# Human Capital Accumulation and Productivity Improvements in Asian Cassava Systems: Are Participatory Research Approaches Beneficial?

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*Abstract*

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Recently, discussion has reemerged over the value of integrated pest and crop management training, through intensive approaches such as farmer field schools or participatory training, as a development approach (Feder et al, 2004). This paper develops a model of human capital accumulation through participatory research and tests several hypotheses on the effectiveness of this approach to increase the adoption of soil conservation and fertility management innovations and improve farm productivity in southeast Asia. Bivariate Probit models with treatment effects are estimated using full information maximum likelihood (Evans and Schwab, 1995; Trost and Lee, 1984) and covariates related to changes in land allocation and productivity, measured before project and after project intervention, are investigated. We follow Greene (1998) to control for simultaneity between adoption and impact by using the predicted adoption decision from the second set of regressions to calculate productivity differentials.

Overall, we find that treatment affects associated with the participatory research activities are significant and positive in explaining the differential adoption rates of intercropping, hedgerows, contour ridging, the usage of farm yard manure and chemical fertilizer. The positive relationship between the adoption of soil conservation and fertility management techniques and participation, given very limited productivity impact, may indicate the "value" of the participatory approach to illustrate the social costs of land degradation, sensitize participants towards internalizing these costs, and demonstrate the importance of long-run strategies to preserve land productivity, or both. 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.

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## 1. Introduction

Recently, discussion has reemerged over the value of integrated pest and crop management training, through intensive approaches such as farmer field schools or participatory training, as a development approach (Feder et al, 2004). This paper develops a model of human capital accumulation through participatory research and tests several hypotheses on the effectiveness of this approach to increase the adoption of soil conservation and fertility management innovations and improve farm productivity in southeast Asia. In order to derive the econometric relationship between participation, the adoption of soil conservation and soil fertility management practices, behavioral and productivity impacts, a set of recursive econometric models are estimated. This recursive sequence of models is estimated to understand how various determinants, and the accumulation of their effects, influence behavioral and productivity outcomes.

In Southeast Asia, many of the poorest farmers live in areas that have limited crop production potential. Cassava (*Manihot esculenta* Crantz) is an important crop on these marginal 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. 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 already depleted by other crops or which are inherently infertile. 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 yields to drop, 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, thus decreasing water supply and hydroelectric power productivity.

This paper examines the impact of technologies designed to reduce environmental degradation and increase cassava productivity as well as the approach used to develop these interventions. Few studies attempt to distinguish between these two different types of impacts, however it is important to do so. Research and development resources are being spent on participatory research methods, however it appears that decisions about use of such methods are often based on personal experience and conviction rather than on evidence of their relative contribution to impact. This study contributes to 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 paper is organized as follows: section two discusses some conceptual issues related to assessing the *ex post* impacts of farmer participatory cropping systems research. Then cassava production in Asia is discussed. Section three presents the farm-level impacts of participation and adoption of new technologies. The final section provides some conclusions.

## 2. Background

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 that form 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 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 (Ashby, 1996; 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 the specific 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).

The use of functional participation does not have major implications for how impact is assessed. Involving farmers may increase or decrease costs during the technology development process (Johnson et al., 2004, Lilja and Aw-Hassan, 2002) and much depends on whether or not the participatory activities replace activities in the conventional research process or if they are included as “add on” activities, therefore generating additional costs. Once developed, however, the technologies are typically diffused through conventional channels. The ultimate benefits of the research at the farm level are still measured in the form of increased productivity (or reduced environmental damage) due to new technologies or practices.

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 refereed 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.

### *Cassava production trends in Asia*

Global 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 1990s Africa increased cassava production at the average annual rate of 2.9%, while production growth in Asia and LAC was stagnant. However, in the last five years Asia has had 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 1990's 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 production (FAO, 2005).

Much of the production gain in Asia is related to increases in yield. In the last five years, the cassava yield in Thailand has increased 2.84% 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 has grown nearly 9% and the yields have increased at and average annual rate of 11% (Table 1).

Forty-five percent of the total land in Thailand is arable land compared to only 23% in Vietnam. Therefore there is also more population pressure on land in Vietnam; Thailand has 0.6 ha/capita arable land and Vietnam has 0.1 ha/capita. In 1994, Thailand had 65% of its potential arable land in use, and Vietnam had 60% (FAO, 2005)[4]. Land degradation patterns are similar in Thailand and Vietnam: about half of the total land in Vietnam and Thailand is considered to be very severely, nearly 30% severely and about 20% moderately degraded.

In 2002, Thailand exported 67% and Vietnam 21% of their respective cassava production. Between 1993-2002, the share of Thailand's exports of total production declined at the annual average rate of –3.7%, and Vietnam's export/total production share increased at the average annual rate of nearly 18%. In recent years, the growth in

[4] Authors' calculations, TERRASTAT, FAO, 2005.

Chinese cassava demand is likely to increase the total quantity imported from both Thailand and Vietnam. Neither country imports cassava. Thailand does not utilize cassava as animal feed, and in 2002, 35% of the total domestic supply of 2.1 million tons cassava was used for human consumption. In Vietnam, 9% of the total domestic supply of 3.5 million tons in 2002 was used for human consumption, and 84% for animal feed.

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, 2004). Similarly, soil and crop management practices have been developed that will minimize erosion when cassava is grown on slopes. 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. Each project site identified and developed technologies best suited for local conditions. Also, the methodology for conducting FPR was developed and disseminated to partner organizations. As a result, specific soil fertility management technology options were identified and further promoted to farmers. In addition, the human capacity of the participating farmers is assumed to be enhanced, because they engaged in the technology development process with the researchers.

## 2. 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. In addition 8 non-project villages were selected which were similar to and were located nearby the selected project villages.

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, averaging 30% of the total number of households.[5]

[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 2. 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 ask 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. Self-assessments are always problematic, however if we take these at face value, the results suggest that the distribution of wealth is less equal in Vietnam than in Thailand.

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. This again is consistent with national trends. Farmers in both countries experienced large yield increases over the period, on average 68% in Thailand and 80% in Vietnam.

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.

#### <u>Project v non-project villages</u>

Before looking at differences between participant and non-participant farmers, it is useful to look at differences between project and non-project villages. Though the number of project and non-project villages was the same, sixty five percent of the households in the sample were from project villages and 35 percent were from non-project villages. These proportions do not vary significantly between countries.

Project and non-project villages are similar in terms of household composition. In Thailand, there are no significant differences in terms of the distribution across wealth categories. In Vietnam households in project villages are more equally distributed across wealth categories than in non-project villages, where there is a higher percent of "better off" households in the sample.

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

<u>Participant v non-participant farmers</u>

In Thailand, participant and non-participant households did not differ in terms of composition (Table 6). In Vietnam, female-head 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, however 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. With the exception of livestock, these same differences between participants and non-participants were observed when only project villages are analyzed.

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, however 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.

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

### *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. 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 3). 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 practice. Thirty one percent adopted contour ridging and 24% adopted hedgerows. Adoption levels did not vary significantly between countries, however 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.

If we restrict the analysis to project villages only, the results do not change significantly for Thailand, but they do change for Vietnam. In Vietnam, there was no difference between participants and non-participants in terms of likelihood of having adopted at least one soil conservation practice. Participants were significantly more likely to have adopted hedgerows (50% v 17%) but significantly less likely to have adopted contour ridging (36% v 60%).

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.

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 percent of households used neither organic nor inorganic fertilizer. In Thailand, participants used significantly more of both types of fertilizers than non-participants. In Vietnam, only farmyard manure use was significantly higher among participants compared to non-participants, and this difference disappears when we look only at households in project villages

### *Econometric Investigations on Project Impact*

In order to derive the econometric relationship between participation, the adoption of soil conservation and soil fertility management practices with behavioral and productivity impacts, three sets of econometric models were estimated. This sequence of models was estimated to understand how various determinants, and the accumulation of their effects, influence behavioral and productivity outcomes.

Productivity and behavioral impacts may be linked to two mechanisms. First, productivity changes can arise from the adoption of embodied technologies designed to conserve soil and manage soil fertility. Secondly, productivity impacts may also arise from disembodied technological change, or the accumulation of human capital, derived from the farmer participatory research. Disembodied factors could be linked to cropping or farming systems changes or improved decision making aptitude resulting in greater managerial efficacy. A schematic representation of the levels of study is presented in Figure 1 to describe the econometric issues in separating the impact of the participation from autonomous adoption of conservation and fertility management techniques.

The first econometric model was estimated to derive the factors that contribute to an individual's decision to participate in the project's activities. The purpose of this equation is to control for treatment effects, against those who did not participate in project activities, in order to capture disembodied effects of participation. The second set of regressions was estimated to understand whether individual, local and institutional factors, plus project participation, affect the adoption of the soil conservation and fertility management techniques[7]. The adoption of these techniques simultaneously affects land allocation and productivity outcomes. Hence, a third set of regressions was estimated to determine whether the adoption of conservation practices and the treatment affects of participatory research activities (the disembodied component) affected behavioral and productivity outcomes. We use 767 observations of the full sample (417 in Thailand and 350 inViet Nam) due to incomplete responses and statistical outliers.

*The Participation Treatment*

The overall participation impact can take three forms. As illustrated in figure 1, treatment effects, in the form of whether the village was selected for a participatory activity, is important to determine the impact of the participatory activities. Hence, village-level selection occurs. Secondly, an individual residing in a village that held participatory research activities can choose whether to participate or not. Those that do not to participate—either because no activity occurred in their village or because they chose not to participate—are coded as "non-participants" and those that did as "participants." The structural differences in the reasons why non-participants did not participate is ignored at this level. We are most concerned with defining a "with participation" treatment effect and a "without participation" effect in order to control for differences occurring because of project activities and the treatment control.

[7] The project also promoted the adoption of new cassava varieties. Data collected on the adoption of new varieties was limited to the percentage of cassava area that was planted to "new" varieties so it was not possible to isolate CIAT promoted varieties from other improved varieties. Furthermore, there was very little variation in adoption rates in Thailand. Almost all farmers reported 100% coverage.

The initial decision focuses on understanding how household, institutional and country-specific factors contribute to an individual's decision to participate in project activities. Two types of activities—participatory trials and training—are aggregated into a single participation variable that takes a value of 1 if the individual participated in any activity. At this point, we are not concerned with whether one activity differed from another but whether active participation, grossly defined, makes a difference in the subsequent decision to adopt soil fertility and conservation practices. Nonparticipation in a control village, or potential village-level spillovers, are controlled for in the productivity measures. Participation (*P*) is modeled:

$$U_i(P=1) > U_i(P=0) = P_i^* = \delta' Z_i + \nu_i \tag{1}$$
$$P_i = 1 \quad if \quad P_i^* > 0 \text{ , 0 } otherwise$$

where $\delta$ is a vector of explanatory coefficients including demographic, wealth, agricultural opportunity costs and site and country specific variables.

We argue that the decision to participate in the activities is a function of demographic characteristics of the household—the gender of the household head, the number of adults and the number of children in the household—wealth characteristics—including a three-level qualitative measure of relative wealth and initial, pre-project land holdings—two variables measuring alternative agricultural activities—a binary variable measuring the presence of fish ponds and a continuous variable measuring the total tropical livestock units owned by the household—a binary variable for the country, where 1 indicates Viet Nam, and four binary variables for the partner institutions active in the project. It is not possible to sign the impact of the gender variable in the participation equation. It could be argued that there are opportunity costs for both genders to participating in the research project, either in the form of domestic or alternative income generating activities. Adult household size is hypothesized to be positively related to participation, while greater number of children may be negatively or positively related. Children (and adults) are not age-class differentiated so young or able children cannot be determined. It may be argued that more children may require greater care-giving, and hence a higher opportunity cost to participation, while more able children may substitute for labor activities thereby reducing the opportunity cost of participation.

Most upland farmers in the project areas are poor in absolute terms. However relative levels of poverty were qualitatively determined with the group. Individuals defined their level of poverty. "Wealthier" individuals may be more able to participate than the poorest of the poor. Initial quantity of farmland is also used as a measure of wealth. It can be argued that farmers with greater landholdings may be more likely to participate than less landed. Alternative agricultural activities are hypothesized to be negatively related to participation as these present competing time commitments and income generating activities for farmers. Country and institution dummies are created to control for other country-and site-specific factors unaccounted for in the limited data available for analysis. Institutional recognition may have affected an individual's decision to participate or not.

Participation, where 1 is equal to individual-level participation in project activities is modeled in binary Probit equation. Results from these equations are presented in Table 4. Results from the full-sample regression are carried into the third set of equations and country-specific equations are provided for information purposes only. The factors affecting participation differed by country. Adult household size was positively related to participation in the pooled sample while insignificant in the country-specific equations. Farmers with large land-holdings were more likely to participate. Country and institution specific differences also existed as determinants of participation. The presence of fish ponds in Thailand and livestock in Viet Nam were positively correlated with participation in the country-specific equations but not in the pooled sample. We continue our focus upon the combined data set to derive general insight into the impact of participation.

The second level of investigation is to determine the factors affecting the adoption of five interventions promoted by the project. Treatment effects, through exposure to participatory research activities, can also impact the adoption of these technologies. The decision to adopt biological-based soil conservation practices—intercropping and hedgerows—mechanical conservation—contour ridging—and soil fertility management—farm yard manure and chemical fertilizer—are modeled controlling for the impact of the participatory activities using a bivariate Probit approach. In the second regression, each adoption equation is modeled simultaneously with the selection equation and thus the treatment effects are allowed to vary across resource management adoption equations. Bivariate Probit models with treatment effects are estimated using full information maximum likelihood (Evans and Schwab, 1995; Trost and Lee, 1984).

The bivariate Probit regressions model the decision to adopt soil conservation and soil fertility management intervention *k*, for producer *i*, ( $A_i^k$ ) simultaneously with the participation decision:

(2)
$$\begin{aligned} &A_i^k = \beta' X_i + \varepsilon_i \qquad for\ k = 1 \ldots 5 \\ &P_i = \delta' Z_i + v_i \\ &\varepsilon_i, v_i \sim BVN(0,0,1,1,\rho)\ where \\ &\rho = Cov[\varepsilon_i, v_i \mid \beta, \delta]. \end{aligned}$$

These decisions are posited as a function of the some of the same explanatory variables in (1) plus additional factors. These additional factors include topography of the village (slope), whether the farm was located near a starch factory or not, the length of time between the data collection and the when the project began, and a dummy variable for whether a participatory activity occurred the respondent's village or not. The hypothesis of no selection/treatment effects can be tested by evaluating the significance of the hypothesis that $\rho$=0.

Because adoption of these practices involves additional labor, household size is posited as positively related to adoption. We are unable to determine the impact of the gender variable for similar reasons described above. We hypothesize that wealthier households will be more likely to adopt these interventions than poorer, as well as households with larger land endowments. Alternative agricultural activities may have mixed signs depending on the adoption decisions. Joint products from hedgerows and intercrops may be intermediate inputs to livestock production and thus tropical livestock units positively related to adoption. The usage of farm yard manure is hypothesized as positively related to livestock holdings because of the supply of manure.

The adoption of soil conservation activities is hypothesized as positively related to hillier terrain. It is difficult to sign the impact of being located near a starch factory. In the short-run, a producer may see biological conservation measures as land competitive and hence the sign would be negative. The presence of a starch factory may be positively related to the adoption of productivity enhancing interventions because of stimulated demand. Project-related factors should all be positive. The "Year" variable measures the length of time between data collection and when the project began. We expect that this variable will be positively related to adoption. The village participation dummy should also be positive. This variable is included because some farmers who answered the questionnaire did not engage in any project activities. This village level dummy is constructed to capture village-level spillovers to non-participants. The results from the selection equations are consistent across adoption regression, and with the binary participation results. Results for the estimation of these five bivariate Probit models are presented in Table 5.

Adult family size, initial land holdings, country and site specific variables are significant. Secondly, the correlation term is positive and significantly different from zero in all equations indicating that the adoption of soil conservation and fertility management techniques was positively influenced by project activities. The weakest effect was between participation and the adoption of contour ridging followed by farmyard manure application. The correlation between the adoption of intercropping and the usage of farmyard manure were similar while the adoption of hedgerows was much greater than all other interventions.

Several general inferences on household demographic characteristics can be made over the adoption regressions. Gender was only significant in the adoption of contour ridging. All other technologies were gender neutral. The number of adult family members was significant only in the adoption of hedgerows. For each additional adult family member, the probability of adopting hedgerows increased by 2.0% when the family participated in project activities[8]. Wealthier farms were less likely to adopt intercropping or hedgerow practices than poorer households. Wealth status did not influence the adoption of other interventions. Farms with larger initial landholdings were more likely to adopt intercropping, hedgerows and use farmyard manure. When evaluated at the mean, the marginal impact of an additional hectare of land on the decision to adopt these interventions was 1.6, 0.4 and 1.1% respectively. The adoption of farmyard and chemical fertilization techniques was positively related to the total count of tropical livestock units owned by the household. For each additional TLU owned by the household, beyond the mean, the probability of adopting farmyard and chemical fertilization practices increased by 3.5 and 0.6% when the household participated in project activities.

Country and community-level differences also impact the adoption decision. There was a 52% greater chance of adopting intercropping in Viet Nam, given participation, while 24 and 34% less probability of adopting contour ridging and farmyard manure. The adoption of hedgerows was positively correlated with the slope of the farm while negatively correlated with the contour ridging and chemical fertilizer adoption. The result for contour ridging is surprising but it may be explained by the dominance of "hilly" land in the sample which may be "too hilly" for this practice.

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[8] All marginal effects are in relation to those households that participated in project activities viz: $\partial\left(A_i^k \mid P_i = 1\right)/\partial X_i$ .

Proximity to a starch factory was negatively related to the adoption of hedgerows and the usage of farmyard manure while positively related to the adoption of chemical fertilizer. This result may reflect the polarity of cassava systems. Hedgerows and farmyard manure systems may be more consistent with cassava produced for home or local market consumption while chemical fertilizer application may be profitable with factory outlets. Time and the dummy variable indicating whether a nonparticipant lived in a village where a participatory activity took place are significant in all equations. The signs on these variables are not consistent across equations but within equations, the signs are always conflicting.

In the third set of equations, covariates related to changes in land allocation and productivity, measured at before project and after project intervention, are investigated. Two measures of changes in land allocation are analyzed: the change in total cropped area and the change in area planted to cassava. Secondly, we investigate the covariates of changes in per hectare cassava yield. Collectively, we denote these four variables (j=1…3) as $C_i^j$. By coupling the participation equation with the impact equation, and following description in Greene (2002), we note that:

$$(3)\qquad \begin{aligned} E\left[C_i^j \mid P_i = 1, \phi_i, \delta_i\right] &= \phi_i W_i + \alpha P_i + E\left[u_i \mid P_i = 1, \phi_i, \delta_i\right] \\ &= \phi_i W_i + \alpha P_i + \rho\sigma_v \lambda(-\delta Z_i) \end{aligned}$$

Where $\rho$ is similar to what was described above, the correlation between error terms in the participation and adoption equations, but now represents the outcome equations. $\Phi$ denotes the coefficients on the vector of explanatory variables used in the third step. We are concerned with the coefficients on the participation variable, α, and the coefficient λ that corrects for the treatment effect. Because these equations are estimated using least squares, the treatment effect variable, λ, is included from equation (1) along with the adoption effect. The total impact of participation will be the summation of the individual effects and hence omission of λ will result in an inconsistent estimate of the treatment effect of the participatory research activities.

We use many of the same variables that explain the adoption of soil conservation and fertility management techniques in the second step and augment the equations with seven additional variables. Changes in area allocation and productivity are simultaneously determined with the adoption of the soil conservation and fertility management techniques. In order to control for this simultaneity, the predicted adoption decisions from the second step are included in these equations. Finally, the area of land planted with improved cassava varieties is included. Econometric estimated of these equations are presented in Table 6.

Results from these equations indicate that household demographics, farm characteristics, country, location and project factors affected behavioral and productivity results. Male headed households were less likely to increase total cropped area than female headed households. Farms with large initial landholdings decreased overall cropped area but their total cassava production increased. Households with more livestock increased cropping area, cassava area and increased total cassava production through this areal expansion.

Country difference emerged. Changes in total cropped area were greater in Thailand but changes in yield and total household production were greater in Viet Nam. The slope variable was significant in all equations. A positive sign on the slope variable indicates that land used for cassava and other agricultural purposes increased on hillier areas more than on flat or rolling areas and that the percentage of land devoted to cassava increased as well. These results indicate that cassava production is moving to more environmentally sensitive production areas. Changes in yields were lower on hillier lands reflecting decreased productive potential of these areas. Overall, total household production increased in hillier areas largely as a result of areal expansion. Secondly, an exogenous market factor, reflected in the presence of a starch factory, was positively related to yield gains and increased household production. Furthermore, access to improved cassava varieties was positively correlated with increased cassava area, cassava land-use specialization and increased yields.

## 4. Conclusions

Project activities also impacted behavioral and productivity outcomes through embodied technology adoption and through disembodied participation effects. The adoption of hedgerows was positively related to changes in cropped area, cassava area, an increase in the percentage of farmland allocated to cassava. Overall, farmers expanded cropped area by expanding cassava area as they adopted hedgerows. The adoption of hedgerows is positively related to increased cassava yield. The adoption of other interventions was not correlated with behavioral or productivity changes. Secondly, disembodied changes, associated with the learning process of the participatory approach impacted behavioral and productivity outcomes. Participation, taken alone, was negatively related to cassava area expansion and to land allocation decisions. Participation did not result in expansionary production practices. It did, however, result in significant gains in cassava yields indicating, perhaps, that participatory research activities increased managerial capacity and expertise.

The results of these two sets of regressions indicate significant and positive impacts. 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). Overall, we find that treatment affects associated with the participatory research activities are significant and positive in explaining the differential adoption rates of intercropping, hedgerows, contour ridging, the usage of farm yard manure and chemical fertilizer. These techniques are important soil conservation and fertility management techniques designed to maintain (or increase) productivity capacity of hillier areas.

On the other hand, most of these soil conservation and fertility management approaches did not increase cassava yields and therefore there may be insufficient private incentive for adoption. The positive relationship between the adoption of soil conservation and fertility management techniques and participation, given very limited productivity impact, may indicate the power of the participatory approach to illustrate the social costs of land degradation, sensitize participants towards internalizing these costs, and demonstrate the importance of long-run strategies to preserve land productivity, or both. Intensive farmer training activities, like the participatory approach, appear to be useful in preventing land degradation and provide an alterative to subsidy-based interventions for increasing the adoption of conservation practices. It is unclear whether the limited productivity impact of other land conservations technologies may be due to the limited time between adoption and when this study was conducted.

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 selection/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 may generate efficiency gains based upon managerial modifications. Secondly, the participatory approach is a 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 basis for more sophisticated investigations of the impact of participatory research activities upon adoption, land allocation and productivity change.

The findings of this evaluation have implications for future design of participatory research activities. Exogenous market activities are driving land-use expansion for cassava. This trend will continue into the future as Asian demand for starchy products increases with income growth. Future research activities may wish to consider this factor when determining the location of participatory activities. The adoption of these technologies was also greater on hillier terrain, another exogenous factor. Hedgerows and intercropping are "pro-poor" technologies (adopted by poorer households) rather than wealthier. The joint multiproduct nature of these technologies may provide diversification benefits. These technologies may be less relevant for regions that are relatively wealthier, or more specialized in cassava production, than others.

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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

Table 2. 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/h) | 16.5 | 14.1 | 15.4*** | 19.4 | 15.5*** | 13.7 | 14.3 | 16.4 | 15.0** |
| Cassava yield, post-project (t/h) | 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

Table 3. 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

Table 4. Probit Estimates of the Determinants of Participation

| | Full Sample | | | Thailand | | | Viet Nam | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | | Std.Err. | Coeff. | | Std.Err. | Coeff. | | Std.Err. |
| INTERCEPT | -2.664 | * | 0.326 | -1.313 | * | 0.296 | -2.537 | * | 0.452 |
| GENDER | 0.226 | | 0.142 | -0.033 | | 0.174 | 0.449 | ** | 0.215 |
| NUMADULT | 0.112 | ** | 0.045 | 0.041 | | 0.054 | 0.084 | | 0.072 |
| NUMCHILD | 0.039 | | 0.054 | 0.101 | | 0.069 | -0.081 | | 0.080 |
| POVERTY | -0.089 | | 0.120 | 0.124 | | 0.186 | -0.202 | | 0.159 |
| LAND1 | 0.038 | * | 0.015 | 0.035 | ** | 0.015 | 0.136 | | 0.099 |
| FISH | 0.169 | | 0.121 | 0.492 | * | 0.143 | -0.246 | | 0.201 |
| TLU | -0.012 | | 0.011 | -0.017 | | 0.015 | 0.057 | *** | 0.033 |
| COUNTRY | 0.145 | | 0.342 | | | | | | |
| MGR01 | 1.711 | * | 0.284 | | | | 1.878 | | 0.303 |
| MGR02 | 2.267 | * | 0.302 | | | | 2.455 | * | 0.320 |
| MGR03 | 2.714 | * | 0.363 | | | | 2.857 | * | 0.381 |
| MGR04 | 1.711 | * | 0.236 | | | | 2.857 | * | 0.381 |
| Log-L | 212.38 | * | | -225.51 | * | | -160.91 | * | |
| % Correct | 74.5 | | | 74.1 | | | 75.1 | | |

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

Table 5. Bivariate Probit Estimates on the Factors Affecting the Adoption of Soil Conservation and Fertility Management Techniques with Treatment Effects

| | Intercropping | | Hedgerows | | Contour Ridging | | Farmyard Manure | | Chemical Fertilizer | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | Std.Err. | Coeff. | Std.Err. | Coeff. | Std.Err. | Coeff. | Std.Err. | Coeff. | Std.Err. |
| Adoption Equation | | | | | | | | | | |
| INTERCEPT | -1.2148 * | 0.4583 | -2.754 * | 0.367 | 0.061 | 0.553 | 1.124 * | 0.414 | 1.056 ** | 0.444 |
| GENDER | -0.066 | 0.179 | 0.135 | 0.150 | 0.299 *** | 0.165 | -0.095 | 0.154 | 0.181 | 0.176 |
| NUMADULT | -0.013 | 0.048 | 0.096 ** | 0.047 | -0.024 | 0.047 | -0.011 | 0.056 | 0.040 | 0.051 |
| NUMCHILD | 0.055 | 0.056 | 0.013 | 0.062 | 0.007 | 0.066 | -0.068 | 0.062 | -0.008 | 0.077 |
| POVERTY | -0.252 ** | 0.126 | -0.369 * | 0.127 | 0.010 | 0.149 | -0.033 | 0.133 | 0.003 | 0.152 |
| LAND1 | 0.049 * | 0.015 | 0.028 *** | 0.016 | -0.014 | 0.011 | 0.038 ** | 0.017 | 0.025 | 0.019 |
| FISH | 0.218 | 0.139 | 0.426 * | 0.123 | 0.373 * | 0.137 | 0.256 *** | 0.139 | 0.270 | 0.178 |
| TLU | -0.010 | 0.027 | 0.001 | 0.011 | -0.010 | 0.018 | 0.085 * | 0.026 | 0.072 ** | 0.030 |
| COUNTRY | 1.386 * | 0.219 | -0.364 | 0.226 | -0.680 *** | 0.367 | -0.858 * | 0.330 | 0.226 | 0.226 |
| SLOPE | -0.199 | 0.184 | 0.806 * | 0.162 | -1.021 * | 0.174 | 0.245 | 0.214 | -0.712 * | 0.213 |
| FACTORY | -0.305 | 0.254 | -0.631 ** | 0.261 | -0.245 | 0.427 | -3.223 * | 0.387 | 0.581 ** | 0.284 |
| TIME | 0.243 * | 0.048 | -0.210 * | 0.043 | 0.332 * | 0.059 | -0.276 * | 0.057 | 0.275 * | 0.064 |
| VPARTIC | -0.677 ** | 0.330 | 2.774 * | 0.308 | -0.837 ** | 0.418 | 3.179 * | 0.484 | -1.278 * | 0.374 |
| Selection Equation | | | | | | | | | | |
| INTERCEPT | -2.671 * | 0.334 | -2.553 * | 0.330 | -2.659 * | 0.339 | -2.612 * | 0.337 | -2.696 * | 0.346 |
| GENDER | 0.223 | 0.150 | 0.203 | 0.150 | 0.225 | 0.151 | 0.229 | 0.150 | 0.233 | 0.149 |
| NUMADULT | 0.109 ** | 0.044 | 0.113 * | 0.043 | 0.112 ** | 0.044 | 0.110 ** | 0.043 | 0.113 ** | 0.044 |
| NUMCHILD | 0.034 | 0.059 | 0.048 | 0.058 | 0.034 | 0.058 | 0.031 | 0.058 | 0.040 | 0.058 |
| POVERTY | -0.094 | 0.128 | -0.101 | 0.127 | -0.095 | 0.128 | -0.102 | 0.127 | -0.083 | 0.130 |
| LAND1 | 0.039 * | 0.013 | 0.038 * | 0.014 | 0.038 * | 0.014 | 0.039 * | 0.013 | 0.039 * | 0.015 |
| FISH | 0.168 | 0.123 | 0.128 | 0.125 | 0.182 | 0.123 | 0.190 | 0.121 | 0.194 | 0.124 |
| TLU | -0.011 | 0.015 | -0.013 | 0.015 | -0.012 | 0.016 | -0.011 | 0.015 | -0.011 | 0.015 |
| COUNTRY | 0.181 | 0.393 | -0.023 | 0.368 | 0.152 | 0.358 | 0.107 | 0.354 | 0.186 | 0.420 |
| MGR01 | 1.691 * | 0.328 | 1.895 * | 0.314 | 1.673 * | 0.289 | 1.667 * | 0.285 | 1.647 * | 0.356 |
| MGR02 | 2.325 * | 0.352 | 2.095 * | 0.326 | 2.350 * | 0.316 | 2.379 * | 0.311 | 2.217 * | 0.365 |
| MGR03 | 2.534 * | 0.394 | 2.940 * | 0.371 | 2.723 * | 0.368 | 2.778 * | 0.365 | 2.849 * | 0.381 |
| MGR04 | 1.755 * | 0.243 | 1.624 * | 0.232 | 1.715 * | 0.250 | 1.666 * | 0.248 | 1.705 * | 0.254 |
| RHO(1,2) | 0.347 * | 0.085 | 0.610 * | 0.059 | 0.176 *** | 0.093 | 0.318 * | 0.081 | 0.222 *** | 0.128 |
| Log-L | -642.97 * | | -649.50 * | | -650.50 * | | -653.53 * | | -593.24 * | |

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

Table 6. Land Allocation and Productivity Differences controlling for Treatment Effects

| | Δ Cropped Area | | | Δ Cassava Area | | | Δ Cassava Yield | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | | Std.Err. | Coeff. | | Std.Err. | Coeff. | | Std.Err. |
| INTERCEPT | -0.230 | | 0.307 | -0.863 | * | 0.239 | -10.518 | * | 2.175 |
| GENDER | -0.212 | ** | 0.100 | -0.028 | | 0.082 | -0.632 | | 0.727 |
| NUMADULT | -0.009 | | 0.034 | 0.005 | | 0.028 | 0.213 | | 0.250 |
| NUMCHILD | 0.025 | | 0.038 | 0.002 | | 0.032 | -0.074 | | 0.280 |
| POVERTY | 0.098 | | 0.087 | 0.065 | | 0.071 | 0.632 | | 0.631 |
| LAND1 | -0.050 | * | 0.012 | 0.004 | | 0.010 | -0.146 | | 0.090 |
| FISH | -0.038 | | 0.095 | 0.008 | | 0.076 | -1.312 | *** | 0.683 |
| TLU | 0.029 | * | 0.008 | 0.028 | * | 0.006 | 0.003 | | 0.056 |
| COUNTRY | -0.512 | * | 0.147 | -0.134 | | 0.118 | 14.014 | * | 1.061 |
| SLOPE | 0.445 | * | 0.112 | 0.474 | * | 0.084 | -1.478 | *** | 0.775 |
| FACTORY | -0.024 | | 0.194 | -0.015 | | 0.151 | 10.292 | * | 1.372 |
| TIME | 0.038 | | 0.035 | 0.015 | | 0.025 | 0.064 | | 0.236 |
| VPARTIC | -0.173 | | 0.324 | 0.292 | | 0.236 | -1.225 | | 2.211 |
| VARIETY | 0.146 | | 0.176 | 0.278 | ** | 0.134 | 6.323 | * | 1.230 |
| P(INTER) | -0.046 | | 0.250 | -0.198 | | 0.174 | 0.118 | | 1.666 |
| P(HEDGE) | 0.320 | *** | 0.176 | 0.230 | *** | 0.124 | 2.690 | ** | 1.180 |
| P(CONT) | 0.079 | | 0.243 | 0.160 | | 0.166 | -0.336 | | 1.605 |
| P(FYM) | -0.015 | | 0.207 | 0.078 | | 0.144 | -0.734 | | 1.377 |
| P(CHEM) | -0.168 | | 0.250 | -0.064 | | 0.171 | -0.690 | | 1.649 |
| Participation | -0.358 | | 0.650 | -1.005 | ** | 0.457 | 9.069 | ** | 4.350 |
| Selectivity (λ) | 0.275 | | 0.388 | 0.636 | | 0.272 | -4.557 | | 2.592 |
| F(20,746) | 3.93 | * | | 4.79 | * | | 22.91 | * | |

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

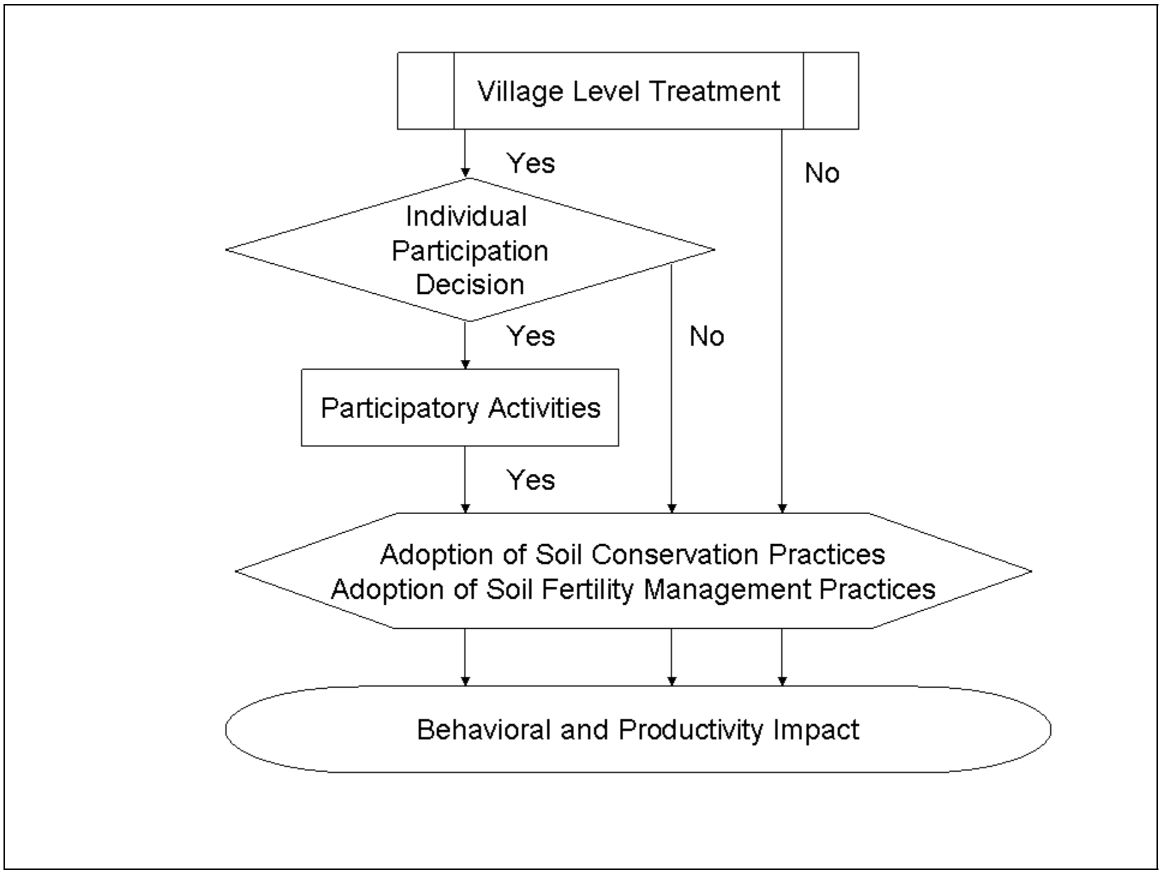


**Figure 1. Treatment effects, adoption decisions, behavioral and productivity impact**