Working with Farmers: The Key to Achieving Adoption of More Sustainable Cassava Production Practices on Sloping Land in Asia[1]

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ABSTRACT

Farmers in Asia like to grow cassava because the crop will tolerate long dry periods and poor soils, and will produce reasonable yields with little inputs. Most farmers realize, however, that cassava production on slopes can cause severe erosion, while production without fertilizer inputs may lead to a decline in soil productivity. Research has shown that cassava yields can be maintained for many years with adequate application of fertilizers, and that there are various ways to reduce erosion. Adoption of erosion control practices, however, has been minimal as farmers generally see little short-term benefits of these practices.

To enhance the adoption of soil conserving practices and improve the sustainability of cassava production, a farmer participatory research (FPR) approach was used to develop not only the best soil conservation practices, but also to test new varieties, fertilization and cropping systems that tend to produce greater short-term benefits. The FPR methodology was initially developed in 2-3 sites each in China, Indonesia, Thailand and Vietnam, but has now extended to about 99 villages in Thailand, Vietnam and China. The methodology includes the conducting of RRAs in each site, farmer evaluation of a wide range of practices shown in demonstration plots, FPR trials with farmer-selected treatments on their own fields, field days with discussions to select the best among the tested practices, scaling-up to larger fields, and farmer participatory dissemination to neighbors and other communities. Based on the results of these trials, farmers have readily adopted better varieties, fertilization and intercropping practices, and many farmers have now adopted the planting of contour hedgerows to control erosion. The resulting increases in cassava yields in Asia over the past eight years have increased the annual gross income of cassava farmers by an estimated 275 million US dollars.

Keywords: cassava, erosion control, farmer participatory research (FPR) and extension (FPE), Thailand, Vietnam, China.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is usually grown by smallholders in upland areas with poor soils and low or unpredictable rainfall. In some countries the crop is grown on steep slopes, but in others it is grown mainly on gentle slopes; in both cases,soil erosion can be serious. Moreover, cassava farmers seldom apply adequate amounts of fertilizers or manures to replace the nutrients removed in the harvested products. Thus, both erosion and nutrient extraction can result in a decline in soil fertility and a gradual degradation of the soil resource.

The fact that farmers do not apply sufficient fertilizers and do not use soil conservation practices when the crop is grown on slopes is more a socio-economic rather than a technical problem. Research has shown many ways to maintain or improve soil fertility and reduce erosion, but farmers usually consider these practices too costly or requiring too much labor. To overcome these obstacles to adoption it is necessary to develop simple practices that are suitable for the local situation and that provide short-term benefits to the farmer as well as long-term benefits in terms of resource conservation. Being highly site specific these practices can best be developed by the farmers themselves, on their own fields, in collaboration with research and extension personnel.

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Thus, a project was initiated, with financial support from the Nippon Foundation in Tokyo, Japan, to develop a farmer participatory methodology for the development and dissemination of more sustainable production practices in cassava-based cropping systems, that will benefit a large number of poor farmers in the uplands of Asia.

MATERIALS AND METHODS

1. First Phase (1994-1998)

The first phase of the project was conducted in four countries, i.e. China, Indonesia, Thailand and Vietnam. The project was coordinated by CIAT and implemented in collaboration with research and extension organizations in each of the four countries. During an initial training course on farmer participatory research (FPR) methodologies, each country designed a work plan to implement the project. The steps in the process, from diagnosing the problem to adoption of suitable solutions, are shown in **Figure 1**. The outstanding feature of this approach is that farmers participate in every step and make all important decisions.

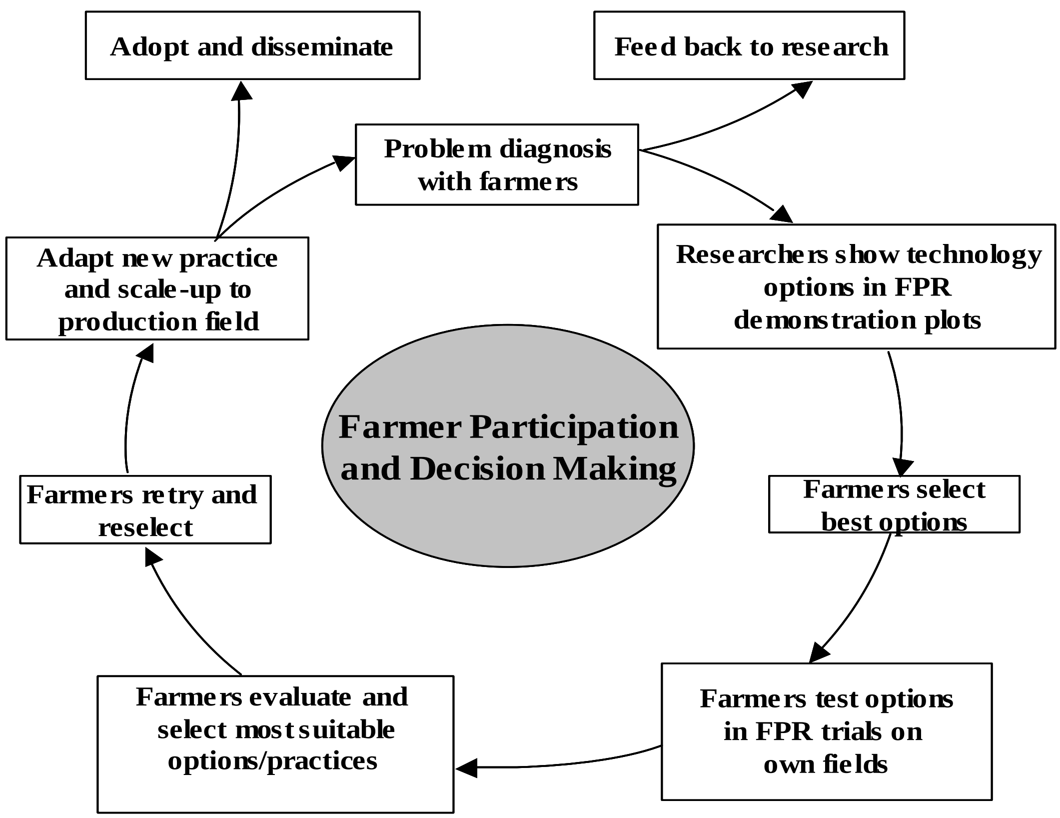

Figure 1. Farmer participatory model used for the development of sustainable cassava-based cropping systems in Asia.

a. Pilot site selection

Suitable pilot sites were pre-selected in areas where cassava is an important crop, where it is grown on slopes and erosion is a serious problem. Detailed information obtained through Rapid Rural Appraisals (RRA) in each site have been reported by Nguyen The Dang *et al.* (1998), Utomo *et al.* (1998), Vongkasem *et al*. (1998) and Zhang Weite *et al.* (1998). After conducting the RRAs, one or two suitable pilot sites (villages or subdistricts) were selected to work with farmers in the development and dissemination of suitable varieties and production practices.

b. Demonstration plots

Each year demonstration plots were laid out on an experiment station or a farmer's field to show the effect of many alternative treatments on yield, income and soil erosion. Farmers from the selected pilot sites visiting the trial were asked to discuss and score the usefulness of each treatment. From this range of many options farmers usually selected 3-4 treatments that they considered most useful for their own conditions. Some farmers then volunteered to test these treatments in FPR trials on their own fields.

In both the demonstration plots and FPR erosion control trials on farmers' fields, a simple methodology was used to measure soil loss due to erosion in each treatment. Plots were laid out along the contour on a uniform slope; along the lower side of each plot a ditch was dug and covered with plastic. Small holes in the plastic allowed runoff water to seep away, while eroded sediments remained on the plastic. These sediments were collected and weighed several times during the cropping cycle. After correcting for moisture content, the amount of dry soil loss per hectare was calculated for each treatment. This simple methodology gives both a visual as well as a quantitative indication of the effectiveness of the various practices in controlling erosion (Howeler, 2001; 2002).

c. FPR trials

The FPR trials did not only involve soil conservation practices, but also new varieties, intercropping systems and fertilization, with the objective of developing a combination of practices that would increase farmers' income, reduce erosion and improve soil fertility. During the first phase of the project, farmers in the four countries conducted a total of 177 FPR erosion control trials, 157 variety trials, 98 fertilizer trials and 35 intercropping trials, for a total of 467 trials. At time of harvest, field days were organized in each site to harvest the various trials by the participating farmers and their neighbors. The yields of cassava and intercrops, the dry soil loss due to erosion, as well as the gross income, production costs and net income were calculated for each treatment and presented in a joint meeting to the farmers. After one or more years of testing in small plots, farmers quickly identified the best varieties and production practices for their area and started using those on larger areas of their production fields (Howeler, 2002).

2. Second Phase (1999-2003)

The second phase of the project was conducted in collaboration with five institutions in Thailand, six in Vietnam and three in China (**Table 1**). During the second phase the emphasis shifted from participatory research (FPR) to extension (FPE) in order to reach more farmers and achieve more widespread adoption.

Table 1. Partner institutions collaborating in the second phase of the Nippon Foundation cassava project in Asia.

1. Research and extension organizations in Thailand
-Department of Agriculture (DOA)
-Department of Agricultural Extension (DOAE)
-Land Development Department (LDD)
-Kasetsart University (KU)
-The Thai Tapioca Development Institute (TTDI)
2. Research and extension organizations in Vietnam
-Thai Nguyen University of Agriculture and Forestry (TNUAF)
-National Institute for Soils and Fertilizers (NISF)
-Vietnam Agricultural Science Institute (VASI)
-Hue University of Agriculture and Forestry (HUAF)
-Institute of Agricultural Sciences of South Vietnam (IAS)
-Tu Duc University of Agriculture and Forestry (TDUAF)
3. Research and extension organizations in China
-Chinese Academy for Tropical Agricultural Sciences (CATAS)
-Guangxi Subtropical Crops Research Institute (GSCRI)
-Honghe Animal Husbandry Station of Yunnan

Once farmers had selected certain practices and wanted to adopt those on their fields, the project staff tried to help them; for instance, in setting out contour lines to plant hedgerows for erosion control, or to obtain seed or vegetative planting material of the selected hedgerow species, intercrops or new cassava varieties.

During both the first and second phase of the project some collaborative research continued on-station in order to develop better technologies that farmers could test on their own fields.

RESULTS AND DISCUSSION

First Phase (1994-1998): Farmer Participatory Research (FPR)

a. FPR trials

Table 2 shows a typical example of an FPR erosion control trial conducted by six farmers having adjacent plots on about 40% slope. It is clear that contour hedgerows of vetiver grass, *Tephrosia candida* or pineapple reduced erosion to about 30% of that in the check plot, while intercropping with peanut and planting vetiver hedgerows markedly increased net income. Results of many other FPR trials have been reported by Nguyen The Dang *et al*. (2001), Huang Jie *et al*. (2001), Utomo *et al*. (2001) and Vongkasem *et al.* (2001).

b. Scaling-up and adoption

After having selected the most promising varieties and production practices from FPR trials, farmers generally like to test some of these on small areas of their production fields, making adaptations if necessary. Some practices may look promising on small plots, but are rejected as impractical when applied on larger areas; this may be due to lack of sufficient planting material (like vetiver grass) or lack of markets for selling the products (like pumpkin or lemon grass).

Table 2. 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 1997 (3rd year).

Treatment[1)]	Slope (%)	Dry soil loss (t/ha)	Yield (t/ha) cassava	Yield (t/ha) peanut[1)]	Gross income[2)]	Product. costs	Net income	Farmers ranking
					-------(mil.	dong/ha)------		
1. C monocult., with fertilizer, no hedgerows(TP)	40.5	106.1	19.17	-	9.58	3.72	5.86	6
2. C+P, no fertilizer, no hedgerows	45.0	103.9	13.08	0.70	10.04	5.13	4.91	5
3. C+P, with fertilizer, no hedgerows	42.7	64.8	19.23	0.97	14.47	5.95	8.52	-
4. C+P, with fertilizer, *Tephrosia* hedgerows	39.7	40.1	14.67	0.85	11.58	5.95	5.63	3
5. C+P, with fertilizer, pineapple hedgerows	32.2	32.2	19.39	0.97	14.55	5.95	8.60	2
6. C+P, with fertilizer, vetiver hedgerows	37.7	32.0	23.71	0.85	16.10	5.95	10.15	1
7. C monocult, with fert., *Tephrosia* hedgerows	40.0	32.5	23.33	-	11.66	4.54	7.12	4

[1)] Fertilizers = 60 kg N + 40 P_2O_5, + 120 K_2O/ha; all plots received 10 t/ha pig manure
TP=farmer traditional practice
[2)] Prices: cassava (C) dong 500/kg fresh roots
peanut (P) 5000/kg dry pods
1US$ = approx. 13.000 dong

Second Phase (1999-2003): Farmer Participatory Research (FPR) and Extension (FPE)

Since the objective of the second phase was to achieve widespread adoption of more sustainable production practices by as large a number of farmers as possible, it was necessary to markedly expand the number of pilot sites and to develop farmer participatory extension (FPE) methodologies to disseminate the selected practices and varieties to many more farmers.

a. Farmer participatory research (FPR)

Implementing the project in collaboration with many different institutions in China, Thailand and Vietnam (**Table 1**), and with generous financial support from the Nippon Foundation, it was possible to expand the number of pilot sites each year. In 2001 the project was working in about 50 sites, and this further increased to 99 sites by the end of the project in 2003 (**Figure 2**). Once the benefits of the new technologies became clear, the number of sites increased automatically, as neighboring villages also wanted to participate in order to increase their yields and income.

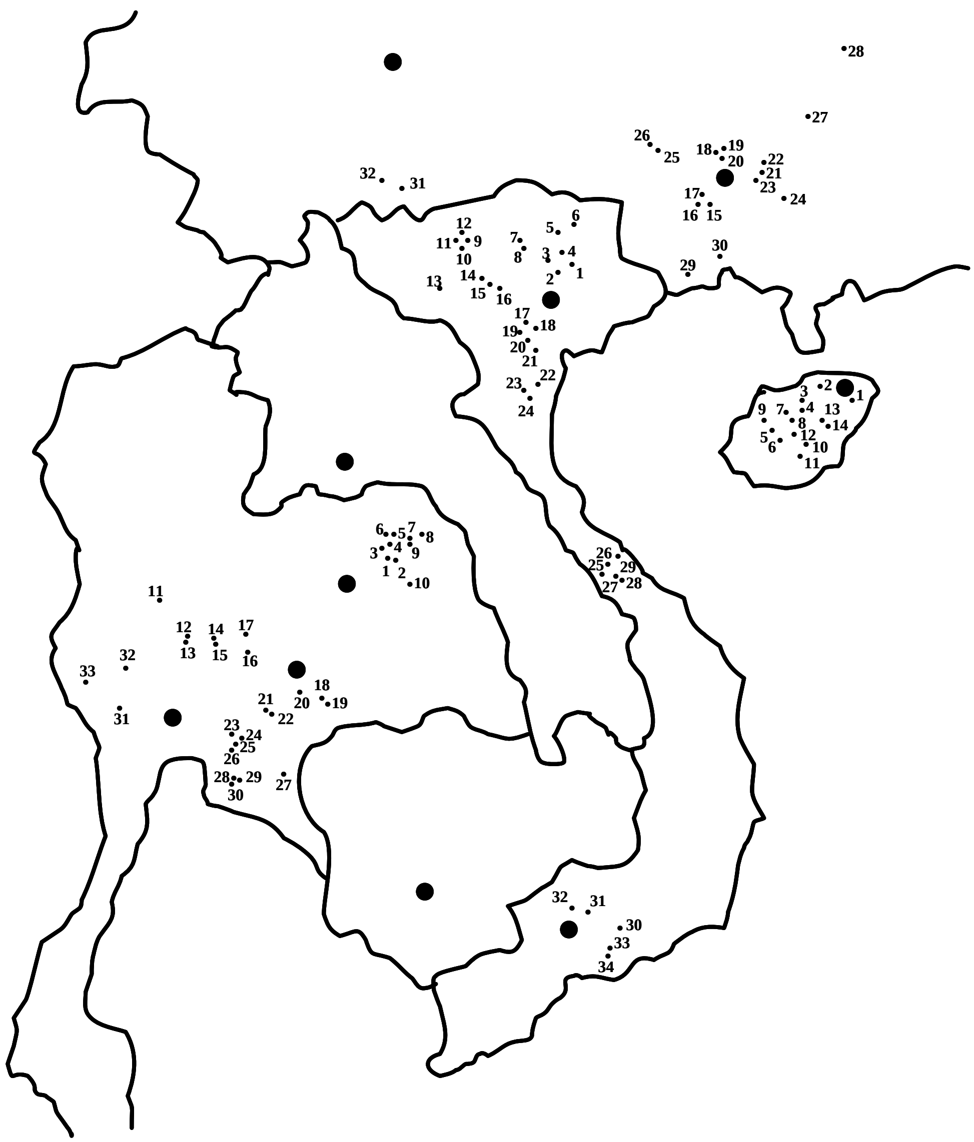

Figure 2. Location of FPR pilot sites in China, Thailand and Vietnam in the Nippon Foundation cassava project in 2003.

Whenever the project extended to a "new" site, the process outlined above was re-initiated, i.e. an RRA was conducted, interested farmers visited demonstration plots and/or made a cross-visit to an already established site, they conducted FPR trials, discussed results and eventually adopted those varieties or practices they had selected as most suitable for their own conditions. **Table 3** shows the number and type of FPR trials conducted in China, Thailand and Vietnam during the second phase of the project. While initially farmers were mainly interested in testing new varieties, fertilization, intercropping and erosion control practices, during the later part of the project they also wanted to test the use of organic or green manures, weed control, plant spacing and even leaf production and pig feeding. During the second phase of the project a total of 1,154 FPR trials were conducted by farmers on their own fields.

Table 3. Number of FPR trials conducted in the 2d phase of the Nippon Foundation Project in China, Thailand and Vietnam.

Country	Type of FPR trial	1999	2000	2001	2002	2003	**Total**
China	Varieties	9	9	20	69	20	**127**
	Erosion control	3	5	8	17	-	**33**
	Fertilization	-	-	-	4	-	**4**
	Intercropping	-	-	-	9	-	**9**
	Pig feeding	-	-	-	59	-	**59**
		12	**14**	**28**	**158**	**20**	**232**
Thailand	Varieties	11	16	16	19	25	**87**
	Erosion control	14	10	6	-	11	**41**
	Chemical fertilizers	16	6	23	17	17	**79**
	Chem.+org fertilizers	-	-	10	11	11	**32**
	Green manures	-	-	13	11	15	**39**
	Weed control	-	-	17	5	10	**32**
	Plant spacing	-	-	3	-	2	**5**
	Intercropping	-	-	16	7	-	**23**
		41	**32**	**104**	**70**	**91**	**338**
Vietnam	Varieties	12	31	36	47	35	**161**
	Erosion control	16	28	29	30	23	**126**
	Fertilization	1	23	36	24	24	**108**
	Intercropping	-	14	32	31	26	**103**
	Weed control	-	3	-	-	3	**6**
	Plant spacing	-	1	7	19	8	**35**
	Leaf production	-	-	2	2	1	**5**
	Pig feeding	-	-	11	16	13	**40**
		29	**100**	**153**	**169**	**133**	**584**
Total		**82**	**146**	**285**	**397**	**244**	**1,154**

b. Farmer participatory Extension (FPE)

The following farmer participatory extension methods were found to be very effective in raising farmers' interest in soil conservation, in disseminating information about improved varieties and cultural practices, and in enhancing adoption of soil conserving practices:

i. Cross-visits

Farmers from new sites were usually taken to visit older sites that had already conducted FPR trials and had adopted some soil conserving technologies. These cross-visits, in which farmers from the older site could explain their reasons for adopting new technologies was a very effective way of farmer-to-farmer extension. After these cross-visits, farmers in some new sites decided to adopt some technologies immediately, while others decided to conduct FPR trials in their own fields first. In both cases, the "FPR teams" of the various collaborating institutions, together with provincial, district or subdistrict extension staff, helped farmers to establish the trials, or they provided seed or planting materials required for the adoption of the new technologies.

ii. Field days

At time of harvest, field days were organized at the site in order to harvest the trials and discuss the results. Farmers from neighboring villages were usually invited to participate in these field days, to evaluate each treatment in the various trials and to discuss the *pros* and *cons* of the various practices or varieties tested.

In a few cases, large field days were also organized with participation of hundreds of neighboring farmers, school children, local and high-level officials, as well as representatives of the press and TV. The broadcasting or reporting about these events also helped to disseminate the information about suitable technologies. During the field days farmers explained the results of their own FPR trials to the other visiting farmers, while literature about the project and the results obtained was distributed.

iii. Training

Research and extension staff involved in the project had previously participated in Training-of-Trainers courses in FPR methodologies, including practical training sessions with farmers in some of the pilot sites. While some participants were initially skeptical, most course participants became very enthusiastic about this new approach once they started working more closely with farmers.

In addition, 2-3 key farmers from each site together with their local extension agent were invited to participate in FPR training courses. The objective was to learn about the various FPR methodologies, the basics of doing experiments as well as the implementation of commonly selected technologies, such as setting out contour lines or the planting, maintenance and multiplication of hedgerow species. By spending several days together in these courses, the farmers and extensionist got to know each other well, and they were encouraged to form a local "FPR team" to help other farmers in their community conduct FPR trials or adopt the new technologies.

iv. Community-based self-help groups

Realising that effective soil conservation practices, such as planting of contour hedgerows, can best be done as a group, farmers from some sites decided to form their own “soil conservation group”. These community-based self-help groups are similar to “Land Care units”, that have been very effective in promoting soil conservation in the Philippines and Australia. In Thailand, the Dept. of Agric. Extension has encouraged farmers to set up these groups as a way of organizing themselves, to conduct FPR trials, to implement the selected practices, and to manage a rotating fund, from which members of the group can borrow money for production inputs. Thus, by 2003, a total of 21 “Cassava Development Villages” had been set up in the pilot sites. Each group needed to have at least 40 members, elect five officers to lead the group, and establish their own bylaws about membership requirements, election of officers, use of the rotating fund, etc. The formation of these groups helped to decide on collective action and to strengthen the community, while people gained confidence and the group became more self-reliant. When necessary, the group could request help from local or national extension services, obtain information about certain production problems, or get planting material of vetiver grass or other species for hedgerows or green manures. Some groups started their own vetiver grass nurseries to have planting material available when needed.

Effect of New Technologies on Cassava Yield and Soil Loss by Erosion

Farmers are interested in testing new technologies only if those technologies promise substantial economic benefits over their traditional practices. Thus, strategic and applied research need to continue to produce and select still better varieties, better production practices and new utilization options. As such, some collaborative research in the area of agronomy and soil management continued.

1. Long-term fertility maintenance:

Long-term NPK trials were continued in four locations, one each in north and south Vietnam, one in Hainan island of China and one in southern Sumatra of Indonesia. **Figure 3** shows the effect of annual applications of various levels of N, P, and K on the yield and starch content of two varieties during the 13th year of continuous cropping in Hung Loc Center in south Vietnam. It is clear that, similar to most other locations, the main yield response was to the application of K, while there were minor responses to the application of N and P and mainly in the higher yielding variety SM 937-26. The combined application of 160 kg N, 80 P_2O_5 and 160 K_2O/ha increased yields from about 10 to 30 t/ha. **Figure 4** shows the absolute and relative response to application of N, P and K as well as the change in P and K status of the soil during the entire 13-year period. Initially there was no response to any nutrient as the organic matter, P and K levels were still adequate and root yields were relatively low. With the introduction of new higher yielding varieties in the 4th year, the root yields increased and nutrient depletion, especially K, increased, leading to an ever more pronounced response to K application. Even after 13 years soil-P remained above the critical level, which explains the lack of a P-response.

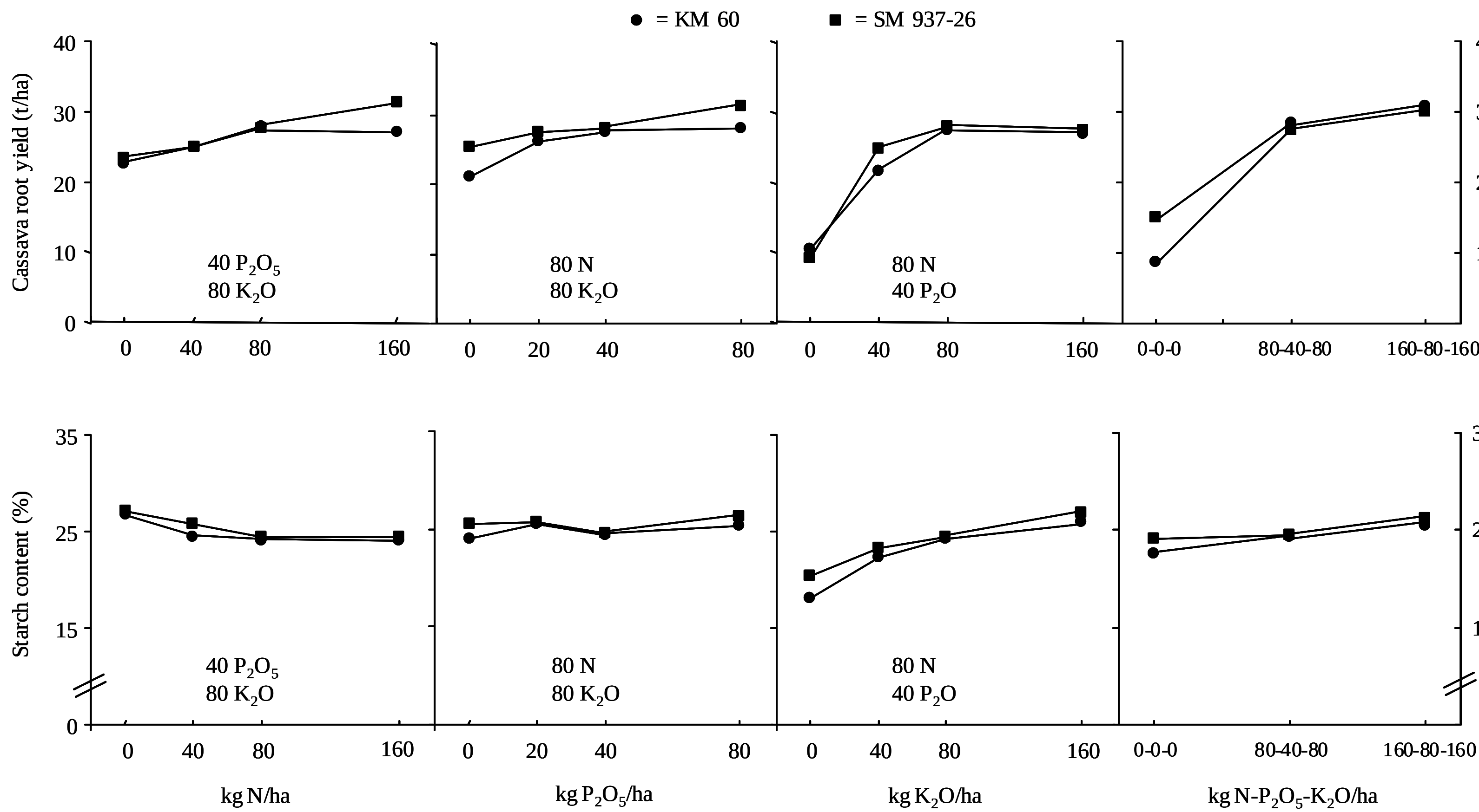

Figure 3. Effect of annual applications of various levels of N, P and K on the root yield and root starch content of two cassava varieties grown at Hung Loc Agric. Research Center, Thong Nhat, Dongnai, Vietnam in 2002/03 (13th year).

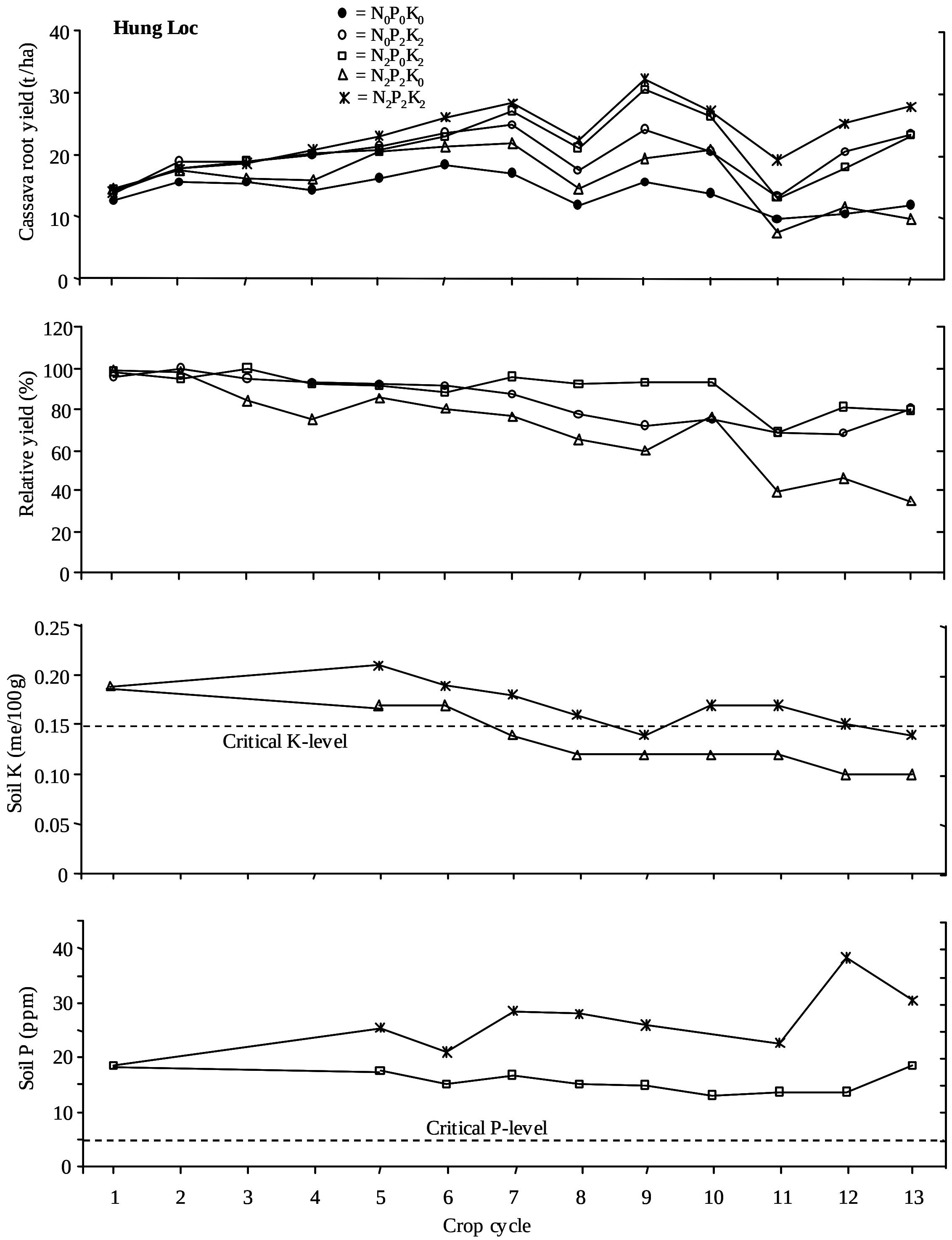

Figure 4. Effect of annual applications of N, P and K on cassava root yield, relative yield (yield without the nutrient over the highest yield with the nutrient) and the exchangeable K and available P (Bray 2) content of the soil during thirteen years of continuous cropping in Hung Loc Agric. Research Center, Dong Nai, Vietnam.

2. Combined use of animal manure and chemical fertilizer

Table 4 shows the effect of combining various rates of farmyard (=pig) manure (FYM) with chemical fertilizers, in this case N and K, in Thai Nguyen University in north Vietnam. Without manure or fertilizers the yield was only 3.25 t/ha; with the application of only 80 kg N and 80 K_2O/ha yields increased to 15.47 t/ha; with a high rate of 15 t/ha of manure it was 13.11 t/ha, while the combined application of 10 t/ha of manure with N and K produced the highest yield of 18.70 t/ha. However, the combination producing the highest net income was 5 t/ha of manure with 80 kg N and 80 K_2O/ha. The net income was much higher using chemical fertilizers alone or in combination with a modest amount of FYM as compared to using only FYM. From this and other trials it is clear that farmers can increase yields and income by reducing their application of pig manure as long as it is combined with adequate levels of N and K in chemical fertilizers.

Table 4. Effect of the application of FYM[1)] and chemical fertilizers on cassava yield and economic benefit at Thai Nguyen University of Agric. and Forestry in Thai Nguyen province in 2001 (2nd year).

Treatments[1)]	Cassava root yield (t/ha)	Height at 8 months (cm)	Leaf life at 3 months (days)	Harvest index	Gross income[2)]	Fert. costs[2)]	Product. costs[3)]	Net income
					------------('000 dong/ha)----------			
1. no fertilizers, no FYM	3.25	87.1	46.5	0.39	1,625	0	2,800	-1.175
2. 5t FYM/ha	7.79	116.6	55.2	0.49	3,895	500	3,300	0.595
3. 10t FYM/ha	10.02	133.9	65.0	0.52	5,010	1,000	3,800	1.210
4. 15t FYM/ha	13.11	151.8	66.1	0.52	6,555	1,500	4,300	2.255
5. 80N+80K_2O/ha, no FYM	15.47	154.5	66.8	0.50	7,735	680	3,580	4.155
6. 80N+80K_2O/ha + 5t FYM/ha	17.98	180.0	68.5	0.48	8,990	1,180	4,080	4.910
7. 80N+80K_2O/ha + 10t FYM/ha	18.70	188.3	70.8	0.49	9,350	1,680	4,580	4.770
8. 80N+80K_2O/ha + 15t FYM/ha	18.50	196.6	73.1	0.48	9,250	2,180	5,080	4.170

[1)] FYM = farmyard manure (pig manure)
[2)] Prices: cassava: dong 500/kg fresh roots
urea (45% N) 2,100/kg
KCl (60% K_2O) 2,300/kg
manure+application 100/kg
[3)]Cost of cassava cultivation: 2.8 mil. dong/ha; cost of chemical fertilizer application: 0.10 mil. dong/ha

3. Green manures and/or chemical fertilizers

Table 5 shows the results of a green manure experiment conducted for two consecutive years in Khaw Hin Sorn station in Chachoengsao province of Thailand. All green manure species were intercropped between cassava rows and planted one month after planting cassava; they were pulled out and mulched two month later. During the first year, the highest cassava yields were obtained with only chemical fertilizers applied at 25 or 75 kg/rai; all green manures competed with cassava resulting in lower yields. During the second year, the highest yield was obtained by application of 75 kg/rai of 15-7-18 fertilizers; however, the mulching and later incorporation of jackbean (*Canavalia ensiformis*) combined with 25 kg/rai of 15-7-18 resulted in higher yields than the same rate of fertilizer by itself. Thus, in this second year the beneficial effect of the *Canavalia* green manure outweighed its competitive effect. For all other green manure species, the competitive effect was still greater than the beneficial effect. *Crotalaria juncea*, *Mucuna* and cowpea were particularly competitive, while mungbean and pigeon pea were intermediately competitive. Considering all costs involved, the application of chemical fertilizers alone generally produced the highest net income, but in both years the combination of a low level of fertilizers with *Canavalia* green manure produced the second highest net income. These and other green manure trials (Howeler *et al*., 1998) indicate that green manures are seldom beneficial during the first year but their beneficial effect increases over time.

Table 5. Effect of green manures and/or chemical fertilizers on the root yield and starch content of cassava, KU 50, as well as net income when grown at Khaw Hin Sorn research station in Khaw Hin Sorn, Chachoengsao, Thailand during two consecutive years in 2002/03 and 2003/04.

	Cassava yield (t/ha)		Starch content (%)		Net income ('000 baht/ha)	
Treatments[1)]	1st year	2nd year	1st year	2nd year	1st year	2nd year
1. Check without GM; 25 kg/rai 15-7-18	46.45	26.28	24.6	23.6	22.36	14.54
2. *Crotalaria juncea;* 25 kg/rai 15-7-18	36.58	20.83	24.3	22.7	16.25	10.04
3. *Canavalia ensiformis;* 25 kg/rai 15-7-18	40.35	27.07	24.9	23.1	19.06	15.16
4. Pigeon pea ICPL 304; 25 kg/rai 15-7-18	38.23	24.18	23.9	23.4	16.96	13.01
5. Cowpea CP 4-2-3-1; 25 kg/rai 15-7-18	38.54	21.66	23.7	22.3	16.87	10.41
6. *Mucuna;* 25 kg/rai 15-7-18	36.73	21.17	24.9	23.8	16.78	10.78
7. Mungbean; 25 kg/rai 15-7-18	40.07	25.08	24.2	23.6	18.54	14.06
8. Check without GM; 75 kg/rai 15-7-18	43.44	32.16	25.5	23.8	18.77	16.89

[1)] GM = green manure; all green manures were planted between cassava rows one month after planting cassava and were pulled up or cut off two months later and mulched; 1 ha = 6.25 rai

4. Effect of various soil conservation practices on cassava yield and soil loss by erosion

Table 6 shows the average effect of various soil conservation practices on relative cassava yields and dry soil loss by erosion from numerous trials conducted in Thailand from 1994 to 2003. Closer plant spacing, lemon grass hedgerows and contour ridging were the most effective in both increasing yields and decreasing erosion. Most other contour hedgerow species, including vetiver grass, decreased cassava yields – mostly by reducing the area available for cropping and by competition with nearby cassava – but were very effective in reducing soil loss by erosion. Most effective in reducing erosion were vetiver grass, *Paspalum atratum* and lemon grass, which reduced erosion by 33 to 47%. Intercropping was usually not effective in reducing erosion, while up-and-down ridging and especially the lack of fertilization markedly increased erosion. Similar results were obtained in Vietnam (**Table 7**) where hedgerows of vetiver grass, *Tephrosia candida* and *Paspalum atratum* all decreased erosion by about 50%, while also increasing cassava yields 10-13%.

Table 6. Effect of various soil conservation practices on the average[1)] relative cassava yield and dry soil loss due to erosion as determined from soil erosion control experiments, FPR demonstration plots and FPR trials conducted in Thailand from 1994 to 2003.

	Soil conservation practices[2)]	Relative cassava yield (%)	Relative dry soil loss (%)
1.	With fertilizers; no hedgerows, no ridging, no intercrop (check)	100	100
2.	With fertilizers; vetiver grass hedgerows, no ridging, no intercrop**	90 (25)	58 (25)
3.	With fertilizers; lemon grass hedgerows, no ridging, no intercrop**	110 (14)	67 (15)
4.	With fertilizers; sugarcane for chewing hedgerows, no intercrop	99 (12)	111 (14)
5.	With fertilizers; *Paspalum atratum* hedgerows, no intercrop**	88 (7)	53 (7)
6.	With fertilizers; *Panicum maximum* hedgerows, no intercrop	73 (3)	107 (4)
7.	With fertilizers; *Brachiaria brizantha* hedgerows, no intercrop*	68 (3)	78 (2)
8.	With fertilizers; *Brachiaria ruziziensis* hedgerows, no intercrop*	80 (2)	56 (2)
9.	With fertilizers; elephant grass hedgerows, no intercrop	36 (2)	81 (2)
10.	With fertilizers; contour ridging, no hedgerows, no intercrop**	108 (17)	69 (17)
11.	With fertilizers; up-and-down ridging, no hedgerows, no intercrop	104 (20)	124 (20)
12.	With fertilizers; closer spacing, no hedgerows, no intercrop**	116 (10)	88 (11)
13.	With fertilizers; C+peanut intercrop	72 (11)	102 (12)
14.	With fertilizers; C+pumpkin or squash intercrop	90 (13)	109 (15)
15.	With fertilizers; C+sweetcorn intercrop	97 (11)	110 (14)
16.	With fertilizers; C+mungbean intercrop*	74 (4)	41 (4)
17.	No fertilizers; no hedgerows, no or up/down ridging	96 (9)	240 (10)

1) number in parenthesis indicates the number of experiments/trials from which the average values were calculated.
2) C = Cassava
** = most promising soil conservation practices; * = promising soil conservation practices

Table 7. Effect of various soil conservation practices on the average[1)] relative cassava yield and dry soil loss due to erosion as determined from soil erosion control experiments, FPR demonstration plots and FPR trials conducted in Vietnam from 1993 to 2003.

	Soil conservation-practices	Rel. cassava yield (%)		Rel. dry soil loss (%)	
		Cassava monoculture	Cassava + peanut	Cassava monoculture	Cassava + peanut
1.	With fertilizers; no hedgerows (check)	100	-	100	-
2.	With fertilizers; vetiver grass hedgerows**	113 (17)	115 (23)	48 (16)	51 (23)
3.	With fertilizers; *Tephrosia candida* hedgerows**	110 (17)	105 (23)	49 (16)	64 (23)
4.	With fertilizers; *Flemingia macrophylla* hedgerows*	103 (3)	109 (4)	51 (3)	62 (3)
5.	With fertilizers; *Paspalum atratum* hedgerows**	112 (17)	-	50 (17)	-
6.	With fertilizers; *Leucaena leucocephala* hedgerows*	110 (11)	-	69 (11)	-
7.	With fertilizers; *Gliricidia sepium* hedgerows*	107 (11)	-	71 (11)	-
8.	With fertilizers; pineapple hedgerows*	100 (8)	103 (9)	48 (8)	44 (9)
9.	With fertilizers; vetiver+*Tephrosia* hedgerows	-	102 (7)	-	62 (7)
10.	With fertilizers; contour ridging; no hedgerows*	106 (7)	-	70 (7)	-
11.	With fertilizers; closer spacing, no hedgerows	122 (5)	-	103 (5)	-
12.	With fertilizers; peanut intercrop; no hedgerows*	106 (11)	100	81 (11)	100
13.	With fertilizers; maize intercrop; no hedgerows	69 (3)	-	21 (3)	-
14.	No fertilizers; no hedgerows	32 (4)	92 1(5)	137 (4)	202 (12)

1) number in parenthesis indicates the number of experiments/trials from which the average values were calculated.
** = most promising soil conservation practices; * = promising soil conservation practices

The beneficial effects of contour hedgerows tend to increase markedly over time. **Figure 5** shows the long-term effect of contour hedgerows of vetiver grass and *Tephrosia candida* on relative cassava yields and soil loss as compared to the check plot without hedgerows; data are average values from three FPR erosion control trials conducted for nine consecutive years in north Vietnam. Although the results are rather variable, there is a clear trend that the two types of hedgerows caused a 20-40% increase in cassava yields and reduced soil losses by erosion to 20-40% of those in the check plots without hedgerows. Vetiver grass tended to become more effective in reducing soil losses than *Tephrosia*, firstly because the grass is more effective in filtering out suspended soil sediments, and secondly because *Tephrosia* hedgerows need to be replanted every 3-4 years, in contrast to vetiver grass which is more or less permanent. While farmers claim that *Tephrosia* improves the fertility of the soil more so than vetiver grass, the data show that vetiver increased cassava yields more than *Tephrosia*, probably by reducing losses of top soil and fertilizers and improving water infiltration and soil moisture content.

Figure 6 shows similar results from a soil erosion control experiment conducted for six consecutive years on about 15% slope at Hung Loc Agric. Research Center in south Vietnam. In this case, contour hedgerows of vetiver grass, *Leucaena* and *Gliricidia* all increased cassava yields as compared to the check plot without hedgerows; they also decreased soil losses by erosion. *Leucaena* was the most effective in increasing yields by supplying nitrogen in leaf prunings, while vetiver was the most effective in reducing erosion. Similar to the data from north Vietnam in **Figure 5**, the effectiveness in controlling erosion increased over time. During the 6th year, the soil loss with vetiver hedgerows was only about 20% of that without hedgerows. These two sets of data indicate that hedgerows of vetiver grass are among the most effective ways to control erosion, and that the effectiveness of all types of hedgerows increases over time.

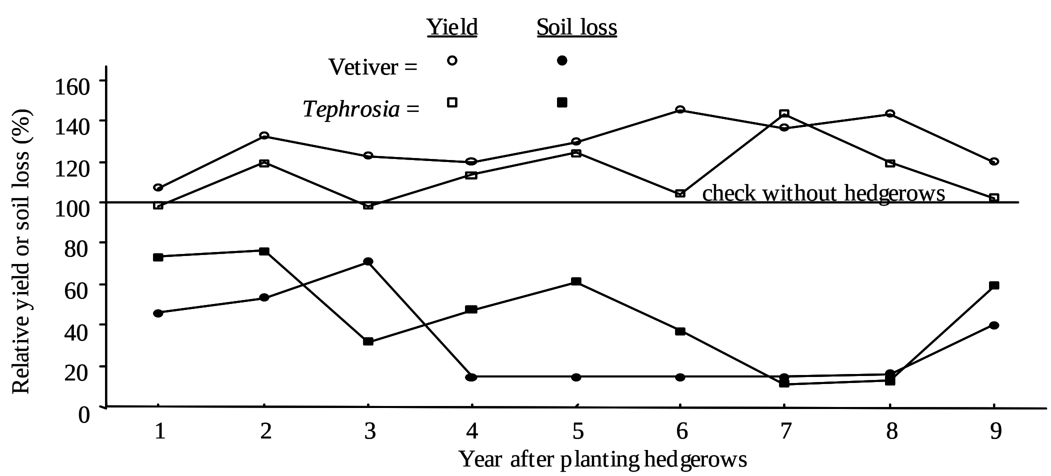

Figure 5. Trend in relative yield and relative soil loss by erosion when cassava was planted with contour hedgerows of vetiver grass or Tephrosia candida during nine consecutive years of cassava cropping. Data are average values for one FPR erosion control trial in Kieu Tung and two trials in Dong Rang in North Vietnam from 1995 to 2003.

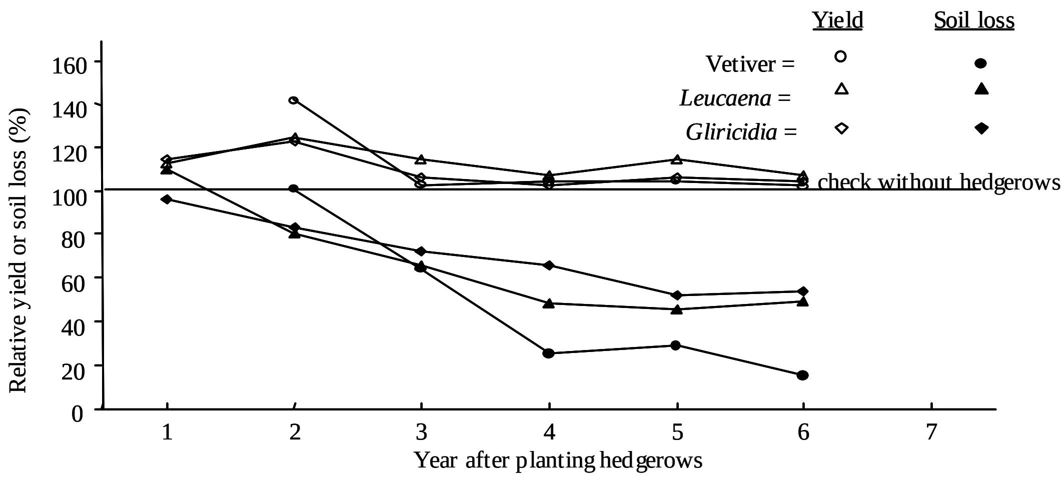

Figure 6. Trend in relative yield and relative soil loss by erosion when cassava was planted with contour hedgerows of vetiver grass, Leucaena leucocephala or Gliricidia sepium in comparison with the check without hedgerows during six consecutive years in Hung Loc Agric. Research Center in South Vietnam from 1997 to 2003.

ADOPTION AND IMPACT

After conducting their own FPR trials, or after a cross-visit to another village where those trials were being conducted, farmers often decided to adopt one or more technologies on their production fields with the hope of increasing yields or income and protecting the soil from further degradation.

In Thailand, practically all of the cassava area is now planted with new varieties and about 75% of farmers apply some chemical fertilizers (TTDI, 2000), although usually not enough nor in the right proportion. As a result of the FPR fertilizer trials, farmers started to apply more K, while the official fertilizer recommendation for cassava was changed from an NPK ratio of 1:1:1 to 2:1:2. After trying various ways of controlling erosion, most farmers selected the planting of vetiver grass contour hedgerows as the most suitable. **Table 8** indicates that by the end of 2003, about 1038 farmers had planted a total of 1.63 million vetiver plants, corresponding to about 145 km of hedgerows.

Table 9 shows how in Vietnam the number of households in the pilot sites adopting the various technology components increased over time, with most farmers adopting new varieties. This is partially due to the testing in FPR variety trials, but is also due to the planting of new varieties by non-participating farmers in or near the pilot sites. During 2002 and 2003 farmers in Van Yen district of Yen Bai province in north Vietnam planted a total of 500 km of double hedgerows of *Tephrosia candida* or *Paspalum atratum* to control erosion, and they planted about 3000 ha of new cassava varieties with improved fertilizer practices. This increased average yields from 10 t/ha to about 30 t/ha.

Table 8. Extent of adoption of vetiver grass contour hedgerows for erosion control in various FPR pilot sites in Thailand in 2003.

				Adoption of vetiver grass hedgerows			
	Province	District	Subdistrict	No. of farmers	Cassava area with vetiver(ha)	Vetiver (no. of plants)	Vetiver hedgerows (km)[1)]
1.	Kalasin	Mueang	Phuu Po	61	49.0	85,500	8.6
2.	Kalasin	Mueang	Khamin	-	-		-
3.	Kalasin	Nong Kungsri	Nong Bua	67	110.4	111,600	11.2
4.	Kalasin	Sahatsakhan	Noonburi	63	59.2	86,170	8.6
5.	Kalasin	Sahatsakhan	Noon Nam Kliang	42	40.6	128,330	12.8
7.	Kalasin	Naamon	Naamon	50	24.0	200,000	20.0
8.	Kalasin	Huay Phueng	Nikhom	65	24.0	40,000	4..0
9.	Kalasin	Don Chaan	Dong Phayung	58	24.0	55,000	5.5
10.	Roy Et	Phoo Chai	Khampha-ung	30	2.9	2,000	0
11.	Kamphaengphet	Khanuwaralakburi	Bo Tham	42	27.2	68,000	3.0
12.	Chayaphum	Thep Sathit	Naayaang Klak	42	27.2	68,000	4.0
14.	Nakhon Ratchasima	Thepharak	Bueng Prue	-	-		-
15.	Nakhon Ratchasima	Thepharak	Bueng Prue	26	34.2	80,000	11.0
16.	Nakhon Ratchasima	Sri Khiiw	Paang Lako	-	-		-
17.	Nakhon Ratchasima	Daan Khun Thot	Baan Kaw	53	49.4	130,000	15.0
18.	Nakhon Ratchasima	Soeng Saang	Noon Sombuun	60	132.5	80,000	10.0
19.	Nakhon Ratchasima	Soeng Saaang	Sratakhian	0	4.8	20,000	2.0
20.	Nakhon Ratchasima	Khonburi	Tabaekbaan	27	24.0	50,000	0
21.	Prachinburi	Naadii	Kaeng Dinso	42	27.2	60,000	4.5
23.	Chachoengsao	SanaamChaikhet	Thung Prayaa	40	7.2	50,000	2.0
24.	Chachoengsao	Thaa Takiap	Khlong Takraw	42	27.2	100,000	5.3
27.	Sra Kaew	Wang Sombuun	Wang Sombuun	42	220.8	90,000	9.0
28.	Chonburi	Bo Thong	Kaset Suwan	60	2.4	30,000	3.0
31.	Ratchaburi	Baan Poong	Khaw Khalung	42	3.2	0	0
32.	Kanchanaburi	Law Khwan	Thung Krabam	42	27.2	80,000	3.0
33.	Kanchanaburi	Sai Yook	Sai Yook	42	3.2	20,000	2.0
	Total 11	**22**	**25**	**1,038**	**951.8**	**1,634,600**	**144.5**

[1)] Cassava area with hedgerows and hedgerow length are approximate, as some hedgerows were damaged by tractor while others needed to be partially replanted because of poor establishment due to drought.

Table 9. Extent of adoption of soil conservation practices and the estimated increase in yield and gross income of farmers in the FPR pilot sites in Vietnam from 2000 to 2003.

Year	Number of farmers	Area with soil conser. (ha)	Cassava yield (t/ha) Farmers' practice[1)]	Cassava yield (t/ha) With soil conservation	Percent yield increase	Increase in gross income (mil VND)[2)] per ha	total	per household
2000	62	21.12	12.11	13.75	13.5	0.574	12.123	0.196
2001	200	59.87	16.50	19.95	20.9	1.112	66.596	0.333
2002	222	88.85	20.60	25.48	23.7	1.952	173.728	0.782
2003	831	612.00	20.60[3)]	25.48[2)]		1.561	955.699	1.150
Total	831	612.00					1,208.146	

[1)] Farmers' practice includes most new technologies except soil conservation
[2)] Fresh root price: in 2000 350 VND/kg
in 2001 350 VND/kg in north, 200 in central and 290 in south
in 2002 400 VND/kg
in 2003 320 VND/kg (estimated)
[3)] Yields estimated from 2002
Source*: Tran Ngoc Ngoan, 2003*

Data in **Table 10** indicate that adoption of soil conservation practices in all sites in Vietnam increased yields, ranging from 13.5% in 2000 to 23.7% in 2002. **Table 10** also shows that the gross income, both per ha and per household, as a result of the adoption of soil conservation practices also increased very markedly over time. Results from both FPR trials and on-station research also indicate that the beneficial effect of contour hedgerows in terms of increasing yields and decreasing erosion increases over time (**Figures 5** and **6**). This is mainly because the planting of contour hedgerows, almost independent of the species used, will result in natural terrace formation, which over time reduces the slope and enhances water infiltration, thus reducing runoff and erosion. Well established hedgerows also become increasingly more effective in trapping eroded soil and fertilizers. Unfortunately, most FPR erosion control trials are conducted for only 1-2 years at the same site, so farmers do not quite appreciate the increases in beneficial effects that result over time. This, coupled with the fact that planting and maintaining hedgerows requires additional labor (and sometimes money for seed or planting material) while hedgerows take some land out of production and have initially little beneficial effect on yield, has hampered the more widespread acceptance and adoption of these soil conservation practices.

Table 10. Trend of adoption of new cassava technologies in the Nippon Foundation project sites in Vietnam from 2000 to 2003.

	Number of households adopting			
Technology component	2000	2001	2002	2003
1. New varieties	88	447	1,637	14,820
2. Improved fertilization	64	123	157	1,710
3. Soil conservation practices	62	200	222	831
4. Intercropping	127	360	689	4,250
5. Pig feeding with cassava root silage	-	759	967	1,172

[1)]Number of project sites: 1999 = 9; 2000=15; 2001=22; 2002=25; 2003=34

Source: *Tran Ngoc Ngoan, 2003.*

In order to determine the effect of this project on adoption of new technologies, an impact assessment was made by an outside consultant. He organized focus group discussions and collected data from farmers in eight representative project sites, as well as from farmers living within 10 km from those sites, who had not participated in the project. **Table 11** shows the percent of households (out of 832) who had adopted various technologies. New varieties were adopted by nearly all cassava farmers in Thailand and 46% in Vietnam; the use of chemical fertilizers had been adopted by 80-90% of households; intercropping by a majority of households in Vietnam, but by very few in Thailand. Contour ridging was adopted by about 30% of households in both Vietnam and Thailand, while contour hedgerows of vetiver grass was adopted by 24% of households in Thailand and only 7% in Vietnam; most farmers in Vietnam preferred the planting of *Tephrosia candida* or *Paspalum atratum*, as these are easier to plant (from seed) and can also serve as a green manure and animal feed, respectively. Thus, it is clear that adoption of specific practices varies from site to site, depending on local conditions and traditional practices.

Table 11. Extent of adoption of new technologies by farmers participating or not directly participating in the Nippon Foundation project in Thailand and Vietnam[1].

	Participants		Non-Participants		Total	
Technologies adopted	Thailand	Vietnam	Thailand	Vietnam	Thailand	Vietnam
Varieties						
- >75% improved varieties	100	48.3	86.6	44.7	90.2	46.1
- about 50% improved varieties	0	34.0	0.3	20.7	0.2	25.7
- mainly traditional varieties	0	16.3	0	34.6	0	27.7
- no cassava	0	1.4	13.0	0	9.6	0.5
Soil conservation practices						
- contour ridging	53.0	31.3	22.0	28.9	30.3	29.8
- hedgerows - vetiver grass	61.5	11.6	9.6	3.7	23.5	6.6
- *Tephrosia candida*	0	32.7	0	6.9	0	16.5
- *Paspalum atratum*	0.9	11.6	0	2.0	0.2	5.6
- pineapple	0	2.7	0	0.8	0	1.5
- sugarcane	1.7	0	0.6	0	0.9	0
- other hedgerows	3.4	7.5	0.3	1.6	1.1	3.8
- no soil conservation	20.5	29.3	70.8	59.3	57.4	48.1
Intercropping						
- with peanut	0.9	40.8	0.6	30.9	0.7	34.6
- with beans	0	23.8	0	27.2	0	26.0
- with maize	10.3	2.7	2.8	3.7	4.8	3.3
- with green manures	20.5	0	4.0	0	8.4	0
- other species	2.6	43.5	1.6	21.5	1.8	29.8
- no intercropping	71.8	20.4	90.4	47.6	85.4	37.4
Fertilization						
- chemical fertilizers	98.3	79.6	84.5	80.1	88.2	79.9
- farm yard or green manure	56.4	65.3	25.5	55.3	33.7	59.0
- no fertilizer	0	16.3	12.4	14.2	9.1	15.0

[1] Data are based on PRRA census forms collected at the end of the project (2003) from 439 households in Thailand and 393 households in Vietnam from farmers that had participated in FPR trials and or training courses, as well as from nearby farmers that had not directly participated in these project activities. Percentages may total more than 100% as households can adopt more than one technology simultaneously.

Source: Agrifood International, 2004

Table 12 shows that during the past eight years the average cassava yields in all three countries increased; this increase ranged from 0.83 t/ha in China to 6.73 t/ha in Vietnam. The increased yields resulted in annual increases in gross income received by farmers of about 150 million US dollars in the three countries, and about 250 million US dollars in all of Asia. In addition, farmers in Thailand received higher prices due to the higher starch content of the new varieties. This was achieved not only by this project, but by the collaborative effort of many researchers, extensionists, factory owners and farmers, with strong support from national governments.

Table 12. Estimation of the annual increase in gross income due to higher cassava yields resulting from the adoption of new cassava varieties and improved practices, in China, Thailand and Vietnam, as well as in Asia as a whole.

Country	Total cassava area (ha)[1]	Cassava yield (t/ha)[1] 1994	Cassava yield (t/ha)[1] 2003	Yield increase (t/ha)	Cassava price ($/tonne)	Increased gross income due to higher yields (mil. US $)
China	240,108	15.21	16.25	1.04	27	6.7
Thailand	1,050,000	13.81	17.55	3.74	22	86.4[2]
Vietnam	371,700	8.44	14.07	5.63	25	52.3
Asia total	3,430,688	12.95	16.12	3.17	25	271.9

[1]Data from FAOSTAT for 2003
[2]In addition, farmers also benefited from higher prices due to higher starch content

Meeting the Challenge

Achieving widespread adoption of soil erosion control practices and adequate fertilization for sustainable cassava production on sloping land is a real challenge because these practices generally require additional labor, have considerable financial costs, may take land out of production or lower cassava yields due to competition, resulting in no immediate economic benefits for farmers. However, several lessons have been learned from the project described above, and steps can be taken to enhance adoption:

1. Farmers are not necessarily interested in conserving soil, but are always interested in increasing yields and income. For that reason, soil conservation practices should be combined with other technologies that do provide short-term economic benefits, such as new higher-yielding varieties, well-balanced fertilization (both organic and inorganic), and intercropping.
2. The long-term beneficial effect of soil conservation practices, fertilization and the use of animal and green manures can only be shown in long-term trials. Thus, some experiments and FPR trials should be continued at the same location and with the same treatments for several years.
3. Seeing is believing. By encouraging farmers to conduct simple erosion control trials on their own fields, they can see the amount of soil lost by erosion using the traditional practice; they also see how simple agronomic practices can markedly reduce these losses, while also increasing yields and income.
4. What is suitable in one location is not necessarily suitable in another. Thus, we should not promote or recommend a single practice, but show farmers a range of possible options, from which they can select those that seem useful, and then test these out in small areas of their own fields before selecting the best one for adoption.
5. Farmers are not necessarily interested in increasing yields, but are most concerned about income. Thus, the data presented to farmers should include the yield, the total crop value (gross income), the

best estimates of all costs of production (including farmer's own labor), as well as net income or profit. This helps farmers to make the right decisions.

6. Farmers are more convinced by listening to other farmers than to researchers or extension workers; and they are more convinced by seeing another farmer using a new practice rather than seeing the same practice in a researcher-managed demonstration plot. For that reason, cross-visits, field days to see FPR trials, local FPR teams and community-based organizations are the most effective ways to disseminate new technologies and achieve adoption.
7. Empower farmers and farm communities to be self-reliant, by seeking information, experimenting, developing their own location-specific technologies, and making their own decisions. Researchers and extension workers facilitate the process, but then step back to let farmers make their own choices.
8. Every institution and every person has its own strength and weaknesses, but by working together they can complement each other, the private with the public sector, breeders with agronomists, researchers with extensionists, and especially local extension workers with farmers. Everyone contributes their knowledge and experience in order to achieve a common goal, a vision of sustainable and adequate food production, and improvements in the livelihoods of all.

CONCLUSIONS

Research on sustainable land use conducted in the past has mainly concentrated on finding solutions to the bio-physical 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 was found to be very 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 at large.

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