The Use of a Farmer Participatory Approach in the Development and Dissemination of More Sustainable Cassava Production Practices[1]

Reinhardt H. Howeler[2]

Abstract

Like other crops, continuous cultivation of cassava without adequate fertilization will generally lead to a decline in soil productivity due to nutrient removal in the harvested products and due to erosion if the crop is grown on slopes. While nutrient extraction by cassava tends to be less than by other crops, the soil loss due to erosion tends to be higher, because of the crop's slow initial development. Past research has shown that many agronomic practices, such as fertilization, minimum tillage, contour ridging, mulching, intercropping and the planting of contour hedgerows of grasses or legumes, are very effective in reducing erosion. However, few of these practices are actually adopted by farmers, mainly because farmers don't realize the actual loss of soil and productivity due to erosion, or the erosion control practices recommended are either not suitable for the local conditions, or are too costly or too time-consuming to implement.

Farmer Participatory Research (FPR) is a new approach that involves farmers directly in decision making and in the development of suitable practices that are not only effective in reducing erosion, but will also increase yields or income. Farmers select from a wide range of options those they consider most useful for their own situation; they test these out in experiments conducted by themselves on their own fields, in collaboration with researchers and extensionists. From the results obtained they decide to continue experimentation, to make necessary adaptations or to adopt the best practices on their own fields.

Results from eight pilot sites in four countries in Asia indicate that farmers readily adopted new higher yielding varieties, some adopted intercropping with peanut or maize, most adopted fertilization with higher rates of N and K, while others are planting contour barriers of grasses or legumes to control erosion. A similar participatory approach is being used to further disseminate the best practices, selected by farmers in the pilot sites, to neighboring villages and surrounding areas. While the methodology used will vary according to circumstances, the fact that farmers are the decision makers and are directly involved in technology development and dissemination remains the most important feature of this approach.

---

[1] Paper presented at the 12th Symposium of the Intern. Soc. Trop. Root Crops, Sept 10-16, 2000 in Tsukuba, Ibaraka, Japan.

[2] CIAT Regional Cassava Office for Asia, Dept. of Agriculture, Chatuchak, Bangkok 10900, Thailand.

I. Introduction

In Asia most cassava is grown on rather acid and very infertile Ultisols (55%), followed by slightly more fertile Inceptisols (18%) and Alfisols (11%) (Howeler, 1992). Most of these soils have a sandy or sandy loam texture - especially in Thailand, Vietnam and on Sumatra island of Indonesia - and have an undulating topography. Cassava soils in southern China and on Java island of Indonesia tend to have a heavier texture, but are located on steeper slopes.

Farmers know that if they grow cassava for many years on the same land without application of fertilizers or manures, their yields will decrease and the soil may become so degraded that no other crops will grow. This is not because cassava extracts excessive amounts of nutrients from the soil; if only roots are harvested and removed from the field, nutrient removal by cassava is actually less than that of most other crops, with a possible exception of K (Howeler, 2000). However, soils can seriously degrade due to erosion. When cassava is grown on slopes, especially in light-textured and low organic matter (OM) soils, erosion can be a serious problem due to its wide plant spacing and slow initial growth (Quintiliano *et al.*, 1961; Margolis and Campo Filho, 1981; Puthacharoen *et al.*, 1998).

Research on erosion control practices has shown that soil losses due to erosion can be markedly reduced by simple agronomic practices combined with soil conservation practices. This includes agronomic practices such as minimum or zero tillage, mulching, contour ridging, intercropping, fertilizer and/or manure application, and planting at higher density; and soil conservation practices such as terracing, hillside ditches and planting contour hedgerows of grasses or legumes. But these practices are seldom adopted by farmers because they were not appropriate for the specific circumstances of the farmers, either from an agronomic or socio-economic standpoint (Ashby, 1985; Barbier, 1990; Fujisaka, 1991; Nappier *et al*., 1991).

CIAT has developed a simple methodology for measuring the effect of soil/crop management treatments on erosion, using plastic-covered ditches dug along the lower edge of each plot to trap eroded sediments; this allows research to be carried out on-farm (**Figure 1)**. Using this simplified methodology, many soil/crop management and erosion control practices can be compared in terms of yield, gross and net income, as well as soil losses due to erosion. This allows farmers to be directly involved in the development and dissemination of more sustainable practices; the practices selected by farmers are likely to be effective in controlling erosion and appropriate for the local conditions, and also provide substantial short-term economic benefits. It was decided to use a farmer participatory approach in seeking solutions, and to enhance the dissemination and adoption of these practices.

II. Farmer Participatory Research (FPR) and Extension (FPE)

Farmer participatory research and extension is an approach in which farmers are directly involved in technology development and dissemination, including problem diagnosis, planning, experimentation on their own fields, selection of best treatments, adaptation, adoption and dissemination of results to other farmers.

In the participatory approach, farmers, researchers and extensionists are considered partners, each contributing their particular knowledge and experience to try to find solutions to existing problems. Once the problems are identified, researchers and extensionists discuss with farmers potential solutions; or they may show farmers various options that might be effective in solving the problem. Once a number of potential options have been selected, farmers may want to test these in FPR trials on their own fields, or they may try out various options on a larger scale in their production fields. Researchers and extensionists usually help farmers set out these experiments, but farmers choose the treatments and manage the crop as they would normally do in their production fields. During the growing cycle farmers observe the effect of each treatment and discuss with other farmers and researchers/extensionists their observations on the advantages and disadvantages of each treatment. At time of harvest, researchers/extentionists help farmers harvest the plots, determine the production and calculate yield; they may also gather other relevant data, such as root starch content in variety trials, or the weight of eroded sediments in erosion control trials. The data are presented to and discussed with farmers, who can then make educated decisions about which treatments they like best, whether they want to make further adaptations and do further testing or are willing to adopt the selected practices on their larger production fields. Once farmers have seen the benefits of certain innovations, they can help disseminate these to other farmers in the community and to other nearby communities, so others can learn from their experiences. This approach has proven to be quite successful in enhancing adoption of soil conservation practices. Research using this approach has been carried out in a project funded by the Nippon Foundation in Tokyo, Japan.

III. The Nippon Foundation Project

1. Objectives and Strategy

The project's objective is to develop appropriate integrated crop/soil management practices for sustainable cassava-based production systems in Asia through the development and use of an interinstitutional and farmer participatory model for testing, selecting and adapting soil/crop management practices that would reduce erosion, improve the soil's productivity and increase farmers' income. A farmer participatory approach was used in order to ensure that the practices were not only effective but also appropriate for the particular conditions in each area or site, and to enhance the adoption of these practices. For technical input about suitable options, the project was able to build on over ten years of collaborative varietal improvement, which had resulted in the release of many new high-yielding and high-starch cassava varieties, as well as on many years of collaborative research on soil fertility maintenance and erosion control that had identified effective measures to control erosion and maintain or improve soil fertility.

2. Implementation

a. Activities

The project's objectives were achieved through three complementary activities:

1. Strategic and applied research to develop new, more effective, technological options, or to solve practical problems identified through FPR.
2. Implementation of FPR in collaboration with researchers, extensionists and farmers in pilot sites in four countries - China, Indonesia, Thailand and Vietnam - to select the most appropriate practices for each location and enhance their adoption.
3. Training courses in FPR methodologies, so more and more people get experience and feel comfortable with this new approach.

b. Institutions

Wherever possible, both research and extension organizations were invited to participate in the FPR project. After an initial FPR training course to introduce the new approach and develop workplans, these trained "FPR teams" started working to implement the project in at least two pilot sites in each country. **Table 1** shows the institutions that collaborated in the first phase of the project, either in the conducting of strategic or applied research, or in the development and implementation of FPR methodologies.

c. Pilot sites

The most suitable pilot sites were identified by selecting areas where cassava was, and is likely to continue to be, an important crop, where cassava is grown on slopes and where erosion and soil fertility decline are serious problems. The number of potential sites was further narrowed down by considering the capacity and interest of farmers and local officials in each site, the accessibility of the sites for researchers and extensionists, as well as other pertinent information obtained through rapid rural appraisals (RRA) conducted either in groups or with individual farmers in the field. **Table 2** shows the most important characteristics of the eight pilot sites selected for the project.

d. FPR trials

Farmers that volunteered to participate in the project discussed and decided on the type of trials they wanted to conduct on their own fields, as well as the treatments they wanted to test. To give farmers an idea about possible options they were invited to visit "demonstration plots", usually set out and managed by researchers, showing many alternative options to maintain soil fertility and reduce erosion. Plots in these demonstrations were generally laid out along the contour of a uniform slope, and had plastic-covered ditches along the lower side to trap eroded sediments (**Figure 1**). Thus, farmers could evaluate each treatment on the basis of yield or income-generating capacity, as well as of the effectiveness in reducing soil losses by erosion. Farmers were asked to score each treatment in the demonstration in terms of usefulness; these scores were used to rank the treatments and make a selection of potential options that could be tested in FPR trials on their own fields. **Table 3** shows average results of demonstration plots laid out on about 20% slope at Thai Nguyen University in north Vietnam, as well as preferences expressed by groups of farmers that visited these plots in 1995, 1996 and 1997. It is clear that farmers selected mainly those treatments giving high net income, but they also chose treatments that were effective in reducing erosion, such as the treatment that had cassava intercropped with peanut and contour hedgerows of *Tephrosia candida* and vetiver grass to control erosion. **Table 4** shows the ranking of treatments by farmers from different sites and different countries. As might be expected, farmers from different regions or countries selected different options, according to their own conditions and traditions. This clearly indicates that no practice can be universally recommended and no one practice will be broadly adopted across regions or countries.

Besides selecting various treatments from the demonstration plots, some farmers also wanted to test treatments that were not included in the demonstration plots, but which they themselves considered potentially useful; this was encouraged.

Once farmers had decided about the type of trials they wanted to conduct and the treatments they wanted to test, researchers and extensionists helped farmers to select the most appropriate sites for each trial, and helped set out the trials and obtain the necessary planting material of new varieties, seeds of intercrops or hedgerow species. For the FPR erosion control trials a site with uniform slope was selected; plots had to be laid out carefully along the contour, so only rainwater falling onto the plot would runoff into the plastic covered ditches below each plot. Researchers and extensionists visited the sites regularly during the crop cycle to discuss with the farmers problems that may have occurred, to help determine the yield of intercrops and to collect and weigh the eroded sediments in the erosion trials once or twice during the cropping cycle. At time of the cassava harvest, researchers, extensionists and all collaborating farmers helped with the harvest of each trial and discussed together observations about the usefulness of each treatment. Yield and soil loss data were calculated quickly to be presented during a group meeting with all farmers, together with economic data of gross income, production costs and the resulting net income of each treatment. As mentioned above, farmers base their decisions mainly on the effect on net income, but also consider the risks associated with each treatment and whether the required labor or money would be available. For instance, in the northeast of Thailand intercrop yields vary markedly from year to year (with many total crop failures) and intercropping tends to be more risky than planting cassava in monoculture.

Table 5 shows a typical example of an erosion control trial conducted by six farmers having adjacent plots on a hillside with about 40% slope in Kieu Tung village of Phu Tho province in Vietnam. Farmers selected mainly those treatments that produced high net income and low levels of erosion. Contour hedgerows of *Tephrosia candida*, pineapple or vetiver grass were all very effective in reducing erosion, usually to less than 20% of that obtained with the traditional practice, while the introduction of intercropping with peanut, and the application of fertilizers also increased yields and net income. **Table 6** shows similar data of FPR erosion control trials conducted in Dampit in East Java, Indonesia. In this case, using the traditional cassava-maize intercropping system, the planting of contour hedgerows of vetiver or lemon grass were most effective in reducing erosion, while these practices also resulted in the highest net income. In other cases (see **Table 7**), however, some treatments that are very effective in controlling erosion (vetiver and lemon grass hedgerows) may result in lower cassava yields and net income because some land has been taken out of production to establish the hedgerows. In that case there are trade-offs to be made between present land productivity and future resource conservation; these trade-off decsions can only be made by farmers themselves. **Table 8** summarizes the results of about 200 FPR erosion control trials conducted in four countries from 1995 to 1998, showing the gross and net income as well as dry soil loss for the best selected treatments in comparison with the traditional farmers' practices. In most cases the selected practices significantly increased net income and decreased soil erosion. Erosion losses varied markedly from year to year, but the effectiveness of the selected treatments in reducing erosion tended to increase over time.

Tables 9 to **12** show examples of FPR variety and fertilizer trials conducted by farmers in pilot sites in Vietnam and Thailand. Farmers selected varieties mainly based on yield and starch content, but may also consider branching habit, storability of planting material, or wind resistance in areas where typhoons are common. **Tables 11** and **12** show that K and N were the most limiting nutrients in Dong Rang, Vietnam, while N was the most limiting in the sandy soils of Sahatsakhan district in Kalasin, Thailand. The application of well-balanced fertilizers increased farmers' net income about 40% in both locations.

e. Adaptation and Adoption

Once farmers were convinced of the usefulness of certain crops, varieties or production practices from their FPR trials, they either made further adaptations, or they adopted the practices directly on their larger production fields (**Table 13**). New varieties having higher yields and starch contents were readily adopted in most sites, and farmers steadily multiplied planting material for their own or neighbors' use. In Hainan, China, participating farmers initially tested and multiplied a large number of superior clones, but over the years narrowed the numbers down to only one or two, which are now planted by almost all farmers in the village.

The use of fertilizers was readily accepted in most sites except in China, where soil fertility was relatively high and could be maintained by fallow rotation. Trials conducted in Vietnam and Indonesia generally highlighted the importance of N and K, and farmers switched from applying mainly P to using mainly N and K, combined with farm-yard manure. In Thailand most farmers apply the compound fertilizer 15-15-15, but some are now switching to the more suitable formula 15-7-18.

Intercropping cassava with peanut (and black bean to a lesser extent) was readily adopted by farmers in all four pilot sites in Vietnam as it increased net income, reduced erosion and was thought to improve soil fertility when crop residues were reincorporated in the soil after harvest. In Thailand intercropping with sweet corn or pumpkin was highly successful in some years and in some sites (see **Table 7**), but also resulted in some total crop failures. Most farmers did not adopt this practice as it required too much labor and was too risky. In China, intercropping was also less successful because of damage by rats, rabbits or human thieves, while labor was also a serious constraint at the particular pilot site in Hainan island.

In Thailand most farmers selected vetiver grass hedgerows as the most effective way to control erosion, but due to the high cost of establishing these hedgerows by vegetative planting material, they are also trying out other grasses that are equally effective in erosion control, are not competitive with the crop, and can be planted from seed, such as *Paspalum atratum, Setaria sphacelata* and *Brachiaria brizantha*; these species are also more useful for feeding cattle, pigs and fish. In Vietnam, for similar reasons, farmers adopted *Tephrosia candida* instead of vetiver grass, eventhough the latter was usually the preferred treatment in small plot trials. Farmers like *Tephrosia* for its multipurpose use as a green manure and a source of firewood; it is very well adapted to the poor soil and climatic conditions of the uplands of central and north Vietnam. In Indonesia where farmers need forages to feed cattle and goats, especially in the dry season, farmers selected and adopted mainly hedgerows of *Gliricidia sepium* and *Leucaena leucocephala* (**Table 13**).

f. Farmer-to-farmer Extension

After completing the first phase (1994-1998) of the project, the Nippon Foundation agreed to fund a second 5-year phase (1999-2003). The second phase has similar objectives and activities as the first phase, but with a shift from mainly farmer participatory research to farmer participatory extension, in order to enhance the dissemination of farmer selected varieties and more sustainable practices to other farmers and other regions, and to increase adoption. Thus, in the second phase the activities will gradually change from conducting small-plot trials with farmers to scaling up to larger fields, and to more informal testing of alternative technologies by a much larger number of farmers. Furthermore, alternative methodologies for FPR and FPE will be developed and tested, while major emphasis will also be placed on training of researchers, extensionists and farmers in FPR methodologies and in the implementation of soil conserving practices; the use of participatory approaches by research and extension institutes will also be encouraged.

In the second phase the project will concentrate most efforts in Thailand and Vietnam, with a limited number of activities continuing in China, including an expansion of the project to Guangxi and Yunnan provinces. In Thailand the project is being implemented in collaboration with five government and private institutions working this year in ten sites in five provinces with about 250 farmers; in Vietnam the project is being implemented in collaboration with six research institutes and universities working in 15 sites with over 350 farmers. In Thailand about 240 farmers have already planted 67 km of vetiver grass contour hedgerows against erosion, covering about 200 ha of cassava, while *Canavalia ensiformis* and cowpea are being planted by some farmers as green manures to improve soil fertility. In Vietnam 93 farmers have so far implemented soil erosion control measures on their farms, mainly the planting of contour hedgerows of *Tephrosia candida*, while more than 73 farmers are now intercropping cassava with peanut and black bean, and hundreds have adopted new varieties and better fertilization practices.

V. Lessons Learned

Convincing farmers to adopt soil conservation practices is an uphill battle unless adequate incentives are provided; but experience shows that once these incentives are withdrawn, farmers quickly revert back to their traditional practices, as most soil conservation structures are costly to establish, time consuming to maintain and may take scarce land out of production (Fujisaka, 1991). Bernsten and Sinaga (1983) calculated that construction of bench terraces in Java island of Indonesia require 750-1800 mandays and cost $1000-2000/ha (1979 prices); they require regular maintenance and about 20% of the land is occupied by terrace risers, lips and water disposal systems. In contrast, planting of agro-forestry systems, such as *Albizia falcata* or *Gliricidia sepium* cost around $100/ha (1982 prices) (Sumitro, 1983). The cost of establishing contour hedgerows of vetiver grass varies with the slope and the cost of labor, but is likely to be between $50 and $200/ha (World Bank, 1990). Farmers are not likely to adopt these systems unless incentives are provided as it may take many years to recuperate the costs of establishment and maintenance through higher yields; in case of hedgerows of shrub legumes for erosion control in maize in the Philippines, it took 5-10 years to obtain greater economic benefits from the hedgerow system as compared to planting maize without hedgerows (Cramb and Nelson, 1998). This is too long a planning horizon for poor upland farmers. Moreover, many recommended soil conservation practices are not suitable for the particular conditions and may be doomed to failure from the start.

To be successful in promoting soil conservation the following issues should be taken into account:

1. *Economic profitability is necessary but not sufficient for adoption to occur, and the time horizon for profitability should be as short as possible.* In the trials discribed above, higher net incomes in the "improved" practices were obtained not so much from the soil conservation practices, but from other innovations in the "package", such as higher yielding varieties, fertilization and intercropping. By testing and adopting the whole integrated system, farmers can obtain economic benefits while significantly reducing erosion (**Table 8**). Improved cultural practices such as closer spacing, reduced tillage, intercropping and fertilization

will all contribute to reducing erosion while they may also increase yield and income. The "right" combination of cost-effective cultural practices and soil conservation practices (hedgerows, agro-forestry) is highly site-specific and must be developed locally in a cooperative effort between farmers, extensionists and researchers. Only those combinations of practices that are profitable in the short-term and effective in erosion control will be adopted. The Nippon Foundation project was able to achieve profitability and raise farmers' interest in the project by the introduction of new varieties, fertilization, intercropping and various new hedgerow species that had previously been developed in on-station research, and that were "on the shelf" for on-farm testing and dissemination. If no good technologies are available for introduction, farmers soon loose interest in participating. The planting of new higher-yielding varieties was the main incentive for farmers to participate in the project and was a very important "entry point" for getting farmers interested in testing methods of soil conservation. For that reason, FPR trials were never limited to only erosion control, but included varieties, intercropping, fertilization, weed control etc.

2. *Some incentives may be necessary.* Since soil conservation structures may be too expensive for farmers to establish on their own, governments should provide some assistance, as society as a whole also benefits from less flooding, more and better quality water, and lower costs of dredging and maintenance of irrigation and hydro- electric generating systems.

   Thus, in Thailand vetiver grass contour hedgerows are being adopted because farmers have seen their effectiveness in reducing erosion; in addition, the government supplies free planting material, helps farmers in setting out contour lines, teaches about multiplication and management of vetiver plants, as well as the use of vetiver leaves in the making of handicrafts as an additional source of income. In Vietnam, adoption of *Tephrosia candida* hedgerows is being facilitated by supplying farmers with good quality seed; similarly, in Indonesia farmers adopted *Gliricidia sepium* contour hedgerows after they received good quality seed from the project.

Financial incentives should be kept to a minimum, as this will not be sustainable in the long run, but some incentives in kind may be useful and necessary to allow farmers to adopt the new technology.

3. *Farmers must be aware of soil erosion and its impact on soil productivity before they will be interested in soil conservation.* Severe soil erosion is usually associated with steep slopes and its impact on soil productivity is most pronounced in shallow soils or in soils having a thin topsoil underlain by a highly infertile subsoil. In that case farmers can clearly see the negative impact of erosion on soil productivity and know that yields will decline unless they protect their soil from erosion. But even in areas with gentle slopes (2-10%) and deep soils, the accumulation of large amounts of runoff water in natural drainage ways can cause severe gulley erosion, break contour ridges and wash away young plants and fertilizers, while the eroded sediments may obstruct roads and irrigation and drainage systems below. By conducting erosion control trials on their own fields and seeing the large amounts of eroded sediments in the plastic-covered ditches, farmers start to appreciate how much soil they are losing each year.

   To be convincing, however, and to be able to obtain accurate data on soil losses, these FPR erosion control trials must be laid out exactly on the contour, and care must be taken that no water runs onto the plots from above or from the sides, and no water leaves the plots across side borders. This is not an easy task, especially if the slope is not uniform; it requires much care and experience at the time these plots are laid out and treatments are established. Researchers and farmers generally like rectangular plots, preferably parallel to roads or field borders, while this type of trial may require trapezoidal or irregularly shaped plots to maintain the sediment-collection ditches along the contour and perpendicular to the natural flow of runoff water.

4. *Give farmers freedom to experiment.* In conducting the trials, farmers should be allowed to not only select the treatments but also their location within the trial, as farmers' fields are not necessarily uniform. Some of this disuniformity can be exploited and much can be learned from letting the farmer select the right treatment for each particular condition. On the other hand, having farmers as a group decide on a set of the same treatments, to be tested by all farmers participating in the trials, facilitates the taking of data and allows the calculation of averages (see **Table 9-12**) across trials within the site, which makes it possible to compare treatments over a range of conditions. Alternatively, some treatments may be common to all trials in the village, while other treatments may be selected by each farmer individually (as was the case in **Table 7**).

5. *Yield calculations must be accurate and based on total cropped area.* To be believable, yield data must be accurate and must reflect the real on-farm conditions. In treatments with intercrops or hedgerows the yield of each crop should be calculated based on the total area of the plot, or of a subplot that includes all crop components. Calculating yields from "effective" plots that exclude border rows and hedgerows will inevitably overestimate the yield of those treatments, and thus mislead farmers into attributing non-existing benefits to those treatments. Also, treatments of "farmers' traditional practices" should be managed

as much as possible like the farmer's production fields; the yields of those plots should be similar to what farmers obtain in nearby production fields. However, asking farmers to plant their trials at a uniform plant spacing will greatly facilitate the accurate determination of yield. In as much as possible, FPR trials should be planted and harvested at the times that farmers in the village normally plant and harvest these same crops.

6. *Local officials and self-help groups should be partners in the project.* When selecting appropriate pilot sites it is important not only to consider the biophysical and socio-economic conditions of farmers, but also to gauge the interest of local leaders and extension officers, and to determine the existence of NGO's or local self-help groups. Working in collaboration with these local officials and groups will greatly facilitate the implementation of the trials and the subsequent adoption of selected practices. Support for the project at the highest levels of government will help to convince local officials that support of, and participation in, the project is not only approved of but also appreciated. Inviting local leaders and extensionists to FPR training courses will contribute much to their understanding of the approach and their active participation in the project. Finally, the presence of NGOs with interest in sustainable agriculture and rural development, as well as the existence of local self-help groups makes it easier to call meetings, initiate the project, conduct the trials and enhance the adoption and implementation of selected practices.

VI. Conclusions

Research on sustainable land use conducted in the past has mainly concentrated on finding solutions to the biophysical constraints, and many solutions have been proposed for improving the long-term sustainability of the system. Still, few of these solutions have actually been adopted by farmers, mainly because they ignored the human dimension of sustainability. For new technologies to be truly sustainable they must not only maintain the productivity of the land and water resources, but they must also be economically viable and acceptable to farmers and the community. To achieve those latter objectives farmers must be directly involved in the development, adaptation and dissemination of these technologies. A farmer participatory approach to technology development has shown to be quite effective in developing locally appropriate and economically viable technologies, which in turn enhances their acceptance and adoption by farmers.

The conducting of FPR trials is initially time consuming and costly, but once more and more people are trained and become enthusiastic about the use of this approach - including participating farmers - both the methodology and the selected improved varieties or cultural practices will spread rapidly. The selection and adoption of those farming practices that are most suitable for the local environment and in tune with local traditions will improve the long-term sustainability of the cropping system, to the benefit of both farmers and society as a whole.

Acknowledgement

The author gratefully acknowledges the financial contributions of the Nippon Foundation in Tokyo, Japan; without its generous support this project would not have been possible. The author also wants to thank his colleagues in national programs for collaborating in this project with dedication and enthusiasm. They collected most of the data presented in this paper, but are too numerous to be acknowledged individually.

References

Ashby, J.A. 1985. The social ecology of soil erosion in a Colombian farming system. Rural Sociology 50(3): 377-396.

Barbier, E.B. 1990. The farm-level economics of soil conservation: the uplands of Java. Land Economics 66(2): 199-211.

Bernsten, R. and R. Sinaga. 1983. "Economics", Technical Appendix VI, Government of Indonesia/USAID, Composite Report of the Watershed Assessment Team. Jakarta: GOI/USAID.

Cramb, R.A. and R.A. Nelson. 1998. Investigating constraints to the adoption of recommended soil conservation technology in the Philippines. *In*: F.W.T. Penning de Vriès, F. Agus and J. Kerr (Eds.). Soil Erosion at Multiple Scales. Principles and Methods for Assessing Causes and Impacts. IBSRAM and Cabi Publishing, Wallingford, Oxon, UK. pp. 99-120.

Fujisaka, S. 1991. Thirteen reasons why farmers do not adopt innovations intended to improve the sustainability of upland agriculture. *In*: Proc. Intern. Workshop on Evaluation for Sustainable Land Management in the Developing World. IBSRAM Proc. No. 12, volume II. pp. 509-522.

Howeler, R.H. 1992. Agronomic research in the Asian Cassava Network - An Overview. 1987 -1990. *In*: R.H. Howeler (Ed.). Cassava Breeding, Agronomy and Utilization Research in Asia. Proc. 3rd Regional Workshop, held in Malang, Indonesia. Oct 22-27, 1990. pp. 260-285.

Howeler, R.H. 2000. Cassava mineral nutrition and fertilization. *In*: R.J. Hillocks, M.J. Thresh and A. Bellotti (Eds.). Cassava: Biology, Production and Utilization. CABI Publishing, Wallingford, UK. (submitted for publication).

Margolis, E. and O.R. Campos Filho. 1981. Determinaçáo dos fatores da equaçáo universal de perdas de solo num Podzólico Vermelho-Amarelo de Glória do Goitá. Anais do 3rd Encontro Nacional de Pesquisa sobre Conservaçáo do Solo, held in Rengife, Pernambuca, Brazil. July 28-Aug 1, 1980. pp. 239-250.

Napier, T.L., A.S. Napier and M.A. Tucker. 1991. The social, economic and institutional factors affecting adoption of soil conservation practices: the Asian experience. Soil and Tillage Research. 20: 365-382.

Putthacharoen, S., R.H. Howeler, S. Jantawat and V. Vichukit. 1998. Nutrient uptake and soil erosion losses in cassava and six other crops in a Psamment in eastern Thailand. Field Crops Research. 57: 113-126.

Quintiliano, J., A. Margues, J. Bertoni and G.B. Barreto. 1961. Perdas por erosao no estado de S. Paulo. Brigantia. 20(2): 1143-1182.

Sumitro, A. 1983. "Tree Crop Management" Technical Appendix V. Government of Indonesia/USAID. Composite Report of the Watershed Assessment Team, Vol. 3. Jakarta: USAID.

World Bank, 1990. Vetiver Grass. The Hedge Against Erosion. (3rd ed). The World Bank, Washington DC, USA. 78 p.

Table 1. Institutions collaborating with CIAT in the Nippon Foundation Project on Improving the Sustainability of Cassava-based Cropping Systems in Asia.

Country/Province	Institution	FPR project	Research
China-Hainan	Chinese Acad. Tropical Agric. Sciences (CATAS)	3	3
China-Guangxi	Guangxi Subtropical Crops Research Institute (GSCRI)		3
China-Guangdong	Upland Crops Research Institute (UCRI)		3
Indonesia-E.Java	Brawijaya University (UNIBRAW)	3	3
Indonesia-E.Java	Research Institute for Legumes and Tuber Crops (RILET)	3	3
Indonesia-W.Java	Central Research Institute for Food Crops (CRIFC)		3
Philippines-Leyte	Phil. Root Crops Research and Training Center (PRCRTC)		3
Philippines-Bohol	Bohol Experiment Station (BES)		3
Thailand	Field Crops Research Institute (FCRI) of Dept. of Agriculture	3	3
	Field Crops Promotion Division of Dept. Agric. Extension	3	
	Thai Tapioca Development Institute	3	
	Kasetsart University		3
Vietnam-Thai Nguyen	Agro-Forestry College of Thai Nguyen University	3	3
Vietnam-Hanoi	National Institute for Soils and Fertilizers (NISF)	3	
Vietnam-Ho Chi Minh	Institute of Agric. Sciences (IAS)		3

Table 2. Characteristics of eight pilot sites for the Farmer Participatory Research (FPR) trials in Asia in 1994-1998.

	Thailand		Vietnam			China	Indonesia	
	Soeng Saang	Wang Nam Yen	Pho Yen	Thanh Ba	Luong Son	Kongba	Malang	Blitar
Mean temp. (°C)	26-28	26-28	16-29	25-28	16-29	17-27	25-27	25-27
Rainfall (mm)	950	1400	2000	~1800	~1700	~1800	>2000	~1500
Rainy season	Apr-Oct	Apr-Nov	Apr-Oct	Apr-Nov	May-Oct	May-Oct	Oct-Aug	Oct-June
Slope (%)	5-10	10-20	3-10	30-40	10-40	10-30	20-30	10-30
Soil	± fertile loamy Paleustult	± fertile clayey Haplustult	infertile sandy loam Ultisol	very infertile clayey Ultisol	± fertile clayey Paleustult	± fertile sandy cl.l. Paleudult	infertile clay loam Mollisol	infertile clay loam Alfisol
Main crops	cassava rice fruit trees	maize soybean cassava	rice sweet pot. maize	rice cassava tea	rice cassava taro	rubber cassava sugarcane	cassava maize rice	maize cassava rice
Cropping system[1)]	C monocrop	C monocrop	C monocrop	C+P	C+T	C monocrop	C+M	C+M
Cassava yield (t/ha)	17	17	10	4-6	15-20	20-21	12	11
Farm size (ha)	4-24	3-22	0.7-1.1	0.2-1.5	0.5-1.5	2.7-3.3	0.2-0.5	0.3-0.6
Cassava (ha/hh)	2.4-3.2	1.6-9.6	0.07-0.1	0.15-0.2	0.3-0.5	2.0-2.7	0.1-0.2	0.1-0.2

[1)]C = cassava, P = peanut, T = tarro, M = maize

Table 3. Results of FPR demonstration plots conducted on 18-24% slope at Agro-forestry College of Thai Nguyen University, Thai Nguyen, Vietnam. Data are average values for 1995, 1996 and 1997.

Treatments[1)]	Cassava yield (t/ha)	Net income (mil d/ha)	Dry soil loss (t/ha)	Farmer preference (%)
1. C monoculture., no fertilizers, no hedgerows	4.49	1.87	28.3	0
2. C, with fertilizers (60N-40 P_2O_5-120 K_2O)	16.49	7.67	23.0	0
3. C, with FYM (10 t pig manure/ha)	17.31	7.79	25.3	10
4. C, with FYM+fertilizers	23.56	10.39	24.9	58
5. C, with fertilizers, with *Tephrosia* green manure	19.60	9.63	24.3	2
6. C+P, with fertilizers, *Tephrosia*+vetiver hedgerows	17.53	10.73	5.8	78
7. C, with fertilizers, contour ridging	20.48	9.84	12.6	49
8. C, with fertilizers, *Tephrosia* hedgerows	16.39[2)]	7.51	13.6	16
9. C, with fertilizers *Flemingia* hedgerows	16.29[2)]	7.43	8.0	22
10. C, with fertilizers, vetiver grass hedgerows	18.96[2)]	9.12	4.7	32
11. C+B, with fertilizers, *Tephrosia* hedgerows	17.93	7.93	9.0	12
12. C, with fertilizers, cassava residues incorporated	24.75	12.40	18.1	25
13. C, no fertilizers, residues incorp., *Tephrosia* hedgerows	6.52	3.26	12.8	0
14. C, with fertilizers, *Tephrosia* intercropped+mulched at 3 MAP	18.99	8.73	18.5	0
15. C, with fertilizers no tillage	18.92	9.29	18.1	0
16. C, with fertilizers, closer plant spacing (0.8x0.6 m)	21.66	10.58	18.5	16

[1)]C = cassava, P = peanut, B = black bean; in all treatments except T_7 and T_{15} the soil was prepared with hoe and cassava was planted without ridging; in all treatments except T_{12} and T_{13} the cassava residues were removed after harvest; in all treatments except T_{16} cassava was planted at 1.0x0.8 m;

[2)]In 1997 in T_8, T_9 and T_{10} cassava was intercropped with peanut

Table 4. Ranking of soil conservation practices selected from demonstration plots by cassava farmers from several pilot sites in Asia in 1995/96.

Practice	Thailand		Bietnam		China	Indonesia	
	Soeng Saang	Wang Nam Yen	Pho Yen	Thanh Hoa	Baisha	Blitar	Dampit
Farm yard manure (FYM)				2			
Medium NPK	5						
High NPK					2		
FYM+NPK				1			
Cassava residues incorporated			5				
Reduced tillage	4						
Contour ridging		2					
Up-and-down ridging					5		
Maize intercropping	2					1	1
Peanut intercropping		5			4		2
Mungbean intercropping					3		
Black bean intercrop+*Tephrosia* hedgerows			1	4			
Tephrosia green manure			3	5			
Tephrosia hedgerows			4				
Gliricidia sepium hedgerows						2	4
Vetiver grass barriers	1	1	2	3			
Brachiaria ruziziensis barriers	3	4					
Elephant grass barriers						3	3
Lemon grass barriers		3					
Stylosanthes barriers					1		

Table 5. Effect of various crop management treatments on the yield of cassava and intercropped peanut as well as the gross and net income and soil loss due to erosion in a FPR erosion control trial conducted by six farmers in Kieu Tung village of Thanh Ba district, Phu Tho province, Vietnam in 1998.

Treatments[1)]	Yield (t/ha)		Gross income (mil. d/ha)[3)]			Production costs (mil. d/ha)[3)]				Net income (mil. d/ha)	Dry soil loss (t/ha)	Farmers' ranking
	cassava	peanut[2)]	cassava	peanut	total	seed	fertilizer	labor	total			
1. C monoculture, with fertilizers, no hedgerows (TP)	25.75	-	10.30	-	10.30	-	3.32	2.20	5.52	4.78	18.4	6
2. C+ P, no fertilizers, no hedgerows	18.16	0.47	7.26	2.58	9.84	0.40	2.00	3.50	5.90	3.94	13.3	5
3. C+P, with fertilizers, no hedgerows	20.32	0.51	8.13	2.80	10.93	0.40	3.32	3.70	7.42	3.51	14.0	5
4. C+P, with fertilizers, *Tephrosia* hedgerows	21.60	0.51	8.64	2.80	11.44	0.50	3.32	3.85	7.67	3.77	5.3	3
5. C+P, with fertilizers, pineapple hedgerows	23.33	0.73	9.33	4.01	13.34	0.50	3.32	3.85	7.67	5.67	0.8	2
6. C+P, with fertilizers, vetiver grass hedgerows	26.52	0.38	10.61	2.09	12.70	0.50	3.32	3.85	7.67	5.03	3.1	1
7. C monoculture, with fertilizers, *Tephrosia* hedgerows	25.05	-	10.02	-	10.02	0.10	3.32	2.35	5.77	4.25	6.3	4

[1)]All plots received 10 t/ha of pig manure; fertilizers = 60 kg N+40 P_2O_5+120 K_2O/ha
TP = farmers traditional practice = cassava monoculture + 10 t/ha of pig manure
C = cassava, P = intercropped peanut
[2)]Dry pods
[3)]Prices:

cassava	dong 400/kg fresh roots			
peanut	5,500/kg dry pods			
labor	7,500/day			
pig manure	200/kg (includes transport and application)			
urea (45%N)	3,000/kg	→	60 N	= 0.400 mil. dong
SSP (16%P_2O_5)	1,000/kg	→	40 P_2O_5	= 0.250 mil. dong
K_2SO_4 (50%K_2O)	2,800/kg	→	120 K_2O	= 0.672 mil. dong
			Fertilizers	= 1,322 mil. dong

Table 6. Average results of ten FPR soil erosion control trials conducted by farmers in Sumbersuko village, Dampit, Malang, East Java, Indonesia, in 1997/98.

Treatments[1)]	Yield (t/ha) cassava	Yield (t/ha) maize	Gross income ('000 Rp/ha)	Prod. costs ('000 Rp/ha)	Net income[3)] ('000 Rp/ha)	Dry soil loss (t/ha)
1. C+M; farmer practice, in-line mounds followed by up/down ridging	18.90	1.20	6,063	1,200	4,863	18.10
2. C+M; recommended practices, contour ridging,vetiver hedgerows	22.15	1.35	7,060	1,900	5,160	6.40
3. C+M; recom. practices; contour ridging, lemon grass hedgerows	21.10	1.50	6,897	1,900	4,997	9.45
4. C+M+P-Cp[2)]; recom. practices, contour ridging of cassava row	7.60	0.85	6,962	2,370	4,592	14.65

[1)] C = cassava, M = maize, P = peanut, Cp = cowpea
[2)] Yields of peanut: 620 kg/ha; cowpea: 360 kg/ha
[3)] Prices: cassava Rp 270/kg fresh roots
maize 800/kg dry grain on cob
peanut 4,500/kg dry grain in pod
cowpea 4,000/kg dry grain

Table 7. Average results of seven[1)] FPR erosion control trials conducted by farmers in Sahatsakhan district, Kalasin, Thailand, in 1998/99.

Treatments[2)]	Yield cassava (t/ha)	Yield intercrop (t/ha)	Gross income[3)] cassava	Gross income[3)] intercrop	Gross income[3)] total	Production costs	Net income	Dry soil loss (t/ha)
			('000 B/ha)					
1. Farmer's practice	29.74	-	30.93	-	30.93	14.30	16.63	12.48
2. Contour ridges	29.42	-	30.61	-	30.61	14.86	15.75	8.44
3. Closer plant spacing (0.8x0.8m)	35.66	-	37.09	-	37.09	15.79	21.30	10.91
4. Lemon grass hedgerows	32.81	-	34.12	-	34.12	15.91	18.21	9.60
5. Vetiver grass hedgerows	31.35	-	32.61	-	32.61	15.62	16.99	7.35
6. Sweet corn intercrop	25.76	7,944 ears	26.79	11.92	38.71	16.50	22.21	13.36
7. Pumpkin intercrop	31.19	3,400 pumpkins	32.44	18.36	50.80	16.84	33.96	14.13
8. Peanut intercrop	15.70	1.20	16.37	18.00	34.37	15.68	18.69	29.64

[1)]Only four trials for treatment 7, two for treatment 5, and one for treatment 8

[2)]All treatments fertilized with 312 kg/ha of 15-15-15; no ridging except in T2; plant spacing at 1.0x1.0m except in T3

[3)]Prices:

Prices:	cassava	B 1.04/kg fresh roots
	peanut	15/kg dry pods
	pumpkin	5.40/pumpkin
	sweet corn	1.50/ear

Table 8. Effect of farmer selected soil conservation practices on dry soil loss and gross and net income as compared to the traditional farmers' practice in FPR trials conducted in eight pilot sites in Asia from 1995-1998.

FPR pilot sites	Year	No. of farmers	Dry soil loss(t/ha)	Income ($/ha)	
				Gross	Net
China - Hainan, Baisha, Kongba					
Farmers' practice (C monoculture)	1995	11	47	1220	-
Various intercropping/hedgerows			32	1391	-
Farmers' practice (C monoculture)	1996	4	125	371	-
C+peanut , vetiver hedgerows			89	736	-
Farmers' practice (C monoculture)	1997	4	114	523	-
C+peanut, vetiver hedgerows			60	941	-
Indonesia - E. Java, Malang, Dampit					
Farmer's practice (C monocult, up/down ridge, N)	94/95	D[1]	72	578	545[2]
C+maize, elephant grass hedgerows, NPK			48	1069	993[2]
Farmer's practice (C monoculture, N)	95/96	D[1]	145	317	155[4]
C+maize, elephant grass hedgerows, NPK			134	346	37[4]
Farmer's practice (C+maize, N)	96/97	9	8	615	-
C+maize, vetiver hedgerows, NPK			8	603	-
Indonesia - E. Java, Blitar, Ringinrejo					
Farmers' practice (C monoculture)	94/95	D[1]	27	312	211[2]
C+maize, *Gliricidia* hedgerows			28	588	509[2]
Farmers' practice (C+maize)	95/96	D[1]	28	307	157[4]
C+maize, *Gliricidia* hedgerows			23	247	97[4]
Farmers' practice (C+maize)	96/97	2	55	697	597[2]
C+maize, *Gliricidia* hedgerows			25	740	641[2]
Thailand - Nakorn Ratchasima, Soeng Saang					
Farmers' practice (up/down ridging)	95/96	9	25	1254	870[4]
Vetiver hedgerows, no ridging			8	1480	1071[4]
Farmers' practice (up/down ridging)	96/97	7	4	893	322[4]
Vetiver hedgerows, no ridging			4	871	250[4]
Farmers' practice (up/down ridging)	97/98	1	24	644	-
Vetiver hedgerows, no ridging			8	521	-

Table 8. continued

FPR pilot sites	Year	No. of farmers	Dry soil loss(t/ha)	Income ($/ha)	
				Gross	Net
Thailand - Sra Kaew, Wang Nam Yen					
Farmers' practice (up/down ridging)	95/96	6	18	1378	948[4)]
Vetiver hedgerows, no ridging			15	1110	685[4)]
Farmers' practice (up/down ridging)	96/97	6	48	884	384[4)]
Vetiver hedgerows, no ridging			10	724	199[4)]
Farmers' practice (up/down ridging)	97/98	1	17	815	-
Vetiver hedgerows, no ridging			1	496	-
Vietnam - Thai Nguyen, Pho Yen					
Farmers' practice (C monoculture, no fertilizers)	1995	6	30	1024	753[3)]
C+peanut, vetiver hedgerows, NPK			19	1047	892[3)]
Farmers' practice (C monoculture, no fertilizers)	1996	5	8	629	424[3)]
C+peanut , *Tephrosia* hedge., contour ridg., NPK			5	815	606[3)]
Farmers' practice (C monoculture, no fertilizers)	1997	5	8	535	336[3)]
C+peanut, *Tephrosia* hedge., contour ridg., NPK			3	1041	817[3)]
Vietnam - Phu Tho, Thanh Ba, Kieu Tung					
Farmers' practice (C+peanut, no hedge., no fert.)	1995	6	54	1347	921[3)]
C+peanut, vetiver hedgerows, NPK			43	1653	1129[3)]
Farmers' practice (C monocult., no hedge., no fert.)	1996	6	28	695	459[3)]
C+peanut , vetiver hedgerows, NPK			25	1525	1187[3)]
Farmers' practice (C monocult., no hedge., no fert.)	1997	6	106	871	533[3)]
C+peanut, vetiver hedgerows, NPK			32	1464	923[3)]
Vietnam - Hoa Binh, Luong Son, Dong Rang					
Farmers' practice (C monocult., no hedge., no fert.)	1995	1	10	481	139[4)]
C+peanut, *Tephrosia* hedgerows, NPK			1	978	49[4)]
Farmers' practice (C+taro, no hedge., no fert.)	1996	3	43	635	568[2)]
C+peanut , vetiver hedgerows, NPK			2	1012	873[2)]
Farmers' practice (C+taro, no hedge., no fert.)	1997	1	3	522	20[4)]
C+peanut, *Tephrosia* hedgrows, NPK			0	698	99[4)]

[1)] D = demonstration plots
[2)] Gross income minus fertilizer and manure costs
[3)] Gross income minus all material costs
[4)] Gross income minus labor and material costs

Table 9. Average results of 15 FPR variety trials conducted by farmers in Tien Phong and Dac Son villages of Pho Yen district, Thai Nguyen province, Vietnam in 1998.

Variety	Cassava yield (t/ha)	Gross income[1)]	Production costs	Net income	Farmers' preference (%)
		(mil. dong/ha)			
1. Xanh Vinh Phu	16.89	8.45	2.90	5.55	7
2. KM 60	20.40	10.20	2.90	7.30	65
3. KM 95-3	18.45	9.22	2.90	6.32	0
4. CM 4955-7	24.62	12.31	2.90	9.41	82
5. KM 94	21.91	10.96	2.90	8.06	50
6. SM 17-17-12	25.44	12.72	2.90	9.82	100

[1)]Price: cassava dong 500/kg fresh roots

Table 10 Average results of seven FPR variety trials conducted by farmers in Sahatsakhan district, Kalasin, Thailand in 1999/2000.

Varieties	Root yield (t/ha)	Starch content (%)	Starch yield (t/ha)	Gross income[1)] ('000 B/ha)	Production costs[2)] ('000 B/ha)	Net income ('000 B/ha)
1. Rayong 1	20.15	22.6	4.55	13.70	12.38	1.32
2. Rayong 5	20.43	22.6	4.62	13.89	12.44	1.45
3. Rayong 90	19.91	26.1	5.20	13.54	12.33	3.00
4. KU-50	23.44	24.2	5.67	15.94	13.04	3.60
5. Rayong 72	25.42	22.5	5.72	17.28	13.43	3.85

[1)]Price: B 0.68/kg fresh roots at 23% starch; increase or decrease of B 0.03 for every per cent starch above or below 23%

[2)]Cost of land preparation, planting, weeding, fertilization: B 8,350/ha
Cost of harvest and transport: B 200/t roots

Table 11. Average results of six FPR fertilizer trials conducted in Sahatsakhan district, Kalasin province, Thailand, in 1999/2000.

Fertilizers applied (kg N-P_2O_5-K_2O/ha)	Root yield (t/ha)			Gross income[1)]	Fertilizer cost[1)]	Production costs[2)]	Net income
	KU-50	Rayong 5	Average	('000 B/ha)			
1. 0-0-0	15.50	11.05	13.27	9.02	0	7.59	1.43
2. 0-50-50	15.10	12.20	13.65	9.28	2.07	10.59	-1.37
3. 50-0-50	20.45	12.10	16.27	11.06	1.24	10.28	0.78
4. 50-50-0	18.10	15.92	17.01	11.57	1.98	11.17	0.40
5. 23-23-23[3)]	20.50	17.50	19.00	12.92	1.28	10.87	2.05
6. 46-46-46[3)]	20.05	16.40	18.22	12.39	2.56	11.99	0.40

[1)] Prices: cassava B 0.68/kg fresh roots
urea (45% N) 265/50kg
TSP (45% P_2O_5) 630/50kg
KCl (60% K_2O) 400/50kg
15-15-15 410/50kg

[2)]Production costs without fertilization and without harvest and transports: B 4,937/ha
Cost of harvest + transport: B 200/t roots; fertilizer application: B 850/ha

[3)]Applied as 15-15-15 compound fertilizers

Table 12. Average results of three FPR fertilizer trials conducted in Dong Rang village, Luong Son district, Hoa Binh, Vietnam, in 1999.

Fertilizers applied (kg N-P_2O_5-K_2O/ha)	Cassava yield (t/ha)	Gross income[1)]	Fertilizer cost[1)]	Total product. cost	Net income
		(mil. dong/ha)			
1. 0-0-0	14.15	4.67	0	3.00	1.67
2. 0-40-80	15.78	5.21	0.56	3.66	1.55
3. 40-0-80	16.56	5.46	0.51	3.61	1.85
4. 40-40-0	15.46	5.10	0.43	3.53	1.57
5. 40-40-80	18.82	6.21	0.75	3.85	2.36

[1)]Prices :

cassava	dong	330/kg fresh roots
urea (46% N)		2200/kg
fused Mg.phos (15% P_2O_5)		900/kg
KCl (60% K_2O)		2400/kg

Table 13. Technological components selected and adopted by participating farmers from their FPR trials conducted from 1994 to 1998 in four countries in Asia.

Technology	China	Indonesia	Thailand	Vietnam
Varieties	SC8013***[1)] SC8634* ZM9247* OMR35-70-7*	Faroka*** 15/10* OMM90-6-72*	Kasetsart 50*** Rayong 5*** Rayong 90**	KM60*** KM94* SM95-3*** SM1717-12*
Fertilizer practices	15-5-20+Zn +chicken manure 300kg/ha*	FYM 10 t/ha (T)+ 90 N+36 P_2O_5+ 100 K_2O**	15-15-15 156 kg/ha***	FYM 10 t/ha (TP)+ 80 N-40P_2O_5+ 80 K_2O**
Intercropping	monoculture(TP) C+peanut*	C+maize(TP)	monoculture(TP) C+pumpkin* C+mungbean*	monoculture(TP) C+taro(TP) C+peanut***
Soil conservation	sugarcane barrier*** vetiver barrier*	*Gliricidia* barrier** *Leucaena* barrier* contour ridging**	vetiver barrier*** sugarcane barrier**	*Tephrosia* barrier*** vetiver barrier* pineapple barrier*

1) * = some adoption
** = considerable adoption
*** = widespread adoption
TP = traditional practice; FYM=farmyard manure.