Farmer Participation in Research and Extension: The Key to Achieving Adoption of More Sustainable Cassava Production Practices on Sloping Land in Asia and their Impact on Farmers' Income

Reinhardt H. Howeler[1,2]

ABSTRACT

Cassava (*Manihot esculenta* Crantz) is the third most important food crop in southeast Asia, where it is usually grown by smallholders in marginal areas of sloping or undulating land. Farmers grow cassava because the crop will tolerate long dry periods and poor soils, and will produce reasonable yields with minimum inputs. Most farmers realize, however, that cassava production on slopes can cause severe erosion, while production without fertilizer or manure inputs will lead to a gradual decline in soil productivity. Current production practices may thus not be sustainable.

Research has shown that cassava yields can be maintained for many years with adequate application of fertilizers or manures, 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, while initial costs of establishing these practices may be substantial.

In order to enhance the adoption of soil conserving practices and improve the sustainability of cassava production under a wide range of socio-economic and bio-physical conditions, a farmer participatory research (FPR) approach was used to develop not only the most suitable soil conservation practices, but also to test new cassava varieties, fertilization practices 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. 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 of selected practices to larger fields, and farmer participatory dissemination to neighbors and neighboring communities. Based on the results of these trials, farmers in the pilot sites have readily adopted better varieties, fertilization and intercropping practices, and many farmers have adopted the planting of contour hedgerows to control erosion.

In the second phase of this Nippon Foundation supported project, the farmer participatory approach for technology development and dissemination was further developed in about 34 pilot sites each in Thailand and Vietnam, and in 31 sites in southern China. Farmers were generally very interested to participate in these trials. After becoming aware of the seriousness of erosion in their cassava fields, they have shown a willingness to adopt simple but effective practices to reduce erosion while at the same time obtaining short-term benefits from the adoption of new varieties and other improved practices. The testing by farmers on their own fields of new cassava varieties and fertilization practices in addition to soil conservation practices was found to be of crucial importance for the adoption of more sustainable production practices. 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 272 million US dollars.

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

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the third most important food crop (after rice and maize) grown in southeast Asia and is used for human consumption, animal feed and for industrial purposes. It 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,

---

[1] CIAT, Cassava Office for Asia, Department of Agriculture, Chatuchak, Bangkok 10900, Thailand.

[2] The many other persons that contributed significantly to this project are acknowledged at the end of the paper.

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.

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.

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). **Table 1** is an example of information obtained from RRAs conducted in Vietnam, while **Table 2** shows a summary of information obtained from RRAs' conducted in several pilot sites in four countries. The detailed information from each site can serve as baseline data to monitor progress and evaluate the impact of newly adopted technologies. After conducting the RRAs, the most suitable pilot sites (villages or subdistricts) were selected to work with farmers in the development and dissemination of new varieties and production practices.

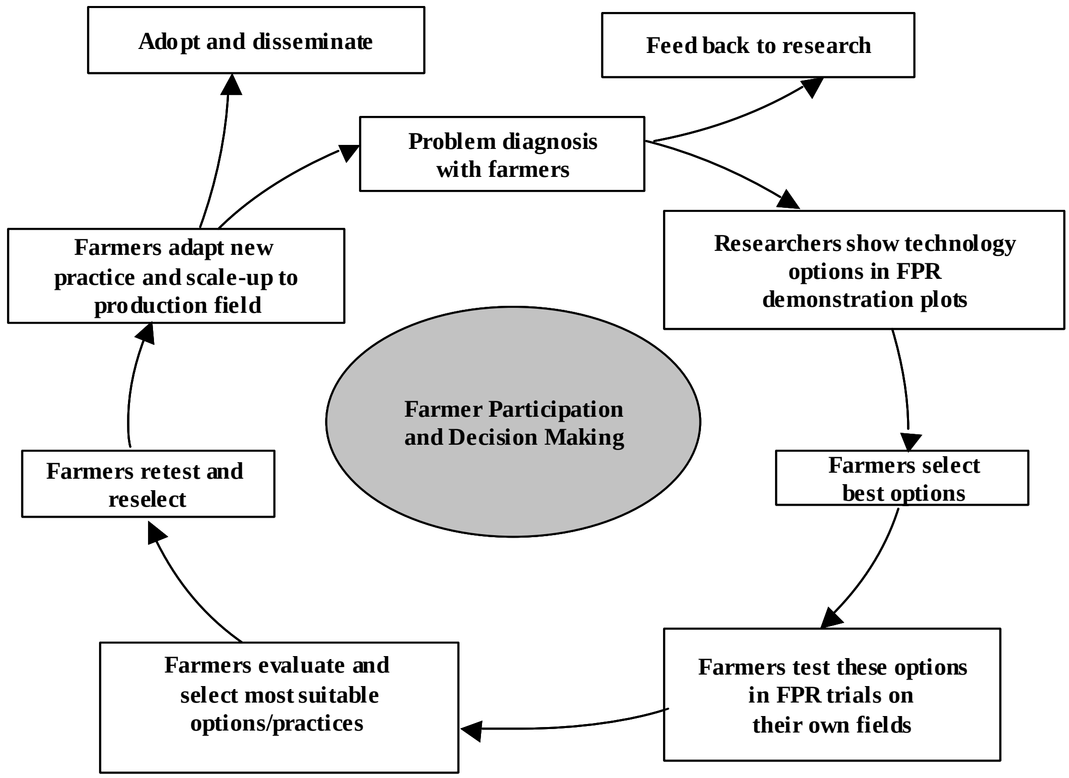


Figure 1. Farmer participatory model used for the development of sustainable cassava-based cropping systems in Asia.

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. **Table 3** shows that farmers from different sites have different priorities and thus rank options quite differently. 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 carefully and exactly along the contour on a uniform slope; it is important that runoff water does not enter the plots either from above or from the sides. Along the lower side of each plot a ditch was dug and covered with plastic (**Figure 2**); small holes in the plastic allowed runoff water to seep away, while eroded sediments remained on the plastic. These sediments were collected and weighed monthly or at least 2-3 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).

Table 1. Cropping systems, varieties and agronomic practices, as determined from RRAs conducted in four FPR pilot sites in Vietnam in 1996/97.

Province	Hoa Binh	Phu Tho	Thai Nguyen	
District	Luong Son	Thanh Ba	Pho Yen	
Village		Phuong Linh		
Hamlet	Dong Rang	Kieu Tung	Tien Phong	Dac Son
Cropping system[1]				
-upland	tea	C monoculture	C+P or C+B	C monocult. or
	C+T	C+P	or 2 yr C rotated	C-P rotation
	C monoculture	tea, peanut	with 2 yr fallow	or C-B, C-SP
	peanut, maize	maize	sweet potato	sweet potato
Varieties				
-rice	CR 203, hybrids from China	DT 10, DT 13, CR 203	DT 10, DT 13 CR 203	CR 203 DT 10, DT 13
-cassava	Vinh Phu, local	Vinh Phu, local	Vinh Phu	Vinh Phu
Cassava practices				
-planting time	early March	early March	Feb/March	Feb/March
-harvest time	Nov/Dec	Nov/Dec	Nov/Dec	Nov/Dec
-plant spacing (cm)	100x80	80x80; 80x60	100x50	100x50
-planting method	horiz./inclined	horizontal	horiz./inclined	horizontal
-land preparation	buffalo/cattle	by hand/cattle	buffalo	buffalo
-weeding	2 times	2 times	2 times	2 times
-fertilization	basal	basal+side[2]	basal+side[3]	basal+side[4]
-ridging	mounding	flat	flat	flat
-mulching	rice straw	peanut residues	peanut residues	peanut residues
-root chipping	hand chipper	knife	small grater	small grater
-drying	3-5 days	3-5 days	2-4 days	2-4 days
Fertilization				
-cassava				
-pig manure (t/ha)	5	5	3-5	8-11
-urea (kg/ha)	0	50-135	83	83-110
-SSP (18% P_2O_5) (kg/ha)	50-100	0	140	0-280
-KCl (kg/ha)	0	0	55	0-280
-rice				
-pig/buffalo manure	5	0	-	-

(t/ha)				
-urea (kg/ha)	120-150	80	-	-
Yield (t/ha)				
-cassava	11-12	8-15	8.5	8.7
-rice (per crop)	3.3-4.2	4.2	3.0-3.1	2.7-3.0
-taro	1.9-2.2	-	-	-
-sweet potato	-	-	8.0	3.3
-peanut	0.8-1.2	0.5-1.1	1.4	1.3
pigs (kg live weight/year)	100-120	-	-	-

[1)]C=cassava, P=peanut, B=black bean, T=taro, M=maize
C+P=cassava and peanut intercropped; C-P=cassava and peanut in rotation
[2)]urea at 2 MAP
[3)]urea when 5-10 cm tall; NPK+FYM when 20 cm tall
[4)]NPK when 30 cm tall; hill up

Table 2. Characteristics of eight pilot sites for the Farmer Participatory Research (FPR) trials in Asia in 1994/95.

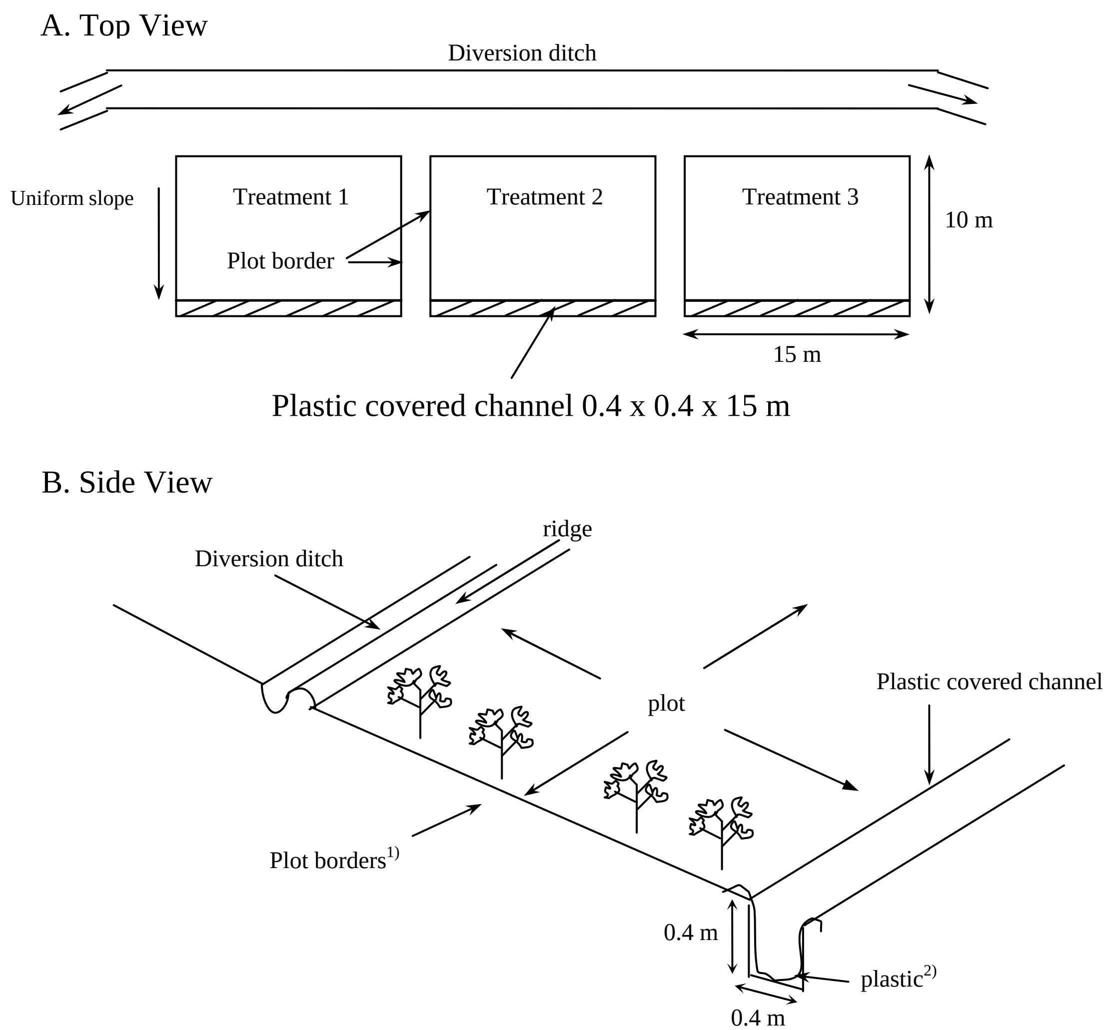
	Thailand		Vietnam			China	Indonesia	
	Soeng Saang	Wang Nam Yen	Pho Yen	Thanh Ba	Luong Son	Kongba	Malang	Blitar
Mean temp. (^{o}C)	26-28	26-28	16-29	25-28	16-29	17-27	25-27	25-27
Rainfall (mm)	950	1400	2000	~1800	~1700	~1800	>2000	~1500
Rainy season	Apr-Oct	Apr-Nov	Apr-Oct	Apr-Nov	May-Oct	May-Oct	Oct-Aug	Oct-June
Slope (%)	5-10	10-20	3-10	30-40	10-40	10-30	20-30	10-30
Soil	± fertile	± fertile	infertile	very infertile	± fertile	± fertile	infertile	infertile
	loamy	clayey	sandy loam	clayey	clayey	sandy cl.l.	clay loam	clay loam
	Paleustult	Haplustult	Ultisol	Ultisol	Paleustult	Paleudult	Mollisol	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 monocrop	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, T = taro, M = maize

Table 3. Ranking of conservation farming practices selected from demonstration plots as most useful by cassava farmers from several pilot sites in Asia in 1995/96.

	Thailand		Vietnam		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		
Farm yard manure (FYM)				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		



[1)]Plot border of sheet metal, wood or soil ridge to prevent water, entering or leaving plots.
[2)]polyethylene or PVC plastic sheet with small holes in bottom to catch eroded soil sediments but allow run-off water to seep away. Sediments are collected and weighed once a month.

Figure 2. Experimental lay-out of simple trials to determine the effect of soil/crop management practices on soil erosion.

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. The FPR trials usually had 4-6 treatments, with one treatment representing the farmer's traditional variety or practice. Plot size varied from a minimum of 30 m^2 to a maximum of 100 m^2. Treatments were not replicated, but wherever possible, farmers within one village conducting the same type of trial were encouraged to use the same treatments so that each trial could be considered a replication and results could be averaged over those replications. This increased the confidence in the reliability of the results.

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 to the farmers. Farmers and extension workers from the area discussed the results and then indicated their preferences for a particular treatment or production practice by raising their hands.

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 4**). During the second phase the emphasis shifted from the development and use of farmer participatory research (FPR) methodologies to farmer participatory extension (FPE) in order to reach more farmers and achieve more widespread adoption.

Table 4. 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 solve problems identified at the farm level, or to develop better technologies that farmers could later test on their own fields.

RESULTS AND DISCUSSION

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

a. FPR trials

Table 5 shows a typical example of an FPR erosion control trial conducted by six farmers having adjacent plots on about 40% slope. 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 also markedly increased net income. Farmers clearly preferred those treatments that were most effective in both increasing net income and reducing soil erosion, such as hedgerows of vetiver grass or pineapple. 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).

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 1997 (3rd year).

	Slope	Dry soil loss	Yield (t/ha) -----------------	Gross income[2)]	Product. costs	Net income	Farmers ranking

Treatment[1]	(%)	(t/ha)	cassava	peanut[1]	-------(mil. dong/ha)-----			g
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

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). Also, to be effective, hedgerows need to follow the contour rather precisely; otherwise they can cause serious gulley erosion by channeling runoff water to the lowest spot. Contour hedgerows also force farmers to plow along the contour, which is more difficult and more costly; moreover it makes planting in neat straight lines, using tight strings as a guide, impossible. Thus, there are very practical reasons why farmers may be reluctant to adopt some of these soil conservation practices. **Table 6** shows the particular technologies that farmers had adopted in the four countries at the end of the first phase of the project.

Table 6. 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* KM95-3*** 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+40 P_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=farm yard manure.

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 3**). 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.

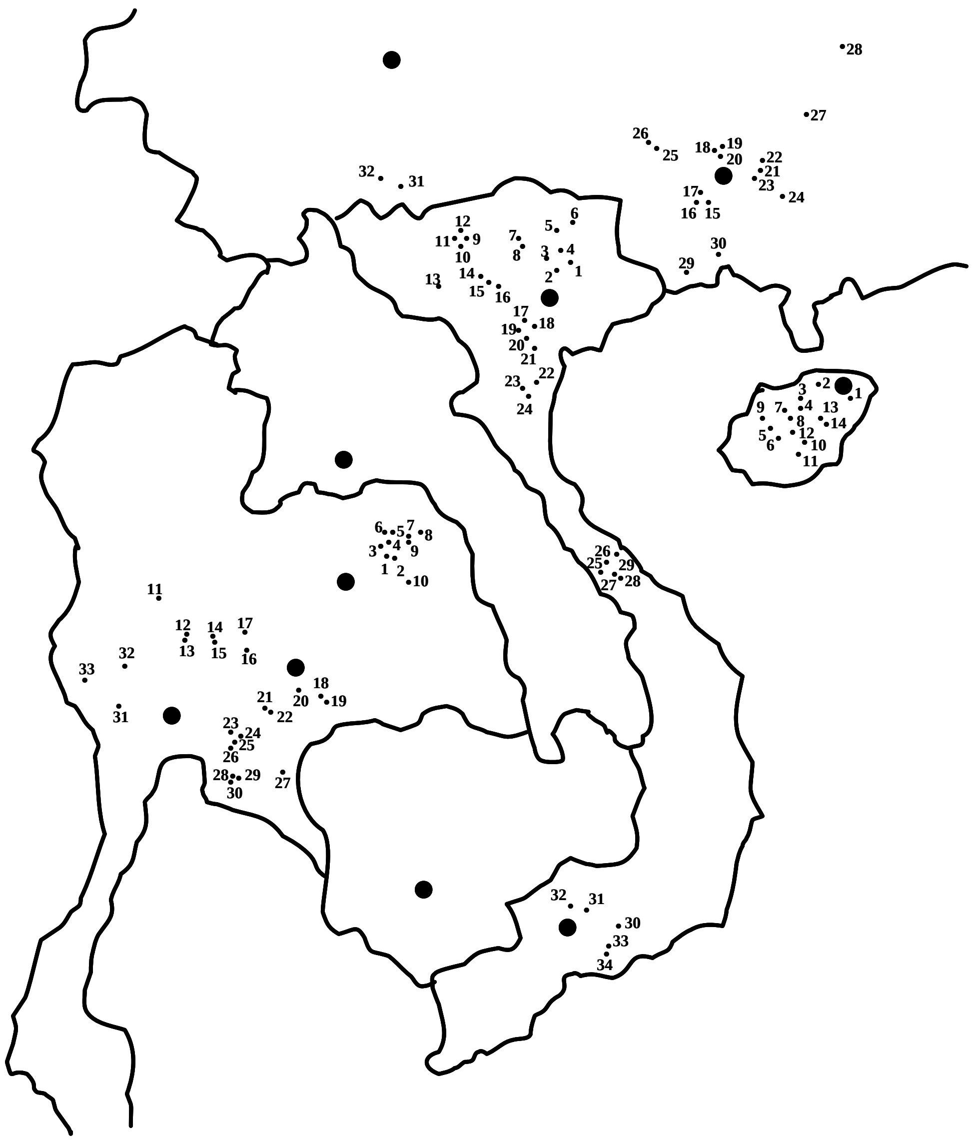


Figure 3. Location of FPR pilot sites in China, Thailand and Vietnam in the Nippon Foundation cassava project in 2003.

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 7** 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 five years of the second phase of the project a total of 1,154 FPR trials were conducted by farmers on their own fields. **Tables 8** to **12** are just a few examples of the various types of FPR trials conducted by farmers in different sites in Thailand and Vietnam.

Table 7. 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**

Table 8. Results of an FPR variety trial conducted by a farmer in Am Thang commune, Son Duong district, Tuyen Quang, Vietnam in 2002.

Treatments[1)]	Cassava yield (t/ha)	Gross income	Product. costs	Net income	B/C	Farmers' preference[2)] (%)
		----------('000 dong/ha)--------				
1. Vinh Phu	20.70	10,350	4,330	6,020	2.39	7.9
2. La Tre (SC205)	21.40	10,700	4,330	6,370	2.47	10.5
3. KM60	29.20	14,600	4,330	10,270	3.37	21.0
4. KM94	37.50	18,750	4,330	14,420	4.33	94.7
5. KM95-3	32.80	16,400	4,330	12,070	3.79	26.3
6. KM98-7	25.40	12,700	4,330	8,370	2.93	10.5

[1)] fertilized with 1,100 kg/ha of 7-4-7 fertilizers = 1.43 mil. dong/ha
[2)] out of 38 farmers

Table 9. Average results of three FPR erosion control trials conducted by farmers in Suoi Rao and Son Binh villages, Chau Duc district, Baria-Vungtau, Vietnam in 2003/04.

Treatments	Dry soil loss (t/ha)	Cassava yield (t/ha)	Maize+ hedgerow yield (t/ha)	Gross income[1)]	Product. costs[2)]	Net income	Farmers' preference (%)
				——('000 dong/ha)——			
1. cassava monoculture, no hedgerows	77.12	26.34	-	10,536	6,079	4,457	20
2. C+ pineapple hedgerows	11.65	27.02	-	10,808	6,279	4,529	0
3. C+ *Paspalum atratum* hedgerows	12.18	30.13	11.40	12,052	6,279	5,773	65
4. C+ vetiver grass hedgerows	9.94	28.33	8.84	11,332	6,279	5,053	15
5. C+ maize intercrop	14.30	17.86	3.25	10,394	7,969	2,425	0

[1)] Prices:	cassava	dong		400/kg fresh roots
	maize			1,000/kg dry grain
[2)] Costs:	labor			20,000/manday
	cassava fertilizers			1,279,000 dong/ha
	maize fertilizers			550,000 dong/ha
	cassava stakes			500,000 dong/ha
	maize seed			440,000 dong/ha
	labor for cassava without HR (210 md/ha)		=	4.2 mil. dong/ha
	labor for maize (40 md/ha)		=	0.8 mil. dong/ha
	labor for fertilizer application (5 md/ha)		=	0.1 mil. dong/ha
	labor for hedgerow cutting/maintenance		=	0.2 mil. dong/ha

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.

Table 10. Results of an FPR fertilizer and manure trial conducted in Khut Dook village, Baan Kaw, Daan Khun Thot, Nakhon Ratchasima, Thailand in 2002/03.

Treatments[1]	Root yield (t/ha)	Starch content (%)	Gross income[2]	Fertilizer cost[3]	Production costs[3]	Net income
			———('000 B/ha)———			
1. No fertilizers or manure	18.75	25.0	21.56	0	10.87	10.69
2. Chicken manure+rice hulls, 400 kg/rai	30.42	26.2	34.98	2.50	17.15	17.83
3. Pelleted chicken manure, 100 kg/rai	26.70	21.1	30.71	2.00	15.39	15.32
4. 15-7-18 fertilizer, 50kg/rai	29.68	24.1	34.13	2.66	16.73	17.40
5. 13-13-21 fertilizer, 50kg/rai	32.22	27.4	37.05	3.13	17.89	19.16
6. 16-20-0 fertilizer, 50kg/rai	26.08	25.9	29.99	2.50	15.61	14.38
7. 15-15-15 fertilizer, 50kg/rai	30.36	26.9	34.91	2.81	17.07	17.84

[1] 1ha = 6.25 rai

[2] Prices: cassava baht 1.15 /tonne irrespective of starch content

[3] Costs:

chicken manure	1.0 /kg
pelleted chicken manure	3.20 /kg
15-7-18	8.50 /kg
13-13-21	10.0 /kg
16-20-0	3.0 /kg
15-15-15	9.0 /kg

harvest + transport roots 270 /tonne
cassava production without fertilizer or harvest 12,757 /ha

Table 11. Average results of four FPR intercropping trials conducted by farmers in Tran Phu commune, Chuong My district, Ha Tay, Vietnam in 2003.

Treatments	Cassava yield (t/ha)	Intercrop yield (t/ha)	Gross income[1]	Seed costs[2]	Product. costs[2]	Net income
			('000 d/ha)			
1. Cassava monoculture	24.54	-	9,816	0	5,460	4,356
2. C+1 row peanut	21.93	1.187	14,707	480	8,115	6,592
3. C+2 rows peanut	22.52	2.000	19,008	960	8,595	10,413
4. C+2 rows mungbean	21.42	0	8,568	2000	9,635	-1,067
5. C+2 rows soybean	21.28	0.162	9,322	800	8,435	887

[1] Prices: cassava: dong 400/kg fresh roots
peanut: 5,000/kg dry pods
soybean 5,000/kg dry seed
[2] Costs: labor: dong 15,000/manday
NPK fertilizers: = 0.86 mil. dong/ha
peanut seed (80 kg/ha): 12,000 /kg = 0.96 mil dong/ha for 2 rows
mungbean seed (80 kg/ha): 25,000 /kg = 2.00 mil dong/ha for 2 rows
soybean seed (80 kg/ha) 10,000 /kg = 0.80 mil dong/ha for 2 rows
labor for cassava monoculture without fertilizers = 4.5 mil. dong/ha (300 md/ha)
labor for cassava intercropping without fertilizers = 6.675 mil.dong/ha (445 md/ha)
labor for cassava fertilizer application = 0.10 mil. dong/ha

Table 12. Average results of five FPR pig feeding trials on adding ensiled cassava leaves to the diet, conducted by farmers in Huong Ha commune, A Luoi, Thua Thien-Hue, Vietnam in 2001/02.

Treatments	No. of pigs	Life weight (kg)		LWG[1] (g/day)	FCR[2] (kg DM/kg gain)	Feed cost[5] (VND/kg gain)
		initial	3 months			
Control diet[3]	6	24.30	52.50	313.3	4.83	10,745
Control +13% ECL[4]	6	26.92	57.75	342.5	4.36	7,862
F test						*

[1] LWG = live weight gain
[2] FCR = feed conversion ratio
[3] Control diet of rice bran, ensiled cassava roots (32% as DM), fish meal and sweet potato (SP) vines
[4] 13% ensiled cassava leaves replaced part of fish meal, all SP vines; cassava leaves had been ensiled with 20% fresh grated cassava roots
[5] Prices: rice bran dong 2,000/kg
fish meal 6,000/kg
cassava roots 320/kg
fresh SP vines 400/kg
cassava leaves 3,000/20 kg

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 extension pamphlets and booklets about the farmer-selected technologies were 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. Subsequently, the Dept. of Agric. Extension in Thailand 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 credit 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 in Thailand. 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 4** 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 14th year of continuous cropping in Hung Loc Agricultural Research 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.

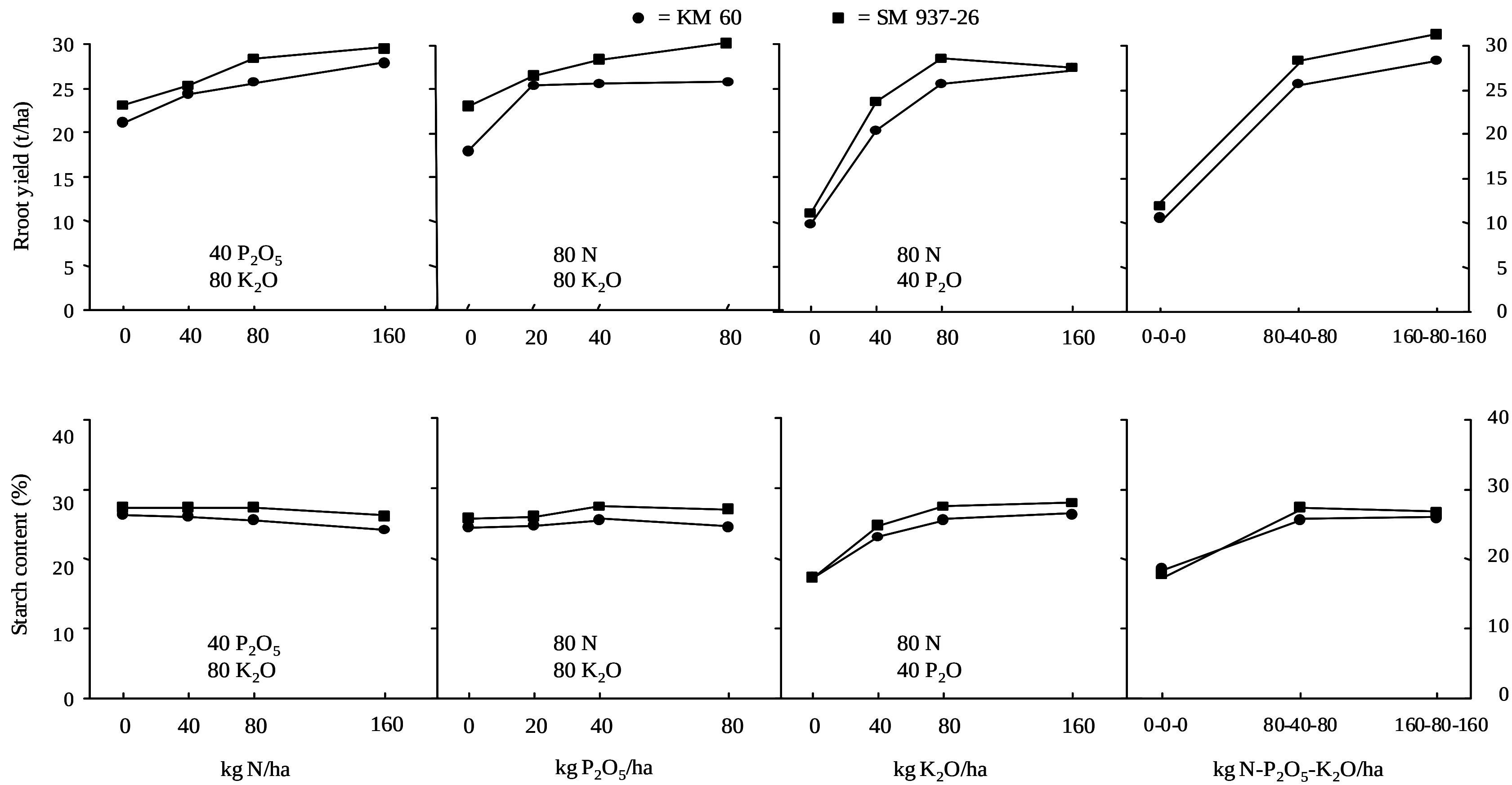


Figure 4. Effect of annual applications of various levels of N, P and K on the root yield and starch content of two cassava varieties grown at Hung Loc Agric. Research Center in Thong Nhat, Dong Nai, Vietnam in 2003/04 (14th year).

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

Table 13 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 where hedgerows of vetiver grass, *Tephrosia candida* and *Paspalum atratum* all decreased erosion by about 50%, while also increasing cassava yields 10-13% (Howeler *et al*., 2004; 2005).

Table 13. 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

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 by farmers 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 a more or less permanent barrier. While farmers claim that *Tephrosia* improves the fertility of the soil more so than vetiver grass, the data show that vetiver grass increased cassava yields more than *Tephrosia*, probably by reducing losses of top soil and fertilizers and improving water infiltration and soil moisture content.

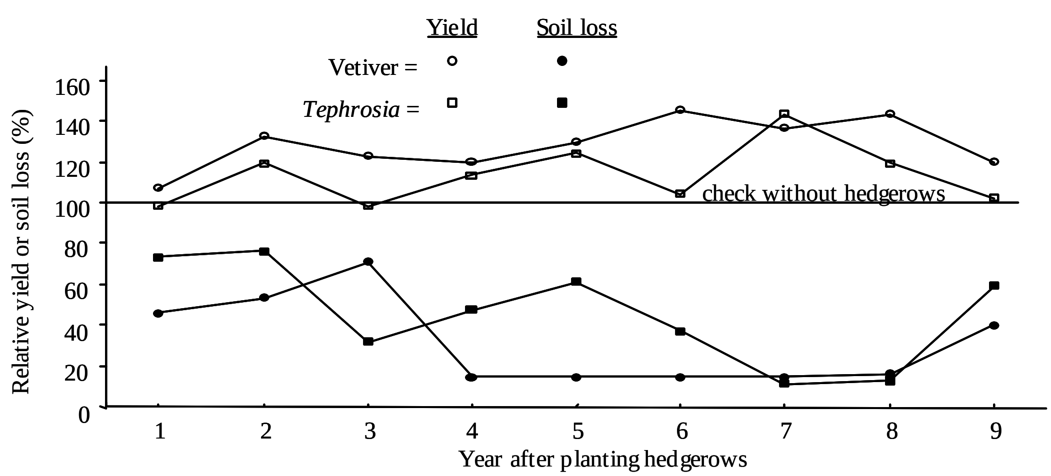


Figure 5. Trend in relative yield and relative soil loss by erosion when cassava was planted with contour hedgerows of vetiver grass or Tephrosia candida during nine consecutive years of cassava cropping. Data are average values for one FPR erosion control trial in Kieu Tung and two trials in Dong Rang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

ADAPTATION

After 2-3 years of testing of various options in FPR trials, slowly narrowing down the number of best options, farmers started to adopt some of the tested varieties or practices on their bigger production fields. In some cases they made adaptations so as to make the practices more suitable on a larger scale. For instance, in Thailand farmers planted contour hedgerows of vetiver grass on their fields, but left enough space between hedgerows (usually 30-40 m) to facilitate land preparation by tractor. In some cases, especially in Vietnam, farmers planted hedgerows on plot borders rather than along contour lines. This reduces the amount of land occupied by hedgerows, but also reduces their effectiveness in controlling erosion.

While contour hedgerows of vetiver grass are usually the most effective in reducing soil losses by erosion in experiments and FPR trials conducted in small plots on a uniform slope, when this practice is scaled up to a larger production field the results are often disappointing. In areas of rolling terrain large amounts of runoff water may accumulate and run down-slope in natural drainage ways. The force of the water is likely to wash out vetiver grass recently planted along the contour across the drainage way, and this may result in serious gully erosion. Attempts to repair these gullies by placing sand bags or other obstacles across them have usually failed as these obstacles too are washed away. Over the past few years farmers and project staff have experimented informally with ways to reduce the speed of water in these gullies. They found that it is most effective to place a row of soil-filled plastic fertilizer bags across the gully in line but slightly below the washed out vetiver hedgerow. The bags need to be secured in place by pounding bamboo stakes into the soil behind them (**Figure 6**). Once eroded soil is deposited in the gully above the soil bags, vetiver grass can be planted in this moist and fertile sediment. When the vetiver grass is well-established across the gully and in line with the rest of the hedgerow, this will further slow the speed of runoff water resulting in further deposition of sediments in the gully above the vetiver hedgerow. This allows weeds to reestablish in the gully bottom protecting the gully from further erosion. With the next plowing along the contours, parallel to the hedgerows, the gully will generally be filled up again with soil, while the hedgerow prevents further gully formation (**Figure 6**). In some sites in Thailand, terraces of up to a meter height were formed within two years by the placing of soil bags and planting of vetiver hedgerows across the gully. This local adaptation of the traditional contour hedgerow system markedly increased its effectiveness under real field conditions.

ADOPTION

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. By the end of 2003, about 1,038 farmers had planted a total of 1.63 million vetiver plants, corresponding to about 145 km of hedgerows (Howeler *et al*., 2003a, 2003b; 2004a, 2004b, 2005; Wilawan Vongkasem *et al*., 2003).

In Aug 2002 a participatory monitoring and evaluation (PM&E) was conducted in four pilot sites in Thailand where the project had been initiated at least four years earlier. Using focus group discussions and participatory evaluation methodologies, data were collected on the extent of adoption of the various technologies and the reasons for adoption or non-adoption. **Table 14** shows that new varieties had been adopted in 100% of the cassava growing areas in all four sites. Application of chemical fertilizers varied from 79-100%, vetiver hedgerows were planted in 22-55% of the cassava area, green manures in 0-50% and

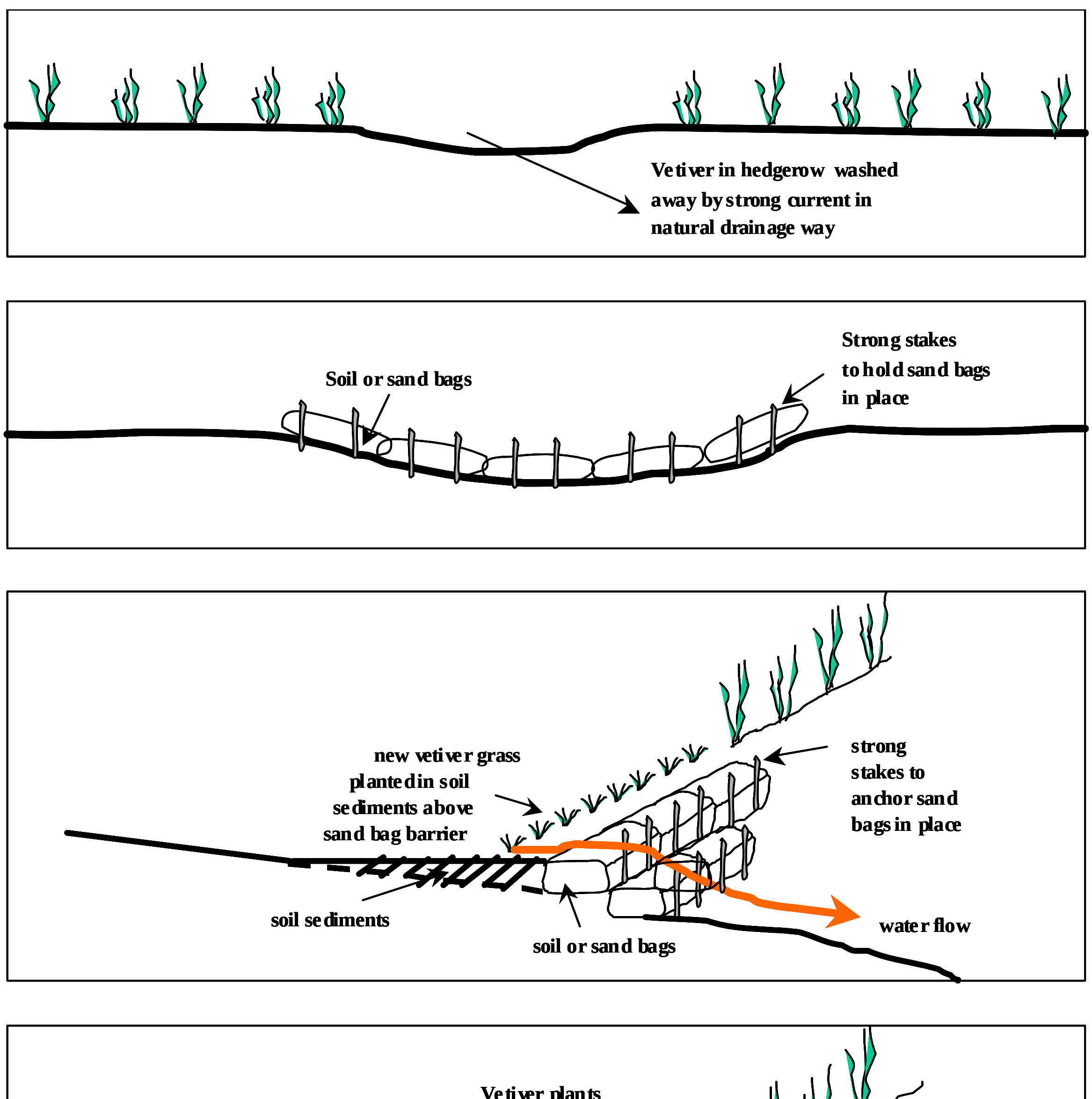


Figure 6. Simple and effective way to repair gullies by placing soil bags across gully and planting vetiver grass in the soil sediments accumulating above the barrier.

intercropping was not adopted at all, mainly due to lack of labor for managing intercrops. **Table 15** shows in more detail how the various technologies changed over the years, mainly as a result of conducting FPR trials on their own fields. While in most sites some new varieties (Rayong 3, Rayong 60, Rayong 90) were already planted before the project started, the mix of new varieties changed over the years as higher yielding varieties were released, tested and adopted. The data also indicate how the use of chemical fertilizers not only increased over time, but also changed from the standard 15-15-15 to various formulations high in N and K and low in P.

Table 14. Extent of adoption[1)] of various cassava technology components in four pilot sites in Thailand in 2002 as a result of the Nippon Foundation project.

Technology component	Baan Khlong Ruam Sra Kaew		Thaa Chiwit Mai Chachoengsao		Sapphongphoot Nakhon Ratchasima		Huay Suea Ten Kalasin	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Varieties	480	100	469	100	396	100	228	100
Chemical fertilizers	480	100	469	100	364	92	180	79
Vetiver grass hedgerows	139	29	94	20	218	55	89	39
Green manures	72	15	0	0	0	0	114	50
Intercropping	0	0	0	0	0	0	0	0

[1)] Estimated by farmers in each site during Participatory Monitoring and Evaluation (PM&E) in Aug 2002

Table 16 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. For instance, 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. **Figure 7** shows how the number of farmers in the pilot sites adopting various soil conservation measures increased year after year, initially mostly in Thailand but subsequently also in Vietnam.

Data in **Table 17** 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. As a result of the adoption of soil conservation practices, gross income, both per ha and per household, 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 increased over time (**Figure 5**) (Howeler *et al*., 2005). 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

Table 15. Change in the use of new cassava production technologies[1)] in four pilot sites[2)] in Thailand from 1995 to 2002[2)] as a result of the Nippon Foundation project.

Technology component	Baan Khlong Ruam			Thaa Chiwit Mai			Sapphongphoot			Huay Suea Ten		
	1993	1995	2002	1995	1997	2002	1995	1997	2002	1995	1997	2002
Varieties	R90 (60%) R3 (30% R60 (10%)	R90 (60%) R5 (20%) KU50 (20%)	R5 (67%) R90 (19%) KU50 (12%) R72 (2%)	R1 (94%) R60 (3%) R5 (3%)	KU50 (41%) R60 (32%) R5 (22%) R90 (5%)	KU50 (81%) R5 (18%) R72 (1%)	R1 R60 R90	KU50 R5 R90	KU50 (91%) R90 (5%) R72 (3%) R5 (1%)	R1 R90 KU50	KU50 R5 R90	KU50 (54%) R5 (20%) R90 (15%) R72 (11%)
Chemical fertilizers	not apply	15-15-15 13-13-21	15-15-15 (35%) 13-13-21 (17%) 21-4-21 (13%) 14-4-24 (10%) 16-20-0 (5%) other (20%)	not apply	15-15-15	15-15-15 (50%) 13-13-21 (38%) other (12%)	not apply or 15-15-15 (little)	15-15-15 46-0-0	15-15-15 (44%) 46-0-0 (27%) 13-13-21 (4%) other (25%)	not apply or 15-15-15 (little)	15-15-15 and 16-8-8 mixed at 2:1 ratio	15-15-15 (47%) 16-8-8 (33%) 21-0-0 (12%) 46-0-0 (7%) 13-13-21 (1%)
Vetiver grass	not plant	46%	29%	not plant	3%	20%	not plant	70%	55%	not plant	32%	39%
Green manures	not plant	not plant	*Canavali a* (little)	not plant	not plant	*Canavali a* (little)	not plant	not plant	*Canaval ia* (little)	not plant	*Canavali a* (20%)	*Canavali a* (50%)

cowpea (little	*Crotalaria* (little)

[1)] Date collected from Participatory Monitoring and Evaluation (PM&E) with farmers in Aug 2002; percentages are in terms of cassava area.
[2)] Baan Khlong Ruam village, Wang Soombuun district, Sra Kaew province
Thaa Chiwit Mai village, Sanaam Chaikhet district, Chachoengsao province
Sapphongphoot village, Soeng Saang district, Nakhon Ratchasima
Huay Suea Ten village, Sahatsakhan district, Kalasin province
[3)] Nippon Foundation project started in these pilot sites around 1997, except in Baan Khlong Ruam where it started in 1995.

Table 16. 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*

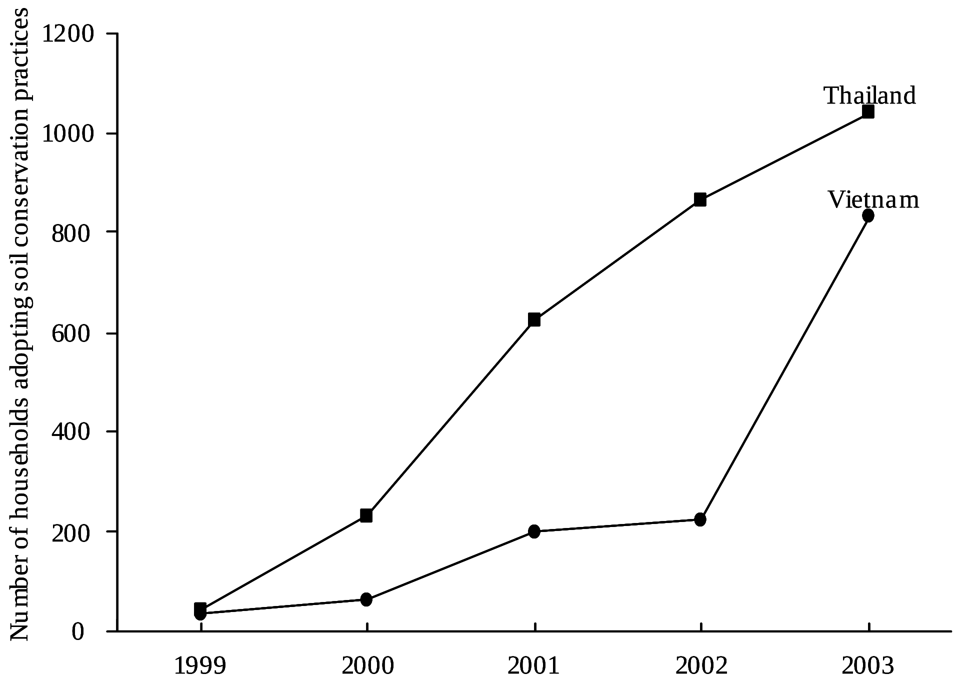


Figure 7. Number of farmers adopting soil conservation measures in their cassava fields in FPR pilot sites in Thailand and Vietnam from 1999 to 2003.

Table 17. 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)]	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[3)]		1.561	955.699	1.150
Total	**831**	**612.00**					**1,208.146**	

[1)] Farmers' practice includes most new technologies except soil conservation [3)] Yields estimated from 2002

[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)

***Source**: Tran Ngoc Ngoan, 2003*

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 18 shows in more detail how the adoption of various technologies increased over time in one commune in Pho Yen district of Thai Nguyen province where the project first started working in 1994. Since 1995 farmers have conducted FPR trials on new varieties, more balanced fertilization, intercropping, and erosion control. After some years of testing farmers initially adopted new varieties and intercropping in small areas of their land. This was followed by better fertilization and erosion control; the latter was adopted by only a small number of farmers as most cassava fields in the commune are on gentle slopes or on terraced land. It is clear that the adoption of new technologies increased yields significantly, of both the local variety Vinh Phu and the new varieties, mainly KM 95-3 and KM 98-7. The gradual increases in yield, from 8.5 t/ha in 1994 (see **Table 1**) to 36.8 t/ha in 2003 was accompanied by an increase in area planted using new technologies, resulting in about a 20-fold increase in net income and marked improvements in the livelihood of farmers in this commune.

Table 19 summarizes the extent of adoption of new cassava technologies in FPR pilot sites in 15 provinces of Vietnam in 2003 and the resulting increase in gross income due to higher yields obtained. Although balanced fertilization produced the greatest yield increase, it was not adopted over a very wide area. New varieties were most widely adopted resulting in the greatest increase in gross income. The total annual increase in gross income due to adoption of new technologies in the FPR sites was estimated at 1.67 million US dollars or $72.92 per household.

ASSESSMENT OF IMPACT

In order to determine more precisely 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 - four sites in Thailand and four in Vietnam - as well as from farmers living within 10 km of those sites, who had not participated in the project. **Table 20** shows the percent of households (out of 767) who had adopted various technologies. New varieties were adopted[3] by nearly all cassava farmers in the eight sites in Thailand and by 70% of farmers in Vietnam; the use of chemical fertilizers had been adopted by 85-90% of households in the eight sites in each country; intercropping by nearly 60% of households in Vietnam, but by only 13% in Thailand. Contour ridging was adopted by about 30% of households in both Vietnam and Thailand, while contour hedgerows were adopted by 23% of households in Thailand and 25% in Vietnam; in Thailand these hedgerows were almost exclusively vetiver grass, while in Vietnam most farmers 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 20** also indicates that there were highly significant differences in the adoption of almost all the technologies between participating and non-participating farmers (with the exception of contour ridging and the use of chemical fertilizers in Vietnam), with participating farmers have a greater extent of adoption than non-participating farmers. In this case, "participants" were defined as farmers who had conducted at least one FPR trial and/or had participated in an FPR training course, while "non-participants" had done neither, but may have attended a farmer field day organized by the project. It can be seen that new varieties and the use of chemical fertilizers were readily adopted by both participants and non-participants, while, adoption of soil conservation practices and intercropping was both less widespread and largely limited to participating farmers. This clearly points to the difficulty of achieving spontaneous and widespread adoption of soil conservation practices.

But how does adoption of these new technologies translate into higher yields and income? **Figure 8** shows the cassava yields that farmers reported before and after the project, corresponding more less to the second phase of the project, or from 1999 to 2003. In Thailand the yields of participating farmers increased from 19.4 to 25.8 t/ha (33%), while yields of non-participating farmers increased from 15.5 to 20.3 t/ha (31%); in Vietnam project participants increased yield from 13.7 to 28.2 t/ha (106%) while non-participants increased their yields from 14.3 to 23.9 t/ha (67%) (Lilja/Johnson *et al*., 2005). Thus, in both countries yields increased very markedly, but these increases were greater for participants than for non-participants, especially in Vietnam. For comparison, **Figure 8** also shows the increase in yield for the whole country, as

[3] Planted in 50% or more of the farmer's total cassava area

reported by FAO during approximately the same time period. Yields for the whole of Vietnam are considerably below those reported by the farmers in the focus groups; but the yield increases are similar to those reported by the non-participants. In Thailand the initial yields in the country were similar to those of non-participating farmers, but after-project yields were much higher for participants as well as nearby non-participants than for the country as a whole. This indicates that participating farmers benefited most from their experiences but that nearby farmers also benefited indirectly from the project.

Table 21 shows that during the past nine years the average cassava yields in all three countries increased; this increase ranged from 1.03 t/ha in China to 5.65 t/ha in Vietnam. The increased yields resulted in annual increases in gross income received by farmers of about 145 million US dollars in the three countries, and about 270 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 18. Impact of the adoption of new cassava varieties and improved production practices on the livelihoods of farmers in Tien Phong commune, Pho Yen districtl of Thai Nguyen, Vietnam.

Year	Variety or practice[1)]	No. of farmers	Cassava area (ha)	Cassava yield (t/ha)	Peanut yield (t/ha)	Gross income[2)]	Production costs	Net income	Total net income (mil.dong)
						——(mil. dong/ha)——			
1994[3)]	Vinh Phu	115	50	8.5	-	3.40	2.93	0.47	23.50
	New varieties	0	-	-	-	-	-	-	-
			50						**23.50**
2000	Vinh Phu	NA[4)]	NA	21.5	-	NA	NA	NA	NA
	New varieties	25	1.31	30.9	-	15.45	4.36	11.10	14.54
	Intercropping	37	2.59	29.3	0.81	18.70	6.16	12.54	32.48
	Erosion control	4	0.20	24.7	-	12.35	4.66	7.69	1.54
			>4.10						**>48.56**
2001	Vinh Phu	61	2.17	22.7	-	11.35	4.36	6.99	15.17
	New varieties	122	4.70	29.0	-	14.50	4.36	10.14	47.66
	Intercropping	40	3.38	26.2	0.77	16.94	6.16	10.78	36.44
	Erosion control	4	0.20	NA	-	NA	NA	NA	NA
			10.45						**>99.27**

2002	Vinh Phu	18	0.64	25.4	-	12.70	4.33	8.37	5.36
	New varieties	100	5.16	33.7	-	16.85	4.33	12.52	64.60
	Intercropping	118	3.69	32.3	1.73	24.80	6.13	18.67	68.89
	Balanced fert.	48	2.95	33.4	-	16.70	4.83	11.87	35.02
	Erosion control	5	0.18	25.4	-	12.70	4.63	8.07	1.45
			12.62						**175.32**
2003	Vinh Phu	NA	NA	NA	-	NA	NA	NA	NA
	New varieties	225	17.00	36.8	-	18.40	4.33	14.07	239.19
	Intercropping	120	11.00	36.0	0.67	21.35	6.13	15.22	167.42
	Balanced fert.	54	3.40	33.6	-	16.80	4.83	11.97	40.70
	Erosion control	5	0.60	27.0	-	13.5	4.63	8.87	5.32
			>32.00						**>452.63**

[1)]In Tien Phong farmers traditionally grow mainly Vinh Phu variety but have now largely changed to KM 95-3
and KM 98-7; the new practices include intercropping with peanut, balanced fertilization of 10 t/ha of pig
manure plus 80N-40P_2O_5-80 K_2O, and erosion control by contour hedgerows of *Tephosia candida*

[2)]Price of cassava in 1994: 400 VND/kg fresh roots
Price of cassava in 2000-2003: 500 VND/kg fresh roots
Price of peanut in 2000-3003: 5,000 VND/kg dry pods

[3)]Data from RRA at the start of project

[4)]NA = data not available

Table 19. Extent of adoption of new cassava production technologies in FPR pilot sites in 15 provinces of Vietnam in 2003/04, the effect on cassava yields, and the increase in gross income resulting from the yield increase in those sites.

Technology component	No. of households	Area (ha)	Cassava yield (t/ha)		Increase in gross income ('000 US$)[2)]
			Farmers' practice[1)]	Improved technology	
1. New varieties	14,820	7,849	19.93	28.95	1,462
2. Balanced fertilization	1,710	607	21.37	30.50	114
3. Soil conservation practices	831	612	20.60	25.48	62
4. Intercropping	4,250	160	29.95	28.94	15 [4)]
5. Root and leaf silage for pig feeding	1,172	-[3)]	-	-	12
Total	**22,833**	**9,228**			**1,665**

[1)] Farmers' practice usually includes most new technologies except the technology being tested

[2)] based on a price of 320 VND/kg fresh roots in 2003/04; 1 US$ = 15,500 VND

[3)] 3,370 pigs

[4)] increase in gross income from the harvest of intercrops

Source: *Tran Ngoc Ngoan, 2003.*

Table 20. Extent of adoption (percent of households)[1] of new technologies by participating and non-participating farmers in the cassava project in Thailand and Vietnam in 2003 (n=767).

	Thailand			Vietnam			Full sample		
	Partic.	Non-partic.	Total	Partic.	Non-partic.	Total	Partic.	Non-partic.	Total
Varieties									
-100% improved varieties	100	88.0	91.1***	50.0	38.8	42.9***	73.2	67.3	69.1***[2]
-75% improved varieties	0	11.7	8.6	5.6	6.7	6.3	3.0	9.6	7.6
-50% improved varieties	0	0.3	0.2	26.2	18.3	21.1	14.0	7.9	9.8
-25% improved varieties	0	0	0	4.0	5.4	4.9	2.1	2.3	2.2
-No improved varieties	0	0	0	14.3	30.8	24.9	7.7	13.0	11.3
Soil conservation practices									
-contour ridging	52	22	30***	35	31	33	43	26	31***
-hedgerows	60	10	23***	50	12	25***	54	11	24***
-vetiver grass	60	10	23***	10	3	5**	33	7	15***
-*Tephrosia condida*	0	0	0	38	6	18***	20	3	8***
-*Paspalum atratum*	1	0	0*	12	2	6***	7	1	3***
-Pineapple	0	0	0	2	1	1	1	0	1
-sugarcane	2	1	1	0	0	0	1	0	1
-other hedgerows	3	0	1*	7	1	3***	5	1	2***
-no soil conservation	21	72	59***	23	58	45***	22	67	53***
Intercropping	28	8	13***	79	49	59***	55	25	34***
-with peanut	1	1	1	47	33	38***	26	14	18***
-with beans	0	0	0	27	29	29	14	12	13
-with maize	3	10	5***	2	3	3	6	3	4*
-with green manures	19	4	8***	0	0	0	9	2	4***
-with other species	3	2	2	39	15	24***	22	7	12***
Fertilization									
-chemical fertilizers	98	86	89***	85	86	86	91	86	87***
-farm-yard or green manure	55	25	33***	74	60	65**	65	40	48***
-no fertilizer	0	13	9***	12	8	9	6	11	9*

[1]Percentages may total more than 100 % as households can adopt more than one type of technology simultaneously

Significant differences between participants and non-participants: * P<=0.10 ** P<=0.05 *** P<=0.01

[2]Level of significance in this case refers to differences between participants and non-participants in terms of the categorical distribution, not the adoption levels

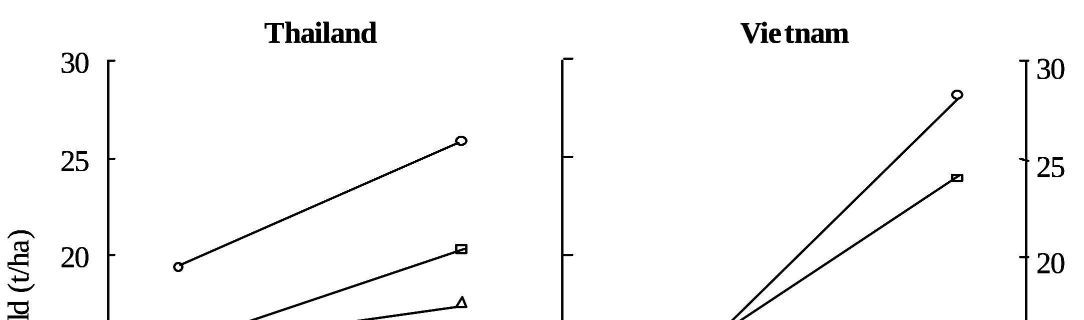


Table 21. Estimation of the annual increase in gross income due to higher cassava yields resulting from the adoption of new cassava varieties and improved practices, in China, Thailand and Vietnam, as well as in Asia as a whole.

Country	Total cassava area (ha)[1]	Cassava yield (t/ha)[1]		Yield increase (t/ha)	Cassava price ($/tonne)	Increased gross income due to higher yields (mil. US $)
		1994	2003			
China	240,110	15.22	16.25	1.03	27	6.7
Thailand	1,050,000	13.81	17.55	3.74	22	86.4[2]
Vietnam	371,900	8.41	14.06	5.65	25	52.5
Asia total	3,463,460	12.93	16.04	3.11	25	269.3

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

RATE OF RETURN ON THE RESEARCH INVESTMENT

To calculate the internal rate of return (IRR) on investiment of this project, we need to calculate the total costs and the total benefits that can be attributed directly to the project. The total costs of the project in Thailand and Vietnam were calculated as 2/3 of the Nippon Foundation annual budget over a 10-year period, plus contributions for salaries of national staff and other expenses provided by the two national governments. These costs totaled about 3.5 million US dollars (Lila/Johnson *et al*., 2005).

Benefits were calculated by adding up the incremental yield increases obtained as a result of participation in the project (9.1 t/ha), by the adoption of contour hedgerows (2.7 t/ha) or of new varieties (up to 6.3 t/ha depending on the extent of adoption) multiplied by the average area in each village affected by either participation or the particular technology adopted. According to these calculations each village on average increased their cassava production by 1,895 tonnes as a result of the project. Since there were 67 project villages in Thailand and Vietnam and the price of fresh cassava roots was about 25 US dollars per tonne, this translates into a total annual benefit of 3.2 million US dollars. If we assume a linear rate of adoption between 1998 and 2004 the project had an IRR of 33% over that period, or an IRR of 37% if we assume that adoption will continue at a similar rate until 2008 (Lilja/Johnson *et al*., 2005).

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.

REFERENCES

FAOSTAT, 2004. http://apps.fao.org

Howeler, R.H. 2001. The use of farmer participatory research (FPR) in the Nippon Foundation Project: Improving the sustainability of cassava-based cropping systems in Asia. *In*: R.H. Howeler and S.L. Tan (Eds.). Cassava's Potential in Asia in the 21st Century: Present Situation and Future Research and Development Needs. Proc. 6th Regional Workshop, held in Ho Chi Minh city, Vietnam. Feb 21-25, 2000. pp. 461-489.

Howeler, R.H. 2002. The use of a participatory approach in the development and dissemination of more sustainable cassava production practices. *In*: M. Nakatani and K. Komaki (Eds.). Potential of Root Crops for Food and Industrial Resources. Proc. 12th Symp. Intern. Soc. Trop. Root Crops, held in Tsukuba, Japan, Sept 11-16, 2000. pp. 42-51.

Howeler, R.H. 2004. A participatory and inter-institutional project to enhance the sustainability of cassava production in Thailand, Vietnam and China: Its impact on soil erosion and farmers' income. Paper presented at Intern. Conf. on Interdisciplinary Curriculum and Research Management in Sustainable Land Use and Natural Resource Management, held in Bangkok, Thailand. Aug 17-19, 2004.

Howeler, R.H., W. Watananonta, W. Vongkasem, K. Klakhaeng, S. Jantawat, S. Randaway and B. Vankaew. 2003b. Working with farmers: The key to adoption of vetiver grass hedgerows to control erosion in cassava fields in Thailand. *In:* P. Truong and Xia Hanping (Eds.). Vetiver and Water. Proc. 3rd Intern. Conf. On Vetiver and Exhibition, held in Guangzhou, P.R. China. Oct 6-9, 2003. pp. 12-22.

Howeler, R.H., W. Watananonta and Tran Ngoc Ngoan. 2004a. Farmers decide: A participatory approach to the development and dissemination of improved cassava technologies that increase yields and prevent soil degradation. *In:* Proc. 13th Symp. Intern. Soc. Tropical Root Crops, held in Arusha, Tanzania. Nov 10-14, 2003. (in press)

Howeler, R.H., W. Watananonta, W. Vongkasem and K. Klakhaeng. 2004b. Working with farmers: The challenge of achieving adoption of more sustainable cassava production practices on sloping land in Asia. Paper presented at SSWM 2004 International Conference on Innovative Practices for Sustainable Sloping Land and Watershed Management, held in Chiangmai, Thailand. Sept 5-9, 2004.

Howeler, R.H., W. Watananonta and Tran Ngoc Ngoan. 2005. Working with farmers: The key to achieving adoption of more sustainable cassava production practices on sloping land in Asia. Paper presented at UPWARD Network Meeting, held in Hanoi, Vietnam. Jan 19-21, 2005. Paper available on CD.

Huang Jie, Li Kaimian, Zhang Weite, Lin Xiong and R.H. Howeler. 2001. Practices and progress in farmer participatory research in China. *In*: R.H. Howeler and S.L. Tan (Eds.). Cassava's Potential in Asia in the 21st Century: Present Situation and Future Research and Development Needs. Proc. 6th Regional Workshop, held in Ho Chi Minh city, Vietnam. Feb 21-25, 2000. pp. 413-423.

Lilja, N./N. Johnson, T. Dalton, R. Howeler and P. Calkins. 2005. Impact of participators natural resource management research in cassava-based cropping systems in Vietnam and Thailand. Paper submitted for publication to the Systemwide Participatory Impact Assessment (SPIA). 31p.

Nguyen The Dang, Tran Ngoc Ngoan, Le Sy Loi, Dinh Ngoc Lan and Thai Phien. 1998. Farmer participatory research in cassava management and varietal disseminationin Vietnam. *In*: R.H. Howeler (Ed.). Cassava Breeding, Agronomy and Farmer Participatory Research in Asia. Proc. 5th Regional Workshop, held in Danzhou, Hainan, China. Nov 3-8, 1996. pp. 454-470.

Nguyen The Dang, Tran Ngoc Ngoan, Dinh Ngoc Lan, Le Sy Loi and Thai Phien. 2001. Farmer participatory research in cassava soil management and varietal dissemination in Vietnam – Results of Phase 1 and plans for Phase 2 of the Nippon Foundation project. *In*: R.H. Howeler and S.L. Tan (Eds.). Cassava's Potential in Asia in the 21st Century: Present Situation and

Future Research and Development Needs. Proc. 6th Regional Workshop, held in Ho Chi Minh city, Vietnam. Feb 21-25, 2000. pp. 383-401.

Thai Tapioca Development Institute (TTDI). 2000. Cassava production situation in 1999/2000, according to a survey of farmer groups' leaders. 27p. (mimeograph) (in Thai)

Tran Ngoc Ngoan. 2003. Evolution of FPR methodologies used and results obtained in Vietnam. Paper presented at End-of-Project Workshop, held in Thai Nguyen, Vietnam. Oct 27-30, 2003.

Utomo, W.H., Suyamto, H. Santoso and A. Sinaga. 1998. Farmer participatory research in soil management in Indonesia. *In*: R.H. Howeler (Ed.). Cassava Breeding, Agronomy and Farmer Participatory Research in Asia. Proc. 5th Regional Workshop, held in Danzhou, Hainan, China. Nov 3-8, 1996. pp. 471-481.

Utomo, W.H., Suyamto and A. Sinaga. 2001. Implementation of farmer participatory research (FPR) in the transfer of cassava technologies in Indonesia. *In*: R.H. Howeler and S.L. Tan (Eds.). Cassava's Potential in Asia in the 21st Century: Present Situation and Future Research and Development Needs. Proc. 6th Regional Workshop, held in Ho Chi Minh city, Vietnam. Feb 21-25, 2000. pp. 424-435.

Vongkasem, V., K. Klakhaeng, S. Hemvijit, A. Tongglum, S. Katong and D. Suprahan. 1998. Farmer participatory research in soil management and varietal selection in Thailand. *In*: R.H. Howeler (Ed.). Cassava Breeding, Agronomy and Farmer Participatory Research in Asia. Proc. 5th Regional Workshop, held in Danzhou, Hainan, China. Nov 3-8, 1996. pp. 412-437.

Vongkasem, W., K. Klakhaeng, S. Hemvijit, A. Tongglum, S. Katong, D. Suparhan and R.H. Howeler. 2001. Reducing soil erosion in cassava production systems in Thailand – A farmer participatory approach. *In*: R.H. Howeler and S.L. Tan (Eds.). Cassava's Potential in Asia in the 21st Century: Present Situation and Future Research and Development Needs. Proc. 6th Regional Workshop, held in Ho Chi Minh city, Vietnam. Feb 21-25, 2000. pp. 402-412.

Vongkasem, W., K. Klakhaeng, W. Watananonta and R.H. Howeler. 2003. The use of vetiver for soil erosion prevention in cassava fields in Thailand. Paper presented 3rd Intern. Conf. On Vetiver and Exhibition, held in Guangzhou, P.R. China, Oct 6-7, 2003.

Zhang Weite, Lin Xiong, Li Kaimian and Huang Jie. 1998. Farmer participatory research in cassava soil management and varietal dissemination in China. *In*: R.H. Howeler and S.L. Tan (Eds.). Cassava's Potential in Asia in the 21st Century: Present Situation and Future Research and Development Needs. Proc. 6th Regional Workshop, held in Ho Chi Minh city, Vietnam. Feb 21-25, 2000. pp. 389-411.

Acknowledgement

The following persons in national programs were actively involved in the second phase of the project and contributed significantly to its success:

Mr. Watana Watananonta, Project Coordinator for Thailand, DOA, Bangkok, Thailand
Dr. Surapong Charoenrath, Field Crops Research Inst., DOA, Bangkok, Thailand
Mr. Danai Suparhan, Rayong Field Crops Research Center, DOA, Thailand
Mr. Somphong Katong, Rayong Field Crops Research Center, DOA, Thailand
Mr. Samnong Nual-on, Kalasin, Field Crops Res. Station, DOA, Thailand
Mr. Suttipun Brohmsubha, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Mr. Kaival Klakhaeng, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Mrs. Wilawan Vongkasem, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Mr. Suwit Phomnum, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Mr. Apichart Chamroenphat, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Mr. Chanchai Wiboonkul, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Ms. Sunan Muuming, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand

Ms. Naruemol Pukpikul, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Mrs. Chonnikarn Jantakul, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Ms. Methinee Keerakiat, Bureau Agric. Com. Prom. and Mgmt., DOAE, Bangkok, Thailand
Mr. Somchit Chinno, Provincial Ext. Office, Kalasin, DOAE, Thailand
Mrs. Nuttaporn Jaruenjit, District Ext. Office, Naamon, Kalasin, DOAE, Thailand
Mr. Chaipipop Yotachai, District Ext. Office, Huay Phueng, Kalasin, DOAE
Mr. Thinnakorn Withayakorn, District Ext. Office, Sahatsakhan, Kalasin, DOAE, Thailand
Mr. Nava Takraiklaang, District Ext. Office, Donchaan, Kalasin, DOAE, Thailand
Mrs. Anurat Srisura, Provincial Ext. Office, Nakhon Ratchasima, DOAE, Thailand
Mr. Choosak Aksonvongsin, District Ext. Office, Daan Khun Thot, DOAE, Thailand
Mr. Wirawudhi Kaewpreechaa, District Ext. Office, Daan Khun Thot, DOAE, Thailand
Mr. Chatphon Wongkaow, District Ext. Office,Khanuworalakburi, Kamphaengphet, DOAE, Thailand
Mr. Sanga Saengsuk, Provincial Ext. Office, Kanchanaburi, DOAE, Thailand
Mr. Parinya Phaithuun, District Ext. Office, Lawkhwan, Kanchanaburi, DOAE, Thailand
Mr. Sonsing Srisuwan, District Ext. Office, Thepsathit, Chayaphum, DOAE, Thailand
Mr. Numchai Phonchua, District Ext. Office, Thatakiap, Chachoengsao, DOAE, Thailand
Mr. Prayoon Kaewplod, Provincial Ext. Office, Chachoengsao, DOAE, Thailand
Mr. Sanit Taptanee, District Ext. Office, Nadi, Prachinburi, DOAE, Thailand
Mr. Sanit Phuumphithayanon, Provincial Ext. Office, Chayaphum, DOAE, Thailand
Mr. Banyat Vankaew, TTDI, Huay Bong, Nakhon Ratchasima, Thailand
Mr. Preecha Petpraphai, TTDI, Huay Bong, Nakhon Ratchasima, Thailand
Mrs. Supha Randaway, Land Development Dept. Bangkok, Thailand
Mrs. Kittiporn Srisawadee, Land Development Dept. Bangkok, Thailand
Mr. Decha Yuphakdee, Land Development Dept., Nakhon Ratchasima, Thailand
Dr. Somjat Jantawat, Kasetsart University, Bangkok, Thailand

Dr. Tran Ngoc Ngoan, Project Coordinator for Vietnam, Thai Nguyen Univ., Vietnam
Dr. Nguyen The Dang, Thai Nguyen University, Thai Nguyen, Vietnam
Mr. Nguyen Viet Hung, Thai Nguyen University, Thai Nguyen, Vietnam
Mr. Nguyen The Nhuan, Thai Nguyen University, Thai Nguyen, Vietnam
Dr. Thai Phien, National Institute of Soils and Fertilizers, Hanoi, Vietnam
Mr. Tran Minh Tien, National Institute of Soils and Fertilizers, Hanoi, Vietnam
Mr. Nguyen Hue, National Institute of Soils and Fertilizers, Hanoi, Vietnam
Mrs. Trinh Thi Phuong Loan, Root Crops Research Center, VASI, Hanoi, Vietnam
Mr. Hoang Van Tat, Root Crops Research Center, VASI, Hanoi, Vietnam
Mrs. Nguyen Thi Cach, Hue University of Agriculture and Forestry, Hue, Vietnam
Mrs. Nguyen Thi Hoa Ly, Hue University of Agriculture and Forestry, Hue, Vietnam
Dr. Hoang Kim, Hung Loc Agric. Research Center, IAS, Dong Nai, Vietnam
Mr. Nguyen Huu Hy, Hung Loc Agric. Research Center, IAS, Dong Nai, Vietnam
Mr. Vo Van Tuan, Hung Loc Agric. Research Center, IAS, Dong Nai, Vietnam
Mr. Tong Quoc An, Hung Loc Agric. Research Center, IAS, Dong Nai, Vietnam
Mr. Tran Cong Khanh, Hung Loc Agric. Research Center, IAS, Dong Nai, Vietnam
Dr. Tran Thi Dung, Thu Duc University of Agric. and Forestry, HCM, Vietnam
Mrs. Nguyen Thi Sam, Thu Duc University of Agric. and Forestry, HCM, Vietnam

Mr. Li Kaimian, Chinese Academy Tropical Agric. Sciences, Hainan, China
Mr. Huang Jie, Chinese Academy Tropical Agric. Sciences, Hainan, China
Mr. Ye Jianqiu, Chinese Academy Tropical Agric. Sciences, Hainan, China
Mr. Tian Yinong, Guangxi Subtrop. Crops Res. Inst., Nanning Guangxi, China
Mr. Li Jun, Guangxi Subtrop. Crops Res. Inst., Nanning Guangxi, China
Mr. Ma Chongxi, Guangxi Subtrop. Crops Res. Inst., Nanning Guangxi, China
Mrs. Chen Xian Xiang, Guangxi Subtrop. Crops Res. Inst., Nanning Guangxi, China
Mrs. Pan Huan, Guangxi Subtrop. Crops Res. Inst., Nanning Guangxi, China
Mr. Liu Jian Ping, Honghe Animal Husbandry Station, Mengzhe, Yunnan, China

We also want to express our gratitude to the Nippon Foundation in Tokyo, Japan, which generously supported this project over a ten-year period, from 1994 to 2003.