Building Research on Farmers' Innovations: Low-Cost Natural Vegetative Strips and Soil Fertility Management*

Marco Stark[1], Dennis P. Garrity[2], Agustin Mercado, Jr.[1], and Samuel C. Jutzi[3]

Abstract

Contour hedgerows using nitrogen-fixing trees have been widely promoted in Southeast Asia to minimize soil erosion and improve crop yield, but few farmers have taken them up. This is partly because establishing and managing such hedgerows is very labor-intensive. The spontaneous use and rapid dissemination of narrow buffer strips consisting of natural vegetation, so-called Natural Vegetative Strips (NVS), among farmers in the Philippine uplands has provided a low-cost, yet effective alternative to the establishment of tree hedgerows. Formal research on this farmer technology proved that NVS are at least as effective in controlling soil erosion as tree hedgerows, while causing minimal competition effects on the associated field crop and requiring only a fraction of the labor needed to establish and maintain pruned tree hedgerows. As in conventional hedgerow systems, however, natural terrace formation resulting from the redistribution of sediment from upper to lower terrace zones, a process called 'scouring', leads to the development of a soil fertility gradient. The result is a significantly lower crop yield on the degraded upper terrace. The assessment of farmers' strategies to improve crop yield on the upper terrace concluded that practices, which increase soil organic matter levels and raise the soil pH, may be needed to sustain yield in NVS systems in the long run. Future collaborative research by the International Centre for Research in Agroforestry (ICRAF), national agricultural research institutions and farmers will focus on validating and adapting the NVS technology under the contrasting conditions of the shallow, marine limestone-derived soils typical of the central Philippines. This is another major soil environment in Southeast Asia. The evolution of NVS systems to more complex agroforestry systems through the planting of fruit and timber trees along the contour strips will be further assessed. Facilitating and strengthening the collaborative efforts of farmers, local governments and technical providers (researchers, technicians) will be more widely tested as a successful model for the efficient development and dissemination of appropriate soil conservation technologies.

1. Introduction

Land degradation is one of the most serious human-induced limitations to the sustainability of agricultural production in the humid tropics of Southeast Asia. The decline of natural forests and the intensification of upland farming due to rising population pressure have significant detrimental effects on the land and water resources of both upland and lowland areas. The loss of natural resources increasingly threatens the food and nutritional security of rural smallholder communities, especially in the marginal sloping uplands.

---

* Paper presented at the Environmental Education Network of the Philippines (EENP) conference, held at Misamis Oriental State College of Agriculture (MOSCAT), Claveria, May 31 – June 1, 2000

1 ICRAF-Philippines, Claveria, Misamis Oriental 9004, Philippines. Corresponding author: Marco Stark, Email: mstark@mozcom.com.

2 Southeast Asian Regional Research Program, International Centre for Research in Agroforestry, P.O. Box 161, Bogor 16001, Indonesia, Email: d.garrity@cgiar.org

3 Agricultural Department, FAO, Via delle Terme di Caracalla, 00100 Rome, Italy, Email: samuel.jutzi@fao.org

Contour hedgerows using nitrogen-fixing trees have been widely promoted in Southeast Asia to minimize erosion, restore soil fertility and improve crop productivity, but their uptake by farmers has been low. A major reason for the low adoption of contour hedgerows is the high labor cost associated with establishing and pruning the hedgerows. The establishment and maintenance of natural vegetative strips (NVS) on contours, a technology which evolved from farmers' adaptive field experimentation as described in this paper, takes only a fraction of the labor needed compared to conventional contour hedgerows systems.

2. Traditional contour hedgerows and farmers' modifications

Claveria is an upland area in Northern Mindanao, Philippines (8°38' N, 124°55' E) with moderate rainfall (2200 mm year^{-1}) and degraded acidic soils (pH 4.5 - 5.2; high P fixation capacity). The area loses up to 200 t ha^{-1} a year of topsoil from cultivated fields, mainly because more than half of the cropping (mostly corn and vegetables) is done on lands of more than 15% slope (at 400 – 800 m above sea level) (Fujisaka *et al.,* 1994).

Research in Claveria is being conducted by the International Centre for Research in Agroforestry (ICRAF) since 1993, in the context of the global Alternatives to Slash-and-Burn (ASB) Project. The ASB project is coordinated by ICRAF and is supported by a number of international and national research and development institutions worldwide. Work under the project is based on the following premise: Traditional slash-and-burn (or shifting cultivation) systems with prolonged fallow periods are no longer feasible in most parts of the tropics; farming systems which imitate in part the structure and processes of natural forest vegetation, such as agroforestry systems[4], have a high potential to increase the productivity of farming systems and sustain continuous crop production.

Research is carried out since 1994 at eight benchmark sites in the tropical regions of Latin America, Africa and Asia, which represent the range of bio-physical and socio-economic conditions where slash-and-burn is important. The ASB project has two main objectives: the reclamation of already deforested and degraded lands, and the prevention of damage by deforestation itself through promoting sustainable alternatives to unsustainable slash-and-burn agriculture (Bandy *et al.*, 1993). Building on existing farming practices and farmer participation is an essential component in the research and development process.

Research at the benchmark site in the Philippines (Northern Mindanao) addresses the situation where rapidly increasing population pressure on land due to immigration from

---

[4] Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs) are grown in association with herbaceous plants (crop, pasture) or livestock, in a spatial arrangement, a rotation, or both. There are usually both ecological and economic interactions between the trees and other components of the system (Lundgren, 1982; Maydell, 1986). The definition was recently revised to underline the dynamic character of the natural resource management system and the increased social, economic and environmental benefits associated with agroforestry in smallholder production (Leakey (1996).

lowland areas accelerates soil degradation and forest destruction in the agro-ecological region of the monsoonal rainforest. ICRAF's strategic research program focuses on agroforestry land use options as potentially best-bet strategies for the sustainable management of rainforest margins, degraded *Imperata* grasslands and fragile sloping farm lands in the Southeast-Asian region (Garrity, 1997).

In Claveria, the main tree species originally introduced for contour hedgerows (in the mid 1980s when the International Rice Research Institute [IRRI] was conducting research in the area) were *Gliricidia sepium* (madre de cacao), *Flemingia macrophylla, Desmodium rensonii*, and others, planted in combination with *Pennisetum purpureum* (napier grass). But farmers in Claveria did not adopt the new technique as expected. Instead they quickly adapted it to minimize their labor inputs, by simply leaving marked contour lines un-ploughed during land preparation. The 50-cm wide contour strips they left were rapidly covered by naturally occurring grasses and herbs. Some farmers piled crop residues along the contour lines to form "trash bunds" which also evolved into Natural Vegetative Strips, or NVS, after the residues decayed. The natural vegetative strips proved at least as effective as the planted hedgerows in controlling soil erosion (Agus, 1993) with but a fraction of the work. The strips are also less competitive with crops than planted tree or grass hedgerows (Ramiaramanana, 1993).

The indigenous use of natural vegetative is not unique to Claveria. In Matalom, a municipality in Leyte, farmers have used natural vegetative strips traditionally to control soil erosion on the slope, for more than five decades.

In retrospect, the farmers' rejection of the tree hedgerow system seems an obvious and logical economic decision. We found that the time spent in pruning the hedgerows and using the prunings as green manure in the alleys did not pay off in terms of increased crop yields, particularly on phosphorus-deficient acidic soils such as those found in Claveria. Today, over a thousand farmers in the area use the NVS technology. In many cases the strips are a base for the establishment of fruit and timber trees, fodder grasses, or other perennial cash crops.

However, the natural vegetative strips do not provide the large amounts of biomass that are necessary to maintain soil fertility on the alleys between the contour strips. This means that a cropping system based on natural vegetative strips will need to rely on nutrient imports to maintain soil fertility and sustain continuous crop production.

3. Scouring and sustainability concerns

In the process of natural terrace formation, soil is eroded from the upper to lower parts of the alley between the contour strips. It results in the development of a fertility gradient across the alleyway. This is true irrespective of the hedgerow species. However, the effect is best studied in NVS systems, as the effect of soil fertility scouring in pruned tree hedgerow or fodder grass systems is overlaid by competition effects of vigorous hedgerow species (Garrity, 1996).

The upper side of each alley exhibits lower organic matter and nutrient content (**Figure 1 and 2**), lower soil pH, and higher aluminum saturation, resulting in reduced crop yields (**Figure 3**) (Stark 1999). However, the gradual soil displacement to the lower parts of the alley (known as 'scouring') can be desirable, as it further slows erosion and makes it easier to do field operations on the slope. The scouring effect seems particularly prominent where draft animals are used for plowing, as is the case in Claveria (Garrity 1995).

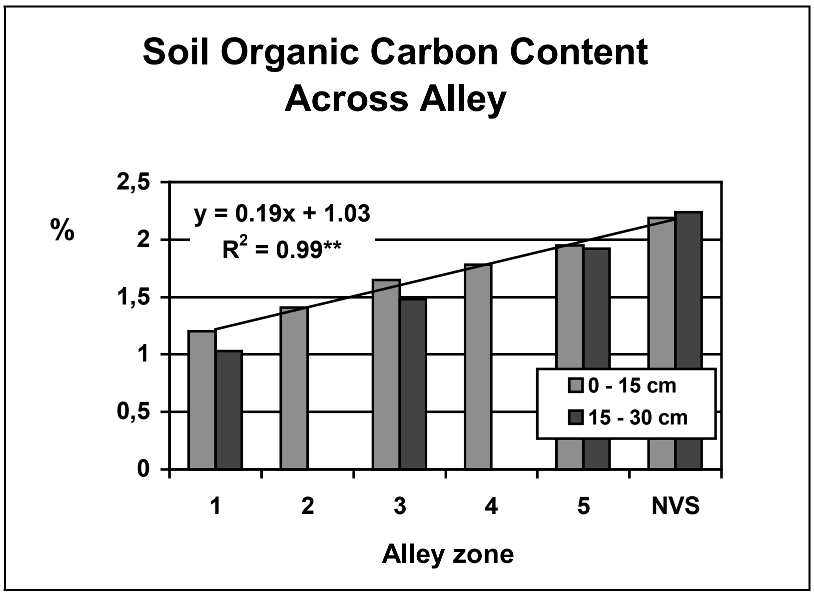

Figure 1: Soil organic carbon content across a single alley between NVS contours at two different soil depths (regression line fitted to topsoil values; unreplicated data; 6 sub-samples from 2 alleys at the middle of the slope combined; farmer's practice; August 1995)

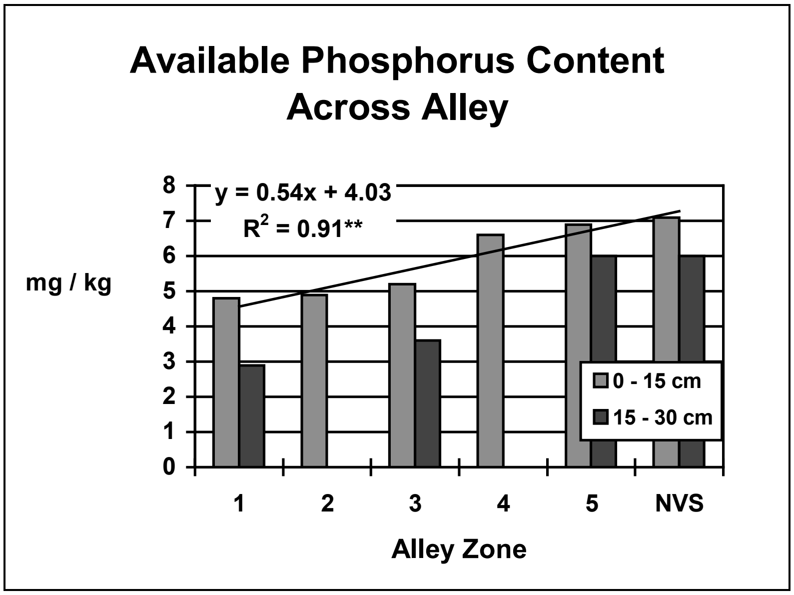

Figure 2: Available Phosphorus (Bray II) content across a single alley between NVS contours at two different soil depths (regression line fitted to topsoil values; unreplicated data; 6 sub-samples from 2 alleys at the middle of the slope combined; farmer’s practice; August 1995)

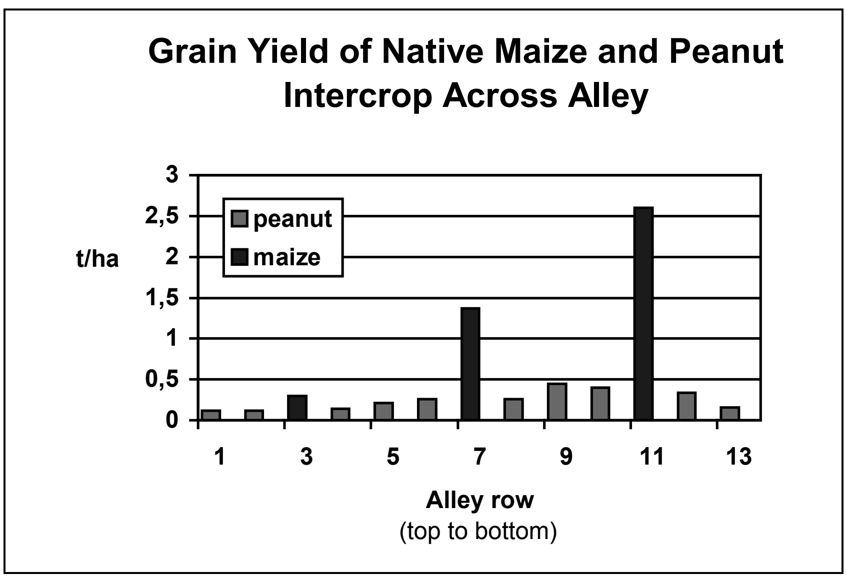

Figure 3: Yield of unfertilised native maize and peanut intercrop across a single alley between vegetative contour strips (grain at 14 %, nuts at 12 % moisture content; 1. crop 1995, farmer’s practice; n = 3)

Appropriate soil management and the external input of nutrients (manures or fertilizers) are needed to cope with the development of a fertility gradient between the contour strips, and to compensate for the regular exporting of nutrients with the harvested crop and the competition effects of some vigorous fodder grass and natural vegetative strip species.

4. Farmers' experiences

When researchers first observed the effects of soil scouring, concerns were raised that farmers might be discouraged from using contour vegetative strip systems if they experienced reduced yields in the upper alleyways. However, increasing numbers of farmers in Claveria continued establishing natural vegetative strips on their sloping fields. To get more insights, we surveyed 30 adopters of natural vegetative strips or fodder grass strips. Most farmers had observed the adverse effects of scouring on plant height and crop yields on the upper part of each alley (typically three to four rows of corn). They attributed this to water run-off and tillage operations and believed that scouring had only a short-term effect on crop performance (3–5 years). This did not deter them from contour farming, as many farmers had their own methods in reducing the effects of soil fertility scouring on crop yield (**Table 1**), for example by placing up to twice as much mineral fertilizer as normal on the upper 3 - 4 rows of corn on the alleys. Most respondents believed that the positive effects of increased overall harvest from the contoured field and the increase in land value due to contouring outweighed the drawbacks of upper alley yield depression.

We therefore concluded that natural vegetative strips would be even more attractive after improvements in soil (as well as labor) management, especially by including farmers' indigenous strategies as basic principles in future research efforts.

Table 1: Farmers' practices to reduce or reverse the negative effects of soil fertility scouring on crop yield (n=30)

Methods to Overcome Scouring Effects		
	Count	Percent of farmers
1. Up to two times more fertilizer on upper alley crop rows	12	40.0
2. Apply fertilizer uniform across alley	5	16.7
3. More mulch on upper alley rows	4	13.3
4. Biased application of crop residues towards upper alley	2	6.7
5. Apply more lime on upper alley crop rows	2	6.7
None	10	33.3
Total	35	

Multiple responses

5. Trials in farmers' fields

We selected five farmers' fields with natural vegetative strips as experimental sites. The slope in these fields is 20 to 30% and the terraces are at different stages of development. All the fields show signs of soil fertility scouring. The study aimed to improve crop yields on the upper alley zones, and to improve fertilizer use efficiency across the alleyways. In the longer term, we expect to rehabilitate degraded soils on upper alley zones, and to extrapolate results by modeling the processes driving nutrient balances and soil organic carbon levels in the different zones across the alleys.

When we skewed the **application of nitrogen, phosphorus and potassium fertilizers**, with up to three times more applied on the degraded upper alley zones compared to the more fertile lower zones, yields were increased dramatically in the upper alley (zones 1 and 2) (**Figure 4**). The practice did not, however, significantly increase crop yields for the alley as a whole. The grain yield increase on the upper alley was counter-balanced by a smaller yield increase on the lower alley zones (4 and 5), which received less fertilizer inputs. This result was derived from data collected over four cropping seasons. Nutrient application on more fertile lower alley zones achieved higher fertilizer use efficiency (due to more favorable physical and chemical soil conditions) which explained why there was no particular advantage in skewing fertilizer applications, as opposed to a uniform distribution of N, P and K across the alley.

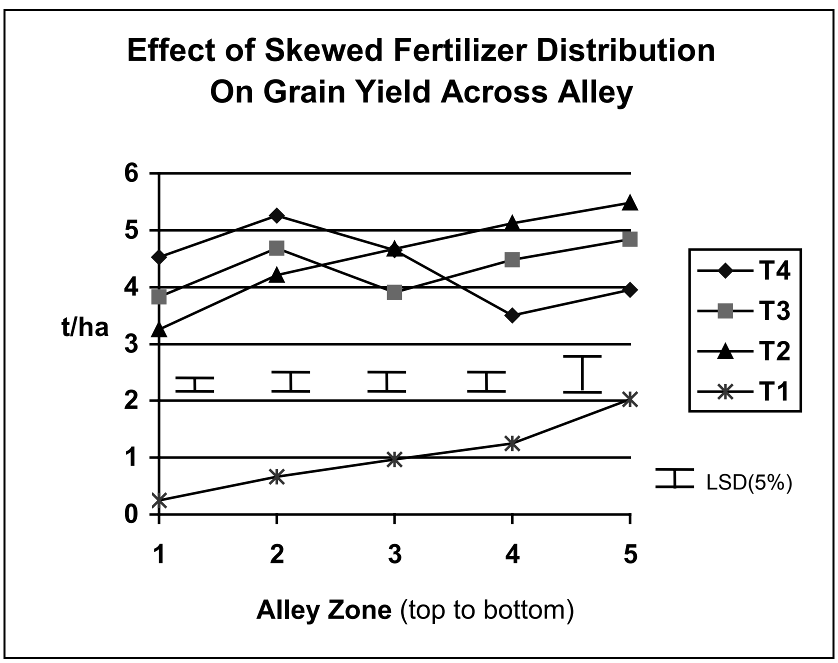

Figure 4: Effect of fertilizer treatments on hybrid maize grain yield across alley zones; 1st crop 1996 (treatments: T1 - zero NPK, T2 - uniform NPK, T3 and T4 - 1.5 and 3.0 times more NPK, respectively, on zones 1 and 2; LSD values computed separately by alley zone; results in the 2nd crop '95, 2nd crop '96 and 1st crop '97 were similar)

Another experiment showed that crop yields on degraded upper alley zones significantly improved when all of the **residues** from the previous maize crop were concentrated on the upper part of the alley (**Figure 5**). Also, the application of **lime** to raise the soil pH improved the yield of maize (Stark 1999). However, these results were derived from a single cropping season only, and the long-term treatment effects need to be assessed.

Research on reducing soil movement through conservation tillage was conducted by Thapa *et al.* (1996). Research findings showed that **ridge tillage**, a minimum tillage technology, can minimize scouring effects on crop yield by significantly slowing down terrace development (while considerably reducing labor cost).

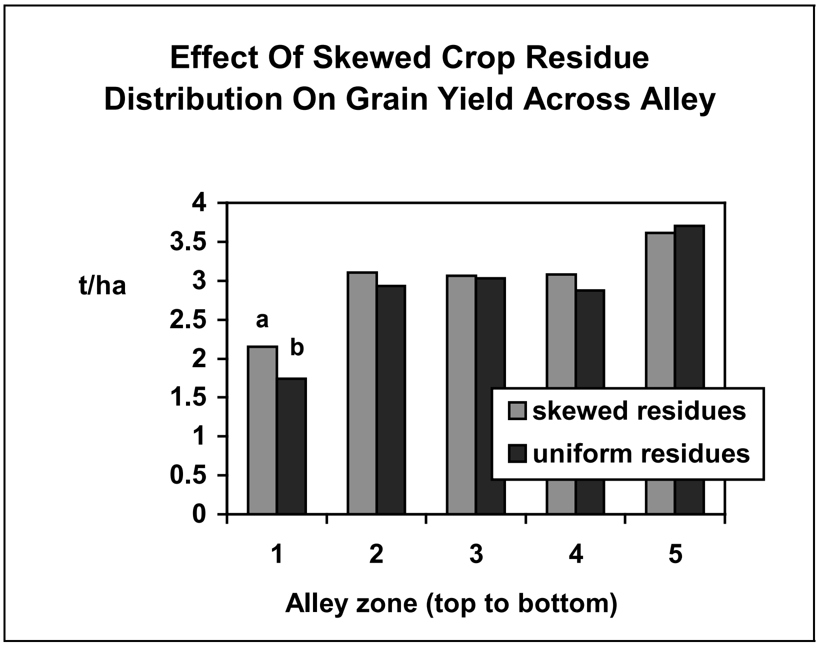

Figure 5: Hybrid maize grain yield response to crop residue distribution (skewed residues: 10 t per ha on zones 1 and 2, and 2 t per ha on other zones; uniform residues: 4 t per ha on all zones; letters ‘a’ and ‘b’ indicate significant differences between means at zone 1; $P < 0.05$; ANOVA by zone; LSD test; n = 12)

We also investigated **labor-saving techniques** to establish the natural vegetative strips. Again, the ideas for the treatments we tested came from our farmer collaborators in Claveria. A survey showed that most farmers had substituted labor-intensive methods, using the A-frame, for simple eye-estimate to determine the semi-contour line. Field measurements were done to detect how much the semi-contour lines determined by simple eye-estimate were located off the real contour, and how this compared to A-frame contours. The eye-estimate resulted in a larger difference between farmers’ estimated contour lines and the real contour lines (7 % off-contour) than the A-frame method (3 % off-contour) on fields with an average of 30 % slope. However, the difference of 4 % seems relatively small, and there appears to be no difference in the efficiency of the NVS to control soil erosion since strips act as sediment filters rather than barriers. It was, therefore, recommended that farmers establish the first contour line at the middle of the slope by A-frame and that they use this line as a reference for laying out subsequent contour lines by eye-estimate. This made contour strip establishment even more convenient, and has further stimulated adoption.

We also observed that most farmers in Claveria prefer **wider hedgerow spacing** to minimize crop area loss, than the recommended width determined by one meter vertical drop. On-going experiments are investigating the effects of different vertical intervals between hedgerows on sediment loss and crop area reduction. Results show that as hedgerow density increases, soil loss declines, but at a decreasing rate. The establishment of hedgerows at 2 to 4 m vertical interval seems most practical, considering that farmers' need to balance efficiency in controlling soil erosion with crop area loss, strip species competition, and labor inputs for establishment and maintenance (Mercado *et al.*, 1997).

6. Conclusions: future research directions

The redirection of research at ICRAF's research site in northern Mindanao, from testing traditional hedgerow species and assessing introduced soil management techniques, to building research largely on farmers' indigenous knowledge, is a milestone in itself. Researchers have learned that natural vegetative strips are the most appropriate method for soil conservation under the conditions prevailing in the area, because they require minimal labor and zero material inputs, and are adaptable to farmers' specific farming objectives. Researchers also realized that soil fertility scouring is of lesser concern to farmers than initially thought. However, certain aspects require more in-depth investigation, such as the long-term effects of selective application of nutrient inputs and lime to favor growth in the upper alleys. Crop residues and low-cost rock phosphate are of special interest under low-input cropping conditions.

The NVS technology, along with improved soil fertility management practices, still needs to be validated in and adapted to the contrasting conditions of the shallow, marine limestone-derived soils typical of the central Philippines. This is another major, contrasting soil environment that is common in several other countries in Southeast Asia, including eastern Indonesia, parts of Vietnam, and southern China. Because on shallow soils, scouring can strip away the topsoil entirely in the upper alleyways, right down to unconsolidated limestone rock, the imperative is much greater to slow down the rate of soil redistribution, or to prevent it from occurring. Reduced tillage systems will therefore need to receive much more research attention for these situations. A process-based understanding of soil fertility changes, particularly soil organic carbon levels, is needed to allow confident extrapolation of NVS and associated soil management techniques to a wider range of humid tropical environments. Computer models can be used to facilitate this work.

In view of farmers' growing interest in planting cash perennials on the NVS, we have lately widened our research focus to include the suitability and management of a range of timber and fruit tree species planted on the contour strips and their interaction with associated field crops. Promoting natural vegetative strips as a base for planting fruit and timber trees we will not only widen their use, but also demonstrate that farmers can make more productive use of the contour strips. The local farmers' interest in tree planting has increased sharply in recent years due to rising wood and fruit prices, and due to a more dynamic extension system based on the Landcare approach. This involves self-governing farmer groups, assisted by technicians, researchers, and local government, working to develop and disseminate technologies that suit the diverse range of circumstances in upland farming.

The work conducted by ICRAF underlines that there is more to participatory research than just involving rural people as workers and informants in research programs defined by outsiders (Rocheleau, 1991), or using on-farm research to validate and demonstrate new technologies which have previously been developed elsewhere under controlled experimental conditions (Sumberg and Okali, 1991). Both scientists and local people have unique areas of expertise which collectively provide a better base for development than either alone (Fujisaka, 1989). Research collaboration in the sense of Participatory Action Research (PAR) needs to be strengthened by ensuring that farmers participate in the whole research and knowledge dissemination process as equal partners. They, hereby, assume the role of researchers themselves, and exert active control over the process (keywords: ownership, empowerment). Researchers and extensionists should focus more on their role as facilitators, catalysts and consultants (Rahman, 1984; Schönhut and Kievelitz, 1993), joining farmers as equal partners in the process of learning to solve local problems.

7. References

Agus, F. (1993): Soil processes and crop production under contour hedgerow systems on sloping Oxisols. PhD dissertation, North Carolina State University, Raleigh, NC, USA.

Bandy, D.E., Garrity, D.P. and Sanchez, A. (1993): The worldwide problem of slash-and-burn agriculture. Agroforestry Today 5(3): 2-6.

Fujisaka, S. (1989): A method for farmer-participatory research and technology transfer: upland soil conservation in the Philippines. Experimental Agriculture 25: 423-433.

Fujisaka, S., Jayson, E. and Dapusala, A. (1994): Trees, grasses, and weeds: species choices in farmer-developed contour hedgerows. Agroforestry Systems. 25: 13-22.

Garrity, DP. (1995): Improved agroforestry technologies for conservation farming: Pathways toward sustainability. In: Proc International Workshop on Conservation Farming for Sloping Uplands in Southeast Asia: Challenges, Opportunities and Prospects. IBSRAM, Bangkok, Thailand. Proceedings No 14: 145-168.

Garrity, D.P. (1996): Tree-soil-crop interactions on slopes. In: Ong, C.K. and Huxley, P.: Tree-crop interactions. A physiological approach. Wallingford, UK: CAB International: 299-318.

Garrity, D.P. (1997): ICRAF' mission in Asia: a test of three-systems hypotheses. In: PCARRD: Developments in agroforestry research. PCARRD Book Series No. 160/1997. Los Baños, Laguna, Philippines: PCARRD (Philippine Council for Agriculture, Forestry and Natural Resources Research and Development): 8-21.

Leakey, R. (1996): Definitions of agroforestry revisited. Agroforestry Today 8 (1): 5-7.

Lundgren, B. (1982): Introduction (Editorial). Agroforestry Systems 1: 3-6.

Maydell, H.-J. von (1986): Agroforstwirtschaft in den Tropen und Subtropen. In: Rehm, S. (ed.): Grundlagen des Pflanzenbaus in den Tropen und Subtropen. Stuttgart, Germany: Eugen Ulmer: 169-190.

Mercado, A.R., Garrity, D.P., Sanchez, N. and Laput, L. (1997): Effect of natural vegetative filter strips density on crop production and soil loss. Paper presented at the '13th Annual Scientific Conference of the Federation of Crop Science Societies of the Philippines', Baguio, May 25-29, Philippines.

Rahman, A. (1984): Participatory organisations of the rural poor. Geneva, Switzerland: International Labor Office (ILO).

Ramiaramanana, D.M. (1993): Crop-hedgerow interactions with natural vegetative filter strips on sloping acidic land. MSc. thesis. Los Baños, Philippines: University of the Philippines.

Rocheleau, D. (1991): Participatory research in agroforestry: learning from experience and expanding our repertoire. Agroforestry Systems 15: 111-138.

Schönhut, M. and Kievelitz, U. (1993): Partizipative Erhebungs- und Planungsmethoden in der Entwicklungszusammenarbeit: Rapid Rural Appraisal, Participatory Appraisal; eine kommentierte Einführung. Eschborn, Germany: GTZ.

Stark, M. (1999): Soil Management Strategies to Sustain Continuous Crop Production between Vegetative Contour Strips on Humid Tropical Hillsides: Technology Development and Dissemination Based on Farmers' Adaptive Field Experimentation in the Philippines. PhD dissertation. Witzenhausen, Germany: University of Kassel.

Sumberg, J. and Okali, C. (1991): Farmers, on-farm research and new technology. In: Chambers, R., Pacey, A. and Thrupp, L.A. (eds.): Farmer first: farmer innovation and agricultural research. London: Intermediate Technology Publications: 109-114.

Thapa, B., Cassel, D.K., Garrity, D.P. and Mercado, A.R. (1996): Sustainable soil management systems on acid steepland soils in the humid tropics. Paper presented at the '12th Annual Scientific Conference of the Federation of Crop Sciences Societies of the Philippines', May 13-18, Davao, Philippines.

Acknowledgement

The work presented in this paper was supported partly by the *Studienstiftung des Deutschen Volkes*. Special thanks go to the entire ICRAF-Philippines staff and the farmers involved in the research.