
Rottboellia cochinchinensis	14.40	0.05	10.50
Ageratum conyzoides	10.09	0.05	13.00
Others	19.68	0.06	24.70
Mean	16.31	0.06	15.80

Pruning biomass and N contribution (gha^{-1})

Hedgerow species	T2		T3		T4		T5	
	Biomass $Kg\ ha^{-1}$	N yield gha^{-1}	Biomass $Kg\ ha^{-1}$	N yield gha^{-1}	Biomass $Kg\ ha^{-1}$	N yield gha^{-1}	Biomass $Kg\ ha^{-1}$	N yield gha^{-1}
Chromolaena odorata	60.08	1575	117.66	3085	206.99	5383	374.25	9719
Imperata cylindrica	19.43	199	39.72	407	82.16	855	138.12	1417
Rottboellia cochinchinensis	-	-	-	-	0.25	3.8	0.3	6
Ageratum conyzoides	-	-	0.03	0.2	2.4	24	2.72	27
Others	24.08	510	47.16	998	89.65	1898	163.7	3464
Total	103.59	2284	204.57	4490.2	381.45	8163.8	679.09	14633

Pruning biomass and N contribution (gha^{-1})

Hedgerow species	T2		T3		T4		T5	
	P	K	P	K	P	K	P	K
Chromolaena odorata	5.76	1183.59	11.27	1832.45	19.76	3931.59	35.7	7066.04
Imperata cylindrica	1.24	107.37	2.52	229.65	5.16	555.22	8.77	798.68
Rottboellia cochinchinensis	-	-	-	-	0.009	2.92	0.016	5.89
Ageratum conyzoides	-	-	-	-	-	-	-	-
Others	1.3	681.06	2.64	1333	5.02	2535.74	9.17	4628.03
Total	8.3	1972.02	16.43	3395.1	29.95	7025.47	53.66	12498.64

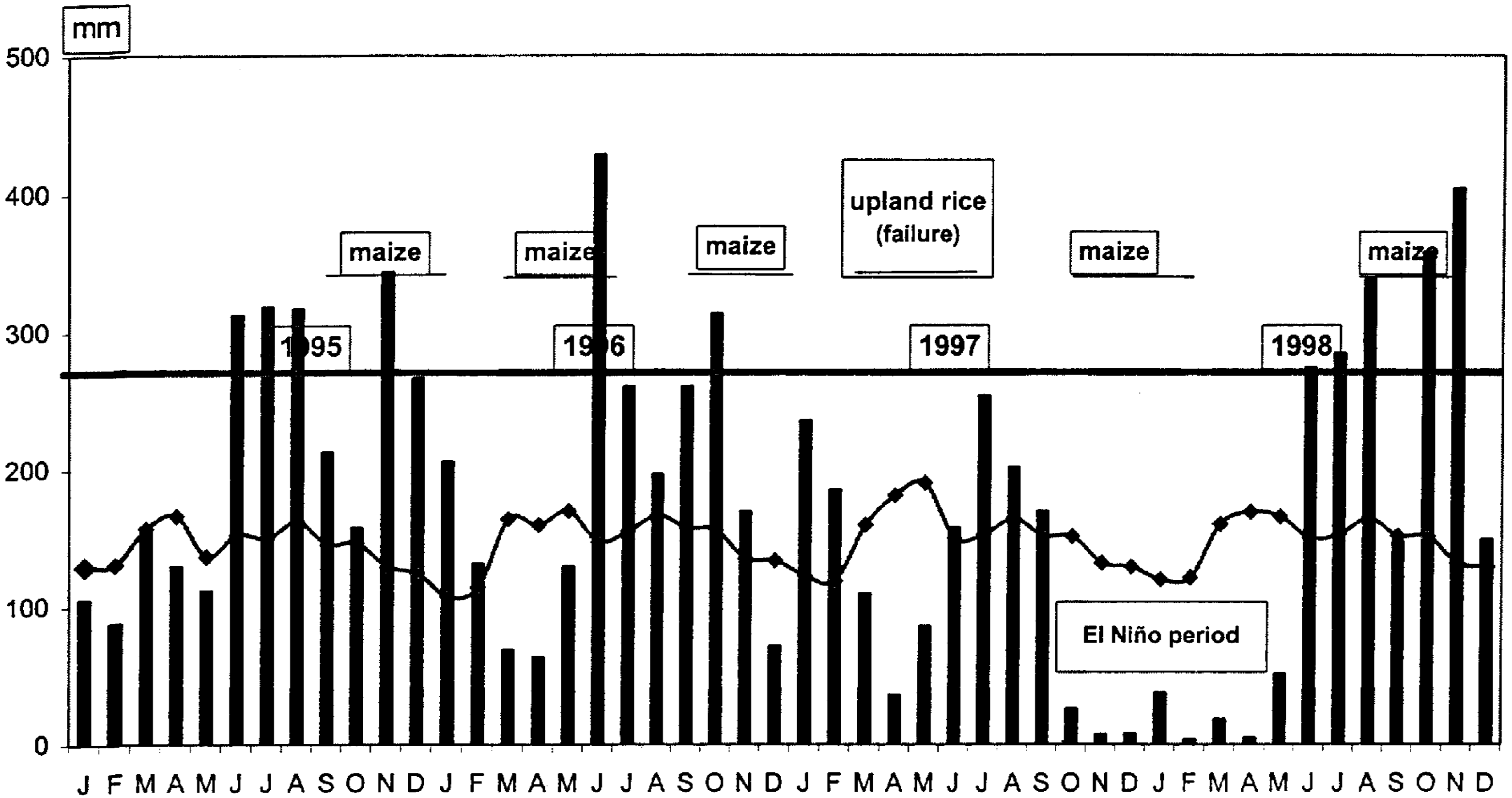

Figure 1. Monthly Rainfall, pan evaporation and crop phenology
Claveria, Misamis Oriental

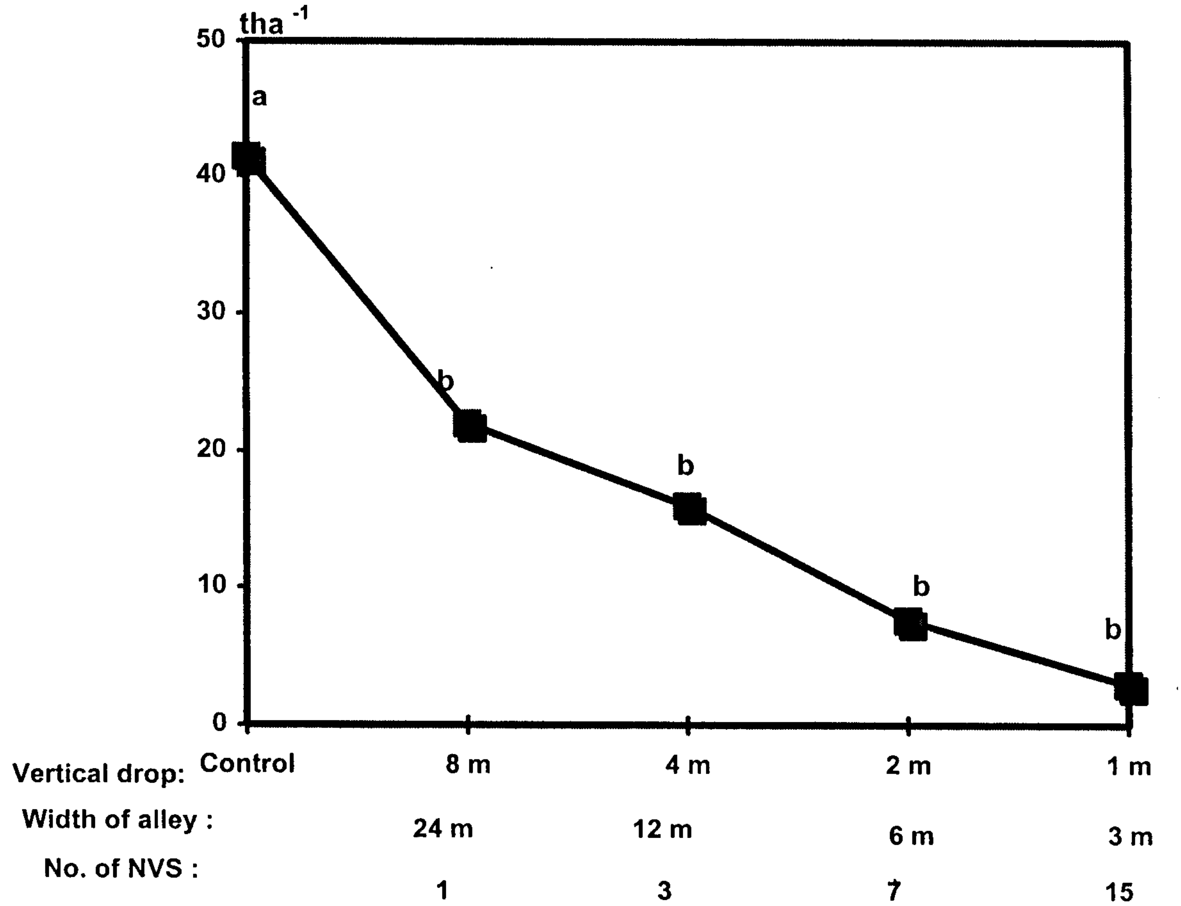

Figure 2. Annual soil loss as affected by different natural vegetative filter strips (NVS) density. Claveria, Misamis Oriental, Philippines. (Mean of 3 years)