# Household Participation in a Payments for Environmental Services Program: the Nhambita Forest Carbon Project (Mozambique)

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Abstract
Quantitative research on the household participation in Payments for Environmental Services (PES) program remains scarce. This paper aims to determine the key factors influencing household participation in a PES program in Mozambique. Questionnaire based quarterly surveys were conducted of 290 randomly selected households. We used Instrumental Variables technique to identify the factors influencing household participation. The instrumental variables used for forest dependence were household head born in the village, duration of residence of the household head in the village, ethnicity of the household head, business ownership of the household head, and off-farm income of the household. The results show that education of household head and households' trust towards community members positively influenced household participation in PES, while forest dependence influenced it negatively. Future PES projects may thus need to focus more on developing social capital and resource dependence of households.

Keywords: PES, instrumental variables, household surveys, agro-forestry, carbon sequestration, household participation, Mozambique

## 1. Introduction

Human society derives a variety of benefits from ecosystems, known as ecosystem services or environmental services (ES) (MEA, 2005). Payments for Environmental Services (PES), an incentive based environmental policy tool, has gained much traction recently (Landell Mills and Porras, 2002; Pagiola et al., 2005; Wunder, 2005; Zbinden and Lee, 2005; Wunder, 2007; Jack et al., 2008). PES is a voluntary and conditional transaction between an ES buyer and an ES provider, on the provision of a well defined ES or a land use presumed to deliver that ES (Wunder, 2007).

PES programs have been used to finance conservation in many geographic regions (Landell-Mills and Porras, 2002; Pagiola et al., 2007; Fisher et al., 2008; Jindal et al., 2008) and have largely focused on watershed protection, biodiversity conservation and carbon sequestration[1]. In the developing world, Costa Rica, Mexico and China have been leading efforts to make direct payments through governments to landowners or land users – typically at the household level – for undertaking specific land use practices that would increase the provision of water, biodiversity or carbon services (Uchida et al., 2007; Bennett, 2008; Pagiola et al. 2008; Jack et al., 2008; Gong et al., 2010).

Households that participate in PES programs generally derive a small net financial benefit (Wunder, 2008; Mahanty et al., 2013). However, a key challenge of PES programs is selecting the households to participate in a project. Relatively limited research has investigated household participation issues (Miranda et al., 2003; Kosoy et al., 2008; Pagiola et al., 2008; Arriagada et al., 2009; Pagiola et al., 2010; Fisher, 2012; Mahanty et al., 2013), despite the fact that PES programs often have a stated objective of benefiting the poor. In Africa, only one case study has

[1] See (Landell-Mills and Porras, 2002; Pagiola et al., 2002; Wunder, 2005; Wunder, 2006; Uchida et al. 2007; Bennett, 2008; Kosoy et al., 2008; Jindal et al., 2008; Muñoz-Piña et al., 2008; Pagiola et al., 2008; Wunder, 2008; Gong et al., 2010; Hegde and Bull, 2011).

examined the reasons, including cash payments and other environmental values, for household participation in a PES program in Uganda (Fisher, 2012). While these studies have provided some insights, none of them has empirically examined how household's forest resource dependence will influence participation decision, particularly where participants self-select to participate.

Building on the previous work, we focus on one of the few longstanding African PES cases: Nhambita in Sofala Province, Central Mozambique. Using econometric analysis, we determine socio-economic factors influencing household participation, focusing on self-selection bias in the participant sample. The program in question had a fairly low household participation rate (30%), which may raise concerns about the adequacy of ES provision and the program's capacity to alleviate poverty. Our findings add to the PES debate by highlighting participation determinants, particularly in an African context characterized by extreme poverty. The remainder of this paper introduces the study site, describes the experimental design, identifies the key results and discusses the main findings.

## 2. Methods

### 2.1 Study area

This study was undertaken in Chicale *Regulado* (Traditional Authority) located in the buffer zone of the Gorongosa National Park (GNP) in Sofala Province, Mozambique (Figure 1). Chicale *Regulado* covers a total of about 20 $km^2$ area, with over 1,100 households spread over five villages: Nhambita, Bue Maria, Munhanganha, Pungue and Mbulawa (Hegde, 2010). The first three are located close to each other within the GNP buffer zone. Mbulawa is located outside of the GNP, while one part of Pungue is located inside the Park and the other outside. Table 1 summarizes some of the key characteristics of the five villages under study.

**Insert Figure 1**

**Insert Table 1**

Traditionally, households in Chicale *Regulado* practice shifting cultivation where they clear and burn the *miombo* woodland to start their *mashamba* (farm). They grow subsistence crops mainly for 3-4 years, including corn, sorghum, peas, cucumbers and other vegetables, after which they clear land in another location and leave the former *mashamba* site to regenerate for 20-25 years. Households require permission from the *Regulo* (traditional chief) to clear any fresh forest, but enforcement of this is weak.

In 2002, a small scale agro-forestry based carbon sequestration pilot program, known as the Nhambita Carbon Livelihoods Project, was implemented in the *Regulado* (Hegde, 2010). The program offered conditional cash payments to smallholders for planting trees on their farm. Initial program funding was provided by the European Union, which was used for program implementation, livelihood support activities and to cover part of the transaction costs in the pilot phase (2002-2008). Since 2008, the program has been financed from revenue generated from carbon sales (Envirotrade, 2010). A consortium of partners, consisting of EnviroTrade (a private firm based in the UK, and the lead partner), the University of Edinburgh and the Edinburgh Centre for Carbon Management, is implementing the program. The program aims to conserve and regenerate the *miombo* woodlands by offering both conditional financial compensation (i.e. PES) and alternative livelihood options through a community development[2] component. The pilot phase was limited to the villages of Nhambita, Bue Maria and Munhanganha, and was later expanded to Mbalawa and Pungue.

[2] Because of this wider community development component being bundled along with the conditional PES component, this project partly resembles also an Integrated Conservation and Development Project (ICDP).

Households participating in the program must ensure specific minimum seedling survival rates during the first three years, and avoid the clearing or burning of forestland other than that which has been pre-agreed on (thus eliminating commercial charcoal and firewood extraction). In cases of non-compliance, payments will be stopped and the farmer may be asked to return earlier received payments. Seven annual instalments are paid: 30% (year 1), 12% (years 2-6) and 10% (year 7)[3]. After year 7, tree-based benefits (i.e. harvested fruits, small-diameter timber) are assumed to provide sufficient proper incentives for tree retention.

The carbon sequestered is monitored[4] under a Plan Vivo[5] system. The Verifiable Emission Reduction (VER) credits generated are sold in voluntary carbon markets. Part of the proceeds is deposited into a trust fund used to pay participant farmers (conditional payments), while another portion finances village development activities (community benefits). Initial contracts were for US$9 per $tCO_2$ equivalent, but the average price over the course of the program was US$4.5, which was higher than prevailing prices in the voluntary carbon market (UOE, 2008; Jindal et al., 2012).

### 2.2 Research design

Quarterly household surveys were our main source of data. The surveys explicitly integrated quantitative environmental resource use data with household income and tree planting data for PES participant households. In addition to the four quarterly surveys, two annual household

[3] The logic of frontloading the payments is to cover high initial costs and facilitate a productive transition.
[4] Project staff undertakes field monitoring of seedling survival prior to PES releases to farmers, and monitor their clearing and burning practices. Future plans for the project included remotely sensed monitoring.
[5] The system calculates on-farm carbon fixed, determining payments to farmers. Nhambita is registered with Plan Vivo, and its compliance to Plan Vivo Standards has been validated by The Rainforest Alliance.

surveys and two village focus group discussions were undertaken (Hegde, 2010). Questionnaires developed by CIFOR-PEN[6] were customized for our objectives.

Households in each village were selected randomly.[7] We opted for a large sample (335 households), given local heterogeneity, but lost 45 due to temporary or permanent migration, ending up with 290 households.

We used gross[8] income to measure household welfare, defined as the sum of cash income, net gifts/transfers and monetized subsistence income including environmental income (all non-cultivated products collected for subsistence or cash). Incomes were reported in the local currency, *metical* (plural *meticais*; MTS[9]).

Environmental resources were valued by asking households to report sale prices[10]. When not marketed, an individual willingness-to-pay (WTP) value was solicited (Wunder et al., 2011), which were averaged at the village level on a quarterly basis. Most products were not traded, yet households generally reported consistent WTP values, which we cross-checked with locally traded substitute prices wherever possible.

Field work was undertaken from January to December, 2006. Eight enumerators – each of which had at least a high school education – were recruited and trained. These enumerators conducted the interviews in the local language (*Sena*), under the supervision of the lead author.

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[6] Poverty-Environmental Network (PEN) is a project housed at the Center for International Forestry Research (CIFOR) that seeks to collect a uniform tropics-wide data on forest and environmental resource use through a common research method. (http://www.cifor.cgiar.org/pen/_ref/home/index.htm). A copy of a questionnaire used can be obtained from the first author.

[7] Since an official household census was unavailable, we updated the household rosters with village headmen (*Nfumo*'s) by listing all households under their responsibility (Cavendish, 2000). A sample was then drawn using a random number table. Where the selected household was not available (due to multiple-listing or sickness), the next household on the alphabetical list was chosen.

[8] Sum of cash income and subsistence income, without subtracting associated costs (e.g. labor costs, inputs, transportation).

[9] All calculations are based on the old currency; after 2006, the last three digits have been removed (1US$ = 26,500 MTS).

[10] We used consistent conversion rates to turn local measures into standard metrics.

### 2.3 Analytical framework

Evaluating the costs and benefits of participating in any program to modify household behaviour is critical to the implementation of an economic incentive program such as PES (Ostrom, 1999; Jumbe and Angelsen, 2007). Notably, economic theory underpinning agricultural household behaviour has been extensively studied and reported (e.g. Singh et al., 1986).

The following assumptions are made in this analysis. We assume an imperfect labour market in that a household may rent out labour, but does not hire labour (which was typical)[11]. We assume markets for agricultural and forest products to function perfectly (such markets existed even in remote areas), allowing us to focus on income and consumption, rather than individual goods (Jumbe and Angelsen, 2007).

Our model is static, as it does not involve any feedback effect. In following Jumbe and Angelsen (2007), households maximise a twice differentiable quasi-concave utility function, which depends on total consumption[12] (C) and leisure ($L_H$):

$Max\ U = U(C, L_H; H)$ ---------- (1)

The household faces a set of technological, time and budget constraints. Household labour (L) is allocated to forest production ($L_F$), agriculture ($L_G$), wage labour ($L_W$), PES planting and tending ($L_P$) and leisure ($L_H$). Household income includes the value of agricultural commodities ($Q^G$) and forest commodities ($Q^F$) valued at their respective market prices ($P_G$ and $P_F$), as well as wage income ($wL_w$) and exogenous income (E). Agricultural production depends on land area, family labour and exogenous production technology (Ω). Collection of forest commodities depends on labour hours spent, access to forest resources (D), technology (ϕ) and exogenous

[11] Jumbe and Angelsen (2007) also observed this in Malawi. Yet, Nhantumbo and Kowero (2003) considered both hiring in and hiring out labour.

[12] Consumption of a composite commodity consisting of forest, agricultural and market purchased goods, with the price set to unity.

forest resource characteristics (R). Access to forest resources also depends on household and village characteristics (H and V). We posit that PES program participation limits access to forest resources. When the market wage is below shadow wage rate (ω), a household prefers working in agriculture, leisure and possibly forestry.

We are interested in the household participation decision, and thus write the model in a semi-structural form:

$U = U^* (P; P_G, P_F, \omega, E, \Omega, \phi, L_p, H, V, R), P = 0,1$ -------- (2)

The net gain from participation (B) is defined as:

$B = U^* (1) - U^* (0) = B (P_G, P_F, \omega, E, \Omega, \phi, L, H, V, R)$ ----- (3)

A household will participate in the program if the difference in utility between participation and non-participation (B) is non-negative i.e.

P =1 if $B \geq 0$

P = 0 if $B < 0$ ---------- (4)

In this model, participation is assumed to affect utility in four ways. First, participation limits the access to forests, therefore D(1) < D(0). Higher prices of forest products (charcoal, fuelwood and timber) will reduce benefits from participation. In general, we can expect that households that are heavily involved in fuelwood and charcoal production have less incentive to participate in PES.

Second, participant households face reduced agricultural productivity (from less swidden agriculture),[13] and labour costs associated with planting and tending the trees. Factors such as low agricultural prices ($P_G$),and poor technologies (ϕ) will increase the value of B.

[13] Hegde and Bull (2011) found a reduction in crop yields among PES participant households.

Third, participant households require more labour for planting and tending the trees. The higher the labour cost for participation ($L_P$), the lower B is. For the households participating in the labour market, the opportunity costs of time is given by the market wage rate (w). Participation cost increases with the wage rate. For households outside the labour market, we can expect poor households to have a lower shadow wage, and hence to be more likely to participate, *ceteris paribus*.

Fourth, we assume that social capital[14] influences participation (i.e. participation requires that a household perceives the community as friendly, helpful and trustworthy). Research has shown that trust is an important indicator of social capital which facilitates cooperation (Knack and Keefer, 1997; Thoni et al., 2012). We also probed each household's perception of the community as a liveable place which influences long-term decisions such as PES-induced tree planting, and migration plans which are common in rural Africa.

### 2.4 Empirical model

The decision to participate in the PES program depends, *inter alia*, on provided cash income, maintaining resource access, costs for crop production and labour requirements. Our key model is the probit participation model, which is a function of factors influencing household participation, including forest dependence. However, forest dependence is potentially endogenous[15]. This implies that households depending on forest income (e.g. charcoal

[14] Following the World Bank (1998), the term "social capital" is used broadly here to include the institutions, relationships, attitudes and values that govern interactions among individuals and contribute to economic and social development. It includes the shared values and rules for social conduct expressed in personal relationships, trust, and a common sense of "civic" collective responsibility.

[15] Endogeneity here arises because forest dependence is potentially a choice variable, correlated with unobservable variables relegated to the error term. For instance, less able workers might sell more fuelwood and charcoal, and therefore self-select not to participate. Therefore, a failure to control for this correlation would produce a biased estimate of the effect of forest dependence on participation.

producers) may prefer unrestricted forest access, and thus opt not to participate in PES. We thus specify the following interrelationships between forest dependence and PES participation:

$y_i^* = Z_i\beta + u_i$ (forest dependence) ---------- (5)

$P_i = W_i\zeta + \phi y_i + e_i$ (participation) ---------- (6)

Where $y_i^*$ is a latent variable for forest dependence; Pi is a dummy variable for the participation; i = 1,.....N denotes households; $y_i$ denotes forest dependence as the ratio of forest cash income (sum of cash income earned from sale of forest products) to the household income; $Z_i$ and $W_i$ are vectors of exogenous variables that determine forest dependence and participation, respectively; $\beta, \zeta$ and $\phi$ are unknown parameters and $e_i$ and $u_i$ are the error terms. Since the aim of this study is to examine the link between forest dependence and participation, we focus on the coefficient in equation (6).

From (5) and (6) $y_i$ and $y_i^*$ are related as $y_i > 0$ if $y_i^* > 0$ and $y_i = 0$ if $y_i^* \leq 0$. Further, $y_i^*$ and $e_i$ are correlated because the same characteristics influence $P_i$ and $y_i^*$. As a result of this relationship, determining the impact of forest dependence on participation is not straight forward, since the correlation between $y_i^*$ and $e_i$ will produce biased estimates of determinants of PES participation.

Given the considerable overlap between the determinants of forest dependence (5) and participation (6), we jointly estimate the two equations. Instrumental Variables probit based on Amemiya Generalised Least Squares (AGLS) with endogenous variables permits a solution to this problem (Maddala, 1983; Newey, 1987). Specifically, it produces a new $\hat{y}_i$ (predicted $y_i^*$) that is uncorrelated with the resulting error term, $e_i$. Because $Z$ is assumed to be uncorrelated with $e_i$, it serves as the instrument in producing $\hat{y}_i$. Inclusion of instrumented $\hat{y}_i$ into the

participation equation purges any correlation between forest dependence and new error term, $u$ and produces unbiased estimates of PES participation determinants (Alon, 2007).

The instrumental variables included in $Z_i$ are the following: (i) Household head born in the village: A dummy = 1 if the household head was born in the village; (ii) Duration of residence: Number of years the household head has been living in the village; (iii) Ethnicity: dummy = 1 if household head belongs to village major ethnic group; (iv) Business ownership: dummy = 1 if household operated some kind of business; and (v) Off-farm income: Income earned from wages and remittances. These are plausible instruments for forest dependence. There is literature suggesting that household factors such as ethnicity, migrant status and off-farm income determine forest use in Africa and elsewhere (Sah and Heinen, 2001; Jumbe and Angelsen, 2007; Balslev et al., 2010; Houehanou et al., 2011; Nawrotzki et al., 2012). If the household head was born in the village, s/he is likely to have more knowledge about the surrounding forest resources, favouring increased forest extraction. Similarly, research has found that migrant village members use forest resources more heavily than long-term resident natives (Sah and Heinen, 2001). The purpose of the ethnicity variable was to capture any influence on the collection of woodlands products. Business and off-farm employment provide alternative livelihoods to the collection and sale of woodlands products, which may explain the correlation between off-farm income and forest dependence. There is no reason for these variables to be correlated with PES participation, as the program was open to all community members regardless of their socio-economic attributes. The model was estimated in the Instrumental Variables (IV) Probit framework using Stata 10.[16].

[16] StataCorp, 2010.

## 3. Results

### 3.1 Factors influencing program participation

Table 2 summarizes the variable definitions used in the empirical modelling. Table 3 presents the results from the probit regressions. The first model is a simple probit model of PES participation, ignoring the endogeneity between forest dependence and PES program participation. The second model is IV probit model that instruments forest dependence.

**Insert Table 2 and 3**

In the simple probit model, size of agricultural land, household head's education level, length of head's residence in the community, trust, household size and household location in pilot program area (Site 1) positively influenced the household participation decision.

The results of the IV probit estimation offer some interesting insights. To begin with, the Wald test of exogeneity[17] provides evidence that forest dependence is, indeed, an endogenous variable. The validity of the instruments was tested using Amemiya-Lee-Newey over-identification test (Baum et al., 2006)[18], from which we fail to reject the null hypothesis of the validity of the instruments used in the model specification and conclude that the instruments are valid. The results indicate that forest dependence had a statistically significant negative influence on PES program participation. Household head's education and trust positively influenced the household participation decision. The statistical significance of pilot project site variable implied that program participation was likely to be higher in the piloted 'first-generation' program areas where at least one cash payment had been made.

[17] It tests whether rho (which is the correlation between the errors in the full probit equation and reduced-form equation for the endogenous regressor, forest dependence) is equal to zero. Accepting the null hypothesis would have meant that the suspected endogenous variable is in fact exogenous, and therefore, a normal probit could be used.

[18] It tests the joint null hypothesis that the excluded instruments are uncorrelated with the error term (and therefore are valid instruments).

## 4. Discussion

Our research identified various factors influencing household participation. Forest dependence is a key factor that negatively affected participation, as could be expected for a PES program restricting degrading forest uses. At the time, the Nhambita program had low household participation rates (about 30%). They improved subsequently to about 80%, but forest-dependent groups such as charcoal producers unsurprisingly remained marginalised (Jindal et al., 2012). Charcoal production is a key driver of land-use change in Nhambita. Herd (2007) estimated that 35 ha of woodlots were lost annually in the *Chicale Regulado* from charcoal production. Program implementers were thus considering establishing special woodlots for charcoal production and providing more fuel efficient kilns to provide productive alternatives to charcoal producers (Jindal et al., 2012).

Trust[19] was another key factor influencing household participation. Trust fosters cooperation, underpinning economic development in low-income countries with less well-developed financial sectors, insecure property rights, and unreliable contract enforceability (Knack and Keefer, 1997; Thoni et al, 2012). The importance of trust is also confirmed by the positive relationship between program participation and the pilot project site variable. Household participation was high in pilot project site given that the pilot stage households had already received the first-year carbon payments when participation was opened up in the second year, which increased households' sense of trust in the program and motivated more people to participate. Some households indicated during focus group discussions that when the PES program was introduced they mistrusted it, since the idea of making payments for tree planting did not make any sense to them; they were convinced only when they saw payments were made. While initial trust is

[19] Trust was measured by asking a household to rate on a scale of 1 to 3 how trustworthy fellow villagers were perceived.

important, consistent contract enforcement and regular payments will reinforce a sense of household trust during the program implementation stages.

The positive relationship between education and participation confirms the conventional knowledge on the relationship between education and technology adoption including for PES participation (Zbinden and Lee, 2005). Education is known to improve the knowledge, skills, and foster an attitude of being more receptive to innovation, such as a PES program (Pattanayak et al., 2003).

On the other hand, variables such as crop-land availability and potential carbon incomes were not statistically significant for PES participation. This contrasts with findings in Latin America, where land tenure and size were key threshold factors for PES enrolment (Grieg-Gran et al., 2005). In Africa, smallholder farmers operate on multiple smaller plots (typically 0.5-1 ha). The program offered the flexibility of using the same agroforestry system on multiple plots or combining different systems on the same plot (e.g., boundary planting, mixed row planting with crops and fruit orchard). Nevertheless, the size of land was not a significant variable.

Similarly, households that had more cash income other than PES (from produce sales, wages, business) had greater likelihood of participation (see Jindal et al., 2012 for a similar finding). Similarly, Zhou et al. (2008) also noted that an increase in household farm income improved probability of adoption of water saving technology among Chinese farmers. Perhaps regular income flows increase farmers' risk-bearing ability, resulting in more land being allocated to cash crops (Fafchamps, 1992). As expected, the female-headed households are less likely to participate in the program, having lesser labour resource as required for tree planting and nurture.

Planting trees on farm and homesteads is a common practice in rural Africa, so the PES-induced activities did not pose technological limitations for participation (Pagiola et al., 2008). The economic incentive should be the key factor influencing the participation. However, participants are contractually bound to commit their land to tree cover for 25 year, yet cash payments cease after seven years.

The Nhambita program had in place a strong institutional framework involving voluntary participation, flexible and reasonable contracting terms, and a robust monitoring, verification and certification systems (Hegde and Bull, 2011; Jindal et al., 2012). Upon initiation, the program invited all smallholder farmers to join. The participating farmers signed voluntary contracts to plant indigenous and fruit tree plants[20] on their *mashamba* (either on farm boundaries or in mixed rows along with crops) and manage the same for 25 years[21] in return for conditional cash payments. However, the long term success of the program may depend on some continued enforcement of the contracts.

Cash payment to the participating households was estimated to be MTS 5,270,505 per household for the planted area representing 30% payment; this is equivalent to MTS 3,416,000 per ha (MTS 1,626,667 per ha/year, or about US$ 60). This constituted 10% of households' (very low overall) cash incomes - an important share (Hegde, 2010; Hegde and Bull, 2011), though not as high as some PES schemes in Latin America reaching 30% (Miranda et al., 2003; Kosoy et al., 2008). However, some risk from tree planting for crop yields may not have been effectively offset by the program (Hegde and Bull, 2011). Still, the tree species planted also represented an

[20] Trees planted included fruit trees including mango (*Mangifera indica*), cashew (*Anacardium occidentale*), tamarind (*Tamarindus indica*) and ber (*Ziziphus mauritiana*); timber trees included Rhodesian teak (*Pterocarpus angolensis*) rosewood (Swartzia madagascariensis); and multipurpose trees including gliricidia (*Gliricidia sepium*). Please refer to Envirotrade (http://www.envirotrade.co.uk) for a full list of trees planted.

[21] At the time contracts were for 25 years. The contract terms were changed subsequently, increasing the duration to 100 years (EnviroTrade, 2008).

economic asset for the farm households beyond the program period. Considering all the factors, the private benefits of participation may predominantly outweigh private costs.

While the program paid the farmers for PES planting, it also generated broader community-level development benefits, such as building schools or digging wells, which were shared with non-participant households. This component also catalysed forest-based enterprises such as carpentry, beekeeping and nursery units, improved gardening techniques, and so on. In total, the program provided full-time employment for about 100 people, as well as limited seasonal employment for forest fire prevention. Besides cash payments to households for VERs and provision of direct employment, the program also distributed guinea fowls for rearing, beehives for beekeeping and red gram seeds for cultivation (Hegde and Bull, 2011).

High transaction costs of contracting with multiple smallholders can be a key anti-poor participation obstacle in PES programs (Grieg-Gran et al., 2005). Transaction cost was not a dominant factor in our selection of PES participants. The Plan Vivo system applied in the Nhambita PES program is generally believed to be cost-effective in working with a large number of small-scale farmers and rural communities (Cacho et al., 2005). The contract terms offered were quite flexible. However, it is likely that about two thirds of carbon revenues were spent on program overheads and transaction costs, including though community development activities (UOE, 2008). Correspondingly, more PES paid conditionally for more years to farmers might also, hypothetically speaking, have attracted higher participation rates. Strategies were considered to reduce transaction costs, e.g. by bundling practices for enhancing environmental services (UOE, 2008; Jindal et al., 2012). If the program succeeds in paying farmers larger proportions of revenues from carbon sales, this may also strengthen incentives for participation.

## 5. Conclusion

The PES model is experiencing growing adoption in developing countries, but little empirical research informs us about the extent of participation by the ES providers, particularly resource-poor households, especially in Africa. Our analysis focused on the household-level factors that influenced participation in the Nhambita PES program in Mozambique. The program offers cash payments to smallholder farmers for agroforestry planting resulting in carbon sequestration. Three key insights emerge from this study. First, the PES program targeted forest clearing and burning, including charcoal and fuelwood production, as main threats to the *miombo* woodlands. Yet, households that were strongly engaged in these practices chose not to participate in the PES program, as their opportunity costs were likely not covered. While the participation rates have increased since the completion of our field research (Envirotrade, 2010; Jindal et al., 2012), further efforts were still needed to increase participation levels, particularly among the most forest-dependent households (Jindal et al., 2012). Second, the results highlight that social capital, such as indicated by the degree of trust, can be a powerful factor influencing household participation in PES programs. As PES involved long-term contracts with landowners, implementers should pay particularly attention to strengthening social capital. Third, an important part of the carbon revenue was used for community-level infrastructure such as building schools and wells, but this expensive ICDP component may eventually have absorbed too large a share of the carbon revenues, thus leaving PES payments proper insufficiently attractive, triggering too modest household participation.

On aggregate, we believe that the Nhambita PES program and its valuable pilot lessons hold a good potential for informing various PES initiatives and incentive programs in Sub-Saharan Africa. This includes also the emerging Reducing Emission from Deforestation and forest

Degradation (REDD) activities in Mozambique, and the community participation and benefit sharing mechanisms that this process entails.

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Table 1: Key characteristics of the villages

| Characteristics | Nhambita | Bue Maria | Munhanganha | Mbalawa | Pungue |
|---|---|---|---|---|---|
| Location | Within buffer zone | Within buffer zone | Within buffer zone | Outside park | On the park boundary |
| Distance to tarmac road | 9 km | 18 km | 10 km | 1-6 km | 1-4 km |
| Access to markets | Poor | Poor | Poor | Medium | Fair |
| Main forest products | Own use: wild food, grass, fuel, poles & limited use of clay for pottery & timber | Own use:, wild food, grass, fuel, poles, limited timber & fish | Own use: wild food, grass, fuel, poles & limited use of timber & fish | Own use & sale: wild food, fuel, bamboo, charcoal, poles, timber & gold panning | Own use & sale: wild food, fuel, bamboo, poles, fish & gold panning |
| Farming | Mainly subsistence; | Subsistence & commercial (cotton; sesame) | Mainly subsistence; | Mainly subsistence; | Both subsistence & commercial (tobacco; vegetables) |
| Major environmental resource collected | Poles, wild food, clay for pottery | Poles, wild food, fish | Poles, wild food | Poles, wild food, bamboo, charcoal, gold panning | Fish, poles, wild food, gold panning |
| Number of households | 64 | 42 | 65 | 414 | 441 |
| Households sampled | 18 | 15 | 16 | 115 | 126 |
| PES households | 18 | 13 | 11 | 38 | 25 |

Table 2: Definitions of variables used in instrumental variables model

| Variables | Definition | Expected sign |
|---|---|---|
| Dependent variable | | |
| Participation | Dummy variable (0,1) indicating whether a household participated in the PES-program or not (i.e. signed a contract voluntarily & planted and was managing seedlings). | |
| Independent variables | | |
| Forest dependence | ratio of forest cash income (sum of cash income earned from sale of forest products) to the household income | |
| Head's Education | Education level of head of household (years) | +ve |
| Size | Number of members in a household | +ve / -ve |
| Woman head | Dummy variable taking a value of 1 if household head is a woman; zero otherwise | -ve |
| Agri. land | Area of agricultural land (ha) held by a household | +ve |
| Forest dependence | Proportion of income from sale of forest products (timber, bamboo, fuelwood, charcoal, etc.) in the total cash income (%) | |
| Good place | Dummy variable taking a value of 1, if a household rated highest on a score of 3 that the community is a good place to live. | +ve |
| Trust | Dummy variable taking a value of 1 if a household rated 3 on a scale of 1 to 3 that it finds that the fellow villagers can be trusted in general. | +ve |
| Pilot project site | Dummy variable (1,0) indicating whether the household is located in either Nhambita, Mbalawa or Munhanganha where the pilot project was first introduced. | +ve |
| Carbon dependence | Amount of carbon income a household would have earned by participating in the project, which is estimated based on the average payment[22] per ha for the most dominant agroforestry system and expressed as a share of the total cash income. | -ve |
| Woman head | Dummy variable taking a value of 1, if a household is headed by a woman. | +ve/-ve |
| Household size | Sum of the members in a household | +ve |

[22] The average payment per ha was estimated to be about MTS 3,416,000 (equivalent to US$ 129) which represented the upfront 30% payment for the mixed rows planting system which was the most dominant. It is 'potential' income because not all households participate in the project. It is a variable that reflects the carbon price facing a household.

Table 3: Determinants of participation

| Variables | Probit | | IV Probit | |
|---|---|---|---|---|
| | Coefficients | P> \|z\| | Coefficients | P> \|z\| |
| Forest dependence | 0. 0012 (0.0056) | 0.827 | -0. 0429 (0. 0121) | 0.000 |
| Agri. land | 0. 1752 (0. 0729) | 0.016 | 0. 0726 (0. 0829) | 0.381 |
| Head's education | 0. 1593 (0. 0420) | 0.000 | 0. 0905 (0. 0462) | 0.050 |
| Carbon dependence | -0. 0004 (0.0003) | 0.203 | -0. 0002 (0.0003) | 0.399 |
| Trust | 0. 6070 (0. 1917) | 0.002 | 0. 3854 (0. 1933) | 0.046 |
| Good place | -0. 3121 (0. 2801) | 0.265 | -0. 1119 (0. 2696) | 0.678 |
| Pilot project site | 1.5329 (0. 2397) | 0.000 | 0. 7909 (0. 3691) | 0.032 |
| Woman head | 0. 3710 (0. 2541) | 0.144 | -0. 0465 (0. 2398) | 0.846 |
| Household size | 0. 0950 (0. 0328) | 0.004 | 0. 0476 (0. 0322) | 0.139 |
| Constant | -2.8358 (0. 4402) | 0.000 | -1.0358 (0. 7759) | 0.181 |
| Observations | 290 | | 290 | |
| /athrho | - | | 0. 9257 (0. 3639) | 0.011 |
| /lnsigma | - | | 2.7628 (0. 0841) | 0.000 |
| Rho | - | | 0. 7286 (0. 1707) | |
| sigma | - | | 15.8436 (1.3322) | |
| Wald chi2(6) | 85.46 | | 53.65 | |
| Pseudo R2 | 0. 2402 | | - | |
| Prob > chi2 | 0.0000 | | 0.0000 | |
| Wald test of exogeneity (/athrho = 0) | | | chi2(1) = 6.08 | Prob> chi2 = 0.0137 |
| Test of over-identifying restrictions<br>Amemiya-Lee-Newey minimum chi-sq statistic | | | 2.402 Chi-sq(4) | P-value: 0.6623 |

Figure 1. Study area location