Impact of Participatory Natural Resource Management Research in Cassava-Based Cropping Systems in Vietnam and Thailand

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1. Introduction

In Southeast Asia, many of the poorest farmers live in areas with limited potential for crop production. Cassava (*Manihot esculenta* Crantz) is an important crop on these soils, because it is easy to grow, requires few external inputs, and its roots and leaves can be used as human or animal feed. Cassava is also planted as an industrial crop for production of animal feed and starch where market conditions are developed. The wide variety of end uses makes it a popular crop and an effective vehicle for improving the livelihood of poor upland farmers.

Cassava has an ability to thrive on soils which are inherently infertile, in areas where other crops have depleted soils of nutrients and under conditions of moisture stress. Thus cassava is often planted in erosion-prone hillsides, in soils of low nutrient status and regions of uncertain rainfall. Environmental concerns are often associated with cassava grown on steep slopes. The crop's slow initial growth and wide plant spacing do not provide adequate protection of the soil from the direct impact of rainfall thereby generating runoff and erosion. At the farm level, soil erosion can cause crop yield losses reducing agricultural incomes. At the national level, soil erosion produces sediment and silt that can clog irrigation channels and lower the water storage capacity of dams, and load nutrients.

Farmers may or may not be aware of the extent of the soil loss or nutrient depletion or do not have resources to replenish the soils (Hershey *et al.*, 1998). Many soil conservation and soil fertility management technologies are "preventive innovations" because they avoid unwanted future event such as loss of productive soils. Preventive innovations typically have a low rate of adoption because it is hard to demonstrate their advantages since benefits may occur only at some future, unknown time (Rogers, 1983). Also, if the benefits associated with the use of a soil conservation technology accrue primarily beyond the farm, producers may not include those benefits in their decision to adopt the technology. Low adoption rates may also be attributed to how these technologies were

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developed through a centralized research and extension system. The practices may not be widely adopted because farmers do not consider conventional “pipeline” products practical or appropriate.

To address these problems, the Regional Cassava Office for Asia of the International Center for Tropical Agriculture (CIAT), in collaboration with national agricultural research partners in Thailand, Vietnam, Indonesia and China, implemented a Nippon Foundation funded project titled “Improving the Sustainability of Cassava-based Cropping Systems in Asia” between 1994 and 2003. The goal of the project was to increase the living standard of small farmers and to improve agricultural sustainability in less favored areas of Asia by improving the productivity and stability of farming systems where cassava is an important crop. Although prior research had identified many potential soil conservation and fertility management options for use in these cassava systems, they were not adopted by farmers. Therefore the CIAT project was designed with a dual focus of developing technologies and increasing their adoption and effective use. This was to be accomplished by using a farmer participatory research (FPR) approach in which farmers themselves were involved in identifying, testing and promoting promising technologies.

The objective of this paper is to assess the impact of the CIAT project. This involves assessing both adoption and impacts of the project technologies as well as the contribution of the participatory research approach. Few studies attempt to distinguish between these two different types of impacts. A growing share of scarce research and development resources are being allocated to participatory methods, however it appears that the use of such methods are often based on personal experience and conviction rather than on solid evidence of their relative contribution to impact. This study is part of a growing effort to document and measure the impact of participatory methods in natural resource management (NRM) research (Sanginga et al 2002; Sanginga et al., 2001; Johnson et al., 2003; Johnson et al. 2004.)

This chapter is organized as follows: section two discusses some conceptual issues related to assessing the *ex post* impacts of farmer participatory cropping systems and natural resource management research. Section three describes trends in cassava production in Asia and explains the main features and outcomes of the CIAT project. Section four presents the farm-level impacts of participation and adoption of new technologies. The final section suggests some conclusions.

2. Conceptual issues in assessing the *ex post* impact of farmer participation in cropping systems research

Cropping systems research is concerned with improving the productivity and sustainability of agricultural systems. It examines not only crop improvement but also soil and water management, pest control, crop rotations or other activities related to resource use in agriculture. Improving cropping systems generally involves a combination of improved crop varieties, crop husbandry and natural resource management practices.

Agronomically, cropping systems are assessed in terms of both yield and other parameters such as loss of soil or soil nutrients or changes in pest or weed pressure. Economically, the sustainability of cropping systems can be assessed at the farm level by looking at net income over time, amenity gains, increased positive externalities such as greenhouse gas sequestration, or mitigating negative externalities such as soil erosion or nutrient loading.

Few rigorous *ex post* studies documenting the benefits of cropping systems research exist. One reason is that adoption of the soil and water management technologies forming a key part of improved cropping systems management has generally been low. Even when they do work agronomically and are targeted to priority problems faced by upland farmers, soil management technologies are often complex, highly site specific, costly to implement, and slow to yield monetary benefits, making them unattractive to many farmers (Fujisaka, 1994).

Farmer participatory research (FPR) emerged as a potential solution to the problem of limited adoption of cropping systems and natural resource management (NRM) technologies by farmers (Ashby, 2003), and there is a growing body of empirical evidence in support of its effectiveness (e.g., Hinchcliffe et al, 1999; van der Fliert et al., 2001; Johnson et al., 2003). One explanation for why FPR methods might increase adoption is that incorporating farmers into the process of designing and developing technologies increases the probability that the technologies will be relevant and appropriate. This type of FPR is often referred to as "functional" because its purpose is to improve the efficiency of a conventional research process (Ashby, 1996; Pretty, 1994).

Another approach to participatory research seeks not just to improve the final product (the technology) but also to improve the knowledge and capacity for innovation of those who participate in the process (Okali et al, 1994). This type of FPR, known as "empowering," views the research process as an interactive learning experience for both farmers and researchers. This approach is particularly promoted among practitioners in the area of natural resource management, where technologies are often complex and require adaptation to specific agrarian situations. Each farmer has to understand the technology and how to adapt it to his or her own farming system. An inventory of participatory NRM research projects found that 54% of projects reported specific skills development and 69% reported strengthening overall analytical capacity and empowerment among their project outcomes (Johnson et al., 2004).

Empowering participation does have significant implications for how impacts are generated and measured. As with conventional technologies, benefits can still be quantified in terms of increased agricultural productivity or reduced environmental damage, however the sources of the benefits are of two types. Part of any observed increase in productivity can be attributed directly to the superiority of the new technology or practice. These are often referred to as "embodied" effects since they are part of the technology itself. The second source of improved productivity is the increased knowledge or capacity that the farmer obtained by participating in the research process. These are often refered to as "disembodied" effects because they are not part of the technology (Chambers, 1988). These two types of impacts are not independent since a more knowledgeable farmer can make better use of a new technology. Therefore it is important to be able to separate the embodied and disembodied effects in order to accurately evaluate the impact of both the participatory research process and the technology.

3. Project context

Cassava production trends in Asia

World cassava production in 2004 was about 196 million tons, 53% of which was produced in Africa, 30% in Asia, and 17% in Latin America and the Caribbean (LAC). In the 1990s Africa increased cassava production at the average annual rate of 2.9%, while the production growth in Asia and LAC were stagnant. However, in the last five years Asia has experienced 2.9 % average annual production growth, compared to 1.3% in Africa and 1.4% in Asia. Vietnam and Thailand had negative growth rates in the 1990s but in the past five years, Thailand has had 1.4% average annual production growth, and Vietnam has had nearly 20% average annual growth of cassava production (FAO, 2005). Land degradation patterns are similar in Thailand and Vietnam: about half of the total land in Vietnam and Thailand are considered to be very severely, nearly 30% severely and about 20% moderately degraded.

Much of the production gains in Asia are related to increases in yield. In the last five years, the cassava yield in Thailand has increased 2.8% annually while cassava area harvested has declined. In Vietnam, the production gains are related to both area expansion and yield increases. In the past five years, the average annual growth of cassava-harvested area in Vietnam was nearly 9% while yields increased at an average annual rate of 11% (Table 2). Regional derived demand for cassava is expected to increase for livestock feed as demand for meat grows with Asian incomes (Fuglie, 2004).

Table 1: Average annual growth rate of yield and cassava area harvested (%)

Region	**1970-79**		**1980-89**		**1990-1999**		**2000-2004**	
	Δ Yield	Δ Area	Δ Yield	Δ Area	Δ Yield	Δ Area	Δ Yield	Δ Area
World	0.60	1.35	0.88	1.20	0.33	0.88	0.65	1.15
Africa	1.17	0.60	1.17	1.97	0.72	2.19	-0.12	1.45
LAC	-1.79	0.59	0.59	0.01	0.42	-1.26	0.26	1.18
Asia	1.82	3.76	1.30	0.50	0.70	-1.04	2.74	0.16
Thailand	-0.92	12.66	0.32	3.51	1.07	-3.34	2.84	-1.48
Viet Nam	0.28	12.59	1.91	-4.42	-1.04	-1.30	11.01	8.89

Source: Authors' calculations, FAO 2005

Cassava research in Asia

Research shows that nutrient depletion and erosion can be serious problems when cassava is grown as a monocrop on infertile soils and on sloping land. Judicious application of manure or chemical fertilizers will permit continuous cassava production at high levels of yield without nutrient depletion (Howeler, 1996). Similarly, soil and crop management practices have been developed that will minimize erosion when cassava is grown on slopes (Howeler, 1987, 1994, 1995, 1998a, 1998b; Kawano and Howeler, 1997). These practices include minimal land preparation, contour ridging, fertilizer application, mulches, intercropping, and vegetative contour barriers to reduce runoff and enhance deposition of suspended soil behind these barriers.

CIAT holds the world's largest collection of cassava germplasm forming the basis for a comprehensive breeding program. New varieties with higher yield potential, higher starch content, improved plant type, and greater resistance to pests and diseases, have been developed. Since 1983, the CIAT Cassava program in Asia has worked with national cassava breeding programs, selecting from material transferred from CIAT and breeding for local adaptation. Thirty-eight cassava varieties containing genetic material from CIAT have now been released in Asia. These are grown on about 1,506,000 ha (43% of total cassava area). Similarly, there has been an active and collaborative research program on the crop's nutrient, fertilization and soil management requirements.

The CIAT project

The main objective of this project was to develop better cassava production practices that would enhance the sustainability of production by helping farmers increase their income and by protecting the soil resource base from degradation as a result of nutrient depletion and erosion. Both the first (1994-1998) and second (1999-2003) phases aimed at enhancing the adoption of more sustainable production practices by involving farmers directly in the development of site-specific best-bet practices through farmer participatory methods. The first phase of the project developed and tested mainly a FPR methodology, while the second phase used this methodology, implemented in a simplified version in many more sites, and used various farmer participatory extension (FPE) methods in order to disseminate the farmer-selected practices to as many other farmers as possible.

The FPR methodology developed included selection of suitable villages that might benefit from the project, discussions and planning phase regarding implementation with officials at different levels, and a rapid rural appraisal with farmers in the village to obtain basic information and assess their interest in participating. After analyzing the results, the villages were selected based also on the willingness of local leaders to collaborate.

Once a village was selected, interested farmers from the village site(s) were taken on a field trip to visit demonstration plots, or visit another village where farmers had already conducted FPR trials or had adopted some selected practices. At the demonstration plots, farmers evaluated and scored all the varietal trials and soil fertility management options (treatments) and selected a few of most interesting to try out in FPR trials on their own fields (see Table 2 for technologies selected in the first phase).

Researchers and extension workers worked with farmers to develop and select appropriate trials, stake out plots and establish the selected treatments. Typical FPR trials had 4-6 treatments, including the farmer's traditional practice, without replication.

Although the emphasis was on FPR erosion control trials, farmers could also test other technology components such as new varieties, fertilization practices, intercropping, weed control and even pig feeding with cassava roots and leaves. At time of harvest, a field day was organized to let other farmers from the village and surrounding villages evaluate and discuss the results of the various treatments. From these results and discussions farmers then selected the best treatments for either further testing or for adoption in their production fields.

Table 2: Technological components selected by participating farmers from their FPR trials conducted from 1994 to 1998.

Technology	Thailand	Vietnam
Varieties	Kasetsart 50 Rayong 5 Rayong 90	KM60 KM94 KM95-3 SM1717-12
Fertilizer practices	15-15-15 156 kg/ha	FYM 10 t/haa (TP)+ 80N+40P_2O_5+ 80K_2O
Intercropping	monoculture(TP) C+pumpkin C+mungbean	monoculture(TP) C+taro(TP) C+peanut
Soil conservation	vetiver barrier sugarcane barrier	*Tephrosia* barrier vetiver barrier pineapple barrier

TP= traditional practice; FYM = farm yard manure; C=cassava.
Source: Howeler, 2004

Technologies developed

After 2-3 years of testing in FPR trials, farmers decided on the most suitable practices. To enhance the further dissemination of those selected practices, the project used several participatory and conventional extension methods such as organizing cross-visits of farmers from one village to another, field days, either during the crop cycle or at harvest, FPR training courses for farmers and local extension workers. During the first phase of the project, 244 farmers and extension workers attended the FPR training in Thailand, and 292 were trained in Vietnam. In Thailand, the project also set up community-based self-help groups called "Cassava Development Villages." In the second phase of the project, total of 338 FPR trials were conducted in Thailand, and 584 trials were conducted in Vietnam.

Table 3 and Table 4 show the average effect of various soil conservation practices, tested in numerous experiments and FPR trials, on relative cassava yield and soil loss in Vietnam and Thailand, respectively.

Table 3: Technologies tested and developed in Vietnam, 1993-2003

	Soil conservation-practices[1)]	**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)

Note: Effect of various soil conservation practices on the average relative cassava yield and dry soil loss due to erosion as determined from soil erosion control experiments, FPR demonstration plots and FPR trials Figures in parenthesis indicates the number of experiments/trials from which the average values were calculated.

[1)] ** = most promising soil conservation practices; * = promising soil conservation practices

Source: Howeler, 2004.

In summary, the project developed best-bet technologies, using farmer knowledge and participation, through the FPR process. Secondly, the successful elements of the FPR methodology were identified and disseminated to partner organizations using FPE. As a result, specific soil fertility management technology options were diffused to additional non-project farmers. In addition, the human capital of the participating farmers is assumed to be increased because they engaged in the technology development process with the researchers. This hypothesis, among others, is tested in the following section.

Conceptual framework

To evaluate hypotheses that the FPR methodology increased the adoption of soil fertility management and conservation technologies while simultaneously increasing human capital, a farm level decision model is formulated. Farm production is multifunctional and produces two generic products: a commodity output (in this case cassava) and a non-commodity environmental output. The multifunctional and multiproduct farm production function constraint is defined as:

$$(1) \quad 0 = (Y, Y^{NM}, L, A, B, P_t, Z_t \mid \delta_t, \theta_t)$$

Multiproduct output (commodity (Y) and non-commodity(Y^{NM})) is a function of labor (L), land (A), and biochemical inputs (B), P_t, current prices that control for policy or induced innovation effects, and conditioned upon the effective production technology, δ_t, made available by current (R_t) and past research (R_{t-l}) and current (E_t) and past extension delivery (E_{t-l}). In this model we can include the FPR input as part of current and past research activities.

Table 4: Technologies tested and developed in Thailand, 1994-2003

	Soil conservation practices1$^{1)}$	**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; *Leucaena leucocephala* hedgerows, no intercrop*	66 (2)	56 (2)
11.	With fertilizers; *Gliricidia sepium* hedgerows, no intercrop*	65 (2)	48 (2)
12.	With fertilizers; *Crotalaria juncea* hedgerows, no intercrop	75 (2)	89 (2)
13.	With fertilizers; pigeon pea hedgerows, no intercrop	75 (2)	90 (2)
14.	With fertilizers; contour ridging, no hedgerows, no intercrop**	108 (17)	69 (17)
15.	With fertilizers; up-and-down ridging, no hedgerows, no intercrop	104 (20)	124 (20)
16.	With fertilizers; closer spacing, no hedgerows, no intercrop**	116 (10)	88 (11)
17.	With fertilizers; C+peanut intercrop	72 (11)	102 (12)
18.	With fertilizers; C+pumpkin or squash intercrop	90 (13)	109 (15)
19.	With fertilizers; C+sweetcorn intercrop	97 (11)	110 (14)
20.	With fertilizers; C+mungbean intercrop*	74 (4)	41 (4)
21.	No fertilizers; no hedgerows, no or up/down ridging	96 (9)	240 (10)

Note: Effect of various soil conservation practices on the average relative cassava yield and dry soil loss due to erosion as determined from soil erosion control experiments, FPR demonstration plots and FPR trials Figures in parenthesis indicates the number of experiments/trials from which the average values were calculated. C=Cassava.

$^{1)}$ ** = most promising soil conservation practices; * = promising soil conservation practices

Source: Howeler, 2004.

"Knowledge," represented by (θ), or alternatively thought of as a cumulative information management function accrued informally or through formal information delivery systems in the current production period *t* or previous ones (*t-l),* is modeled as an approximation to the individual's stock of human capital. Knowledge growth can be modeled as a stock accumulation balance:

$$(2) \quad \theta_t = \theta_{t-1} - D_t + IA_t$$

Where D_t represents the depreciation of useless information and IA_t represents knowledge acquisition. Information acquisition takes place through active learning processes, like participatory research, or through passive mediums such as mass media or conventional extension field days. The time constraint accounts for the opportunity cost of investing in human capital and is written:

$$(3) \quad l + L(\theta) + IA = T$$

Where *IA* is the time allocated to education or information acquisition. θ*,* therefore, represents the impact of the information acquisition activity. It affects the productivity of farm labor and the amount of time available for leisure (*l*). The farm income constraint is defined as:

$$(4) \quad P^M C^M + w\left(l + IA\right) = P^H (Y - C^H) + P^{NM} Y^{NM} - c\left(r, v, \phi, I, Y, Y^{NM}\right) + NF$$

Where P^M and P^H are the explicit prices of market and household products, *w* is the wage rate for labor, and *wl* and *wIA* are the opportunity cost of leisure and education. On the right hand side is the farm profit equation plus non-farm income (*NF*). The prices for land, labor and biochemical inputs are defined as *r, v,* and *φ* respectively, and *I* represents annualized investment costs associated with the production of Y^{NM}. P^{NM} represent a virtual or market price for the environmental good produced by the farm.

$$(5) \quad U = U(C^M, C^H, Y^{NM}, l; Z)$$

Household utility is maximized over the consumption of market, household, the nonmarket (public good or abated environmental externalities) goods and leisure subject to a vector of exogenous characteristics controlling for market, physical, and research infrastructure capital *Z*. Assuming an interior solution to the maximization of (5) with respect to (3) and (4) (or alternatively (2), (3) and (4) with a multiperiod discounted utility version of (5)) the resulting objective function may be rewritten in reduced form as an indirect function where utility is defined as a function of wages, an implicit wage ($\tilde{w}$) conditioned upon managerial knowledge and S_j is the share of non-market products relative to commodity outputs. V_j is the indirect utility of the level (or intensity) of information acquisition choice *j* where *j=1…m*.

$$(6) \quad V_j = V(w, \tilde{w}(\theta), T, S_j\left(Y^{NM}/Y \mid \delta_t\right), IA_j, Z)$$

Based upon the equations 1-6, there are several descriptive queries and testable hypothesis to be evaluated. First we are interested in the motivation to become involved with traditional versus participatory research and extension activities on crop and resource management. Very little of this is observable to the researcher so we need to rely upon choice decisions to participate, which may demonstrate the expected return to the education component, and the implicit wage impact since this is derived from the calculus of costs and realized benefits.

Secondly, we hypothesize that those individuals that were involved in participatory research and extension activities produce greater nonmarket products, primarily in the form of abated soil-related externalities e.g. erosion, downstream siltation, nutrient mining or soil structure degradation. This is proxied through observation on the adoption and usage of soil fertility and soil conservation interventions.

In order to derive insight into the implicit wage impacts, productivity differences between those that participate and those that do not must be identified. Since we cannot observe these implicit wage impacts directly, we define proxies for their effects in terms of behavioral and productivity changes before and after project intervention. In order to evaluate the net impact upon production, several additional hypotheses are formulated.

Productivity changes are measured in terms of changes in per-hectare yields (converted from local measures) before and after project intervention. We hypothesize that participation positively impacts productivity differences through two mechanisms. The first mechanism is embodied in the adoption of soil fertility management and conservation technologies. The second mechanism is not embodied in any technology per se but is related to human capital accumulation through greater information acquisition as described in (2). This impact is observed by controlling for the treatment effects of the participation decision in the behavioral and productivity impact equations.

4. Estimating adoption and impact at the farm level

Data and methods

To assess the impact of the FPR project, data were collected on over 800 farm households in 16 communities in Thailand and Vietnam in 2003 (Agrifood, 2004). Complete and usable survey formats were obtained from 767 households. Data collection was carried out in 8 villages per country, half of which were villages in which the project worked and half of which were neighboring villages in which the project did not work. All project villages were characterized on the basis of the year the research site was established (newer sites were excluded), slope of the land, presence and extent of government support (Vietnam only), existence of a starch factory (Vietnam only), importance of cassava in the cropping system, and status as “Cassava Development Village” (Thailand only), and a sample of eight villages was drawn to ensure maximum variability. In addition eight non-project villages were selected which were similar to and were located nearby (within 10 km) the selected project villages.

Focus group discussions were conducted in each site, and during the meeting the survey form was distributed to each focus group participant. Focus group participants filled out the forms for their respective households. The survey form asked for information that would have been easily known by participants, such as household membership, the construction of their house, significant property owned by the household, and details of the cassava production systems.

Survey forms were completed by focus group participants, and therefore do not constitute a proportional stratified or random sample. Non-proportional sampling does not negate valid inferences about the village as a whole, since population figures are known from official statistics and in the majority of cases the number of households surveyed comprised a significant proportion of the total households in the village. About 30% of the total number of households were surveyed (Agrifoods, 2004).[5]

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[5] Stratification of households in terms of participation, gender, wealth and poverty in the context of this participatory rapid rural appraisal (PRRA) study are exogenous stratifications, rather than an endogenous stratifications, and so valid parameter estimates are still obtained (Maddala, 1986).

Characteristics of survey villages and households

Selected demographic and other characteristics of sample households are presented in Table 6. Fifty-four percent of households in the sample are from Thailand and 46% from Vietnam. Eighty percent of households were headed by males, and this did not vary significantly between countries. Household composition did vary significantly; households in Vietnam had significantly more children than households in Thailand.

To get an idea of the wealth level, households were asked to rate themselves as "poor," "average" or "better off" as compared to the rest of their community. The results suggest that the distribution of households in terms of relative wealth varies significantly by country. The Vietnam sample contains many more "poor" and "better off" households, while the Thailand sample has more "average" households.

There are also significant differences between countries in terms of agricultural assets and activities. Households in Thailand have much larger average land holdings than their counterparts in Vietnam, 4.5 ha versus just under than 1 ha, respectively. This is consistent with the national statistics on available arable land per capita. Thai farmers' land was also significantly less hilly; farmers in Thailand reported having only flat or rolling land while in Vietnam some farmers reported having hilly land. Thai farmers plant around 60% percent of their land to cassava, and this did not change over the course of the project. The national statistics confirm that in recent years, there has not been significant cassava area expansion in Thailand as compared to rapid expansion in Vietnam. Before the project, Vietnamese farmers were planting about 50% of their land to cassava; however, after the project this had risen to 57%. Cassava yields are significantly higher in Thailand than in Vietnam, though the difference declined from 17% to 9% during the course of the project. Farmers in both countries experienced large yield increases over the period, on average 68% in Thailand and 80% in Vietnam.

Participation in the FPR project

Overall, 31% of households in the sample participated in the FPR project, 26% in Thailand and 36% in Vietnam. A "participant" was defined as someone who had conducted an FPR trial and/or participated in an FPR training course. A "non-participant" had done neither of these things, but may have participated in a field day organized by the project. In terms of the types of participation described in section 2, we are only looking at empowering participation since it is the only type assumed to have direct impacts on farmers.

Project v non-project villages

While the idea was to select project villages that were similar to non-project villages, the data show that project and non-project villages differ significantly in terms of agricultural assets and activities. This is especially the case in Thailand, where project villages had significantly higher initial land area, cassava area, and cassava yields, compared to non-project villages[6]. Project villages also had on average flatter land. Households in project villages also had significantly more livestock, and were significantly more likely to have fishponds. In Vietnam, there were no differences between project and non-project

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[6] Data on project non-project village comparison is not presented.

villages in terms of initial land holdings; however, project villages had, on average, higher initial yields, flatter land, and more livestock and fish[7].

Participant v non-participant farmers

In Thailand, participant and non-participant households did not differ in terms of composition (Table 5). In Vietnam, female-headed households were significantly less likely to have participated than male-headed households.

There were no significant differences between participants and non-participants in terms of their distribution across wealth categories, but there were some significant differences in terms of agricultural activities and assets. In Thailand, participant households had significantly higher land holdings and cassava yields, both before and after the project, compared to non-participants. Participants had much hillier land than non-participants, which might explain their interest in a project aimed at soil conservation. They also had fewer livestock than non-participants, which may also reflect a greater orientation towards crop agriculture

In Vietnam the only differences between participants and non-participants in terms of agricultural assets and activities were that participants planted more area to cassava and obtained higher yields after the project. There were no differences in initial land holdings or yields. If we look only at project villages, the results change quite significantly. Participant households had higher initial land area and cassava area, and lower initial yields. There are no significant differences in post-project yields. Participants had significantly steeper land, and were less likely to have fishponds.

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[7] These differences between project and non-project villages do not prevent us from making inferences based on the results of the analysis of the sample. It does imply that extrapolation of impacts observed in project villages to non-project villages must be done with caution.

Table 5: Selected characteristics of farm households in Thailand and Vietnam

	Total			Thailand		Vietnam		Total	
	Thailand (n=417)	Vietnam (n=350)	Total (n=767)	Participants (n=109)	Non participants (n=308)	Participant (n=126)	Non Participants (n=224)	Participants (n=235)	Non Participants (n=532)
Household Composition									
% Female headed	20	21	20	19	20	15*	24*	17	21
Households Size (# of persons)	4.2	4.6	4.4***	4.3	4.1	4.8	4.5	4.6	4.3*
Number of adults	2.8	2.8	2.8	2.9	2.8	3.0	2.8	2.9	2.8
Number of Children	1.4	1.8	1.***	1.1	1.0	1.8	1.8	1.7	1.5*
Poverty Status									
% Poor	8.4	20.3	13.8***	6.4	9.1	24.6	17.9	16.2	12.8
% Average	84.2	67.1	76.4***	82.6	84.7	66.7	67.4	74.0	77.4
% Better off	7.4	12.6	9.8***	11.0	6.2	8.7	14.7	9.8	9.8
	100	100	100	100	100	100	100	100	100
Agricultural activities and assets									
Pre-project land area (ha)	4.5	.95	2.9***	5.9	4.0***	1.1	0.9	3.3	2.7**
Post-project land area (ha)	4.8	.97	3.0***	6.2	4.2***	1.1	.9	3.5	2.8**
Pre project cassava area (ha)	2.7	.48	1.7***	3.8	2.3***	0.5	0.4	2.1	1.5**
Post project cassava area (ha)	2.9	.56	1.9***	4.2	2.5***	0.6	0.5*	2.3	1.7***
Cassava yield, pre project (t/ha)	16.5	14.1	15.4***	19.4	15.5***	13.7	14.3	16.4	15.0**
Cassava yield, post-project (t/ha)	27.8	25.4	23.4***	25.8	20.3***	28.2	23.9***	27.1	21.8***
Slope of land (0=flat,1=rolling,2=hilly)	1.4	1.7	1.5***	1.6	1.3***	1.7	1.7	1.6	1.5***
Livestock units owned (#)	1.9	3.0	2.4***	1.5	2.1***	3.4	2.8*	2.5	2.4
% with fish pond	33	47	40***	50	28***	48	47	49	36***
Total									

*<=.10 ** <= .05 ***<= .01

Adoption of project technologies

Project v non-project villages

Again, before looking at differences between participants and non-participants, we look briefly at differences between project and non-project villages. Again, there are significant differences between the two types of villages. In Thailand, project villages had significantly higher levels of adoption of all technologies. In Vietnam, only chemical fertilizer use was the same between project and non-project villages.

Participants v non-participants

Adoption of the technologies promoted by the project varied by technology and country (Table 6). Adoption of improved varieties was relatively high in both countries. In Thailand, all households planted improved varieties on at least 50% of their cassava area, and 91% planted only improved varieties. In Vietnam, 75% of households planted improved varieties, and 43% planted them exclusively. In both countries and in the pooled sample, adoption levels were significantly higher among participants than non-participants. If we look only at the project villages, however, we do not see significant differences in level of adoption of new varieties between participants and non-participants in Vietnam, only in Thailand.

Just under half of the households in the survey adopted one or more soil conservation practices. Thirty one percent adopted contour ridging and 24% adopted hedgerows. Adoption levels did not vary significantly between countries, but they did vary between participants and non-participants. In Thailand, participants were much more likely to have adopted contour ridging and hedgerows than non-participants. In Vietnam, half of participants adopted hedgerows compared to only 12% of non-participants. Overall, there is a positive and significant correlation between the adoption of contour ridging and hedgerows and participation.

Just over a third of all households in the sample adopted intercropping: 59% in Vietnam and 13% in Thailand. In the full sample, participants were more likely than non-participants to adopt. When looking at only project villages, only in Thailand were participants significantly more likely to intercrop than non-participants. We find limited evidence of a positive relationship between intercropping and participation.

Fertilizer use was relatively high across all households in the sample, with 87% of households using chemical fertilizers and 48% using farmyard manure. Only 9% of households used neither organic nor inorganic fertilizer. In Vietnam, only farmyard manure use was significantly higher among participants compared to non-participants. As a whole there is a positive correlation between adoption of farm-yard manure and participation but no relationship exists for chemical fertilizer.

Table 6 Extent of adoption (percent of households) of new technologies by participating and non-participating farmers in the cassava project in Thailand and Vietnam in 2003 (n=767).

Technologies adopted	Thailand			Vietnam			Full Sample		
	Participant (n=109)	Non Participants (n=308)	Total (n=417)	Participants (n=126)	Non Participants (n=224)	Total (n=350)	Participants (n=235)	Non Participants (n=532)	TotaL (n=767)
Varieties (% of area in improved)									
- 100%	100	88.0	91.1	50.0	38.8	42.9	73.2	67.3	69.1
- 75%	0	11.7	8.6	5.6	6.7	6.3	3.0	9.6	7.6
- 50%	0	.3	0.2	26.2	18.3	21.1	14.0	7.9	9.8
25%	0	0	0	4.0	5.4	4.9	2.1	2.3	2.2
None	0	0	0	14.3	30.8	24.9	7.7	13.0	11.3
	100	100	100***	100	100	100***	100	100	100***
Soil conservation practices (% adopting)*									
- contour ridging	52	22	30***	35	31	33	43	26	31***
- hedgerows	60	10	23***	50	12	25***	54	11	24***
- no soil conservation	21	72	59***	23	58	45***	22	67	53***
Intercropping	28	8	13***	79	49	59***	55	25	34***
Fertilization (% adopting)*									
- 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*

* Percentages may total more than 100 percent as households can adopt more than one type of technology simultaneously
*<=.10 ** <= .05 ***<= .01

Impact

To assess the impact that these new technologies had on productivity, and the extent to which the project contributed to both adoption and impact, we need to analyze the determinants and outcomes of a series of decisions that farmers made. Figure 1 presents a schematic of these decisions involved in an FPR project. Assuming that his or her village is chosen by the project, each farmer in the village chooses whether to participate in the project activities or not. This decision is likely to be determined by a variety of factors such as the importance of cassava in the individual's farming system or the availability of time or land to dedicate to the project. Personal characteristics are also likely to matter, for example his or her interest in experimentation, or connections to community and existing social networks that would allow access to new information without active participation in the project activities.

When the project is finished and the results of the trials are available, all farmers, both participants and non-participants, face the decision of whether or not to adopt them. This decision is separate from the decision to participate since participants can choose not to adopt and non-participants can choose to adopt. However the decisions are not independent in the sense that some of the same factors that influence the decision to participate are likely also to influence the decision to adopt (Greene, 1998).

Finally, we need to look at the outcomes of participation and adoption. We look at two types of outcomes: behavioral and productivity. The behavioral outcomes are changes in total area planted and area planted to cassava. Given the availability of new technologies, farmers may change their land allocations, reallocating across crops or changing total area planted. This is of particular interest in this project since expansion of area planted, which occurred over the course of the project, might imply moving into more fragile and erosion prone areas. The productivity outcome of interest is the change in cassava yield. Since some of the same farm and farmer characteristics that affect participation and adoption will also likely influence land allocation and production, we must estimate these equations as a system.

This analysis was done via estimations of sets of simultaneous equations, and the results indicate that project activities had a significant impact on adoption of soil management technologies, in particular contour ridging, hedgerows and the usage of farm yard manure. Both project technologies and participation in the project influenced behavioral and productivity outcomes (see Table A1 for variable definitions and descriptive statistics and Table 7 for regression results).[8]

In terms of behavioral outcomes, the results indicate that adoption of contour ridging was negative and significantly related to expansion of total cropped area and cassava area. In addition, the adoption of improved cassava varieties was also significantly related to areal

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[8] Full specification of the regression is available in Dalton et al. 2005 and Dalton, Lilja and Johnson, 2005. These are not included due to space limitations. Additional regression not presented include a binary Probit selection model and five Bivariate Probit soil fertility and conservation adoption decisions with treatment effects following Greene (1998).

expansion of cassava. Slope is also positive and significantly related to area expansion, suggesting that production is moving to more environmentally sensitive areas. However, it appears that farmers are using contour ridging to expand into these areas in a sustainable manner. We find that participation was not significantly related to area expansion indicating that FPR did not contribute to area expansion of cropping activities.

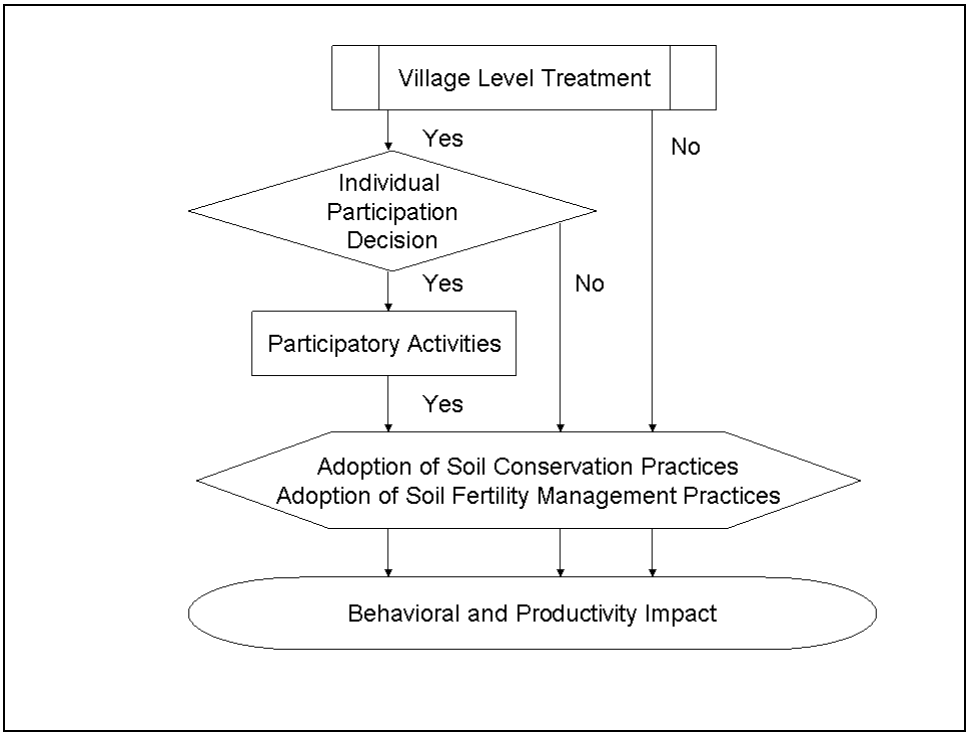

Figure 1. Treatment effects, adoption decisions, behavioral and productivity impact

Farmers with larger initial land holdings expanded relatively less than those with smaller holdings, and female-headed households were more likely to expand their total cropped area than male-headed households.

In terms of productivity, adoption of improved varieties and hedgerows contributed significantly to increased cassava yields. Other technologies appeared to have no significant effect. This is somewhat surprising in the case of, for example, fertilizer. One explanation could be that fertilizer use was widespread, and that we did not collect data on quantity or composition of fertilizers used, just on use or non-use. Yield gains were relatively larger in Vietnam than in Thailand. Another exogenous factors associated with increased yields was the proximity to a starch factory.

Participation in the project had positive and significant impact on yield change, a finding that confirms the importance of the "disembodied" effects associated with FPR. This impact is in addition to the yield gain associated with hedgerow adoption. Since participation is measured as a dummy variable, we cannot say exactly how participation leads to a yield increase independent of the embodied treatment effects. Our hypothesis is that it is related to the enhanced knowledge, experience and managerial capacity gained via participation and experimentation. In addition to the impact on participants, the village-level spillover effect was positive and significant indicating diffusion of techniques to non-participants located in FPR villages.

Table 7: Land Allocation and Productivity Impacts Controlling for Treatment Effects

	Δ Cropped Area		Δ Cassava Area		Δ Cassava Yield	
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
INTERCEPT	-0.834 **	0.363	-1.383 *	0.268	-10.121 *	2.484
GENDER	-0.181 ***	0.098	-0.024	0.074	-0.530	0.677
NUMADULT	0.003	0.033	0.008	0.025	0.247	0.228
NUMCHILD	0.022	0.038	-0.007	0.028	0.002	0.262
POVERTY	0.117	0.086	0.063	0.064	0.963	0.592
LAND1	-0.055 *	0.013	-0.002	0.009	-0.175 **	0.087
FISH	-0.007	0.090	0.036	0.067	-1.162 ***	0.617
TLU	0.028 *	0.008	0.028 *	0.006	-0.008	0.052
COUNTRY	-0.579 *	0.153	-0.187	0.114	13.322 *	1.049
SLOPE	0.506 *	0.108	0.500 *	0.080	-0.807	0.741
FACTORY	-0.094	0.193	-0.015	0.143	8.576 *	1.327
TIME	0.015	0.031	0.005	0.023	-0.302	0.213
SPILL	0.057	0.217	0.256	0.158	2.679 ***	1.472
VARIETY	0.141	0.176	0.257 **	0.130	6.637 *	1.201
P(INTER)	0.069	0.264	0.082	0.191	-0.524	1.789
P(HEDGE)	0.228	0.165	0.143	0.121	3.403 *	1.126
P(CONT)	-0.301 ***	0.155	-0.219 ***	0.113	0.301	1.055
P(FYM)	0.149	0.184	-0.005	0.133	-0.824	1.247
P(CHEM)	-0.085	0.249	0.006	0.181	0.018	1.692
Participation	-0.283	0.433	-0.259	0.316	8.334 *	2.948
Selectivity (λ)	0.256	0.285	0.318	0.207	-2.429	1.933
F(20,746)	4.05 *		4.91 *		23.51 *	

*,**,*** indicates significance at the 10%, 5% and 1% levels respectively.

Rate of return on the research investment

To calculate the rate of return to the investment in this project, we compare the costs of the project to the benefits it generated.

Project Costs

Costs associated with this analysis accrue from three sources: Nippon Foundation costs that financed the overall project, costs associated with the adoption of soil conservation technologies and the opportunity cost of time invested in FPR/FPE activities. Project costs of the Nippon Foundation and local partners are estimated at USD3.96 million over the two phases of the project (Table 8).

Secondly, using partial budgets, the incremental costs associated with adopting the soil conservation and fertility management technologies were estimated (Agrifoods, 2004). Farm-level costs associated with the adoption of these technologies include the opportunity cost of participation, and direct components such as materials required to establish the conservation interventions and acquisition of new cassava plantings. The total costs associated with the project include both the project costs and the farm-level adoption costs. Many of the farm-level costs, for example new cuttings or conservation materials are treated as investment costs and are depreciated over an intermediate term of eight years.

Table 8: Project implementation costs (US$ nominal)

Year	Nippon*	Local-Vietnam	Local-Thailand	Total
1994	290,943	22,222	116,667	429,832
1995	274,303	22,222	116,667	413,192
1996	274,303	22,222	116,667	413,192
1997	274,303	22,222	116,667	413,192
1998	274,303	22,222	116,667	413,192
1999	224,001	22,222	116,667	362,890
2000	229,057	22,222	116,667	367,946
2001	241,360	22,222	116,667	380,249
2002	256,962	22,222	116,667	395,851
2003	231,742	22,222	116,667	370,631
Total	2,571,277	222,220	1,166,670	3,960,167

* Only 2/3 of Nippon costs were included since the project also had activities in other countries.

Benefit Calculation

The project sought to generate production, environmental and human capital benefits. While we document the latter two, it is difficult to fully value them. However, we can value the production benefits obtained via yield increases due to improved technologies and human capital related to cassava production. This can be used as a proxy for total project benefits. It is clearly an underestimate of total benefits since it does not include off-site environmental impacts or spillovers of human capital to non-cassava activities. Since the project was designed to generate plot-level benefits via better crop management, we would expect productivity growth to be the primary impact.

From the yield equation in Table 7, we see that adoption of hedgerows increased yields by 3.4 t/ha while participation in project activities was associated with an increase in yield of 8.3 t/ha. Adoption of improved varieties increased yields by up to 6.6 t/ha. Finally, spillover effects to nonparticipants within the village are also positive and significant adding 2.7t/ha. We value this supply gain at local cassava prices[9].

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[9] Local prices for fresh cassava roots (at 30% starch content) from Nakhon Ratchasima province provided by the Thai Tapioca Trade Association are converted to US$/MT using an average annual exchange rate. These prices are reduced by 15% to account starch content that likely ranges from 20-30%. The average price for the 1994-2003 period was US$27.59/MT. A parallel series does not exist for Viet Nam. Using national FAO data and expert opinion, it was determined that prices for Viet Nam largely exceed those from Thailand. In the absence of firm data for Viet Nam, we use the Thai price as representative. Thus, the benefits for Viet Nam are conservatively estimated. Prices in Viet Nam likely averaged $28-30/MT over the 1994-2003 period.

Estimation of total benefits is restricted to project villages. Participation in project activities was obviously only possible in the villages where the project worked. Adoption of hedgerows occurred overwhelmingly in project villages—only 5% of farmers in non-project villages adopted hedgerows versus 34% in project villages. Use of improved varieties was common in project and non-project villages, but the average percent of cassava area planted to improved varieties was higher in project villages than non-project villages. This suggests that the project had only an incremental impact on varietal adoption in project communities. We assume this incremental increase in area planted to improved varieties that can be attributed to the project at 25%, based on observed differences in adoption levels between project and non-project communities (Table 9).

Table 9: Adoption of improved varieties by project status of village (% hh)

Percent of area in improved varieties	Non-Project village	Project village
0%	22	6
25%	3	2
50%	6	12
75%	12	5
100%	57	76
Total	100	100

Significant level of Chi square statistic = .000

The benefit at the village level is the sum of the benefits for each category of beneficiary, i.e. participants, non-participants, and adopters and non-adopters. To obtain the benefit for each category, we need to know the average incremental increase in production per hectare and the average area planted to cassava for farmers in each category. To extrapolate to the village level, we need to know the total number of households per village, and how they are distributed across beneficiary categories. Table 9 presents this information for the project villages in the sample.

Table 9: Benefits of project by type of beneficiary and by village

	Average yield increase due to project (t/ha)	% of all households in category*	# of all households in category**
P+H+V	11.0	18	25
P+H	9.3	15	21
P+V	7.6	06	8
P	5.9	36	50
NP+H+V	7.7	5	7
NP+H	6.1	7	10
NP+V	4.3	3	5
NP	2.7	9	12
TOTAL		100	137

P=Participant, H = Adopted hedgerows and V = Planted varieties on 100% of area, NP=non-participant spillovers.

* from sample ** based on a sample average of 137 households per village.

According to the analysis, the project resulted in an additional 2,802 tons of cassava per village at equilibrium. To allocate these benefits over time, we assume that this equilibrium is the survey year 2003. Between 1994 and 2002 we assume that the benefits are a fraction of the equilibrium that is directly proportional to the number of farmers that were trained in the FPR/FPE activities. Thus, the adoption profile increases at a logistic rate over the ten year period (Griliches, 1957). These benefits are valued at the farm-level price of cassava which varies from year to year. The gross annual research induced supply shift (GARB) amounted to US$2.12 million in 2003 (the last year of the project).

Assuming that benefits remained the same in the following year, the GARB amounts to US$2.50 million. If we only account for the benefits that accrued during the project implementation period, the estimated internal rate of return (IRR) is 41.2%. If we extrapolate the benefits an additional five years, at the same rate as observed during the survey period, which is consistent with what was observed in communities where the project has been working for several years, then the IRR increases to 49.2%.

Various systematic alterations of the cost and benefit scenarios were simulated in order to determine the sensitivity of the results. These scenarios indicate that when intra-village spillover effects are not included in the base calculations, the IRR decreases to 28.1% during the project period and 38.9% when extrapolated to 2008. Conversely, if we assume that the farm-level costs were underestimated, i.e. the actual costs were higher than estimated costs, the IRR is reduced by approximately 0.5% for every 10% of cost increase. Overall, the IRR calculations are sensitive to the inclusion of the spillover effects and insensitive to the cost calculations.

Another conservative assumption is to lag the benefits by one year to allow for additional learning. If this is done during the project implementation phase, the IRR is reduced to 20.0%, and 34.1% if the benefits are extrapolated five years. This is highly restrictive since some productivity gains accrued even in the first year of experimentation. Despite being extremely conservative, the estimated IRR generates sizeable productivity gains. At a plausible extreme, allowing the benefits to accrue at the same level observed in 2004 for an additional five years and including spillover effects, the IRR is 49.2%. At the most conservative, the IRR is 20.0. Overall, the expected rate of return under reasonable assumptions lies between 34% and 41%. If varietal impacts are eliminated, the IRR for crop, natural resource management, and participation drops to about 30% on average. This result is consistent with results published in Alston et al. (2004). Most importantly though is that the IRR figures only value the incremental productivity gain—only one goal of the projects objectives. All of the IRR calculations *do not include* the non-market contribution of resource degradation abatement or the long-term benefits of human capital accumulation. Tables 3 and 4 provide evidence of soil resource conservation associated with technology adoption that would increase the social rate of return to this project. Finally, there is evidence of an "empowering" effect of participatory research that is not found in conventional passive extension activities. We cannot value the broader impact of empowerment without additional investigations, but we find evidence that it did impact cassava productivity.

6. Discussion

Assessing the impact of a participatory cropping systems research is complex. As this impact study has found out, the initial selection of project villages and project participants determined how benefits were distributed and also found significant diffusion to non-participants. This diffusion effect is contrary to the lack of diffusion effects found in recent studies of Asian farmer field schools for IPM in rice systems (Feder et al., 2004a; Feder et al., 2004b). This may be explained by the diametrically different nature of the technologies: IPM is largely knowledge-based and non-visible to non-participants while soil conservation interventions are visible and tangible[10].

The results indicate significant and positive impacts of CIAT-Asia cassava project activities. First, survey results indicate that land allocated to cassava production is expanding and it is expanding at a faster rate on hillier terrain and in areas located near starch factories. This result is consistent with other published studies that have examined regional trends in cassava production (Fuglie, 2004; FAO, 2005). The technologies promoted by the project are important soil conservation and fertility management techniques designed to maintain (or increase) productivity capacity of hillier areas. The project achieved significant levels of adoption, especially for soil conservation practices. The adoption of hedgerows was linked to productivity impacts, while the adoption of contour ridging to a reduction of cropped area.

Secondly, we find that there are additional benefits to participatory research activities that are not embodied in the adoption of soil conservation or fertility management techniques. Controlling for the treatment effects, participation was positively related to yield increases over non-participants. While this research cannot identify the particular mechanism that generated these effects, several hypotheses have been advanced. Practitioners argue that participatory research activities improve farmers' understanding of the relationships between the components of their farming systems and this may generate efficiency gains based upon managerial modifications. Secondly, the participatory approach is an active learning activity and it may increase human capital and the ability to respond to and moderate production stresses that decrease productivity. We find that these gross measures of participation provide the rationale for more sophisticated investigations on the impact of participatory research activities upon adoption, land allocation and productivity growth.

The expected IRR was estimated to be between 34-41%. The calculations are likely to underestimate the total value of benefits since they are based only on incremental cassava productivity gains. Other benefits that were not incorporated include the abatement of environmental externalities, human capital spillovers to other cropping activities and institutional benefits. The paradoxical finding that few of the soil conservation interventions contributed to productivity gains necessitates additional research. On the one hand it may be explained by soil physics, chemistry and processes. Soil quality improvements generally accrue over the long-run and are slow to become visible. On the

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[10] The authors are grateful to Gershon Feder to suggesting this explanation.

other hand, a series of interesting hypotheses on the value of active training through participatory research and extension merits further investigation. In particular, participatory research activities may provide an alternative vehicle to subsidy payments to enhance the adoption of soil conservation interventions and abate negative environmental externalities generated by agricultural systems in marginal production areas.

References

Agrifood Consulting International. 2004. Integrating Germplasm, Natural Resource, and Institutional Innovations to Enhance Impact: The Case of Cassava-Based Cropping Systems Research in Asia. CIAT-PRGA Impact Case Study. A Report prepared for CIAT-PRGA by Agrifood Consulting International, Ha Noi Vietnam. Consultant report by Timothy Purcell. 506 pages.

Alston, J.M., M.C. Marra, P.G. Pardey, and TJ Wyatt. 2000. "Research returns redux: A meta-analysis of the returns to agricultural R&D." Australian Journal of Agricultural and Resource Economics, 44(2): 185-215

Ashby J. 2003. Introduction: Uniting Science and Participation in the Process of Innovation- Research for Development." In Managing natural Resources for Sustainable Livelihoods, Uniting Science and Participation, Pound B, S. Snapp, C. McDougall and A. Braun (eds). London: Earthscan.

Ashby, J. 1996. What do we mean by participatory research in agriculture? In: New Frontiers in Participatory Research and Gender Analysis. Proceedings of the international seminar on participatory research and gender analysis (PRGA), 9-14 September 1996, Cali, Colombia. Centro Internacional de Agricultura Tropical (CIAT) Publication No.294, pp.15-22.

Dalton, T. N. Lilja and N. Johnson. 2005. Impact of Participatory Natural Resource Management Research in Cassava-Based Cropping Systems in Vietnam and Thailand. CGIAR Systemwide Program on Participatory Research and Gender Analysis (PRGA Program), Cali, Colombia.(Working Document no. 23).

Dalton, T. N. Lilja, N. Johnson and R. Howeler. 2005. “Human Capital Accumulation and Productivity Improvements in Asian Cassava Systems: Are Participatory Research Approaches Beneficial?” Available: http://agecon.lib.umn.edu/cgi-bin/detailview.pl?paperid=16126. Accessed September 14, 2005.

FAO, FAOSTAT, accessed March 6, 2005.

Feder, G., R. Murgai, and J.B. Quizon. 2004a. “Sending Farmers Back to School: The Impact of Farmer Field Schools in Indonesia.” *Rev. of Ag. Economics*. 29(1): 45-62.

Feder, G., R. Murgai, and J.B. Quizon. 2004b. “The Acquisition and Diffusion of Knowledge: The Case of Pest Management Training in Farmer Field Schools, Indonesia” *Journal of Agricultural Economics*, 55(2): 221-243.

Fuglie, K.O. 2004. “Challenging Bennet’s Law: the New Economics of Starchy Staples in Asia.” *Food Policy* 29: 187-202.

Fujisaka, S. 1994. Learning from six reasons why farmers do not adopt innovations intended to improve sustainability of upland agriculture. Agricultural Systems, 46: 409-425.

Greene W. 1998. "Gender Economics Courses in Liberal Arts Colleges: Further Results." *J. of Economic Education*. 29: 291-300

Griliches Z. 1957. Hybrid Corn: An Exploration in the Economics of Technological Change. Econometrica, 24, pp.501-522.

Howeler R. 2004. End-of-the-Project Report: Improving the Sustainability of Cassava-based Cropping Systems in Asia. A report submitted to the Nippon Foundation. 120 p.

Howeler, R.H. 1987. Soil conservation practices in cassava-based cropping systems. *In*: T.H. Tay, A.M. Mokhtaruddin and A.B. Zahari (Eds.). Proc. Intern. Conf. Steepland Agric. in the Humid Tropics. Aug 17-21, 1987. Kuala Lumpur, Malaysia. pp. 490-517.

Howeler, R.H. 1994. Integrated soil and crop management to prevent environmental degradation in cassava-based cropping systems in Asia. *In*: J.W.T. Bottema and D.R. Stoltz (Eds.). Upland Agriculture in Asia. Proc. Workshop held in Bogor, Indonesia, April 6-8, 1993. pp. 195-224.

Howeler, R.H. 1995. Agronomy research in the Asian Cassava Network - towards better production without soil degradation. In: R.H. Howeler (Ed.). Cassava Breeding, Agronomy Research and Technology Transfer in Asia. Proc. 4th Regional Workshop, held in Trivandrum, Kerala, India. Nov 2-6, 1993. pp. 368-409.

Howeler, R.H. (Ed.). 1996. A Benchmark Study on Cassava Production, Processing and Marketing in Vietnam. Proc. Workshop held in Hanoi, Vietnam. Oct 29-31, 1992. 290 p.

Howeler, R.H. 1998a. Cassava agronomy research in Asia - an overview 1993-1996. *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. 355-375.

Howeler, R.H. 1998b. Cassava production practices - Can they maintain soil productivity? *In*: Proc. Intern. Symp. Cassava, Starch and Starch Derivatives, held in Nanning, Guangxi, China. Nov 11-15, 1996. (in press)

Hershey C. *et al*. 2001. Cassava in Asia: Expanding the Competitive Edge in Diversified Markets. *In:* Proc. Validation Forum on the Global Cassava Development Strategy Volume 3. pp. 1-62. IFAD/FAO. Rome.

Hinchcliffe F, J. Thompson, J.N. Pretty, L. Guijt, P. Shah. (eds.) 1999. Fertile Grounds: The Impacts of Participatory Watershed Management. Intermediate Technology Publications. London.

Johnson N, N. Lilja and J.A. Ashby. 2003. Measuring the Impact of User Participation in Agricultural and Natural Resource Management Research. Agricultural Systems. 78(2), pp. 287-306.

Johnson N, N.Lilja, J.A. Ashby, J.A. Garcia. 2004. The Practice of Participatory Research and Gender Analysis in Natural Resource Management Research. Natural Resources Forum. 28, pp. 189-200.

Maddala, G. 1986. Limited Dependent and Qualitative Variables in Econometrics. Cambridge: Cambridge University Press.

Okali, C., J.E. Sumberg and J. Farrington (1994). Farmer Participatory Research: Rhetoric and Reality of . London: IT publications.

Pretty, J., 1994. Alternative systems of inquiry for sustainable agriculture. IDS Bulletin 25, 37–48.

Rogers E. 1983. Diffusion of Innovations. Third edition, The Free Press, New York.

Sanginga, P., Lilja, N., Gurung, B. (Eds.). 2002. Assessing the benefits of rural women's participation in natural resource management. In: Proceedings of the Natural Resource Management (NRM) Small Grants End-of-project Workshop, Cali, Colombia, 13–17 November 2001. PRGA Program Cali, Colombia.

Sanginga, P.; Lilja, N.; Tumwine, J. 2001. Assessing the quality of participation in farmers´ research groups in the highlands of kabale, Uganda. CGIAR Systemwide Program on Participatory Research and Gender Analysis (PRGA Program), Cali, Colombia. 29 p. (Working Document no. 19).

van de Fliert, E.N., Johnson, R., Asmunati, W., 2001. Beyond higher yields: the impact of sweetpotato ICM farmer field schools in Indonesia. Centro Internacional de la Papa (CIP) Program report, CIP, Peru.

Table A1. Descriptive Statistics of Variables used in Regression Analysis

Variable	Description	Type	Mean	Std.Dev.	Minimum	Maximum
PARTIC	Partipation in Project Activities	Binary (1=Yes, 0=No)	0.306	0.461	0.000	1.000
GENDER	Gender	Binary (1=Male, 0=Female)	0.799	0.401	0.000	1.000
NUMADULT	# Adults	Continuous	2.821	1.235	0.000	9.000
NUMCHILD	# Children	Continuous	1.554	1.054	0.000	7.000
POVERTY	Poverty Status	Ordinal (3 levels)	0.960	0.484	0.000	2.000
LAND1	Initial Land Holding (ha)	Continuous	2.899	3.879	0.000	40.000
FISH	Presence of Fish Pond	Binary (1=Yes, 0=No)	0.398	0.490	0.000	1.000
TLU	Tropical Livestock Units Owned	Continuous	2.421	5.223	0.000	99.760
COUNTRY	Country	Binary (0=Thailand, 1=Viet Nam)	0.456	0.498	0.000	1.000
SLOPE	Slope	Ordinal (0=flat, 1=rolling, 2=hilly)	1.541	0.499	0.000	2.000
FACTORY	Proximity to Starch Factory	Binary (1=Yes, 0=No)	0.717	0.451	0.000	1.000
TIME	Years since Initiation of Project Activity	Continuous	4.335	3.669	0.000	9.000
VPARTIC	Village Treatment Dummy	Binary (1=Yes, 0=No)	0.654	0.476	0.000	1.000
MGR01	Institution Dummy	Binary (1=Yes, 0=No)	0.189	0.392	0.000	1.000
MGR02	Institution Dummy	Binary (1=Yes, 0=No)	0.083	0.277	0.000	1.000
MGR03	Institution Dummy	Binary (1=Yes, 0=No)	0.038	0.191	0.000	1.000
MGR04	Institution Dummy	Binary (1=Yes, 0=No)	0.344	0.475	0.000	1.000
VARIETY	% of Area Planted to Improved Cassava Varieties	Ordinal 5 levels (0,1)	0.805	0.340	0.000	1.000
INTER	Adoption of Intercropping	Binary (1=Yes, 0=No)	0.343	0.475	0.000	1.000
HEDGE	Adoption of Hedgerows	Binary (1=Yes, 0=No)	0.243	0.429	0.000	1.000
CONTOUR	Adoption of Contour Ridging	Binary (1=Yes, 0=No)	0.312	0.463	0.000	1.000
FYM	Adoption of Farm Yard Manure	Binary (1=Yes, 0=No)	0.477	0.500	0.000	1.000
CHEMFERT	Adoption of Chemical Fertilizer	Binary (1=Yes, 0=No)	0.875	0.331	0.000	1.000
DLAND	Change in Land Cultivated (ha)	Continuous	0.127	1.067	-5.760	6.400
DCASSAVA	Change in Cassava Area Cultivated (ha)	Continuous	0.141	0.790	-3.200	4.800
DYIELD	Change in Yield (mt/haa)	Continuous	8.016	8.823	-18.750	38.556
DPRODUCT	Change in Total Farm Production (mt)	Continuous	13.623	30.037	-120.000	400.000
DALLOC	Change in Land Allocated to Cassava (%)	Continuous (-1,1)	0.031	0.191	-1.000	1.000