PAYMENTS FOR ECOSYSTEM SERVICES AND FARM HOUSEHOLD BEHAVIOUR: THE CASE OF CARBON IN MOZAMBIQUE'S AGROFORESTS

by

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ABSTRACT

Payments-for-Ecosystem-Services (PES) projects are being developed worldwide to address environmental and economic issues simultaneously. This thesis describes research concerning a PES project in Nhambita Community in Mozambique, where a small agro-forestry based carbon sequestration project is being implemented. The central research question is: Do economic incentives to smallholder farmers result in improved ecosystem services provision and improved household welfare measured by cash income and consumption? Questionnaire-based quarterly household surveys were the main source of data. Data was collected from 290 randomly selected households by eight enumerators who were trained in administering questionnaires in the local language (*Sena*).

The thesis consists of six chapters, two of which are an introduction and conclusion. The remaining four chapters are prepared as manuscripts: the first assesses the contribution of environmental resources to the household economy; the second investigates the *miombo* woodlands' use as household safety net against adverse income shocks, using conditional logit analysis; the third investigates socio-economic factors influencing household participation in the PES project, using 3-stage estimation; and, the fourth and final evaluates the impact of the PES-project on household cash income, consumption, forest use and agricultural production, using propensity score matching. It further examines whether there was any discrimination in the flow of benefits, using decomposition analysis.

The key results are as follows. 1) Poorer households used *miombo* resources for subsistence, while richer households used the same for cash income. 2) Women headed households, which had lower level of cash income, used the woodland resources to the same level as did the male headed households. 3) Use of wild products from *miombo* woodlands was one of the shock coping strategies. 4) Participation in PES-project was influenced by education of household head, length of residence in the community, extent of trust among community members and percentage of cash income derived from sale of forest products. 5) PES-participant households earned higher amount of cash income, had higher consumption and harvested lesser amount of crops, than they would have had they not participated in the project. 6). There were biases in the flow of benefits in favour of richer and male headed households.

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To Ashna & Sangeeta

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Role of co-authors:	Ravi Hegde identified the research problem and research methods and developed the research design under the guidance of Gary Bull, collected and analysed the data and prepared the manuscripts. Gary Bull provided funding, guidance and insightful suggestions throughout the research program.

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Chapter 5:	
Title:	*Performance of an Agro-forestry based Payments-for-Ecosystem Services Project in Mozambique: A household level analysis*
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1 INTRODUCTION

1.1 Overview

Human society receives a variety of goods and services from the ecosystems. The benefits received by mankind from nature are known as ecosystem services. Tropical forests provide a variety of ecosystem services, namely provisioning services such as timber and non-timber products; regulatory services such as carbon sequestration and biodiversity conservation; and cultural services such as recreation and scientific benefits (Daily 1997). The *miombo* woodlands are a critical ecosystem in southern Africa. Due to low per capita income and high population growth within the *miombo* zone, there is a heavy reliance on the *miombo* woodlands for slash-and-burn farming and a variety of wild products for local livelihoods, leading to *miombo* woodland degradation (Dewees et al. 2008; Williams et al 2008; Abbot and Homewood 1999).

When the benefits of the ecosystem services accrue to those who manage them, private markets are likely to provide economic incentives for their continued provision (e.g. agriculture). However, when the benefits of the ecosystem services are mainly available to those who did not directly manage them, it is likely to bring about a misalignment of private and public interests (e.g. carbon sequestration). This usually results in externalities leading to market failure causing under-production of ecosystem services in comparison to the societal requirements (Baumol and Oates 1998; Costanza et al. 1997). Potential policy solutions to externalities problem include public provision, government regulations and incentive based mechanisms encouraging actions by individuals (Jack et al. 2008). Recently, Payments-for-Ecosystem-Services (PES) emerged as a new policy tool to manage the ecosystem services by translating their non-market values into marketable value. For instance, a market mechanism currently exists through the Kyoto and voluntary markets for carbon credits generated from forest carbon projects involving farmers (Nijnik and Bizikova 2008; Capoor and Ambrosi 2009; Hamilton et al. 2008; Jindal et al 2008).

Under the PES model, the conditional cash payments to the ecosystem services providers can, in theory, be a tool to achieve both conservation and poverty reduction strategies in a developing country such as Mozambique (Pagiola et al. 2005; Grieg-Gran et al. 2005). A PES-program will inevitably involve both benefits and costs. The provision of benefits depends on: (a) the ability of ecosystem service providers to participate in the PES program; and (b) the amount of cash payment made to the service providers by the PES-program (Wunder 2008). Therefore, it is

important to investigate both the rate and patterns of household participation in a PES-program and the amount of cash payments made to the participant households. The PES-program costs for the participating service providers may include: restricted access to the resources, changes in input and output prices and changes in the level of agricultural production (Kerr 2002). Therefore it is necessary, even imperative, to evaluate the strengths and weaknesses of the PES model, particularly, in terms of their contribution to the household livelihoods.

1.2 Literature review

1.2.1 Ecosystem services

The Millennium Ecosystem Assessment (MEA) defines the ecosystem services as the benefits people obtain from the ecosystems and classifies the ecosystem services as provisioning services (e.g. food, water, timber, fibre, etc.), regulatory services (e.g. climate regulation, water quality regulation, flood control, etc.), cultural services (e.g. recreational, aesthetic, scientific and cultural benefits) and supporting services (e.g. photosynthesis, nutrient recycling, soil formation, etc.) (MEA 2005).

The MEA estimated that the demand for the ecosystem services increased significantly between 1960 and 2000 with the doubling of the world population and a six-fold expansion in the world economy, and that nearly two thirds of the ecosystem services are on the decline (MEA, 2005). The MEA observed that "*...the benefits reaped from our engineering of the planet have been achieved by running down natural capital assets...*" (MEA 2005). While some amount of natural capital depletion may have been inevitable, the presence of various forms of market failure may have caused more depletion of natural capital than what was socially acceptable (Engel et al. 2008). Market failures, in turn, may have been caused by the presence of externalities, public good nature of the ecosystem services, improper property rights regimes and inadequate information (Tietenberg 2006).

1.2.2 Forest ecosystems

Tropical forests provide a variety of ecosystem services (Daily 1997). With people living in and around most of the world's tropical forests, the management of these ecosystem services is critical (Byron and Arnold 1999; Smith and Scherr 2002). In the African tropical forest, the *miombo* woodlands are a critical ecosystem. *Miombo* is the vernacular term for seasonally dry deciduous woodlands in southern Africa, dominated primarily by the genera *Brachystegia*, *Julbernadia* and/or *Isoberlinia* (Campbell 1996). It is the most extensive tropical seasonal woodland and dry forest formation in Africa, covering some 2.7 million square km in some of the

world's poorest countries (Dewees et al. 2008; Syampungani et al. 2009). Due to low per capita income and high population growth rates in southern Africa, there is heavy reliance on subsistence slash-and-burn farming within the *miombo* zone (Williams et al 2008) and increased *miombo* woodland loss due to increased fuelwood extraction (Abbot and Homewood 1999).

The *miombo* woodlands have several unique features (Dewees et al. 2008). First, they are highly valued as a source of fuel, charcoal and construction. Second, they are scarce in high quality timber species. For instance, Mozambique's national forest inventory indicates that out of the total standing wood volume, only 7% is commercially valuable as timber (Marzoli 2007). Third, many of their trees have fibrous bark which is used extensively in construction, weaving and making bark beehives. Fourth, they have a high proportion of plants that are either unpalatable and/or toxic, primarily from the *Papilionaceace* family. Fifth, they contain some trees (e.g. Caesalpinoid, *Uapaca kirkiana*) which have a symbiotic relation with edible fungi. Sixth, they are an important habitat for beekeeping operations. Seventh and finally, they contain a diversity of insects, for example, the *Saturniidae* family of giant silk moths, whose caterpillars are an important source of protein and cash to the local people.

The *miombo* woodlands make a direct contribution to the livelihoods of the local people. The products provided by the woodlands include fuelwood, charcoal, construction timber, mushroom, fruits, roots and tuber (Campbell 1996; Campbell and Luckert 2002; Cavendish 2000; Dewees et al. 2008; Fisher 2002; Kaimowitz 2002; McSweeney 2002; Sale 1981; Syampungani et al. 2009). The woodlands also have an important subsistence value for the households, as a source of 'famine foods' (Ngaga et al. 2006; Tairo 2007). These *miombo* woodlands products accounted for 30%-40% of the household income in Zimbabwe and Malawi (Cavendish 2000; Fisher 2002).

1.2.3 Tools for management of forest ecosystem services

The environmental economics literature offered a range of policy tools that could be applied to forest resource management (Baumol and Oates 1998; Cubbage et al. 2007; Jack et al. 2008; Sterner 2003). They include command-and-control regulations, integrated conservation and development programs (ICDP), eco-labelling, and more recently the PES approach (Engel et al. 2008).

Command-and-control regulations are typically used to allocate resources that are either not priced or undervalued in the market place (Cubbage et al. 2007). The regulations create legal

instruments that prohibit environmentally damaging practices (e.g. unauthorised logging) or support other interventions aimed at resource conservation and augmentation (e.g. creation of parks and reserves). Some of the environmental economics literature argues that the command and control system is frequently inefficient since it lacks the flexibility of the market based approaches (Baumol and Oates 1998; Engel et al. 2008; Sterner 2003; Tietenberg 2006). Others argue that poor governance and high enforcement costs, which are associated with the regulations, make this approach less popular (Engel et al. 2008). For example, it is known that regulatory restrictions on the use of forests have increased the burden on poor people who tend to use the forests for livelihoods (Cavendish 2000; Hegde and Enters 2000).

ICDP was developed to secure conservation by raising community incomes through environmentally benign practices and by establishing and enhancing direct links between the community economy and the resource base (Ferraro and Kiss 2002; Kiss 1990; Wells and Brandon 1992). ICDPs have not proven to be cost effective in achieving conservation outcomes[1]. Further, the alternate income generation activities devised were not effective in addressing conservation objectives (Ferraro and Simpson 2002; Simpson and Sedjo 1996; Wells et al. 1999; Sayer et al. 2008).

Eco-labelling, a market based approach, emerged in the 1990s to promote sustainable forest management (SFM), to enhance market opportunities for products from sustainably managed forests and finally, to increase public awareness on SFM (Durst et al. 2006; Rametsteiner and Simula 2003; Sell et al. 2007). Initially, tropical forests were the primary focus of certification, but it has languished[2] due to high transaction costs of certification, wide gaps between the existing management standards and the certification requirements and a lack of demand for certified forest products (Durst et al. 2006). Nevertheless, certification could be a successful policy tool in countries where governments enforce forestry laws, provide financial incentives to certify the forest and where large scale and vertically integrated forestry operations are feasible (Ebeling and Yasué 2009).

[1] For instance, after a review of 19 ICDPs in Indonesia, Wells et al. (1999) concluded that *"..very few ICDPs in Indonesia can realistically claim that biodiversity conservation has been or is likely to be significantly enhanced as a result of current or planned project activities.*.". In their assessment, this was due to "*…flaws in basic assumptions and planning, and a failure to address the real threats and capacity constraints that conservation projects face in the field...*".

[2] Durst et al. (2006) concluded that about 92% of the certified area was in temperate and boreal region and about 5% in the tropics. The world's certified forest area was about 320 million ha in 2008, with an estimated round wood supply of 416.4 million m3 which accounted for 26% of the total supply (ITTO 2008).

Recently, the PES approach has emerged as a new policy tool to manage ecosystem services, which compensates individuals or communities for undertaking actions that enhance the provision of ecosystem services (Jack et al. 2008). PES is defined as a voluntary transaction involving at least one buyer and one seller, in which a well defined ecosystem service, or a land use that is likely to secure the ecosystem service, is bought if and only if the provider ensures the secured provision of the ecosystem services (Wunder 2007). The attractiveness of the PES model is that it helps translate external, non-market values of the ecosystem services into real financial incentives for the ecosystem services providers to continue the provision (Engel et al 2008).

The PES model also has limitations. First, there are high transaction costs associated with working with a large number of ES providers (Cacho et al. 2005). Second, there are concerns about the permanence of the ecosystem services provided by the PES-projects (Capoor and Ambrosi 2009). Third and final, the PES projects must demonstrate the added value of the ecosystem services provided against the baseline (Cubbage et al. 2007). Given that a large number of PES-projects are being implemented using donor funds (Jindal et al 2008; UOE, 2008), the issue of 'additionality' of the benefits becomes even more important from the perspective of the long term sustainability of the PES model.

1.2.4 Markets for ecosystem services

There is a growing market for ecosystem services mainly covering carbon sequestration, watershed protection, biodiversity benefits and landscape beauty (Grieg-Gran et al. 2005; Maness 2009). An earlier review identified about 287 initiatives worldwide focusing on forest ecosystem services (Landell-Mills and Porass 2002). The carbon markets can be broadly classified as Kyoto compliant and voluntary markets (Hepburn 2007; Jindal et al 2008). The Kyoto compliant markets are those set up under the flexibility mechanisms of the Kyoto Protocol (Nijnik and Bizikova 2008). A voluntary market is one where individuals, firms and other entities buy carbon credits for purposes other than meeting regulatory targets (Maness, 2009). At less than 1% of the total transacted volume of 389 $MtCO_2e$[3] in the CDM (valued at US$ 6,519 million) in 2008, the LULUCF (Land Use, Land Use Change and Forestry) based carbon assets remain marginal in the carbon market. This is mainly due to the concerns about additionality, leakage and permanence of the GHG reductions and the accuracy of monitoring them, due to which forestry based activities were kept outside of the EU ETS as well as the proposed ETS in Australia and New Zealand

[3] Million tons of carbon dioxide equivalent

(Capoor and Ambrosi 2009). On the other hand, forestry based carbon assets accounted for 18% of transacted volume of 65 $MtCO_2e$ (valued at US$ 331 million) in voluntary market in 2007 (Hamilton et al. 2008).

1.2.5 Forest ecosystem services and household livelihoods

Over time, forest based livelihood modes have changed from hunting and gathering to a combination of slash-and-burn cultivation and settled agriculture at the forest margin. In hunting and gathering, the ecosystem resource use was limited to extraction of the flora and fauna for consumption. Under the slash-and-burn system of agriculture, the forest land serves as a source of agricultural land whose fertility is maintained and restored in a system of rotational fallow, while in settled agriculture, the forest lands serve as agriculture lands on a permanent basis and no longer are a part of the fallow system. Use of certain ecosystem services (e.g. timber and water) is common across the three stages (Sunderlin et al. 2005).

Among the provisioning services provided by forests, both timber and non-timber forest products[4] (NTFPs) are important. Timber is commercially the most important forest product, but the timber income benefits have largely eluded the rural poor except those engaging in illegal logging (Angelsen and Wunder 2003; Sunderlin et al. 2005).

The NTFPs are critical for the livelihoods of the rural poor, although they rarely provide a means of poverty reduction (Campbell et al. 2002; Neumann and Hirsch 2000). The limiting factors include: a) limited markets for the NTFPs, which limits income generating opportunities; b) wide variation in the quantity and quality of the products available over time and space, which reduces their price in the market; and c) remote settings and poor market access resulting in weak bargaining power of the producers relative to the traders (Sunderlin et al. 2005). In spite of these limitations, for example, the collection of wood based fuel (charcoal and fuelwood) could still generate income for smallholder farmers in peri-urban areas, particularly in Africa (Angelsen and Wunder 2003; Sunderlin et al. 2005).

In spite of their low income generation potential, the NTFPs play two key roles. First, they serve as income supplements or ‘gap fillers’ when they are collected to supplement household income.

[4] According to FAO working definition, the term non-timber forest products refers to goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests. Non-timber forest products generally include fuelwood and small timber, but exclude forest ecosystem services (e.g. watershed protection, soil conservation).

They are ‘gap fillers’ in the sense that they make seasonal, but reasonably predictable, contribution to household income as an income supplement, which can be quantified. Second, during income shortfall periods caused by adversities such as household health, unemployment, macro-economic crises and environmental calamity, the NTFPs can serve as a reservoir of food as well as a source of cash income. This ‘safety net role’ of the NTFPs implies that they reduce the vulnerability of the people experiencing the shock (Angelsen and Wunder 2003; McSweeny 2005; Shackleton et al. 2007; Hudson 2005).

1.2.6 PES impacts on household economy

Cash payments to ecosystem service providers are believed to be the main mechanism by which the PES model would contribute to poverty reduction. The effectiveness of the PES programs in alleviating the poverty depends on three factors: (1) the amount of cash payments; (2) poor peoples’ ability to participate in the PES programs; and (3) the extent of poverty in the project area (Pagiola et al. 2005).

The PES-payments can make the poor ecosystem service providers better off in income terms. For instance, the amount of cash payments made to the service providers varied from US$77 to US$640 per household per year in a PES-like scheme in Bolivia (Wunder 2008); and a PES-project paid up to $820 per month in Costa Rica (Miranda et al. 2003). The PES-income accounted for over 10% of the total household income for over a quarter of participants in Costa Rica (Wunder 2008), while the share of PES-income in the total income was up to 30% in Latin America (Kosoy et al. 2008; Miranda et al. 2003).

Household participation rates in the PES-programs determine the effectiveness of the PES programs in addressing poverty. The following factors are found to influence household participation. First, opportunity cost of land is a key driver of household participation in the PES-projects (Wunder 2007). Second, a variety of socio-economic factors including the farm size, land title, education of the decision makers in the family, family labour and off-farm income and influence the household participation decision (Zbinden and Lee 2005). Third, household participation depends on time. As PES-projects tend to get started top-down, the participation rates can be expected to be low at the beginning, but would increase over time, when the project proves its efficiency and effectiveness (Kosoy et al. 2008). Fourth and final, household transaction costs influence household participation (Pagiola et al 2008). When barriers to

household participation cause exclusion of certain groups, the PES-project will have limited capability to address poverty (Grieg-Gran et al. 2005).

Despite the considerable growth in the PES-projects worldwide, empirical research on PES and the project impacts remains sketchy (Engel et al 2008; Wunder 2008). In the last few years, however, a few academic journals, including *Ecological Economics*, *World Development* and *Environment and Development Economics*, have published special sections devoted to PES (Bulte et al. 2008; Engel et al. 2008; Grieg-Gran et al. 2005; Pagiola et al. 2005; Pagiola et al. 2008; Wunder 2008; Zbinden and Lee 2005; Wunder 2008). Some of the issues highlighted in the literature that are relevant for this research include effectiveness, efficiency and distributional aspects of the PES programs. A key limitation in many of the publications is the lack of field-level research to support the conclusions[5]. This dissertation aims to contribute to filling the gap in knowledge.

1.3 Study context

1.3.1 Nhambita carbon project

A small scale agro-forestry based carbon sequestration project was initiated in Nhambita *Regulado* (community) in Sofala Province in Mozambique. Participating smallholder farmers plant trees on farm under agro-forestry (under inter-cropping, boundary planting and homesteads systems) to sequester carbon[6]. The project aim was to contribute to the *miombo* woodland conservation and reduce poverty through income received from carbon sales. Since the Nhambita project was set up prior to the formalisation of the Kyoto Protocol, it is not eligible to participate in the Kyoto markets, and hence it focuses on the voluntary market. Envirotrade, a UK based company, has developed a business model based on carbon offsets. Envirotrade LDA is the Mozambican non-profit contractor set up in partnership with Envirotrade (UK) to facilitate the operation of the project in Mozambique. Envirotrade cooperates with the University of Edinburgh which underpins the research part, and also with the Edinburgh Centre for Carbon Management (ECCM) which monitors the carbon through the Plan Vivo system. The project is funded by the European Union.

[5] For instance, five of the eight publications cited here were theoretical in nature and only three dealt with some aspects of field projects.

[6] At the time of our field work for this dissertation, only agro-forestry model was being implemented. Recently, however, the project also introduced community based forest management, a REDD type project. Details can be seen at (http:/www.*miombo*.org.uk/Documents.html).

1.3.2 Resource tenure

All the land is State-owned in Mozambique. Broadly, there are three types of land in Nhambita: protected land, buffer zone and community land. The protected area lies in the Gorongosa National Park which is currently managed by the Carr Foundation (a US based foundation), in co-operation with the Mozambican Government. As in many protected areas, all human activities (i.e. farming, planting, livestock, hunting, etc.) are prohibited in the Park. The buffer zone is the area immediately adjacent to the Park boundary, which is jointly managed by the government, village communities and other stakeholders. Subsistence farming is allowed in this area, but other commercial activities including commercial hunting or extraction of forest products on a commercial scale are not allowed, except under licence. The community land is managed by the communities under the Land Act (1997) which allows subsistence farming, charcoal production, fishing and hunting.

According to the Land Act (1997), the State owns all the land but may grant use rights to individuals, communities and companies in the form of leases that can last up to 100 years. These leases can be transferred, but cannot be sold or mortgaged. Use rights emerge either through occupancy or by a specific grant through the State. The government can issue use right title documents to individuals, companies, or entire communities and groups. Those who occupy the land for more than ten years acquire permanent use rights as peasants; returnees (households that migrated during civil war and returned after its end) who often do not possess the actual title documents need to prove their occupancy of land. For the benefit of those who lack title documents, courts accept verbal evidence from the community members regarding occupancy of land, which is important because of the high level of adult illiteracy among the Mozambican peasants and returnees. The law also protects the rights of smallholder returnees against the often conflicting claims of large landholders by creating requirements for development plans before the issuance of title.

1.3.3 Project scope

The key threats to the *miombo* woodland ecosystem in Mozambique include encroachment and land clearances for agriculture, unsustainable charcoal production, uncontrolled burning of forests and illegal logging (UOE, 2008). The *miombo* woodlands provide the critical livelihood support to the rural households in Mozambique (Hegde and Bull, 2008). Nhambita community, being located in the buffer zone of the Gorongosa National Park, has a heavy dependence on the *miombo* woodlands. Traditionally, households practice slash-and-burn agriculture (also known as

shifting cultivation) in which farmers clear and burn the *miombo* woodlands to establish their *mashamba* (farm), following which they grow mainly subsistence crops including corn, sorghum, peas, cucumber and other vegetables. After 3-4 years, they clear land in another place leaving the old *mashamba* site for regeneration for the next 20-25 years.

The slash-and-burn cultivation is legally allowed in Mozambique even in the Park buffer zone. A farming household needs to take the permission from the *Regulo* (traditional chief) to clear fresh land, in some cases with payment of a nominal fee. However, there are situations where households skip this step and continue with land clearing, and the cycle continues. In the Park buffer zone, communities are also allowed to collect fuelwood from dead and fallen trees, gather wild fruits, tubers, medicinal herbs for own use; and hunt animals using bow and arrow for subsistence. In the community land outside the Park boundaries, some households also produce charcoal. The charcoal producers generally cut and burn trees to produce charcoal, while some households cut trees to produce head-loads of fuelwood for sale along roadside. These households keep moving from place to place normally when trees from an accessible distance are exhausted. The PES project in Nhambita aims to conserve the woodlands by halting woodland clearing for slash and burn farming and charcoal production. Carbon credits traded in the voluntary market are the primary products from the project, while biodiversity conservation (through *miombo* woodland conservation) was a by-product which is not currently traded in the market.

1.3.4 Current status

The Carbon Livelihoods Project was started as the Nhambita Pilot Project in the second half of 2003. The pilot phase of the project was limited to the villages of Nhambita, Bue Maria and Munhanganha. The smallholder households have signed voluntary contracts with the project implementing agency to plant indigenous and fruit tree plants on their *mashamba* and manage them for 25 years in return for conditional cash payments. The conditions for payments stipulate that the participating household must ensure a minimum seedling survival rate of 80% in the first year, 90% in the second year and 100% in the third year; and that no clearing and burning of forest land is done during the project period, over and above what has been recorded in the map. This excludes slash and burn farming and production of charcoal and fuelwood.

The initial work consisted of preparation of the *Plan Vivo* maps for the participating smallholder farmers. Although the maps were basic, they contained the necessary information including a map of the existing farm with GPS points, current fallow land belonging to the family and also

the abandoned land (by the members of the family during the civil war) which the family may plan to cultivate in the future. Basically, the map captured both the existing and potential land that a family may farm now or in the future. The number of trees to be maintained was used to calculate the amount of carbon which will be fixed, which was the basis for determining the amount of money to be paid to the participating farmers. The cash payments are split into seven annual instalments: 30% in the first year, 12% for each of the next five years, and the remaining 10% in the final year. The carbon credits are sold in the international voluntary carbon markets: a part of the sale deeds (about 30% of the carbon revenue) is deposited in a trust fund which is used to pay the participant farmers and to undertake development activities in the villages.

Besides carbon, the project also has a menu of other forest based activities for the development of the community, such as a carpentry unit, a bee keeping unit, nursery development, field demonstration of improved gardening, etc. and provides full time employment for about 100 people. It also provides limited seasonal employment in forest fire prevention and fire watch activities. Besides the direct employment, the project also distributed guinea fowls for rearing and red gram seeds for cultivation to the households on a pilot scale.

The *Plan Vivo* Foundation is the certifying body for the project. It conducts periodic project audits, approves the technical specifications, coordinates peer reviews, issues the *Plan Vivo* certificates to purchasers of carbon credits on behalf of the project and registers all the certificates issued in a central database. The carbon uptake of the individual tree species was calculated using the CO2FIX-V3 model, the results were then used to build site specific estimates for different planting systems (i.e. boundary planting and planting in mixed rows with crops) based on the numbers of tree species planted and the rotation length. The University of Eduardo Mondlane in Maputo conducts an annual inspection of the forest management activities and submits a report to the Carbon Livelihoods Trust. If required, verification services are available through independent companies such as Smartwood (http:/www.smartwood.org) (UOE, 2008).

The forest carbon projects must satisfy the criteria of permanence, additionality and leakage. Permanence is the certainty that the carbon asset created under the project will last long. Additionality involves providing evidence that the mitigation would not have happened in the absence of the project. Leakage refers to the negation of the beneficial impact of the project outside the project boundaries due to actions of the project participants (Ristea and Maness 2009).

Permanence is one of the largest concerns in the forest based carbon sequestration since forests cannot provide permanent carbon storage facility as natural disturbance and future harvesting may result in unexpected and unavoidable carbon emissions. This is no exception to the Nhambita project. The PES-participant households make a commitment to sustainable land use for 25-years, while they receive the PES payments for the first seven years. The project administration is aware of the fact that the cash payment is frontloaded with a third of payment being made in the first year, and that there is always the risk of losing 30% of the payment should a farmer breach the contract terms.

Additionality involves the identification of "a business as usual" (baseline) position in the absence of land-use change interventions introduced by the project. The additionality tests tend to be subjective as often they are based on persuasive arguments, as many of the outcomes are difficult to quantify in terms of a scientific method or test. Three types of baseline, namely static, deteriorating and improving, have been discussed in the literature (Wunder 2007). The static baseline projects that the present rate of carbon emission would continue in the future in the absence of any intervention, deteriorating additionality argues that the future emissions would get worse and the improving baseline forecasts that the future emissions would improve even without any intervention. The PES project impacts vary significantly depending on which type of base line is used (Wunder 2007).

In LULUCF projects, such as the one in Nhambita, the emphasis is therefore on developing a credible baseline scenario. The baseline is constructed as carbon stored in any existing vegetation (excluding food crops) on a plot at the time of planting, which depends on how many years the site has been fallow. Generally, the longer a site has been left fallow, the higher the baseline will be. When calculating the number of carbon credits that a farmer has for a site, the baseline carbon stock is subtracted from the carbon sequestration achieved by the project activity (UOE 2008). The carbon baseline is developed based on field research involving 28 *mashamba*s and the average accumulation rate is estimated to be 1.1 ton of biomass/ ha /year in the fallow sites, corresponding to 0.55 tC/ ha/yr (UOE, 2008). The project also established permanent sample plots throughout the project area to establish the impact of interventions on the forest environment (UOE, 2008).

Leakage may include unintended forest clearance outside the project areas as a direct consequence of the project. For instance, the project participants can clear an additional forest

area outside the PES project boundary resulting in carbon emission. The patterns of land use change and fire events in Nhambita were monitored by the University of Edinburgh until 2008, after which monitoring was built into the project budget and met from the carbon revenue. Seedling survival and tree growth are monitored by the project staff and records are kept at the office of Envirotrade Lda. There is a proposal to develop satellite monitoring of samples of trees, for example with IKONOS imagery, after the project passes from the pilot stage to implementation stage (UOE, 2008).

The monitoring plan includes annual boundary inspection by the technical team; monitoring by remote sensing plan (annual visual inspection of Modis NDVI for the area); monitoring of key indicator species and other biodiversity factors; consultation with the governing committee and review of reports summarising their activities for the year; inspection of any restoration activities; monitoring fire management programme; verification of compliance to the management plan. (i.e. check on resource extraction figures supplied by the Nhambita Community Association); and checking any leakages. The monitoring ensures that all the conditions for receiving payments as set forth in the contract have been satisfied.

1.4 Research questions

Against the above background, the current research was undertaken in Nhambita Community in Mozambique. The central research question this dissertation attempts to answer is: Do economic incentives to smallholder farmers result in improved ecosystem services provision and improved household welfare as measured by increased household cash income and consumption?

To explore further the specific dimensions of this broad research question, I developed three specific research questions. The specific research questions addressed in this thesis are: a) What is the contribution of the *miombo* woodland resources to the household economy? b) What socio-economic factors influence household participation in the PES-project? c) Do the PES-payments result in improved household cash income and consumption?

As suggested in the literature, evaluating the economic contribution of the ecosystem services is the primary requirement for integrating conservation and development of local communities in the forest margins (Kant 1997). Given that the *miombo* woodlands ecosystem provides a variety of ecosystem services in a broad sense, it is important to quantify their contribution to household income for the purpose of understanding their role in poverty alleviation. The Nhambita PES-

project aims to promote agro-forestry based carbon sequestration and conserve the *miombo* woodlands by halting woodland clearing for slash-and-burn cultivation and production of charcoal and fuelwood. Therefore, quantifying the contribution of the *miombo* woodland resources to household income is necessary because if the poor households are more dependent on the woodlands for cash income than the rich households, exclusion of the poor households from the PES-project does not help achieve the poverty reduction objective. Therefore, it is important to investigate whether the poor households are more dependent on the *miombo* woodland resources than the rich. Similarly, since the women headed households are poorer than the male headed households, it is important to understand whether the former are more dependent on the *miombo* woodland resources than the later.

Addressing the household participation in the PES-project is important because participation determines the supply of ecosystem services. If entry restrictions exist in the PES-project causing exclusion of certain groups, then the PES-project will not be successful in achieving the poverty reduction objective and also the limits the ecosystem service provision. In addition, answering this question is both interesting from a research perspective and also important from a policy perspective, given the low household participation rates in the Nhambita PES-project.

Addressing the question of whether the PES-payments result in improved household welfare is imperative because the PES model is believed to be capable of achieving both the ecosystem conservation (i.e. provision of ecosystem services) and poverty reduction objectives. Given that the Nhambita PES-project offers conditional cash payments for agro-forestry based carbon sequestration, it is important to examine whether there are any impacts on the household welfare, measured in terms of household cash income generation and consumption.

1.5 Research method

The research was undertaken in five villages in the buffer zone of the Gorongosa National Park. Data used in the research was collected using questionnaire surveys. Quarterly household surveys, which explicitly integrated quantitative environmental resource use with household information, were the main source of data. In addition to the four quarterly surveys, two annual household surveys and two village surveys - one each at the beginning of the research and one at the end - were also undertaken. Eight enumerators were trained in administering the questionnaires in the local language (*Sena*) (Hegde and Bull 2008).

1.6 Dissertation structure

The structure of this dissertation follows the guidelines for manuscript based dissertations (FoGS 2008). Following the Introduction are four manuscripts which constitute the main body of the dissertation, which are formatted following the guidelines for submission of manuscripts by the Canadian Journal of Forest Research (CJFR 2008). Figure 1-1 describes the content and linkages in the dissertation.

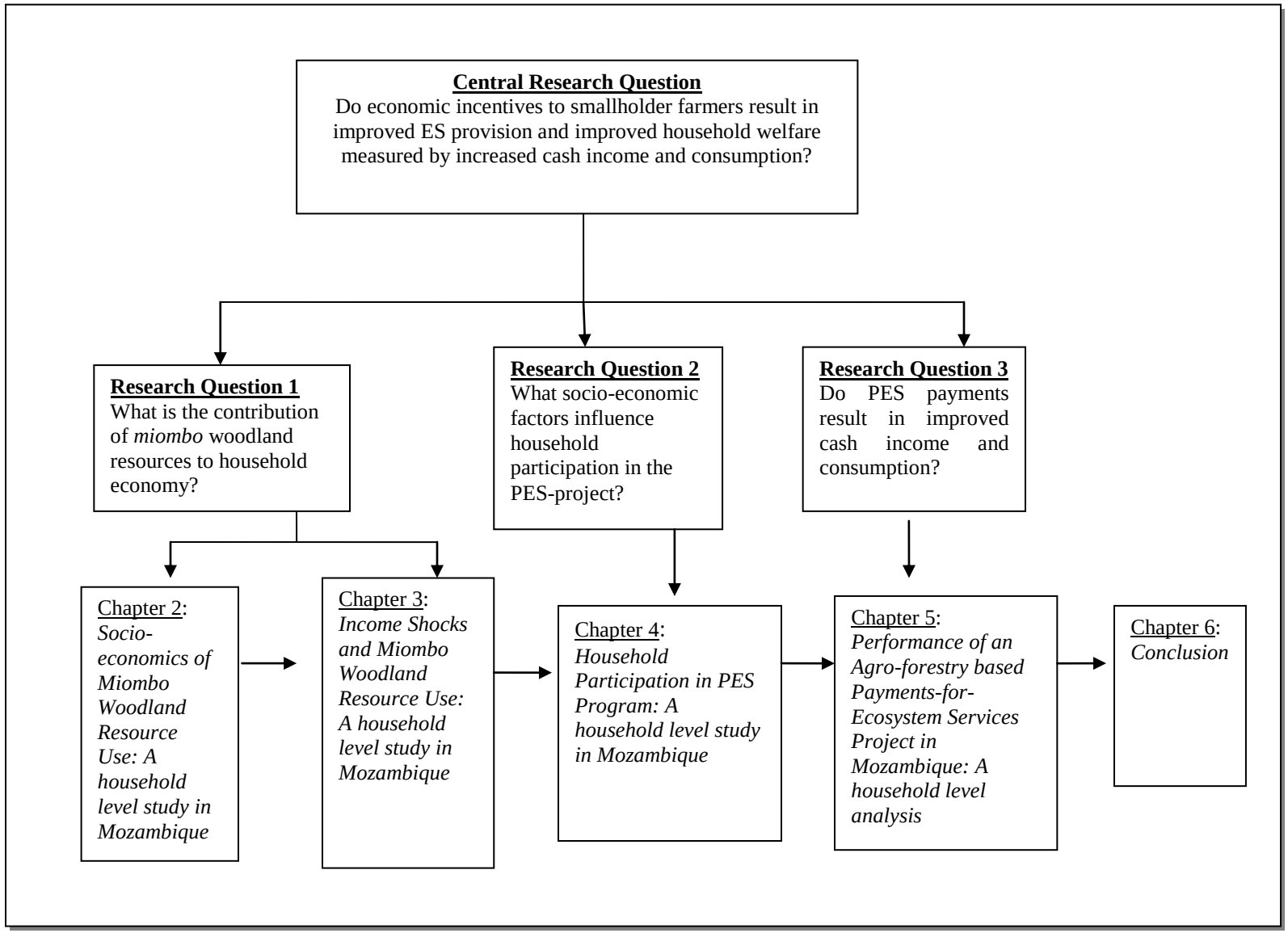

Figure 1-1: Linkages between chapters

In the first manuscript (Chapter 2: *Socio-economics of Miombo Woodland Resource Use: A household level study in Mozambique*), I analyze the livelihoods of the communities in the project area through tabular analysis. I investigate how much do the environmental resources contribute to the household economy, whether the poor households are more dependent on the environmental resources than the rich, and whether the women headed households use more environmental resources than the male headed households. In the second manuscript (Chapter 3: *Income Shocks and Miombo Woodland Resource Use: A household level study in Mozambique*) I investigate whether households' use of the *miombo* woodlands acts as a safety net against adverse, idiosyncratic income shocks. I make use of conditional logit analysis, based on quarterly household data of forest use and shock variables (sickness to family members, death, livestock loss and fire). These two manuscripts assess the contribution of the *miombo* woodlands ecosystem services to the household economy and also help link smallholder households' forest dependence with their decision to participate in the PES-project addressed in the third manuscript.

In the third manuscript (Chapter 4: *Household Participation in Payments for Ecosystem Services Program: A household level study in Mozambique*), I investigate the causes for the low rate of household participation in the PES project. Since the PES project excludes forest clearing and burning, households which carry out forest clearing and tree removal (e.g. shifting cultivators, charcoal producers, fuelwood cutters, etc.) self-select not to participate, which leads to a bias. I make use of 3-stage estimation procedure to correct the bias. This manuscript investigates the factors influencing household participation, whose impacts are evaluated in the fourth manuscript.

In the fourth and final manuscript (Chapter 5: *Performance of an Agro-forestry based Payments-for-Ecosystem Services Project in Mozambique: A household level analysis*) I evaluate the impacts of the PES-project on the household cash income, consumption, forest use and agricultural production, using propensity score matching technique. I also examine whether there was any discrimination in flow of benefits using decomposition analysis. In the final chapter (*Conclusion*), I summarise the results and draw policy conclusions.

Since this is a manuscript-based thesis, there is some overlap in content across manuscripts, particularly when I discuss research method and summary statistics of the sample households.

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2 SOCIO-ECONOMICS OF MIOMBO WOODLAND RESOURCE USE: A HOUSEHOLD LEVEL STUDY IN MOZAMBIQUE[7]

2.1 Introduction

Globally, there has been an increased resolve to find a stronger link between rural poverty and environmental degradation in the developing world. Particular emphasis has been placed on improving the livelihoods of rural poor, while conserving the forest environment. A wealth of literature exists on the contribution of tropical forests to poverty (Godoy et al. 2000; Hegde and Enters 2000; Hegde et al. 1996; Pattanayak and Sills 2001; Peters et al. 1989). The exception, however, is Africa. Although there is evidence that rural households in Africa use environmental resources extensively (Campbell 1996; Campbell and Luckert 2002; Cavendish 2000; Fisher 2002; Kaimowitz 2002; Sale 1981), rigorous analysis of the relationship between rural households and environmental change has been limited and detailed accounts of a full range of environmental resources are scanty.

The *miombo* woodlands in Africa are vital for the welfare of rural communities. Millions of people depend on woodlands for a host of differentiated environmental services; traditional swidden agricultural systems depend on woodlands for nutrients; and woodlands are the source of fodder for livestock (Campbell and Luckert 2002; Kowero et al. 2003). Despite their importance, relatively little is known about the *miombo* woodlands. This is largely due to the lack of reliable data on the use of key environmental resources. As a result, the economic role of woodlands has not been integrated into the system of national accounts. This is an obvious first step in creating a better understanding of the relationship between poverty and environment (Cavendish 2000; Duraiappah 1998).

In many parts of the developing world, household level data is comprehensively captured in the income and expenditure surveys (IES). Typically, these surveys do not account for environmental resources used by rural households for consumption and cash income generation, which lessens their usefulness for the study of poverty and environment relationships. This lack of data

[7] A version of this manuscript has been accepted for publication. Hegde, R. and Bull, G. Q. 2008. Socio-economics of *Miombo* woodland resource use: A household level study in Mozambique. *In* Managing the *Miombo* woodlands of Southern Africa. *Edited by* P. Dewees, World Bank Washington, D.C. Technical Annex 4 (Peer reviewed).

necessitates purposeful collection of micro-level data on household environmental resource use (Cavendish 2000).

Micro level analyses can provide insights that potentially help devise policy interventions for sustainable use of the *miombo* woodlands. Using household-level data collected from villages in the buffer zone of the Gorongosa National Park in Mozambique, this study assesses the economic contribution of woodland resources to household welfare. Specifically, this paper: (a) quantifies the contribution of the *miombo* woodlands to the household economy; and (b) identifies the critical socio-economic factors, such as level of income and gender, which influence woodland resource use. We aim to answer the following questions: (a) How much do environmental resources contribute to the household economy? (b) Are poor households more dependent on environmental resources than the rich? (c) Do women headed households use more environmental resources than male headed households?

We hope that answers to the above questions will be helpful in crafting public policies aiming at poverty alleviation and the *miombo* woodlands conservation.

2.1.1 National overview

Mozambique (Figure 2-1) is one of the world's poorest countries with an area of 79.9 million ha and a population of 19.42 million (GoM 2008)[8]. Approximately 71% of the population lives in rural areas, and 93% of the rural dwellers directly depend on natural resources. In addition, 41% of the urban labor force is dependent upon vocations related to agriculture, forestry and fisheries. Agriculture is extensively practiced with a small fraction (14%) of the total cultivable area (36 million ha) actually cultivated and with low use of inputs (Nhantumbo 2000; Ribeiro 2001). It is estimated that some 24% of the land area (19 million ha) is subject to shifting cultivation, and about 1 million ha is under permanent cultivation (FAO 2005).

The lengthy civil war lasting 16 years combined with droughts and flood alienated about six million people from their land, and adversely affected agricultural activities of those who were not displaced (Simler et al. 2004). According to the National Household Survey of Living Conditions conducted in Mozambique, between 1996 and 1997, about two-thirds of the population lived in absolute poverty. While the poverty rates varied from province to province, Sofala province, where the present research was conducted, had the highest poverty rate (88%).

[8] FAO (2005) provided land use data for the 801, 590 km2 area.

Recently, however, the country made rapid strides in poverty reduction during a period of high economic growth (WorldBank 2005).

Figure 2-1: Study area location

Mozambique is moderately forested with about 39% (30 million ha) of forest area. The forestry sector plays an important role in the national economy by contributing about 4% of the GDP and about 80% of energy needs (FAO, 2005). Although the current rate of deforestation in the country is relatively small (FAO 2005), there are significant human pressures on the woodland resources (Kowero et al. 2003; Ribeiro 2001). The forest products extracted from forests include construction timber, fuelwood, charcoal, and wildlife. In addition to heavy human pressure, forest fires are a major threat, with about 40% of the country being affected by fire every year[9].

2.1.2 Local socio-economic conditions

A socio-economic assessment of Nhambita community in the buffer zone of the Gorongosa National Park (GNP) in Sofala Province reported that 69% of the families earned their cash

[9] Fire is known to be one of the main tools for land clearing for cultivation, hunting, timber harvest and acquisition of other goods and services including charcoal production and honey collection, and for protecting resources from wild animals.

income from farm produce and natural resources. However, the report did not provide estimates of the contribution of forest resources to households (Howell and Convery 1997). Jindal (2004) estimated that annual household cash income fluctuated from a meagre US$9.00 to US$ 2,850.00 in the Nhambita community. The study did not provide detailed account of the total value of environmental resource use and how resource use relates to other socio-economic parameters.

The Nhambita community land was legalized in 2003 after a claim was made under the new Land Act (No. 19/97) which permits communities' ownership of their ancestral land and management of its resources for the benefit of the entire community as per a pre-approved management plan. Part of the community land was taken over by the National Park Authority when the Hunting Reserve was upgraded to the National Park in 1965. To minimize the poaching pressures inside the GNP during its rehabilitation, a buffer zone strategy was used that envisaged involvement of the local community in the management of the GNP (Zolho 2005a).

2.1.3 Climate and geography

The GNP climate is subtropical with alternating cool and dry winters (April-October) and hot wet summers (November-March), with May being the coolest and October being the hottest month. The area lies within the 600 mm and 800 mm per annum rainfall isohyets, and is generally influenced by the Gorongosa Mountain. Most of the rain is received between November to March, with July to September being the driest months (Zolho 2005a).

Geographically, land in Gorongosa consists of eroded surfaces of granite and basaltic gneiss complex of Precambrian times, which, after heavy weathering, result in sandy soils that are generally unsuitable for any form of intensive farming. The vegetation is dry *miombo*, interspersed with evergreen thickets on the deeper alluvial sands. There are a few narrow patches of thick riverine forest along the seasonal streams, such as the Lupice, and river Pungue (Zolho 2005).

2.1.4 Land use

Land use in the GNP and surroundings consists of three types: protected area; buffer zone and community land. The protected area is under State administration while the buffer zone, land immediately adjacent to the GNP boundary, is jointly managed by the government, communities and other stakeholders. While subsistence farming is allowed in the buffer zone, no other commercial activity, including hunting or extraction of forest products for commercial production, is allowed. The community land is managed by the communities under the Land Act.

Activities in the community land include subsistence farming, charcoal production, fishing, hunting, etc.

2.2 Methods

2.2.1 Study area

Our study was undertaken in five villages[10] (Table 2-1) under the Chicale *Regulado* (Traditional Authority), located in the buffer zone of the GNP. The choice of this area was guided by several factors including past research in and around GNP and continued interest and efforts in Park rehabilitation. Further, there is a small scale agro-forestry based carbon sequestration project under implementation in Nhambita *Regulado* (Hegde and Bull 2008; Jindal 2004; Stern 2006).

Table 2-1: Key characteristics of the study 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)
Number of existing households	64	42	65	414	441
Households sampled	18	15	16	115	126
Women headed households in the sample	4	2	3	27	19

Chicale *Regulado* covers 2,000 ha with over 1,100 households spread over five villages, namely Nhambita, Bue Maria, Munhanganha, Pungue and Mbulawa (Table 2-1). Nhambita village is

[10] These villages were comparable to villages in other *Regulado*'s around the GNP, with regard to in terms of location, size and occupation choice.

considered as the centre of the study area. Three villages, Nhambita, Bue Maria and Munhanganha, are located relatively close to each other within the buffer zone. On the other hand, Mbulawa village is located outside the GNP boundary, and Pungue is situated on the GNP boundary such that a part of the village is inside and a part outside. Key characteristics of the villages are shown in Table 2-1.

There is considerable difference between villages in terms of farming systems and environmental resource use patterns. While farming in Nhambita and Munhanganha was mainly subsistence, Bue Maria village had a mix of traditional and commercial agriculture (limited area was under vegetable, cotton and sesame cultivation). Pungue, which being located on the bank of the river Pungue, had relatively more commercial farming systems with tobacco and vegetables being cultivated taking advantage of moisture and fertile soil soon after rains. While households in the first three villages gathered forest products predominantly for subsistence, households in Mbalawa and Pungue had a mix of both subsistence and commercial products. Many households in Mbalawa were engaged in charcoal production and gold panning for sale, besides gathering subsistence environmental products. Households in Pungue undertook fishing (both subsistence and sale) and gold panning, besides gathering subsistence environmental products.

2.2.2 Research design

Data used in the analysis was collected using questionnaire based interviews. Surveys were first used in economic research around the middle of the last century (Ciriacy-Wantrup 1947). Household surveys provide a rich source of information at the household level (Deaton 1997). Questionnaires developed by CIFOR-PEN[11] were adapted and expanded to suit the objectives of the research (Appendices 1-6).

Questionnaire-based quarterly household surveys (Appendix 6), which explicitly integrated quantitative environmental resource use with household information, were the main source of data. In addition to the four quarterly surveys, two annual household surveys (Appendix 4-5) and two village surveys (Appendix 2-3) – one each at the beginning of the research and one at the end – were undertaken.

[11] While CIFOR-PEN research (http://www.cifor.cgiar.org/pen/_ref/home/index.htm) primarily focused on forest-poverty relationships, our research focuses on Payments for Environmental Services (PES). The questionnaire we used included a number of questions on smallholders' participation in the PES-project, species planted, labor investment on caring for the plants, utilization (both actual and planned) of PES-income, perceptions on PES-project and so on.

Quarterly surveys helped in capturing information at short recall, on the types and quantities of environmental products collected, their consumption and sale, along with prices and revenue received; household consumption patterns; quantities of farm inputs used and crop yields obtained; off-farm employment and wage income earned. Past research demonstrated that accuracy will increase significantly when recall period is shortened, particularly for irregular income sources such as forests and woodlands (Campbell et al. 2002). In the study area, there are high seasonal variations both in availability of resources as well as in agricultural harvests, this naturally leads to sharp seasonal differences in earnings and access to food (Cavendish 2000; Simler et al. 2004).

The annual household surveys, conducted at the start and end of the field work, provided information on demography, land use, economic shocks and any changes occurring over the 12-month period.

The village surveys (focus groups) involving key informants, were conducted at the start and end of the field work, providing a good opportunity to raise issues of common importance at the village level. For instance, in the beginning the survey provided an introduction to community demography, helped finalize household sampling issues in consultation with communities, and provided qualitative information on the influence of geography, climate and other issues affecting livelihoods. In addition, it provided a list of all the crops grown and forest products collected in the village, including fish and non-forest environmental products. All of this information was then used to adapt and augment the questionnaire. At the end of the research, the focus groups helped confirm some of the common issues identified during the household level research (e.g. fire in Mbalawa; fire control in Nhambita; etc.).

2.2.3 Sampling

Since official household census was not available, we updated the household rosters with village headmen (*Nfumo*'s) by listing all households under their responsibility (Cavendish 2000). These households were then arranged alphabetically, and then a sample was chosen using a random number table. Where the selected household was not available for interviews, either due to multiple-listing[12] or inability to participate due to sickness or old age, the immediate next household on the list was chosen. Sample size would depend on population heterogeneity,

[12] There were cases where households were listed in more than one village.

required level of precision and availability of resources. Considering the heterogeneity in the area, we decided to use a large sample.

The initial sample consisted of 335 households. However, 45 households were excluded from the analysis, for two primary reasons. First, five households migrated in the middle of the research missing at least two rounds of survey, and were excluded from the analysis. Second, another 40 households were temporarily away during survey months, thereby missing one round of survey; they were also excluded[13]. The remaining 290 households were used for the analysis[14].

2.2.4 Field work

Field work was undertaken from January to December, 2006. Eight enumerators[15] were recruited and trained to administer the questionnaires in the local language[16] (*Sena*). Enumerators went through an intensive 2-week training which included review of the questionnaires, 'in-class' demonstration and mock interviews, which helped address many inconsistencies in phrasing questions and recording responses. Actual interviews were started in a phased manner which helped further refine interview skills of enumerators. Each enumerator was given the responsibility of 40 households either in his native village or in the neighboring village. The survey supervisor and the researcher conducted interviews as well as monitored remaining interviews (which included both 'surprise' visits to the interviews being done by enumerators, post-interview cross checks with the respondents and regular questionnaire scrutiny). The advantage of placing the enumerator in his own village (or neighboring village) was that it helped build trust with the households which in turn helped obtain information which otherwise would be difficult to collect by an outsider. The four rounds of quarterly surveys were held in March-April (1st round), June-July (2nd round), September (3rd round) and November-December (final round) of 2006. The two village (community) surveys and annual surveys were held in March (beginning of the survey season) and November (end of the survey season).

[13] Households missing one round of survey could have been included for analysis by substituting sample average values for missing round. However, the decision to drop all the missed out households was made on the premise that the missing information on specific household response strategies to income shocks can not be bridged by substitution of sample averages.

[14] Comparison of the excluded and included households using available data did not lead us to believe that the excluded households were different from the rest of the households.

[15] Enumerators had varying educational qualification, with diploma (highest), certification course and high school (lowest).

[16] The questionnaire was in Portuguese language, and enumerators translated the questions into *Sena* which does not have script.

2.2.5 Valuation of environmental resources

The environmental resources were valued by asking households to report the price of products collected and sold. Where the product was not marketed, which was the case with most products, households were asked to place a price they would be willing to pay for a product, if they were to buy the same. Since the reported prices differed from household to household, we used quarterly average prices[17] to value products. Despite the fact that most of the products were not traded in the market, households were able to place a value on almost all of their products. To assess the validity of these values, we compared the reported prices of environmental goods with the local prices of their nearest substitutes wherever possible. For example, the value of wild vegetables was compared with cultivated vegetables; the value of wild birds captured was compared with chicken; and, the value of game animals captured was compared with that of farm animals.

The reported quantities of various products were in local measures. We used consistent conversion rates to convert the local measures into standard measures. There were, however, difficulties. For instance, converting *molho* (meaning a bundle or bunch) into standard measures was challenging. For example, fuelwood was always reported in *molho*'s and so were wild vegetables, where the two *molho*'s differed by a large magnitude. The conversion task became even more complex when a catch of rats was also reported in *molho*'s. Direct observation was helpful in devising coarse conversion rules. For instance, one *molho* of fuelwood (weighing approximately 10 kg) was different from a *molho* of wild greens, weighing about a 1 kg; which were different from a *molho* of rats numbering 4 or 5 (medium sized) to 8-10 (small sized).

Quantifying the value of grazing by livestock was also difficult. We valued the number of livestock units sold and consumed at home in each of the four quarters.

2.2.6 Income definition

We used gross[18] (total) income, as the measure of overall household welfare[19], defined as the sum of cash income, net gifts/transfers, subsistence income (from crops and livestock) and

[17] Prices quoted by households, including the local market prices where appropriate, in the quarterly surveys were averaged after the end of the quarterly surveys, and used in the valuations.

[18] The term gross income is to imply that any costs associated with extraction (e.g. labor costs, inputs, transportation, etc.) were not subtracted from the gross value.

[19] Consumption is often preferred to income as a measure of welfare, but in rural Africa consumption and income are not dissimilar (Cavendish 2000). We also measured consumption in this study; it will be examined in subsequent analyses.

environmental income (value of all environmental products collected for consumption and cash income earning. Incomes were reported in local currency *metical* (plural *meticais*; MTS[20]).

2.3 Results and discussion

The analysis is organized into three sections: The first section deals with the comparison of study villages; the second section compares income quartiles; and the third section compares male and female headed households.

2.3.1 Village level comparison

In this section, we provide the evidence to answer the following question: How much do environmental resources contribute to the household economy? Table 2-2 presents a comparison[21] of some socio-economic characteristics of the sample households in the five villages. The statistics in the table are mean values[22].

Table 2-2: Socio-economic summary of households by villages

	Nhambita	Bue Maria	Munhanganha	Mbalawa	Pungue	Prob > F
Household size (number)	5.00	4.87	6.00	6.18	5.76	0.2000
No. of female members	3.06	2.20	2.94	3.19	2.90	0.2965
No. of male members	1.94	2.67	3.06	2.99	2.87	0.1363
Age of household head (Year)	43.33	43.80	46.88	39.89	41.52	0.3500
Years of schooling of household head	2.33	2.53	2.56	2.83	3.32	0.2600
Landholding (ha)	2.58	2.47	2.63	1.97	2.38	0.0286**
Value of assets (MTS)	288,889	1,224,000	486,563	461,478	781,944	0.1229
Duration of residence (Year)[23]	36.22	18.60	16.13	27.81	29.33	0.0038***
Number of women headed households	0.22	0.13	0.19	0.23	0.15	0.7900

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

[20] All calculations in this study are based on old currency; under the currency reforms, the last three digits in the currency have been removed. The exchange rate fluctuated throughout the study period; however, we use a constant exchange rate of 1US$ = 26,500 MTS.

[21] Bonferroni, Sidak and Scheffe pair-wise comparisons were used.

[22] Standard deviation can be obtained from the authors.

[23] Refers to the number of years the head has been living in the village. If the head is born in the same village it represents head's age, if the head is not born in the village then it refers to the number of years the head has been living in the village.

On average, a household in the study area consisted of five to six members, where the differences are not statistically different from each other. Also, there was no statistical difference between the villages in respect of gender composition of the households or age and education level of head of household. The average size of agricultural land in Mbalawa was significantly smaller compared to Pungue. The value of assets held (e.g. bicycle, radio, etc.) by the households in the five villages was also not statistically different from each other. The average duration of residence of the households in Nhambita was the longest (36 years) which was significantly higher than the average duration of residence in Bue Maria or Munhanganha. On average, the households in Mbalawa were formed 16.5 years ago, which was significantly shorter compared to the same in Munhanganha. Table 2-3 compares the cash and non-cash income earnings in the study villages.

Table 2-3: Mean household income by village (MTS)

Income source (MTS)	Nhambita	Bue Maria	Munhanganha	Mbalawa	Pungue	Prob > F
Crop sale	367,778	1,154,200	925,313	129,183	1,123,266	0.0000***
Livestock sale	427,778	1,030,667	1,500,000	358,783	1,123,333	0.0004***
Unprocessed forest products sale	62,500	30,000	0	138,913	49,524	0.7458
Processed forest products sale	0	1,155,000	0	1,872,130	154,405	0.0000***
Non-forestry products sale	14,167	784,000	13,125	1,877,426	943,810	0.0408**
Fish sale	77,500	651,000	140,625	33,957	1,451,369	0.0323**
Wage employment	8,592,500	5,625,600	7,007,438	3,638,844	4,970,833	0.0000***
Business	538,333	1,790,200	85,875	696,129	1,265,809	0.2643
Carbon sale	1,027,455	746,580	579,739	593,152	291,400	0.1200
Other income	1,715,611	740,000	325,000	661,426	1,008,659	0.0832*
Cash income	12,823,622	13,707,247	10,577,114	10,399,942	12,382,646	0.1138
Crops used at home	3,645,528	4,271,867	5,599,813	4,703,583	5,867,175	0.0003***
Livestock use	358,889	521,333	780,000	446,261	585,556	0.4214
Unprocessed forest products used	2,763,333	3,669,000	2,570,813	4,740,470	3,578,131	0.0001***
Processed forest products	43,333	615,000	22,500	414,000	100,833	0.0012***
Non-forestry products use	14,167	10,000	0	98,087	952	0.3991
Fish use	233,750	976,500	267,188	426,674	1,288,274	0.0005***
Non-cash income	7,059,000	10,063,700	9,240,313	10,827,583	11,421,091	0.0012***
Gross income	19,882,622	23,770,947	19,817,427	21,228,668	22,317,557	0.0815*
Cash ratio (%)	63	55	52	46	49	0.0008***

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

There were significant differences in the value of crops and livestock sold. On average, the households in Bue Maria and Pungue sold more agricultural products compared to households in Mbalawa. The households in Munhanganha and Pungue earned more cash income from sale of

livestock. The value of processed forest products sold by the households in Mbalawa was significantly higher compared to those in Pungue. It may be noted that charcoal production is a major activity in Mbalawa. There were significant differences in cash income earned from sale of non-forestry environmental products and fish. On average, the households in Mbalawa earned more income from sale of non-forestry environmental products. Major activities under this category included gold panning, clay, pottery, stones, etc. Similarly, fishing was a major activity in Pungue where many households were involved in fishing in river Pungue. There were also significant differences in wage income earned in different villages. The households in Nhambita earned the highest income from wage, while the households in Mbalawa earned the lowest. There were also differences in income from 'other income' category (remittances, help from friends and relatives, etc.). There were, however, no differences in cash income earned from either carbon sale (PES) or business. Interestingly, in spite of the above differences in incomes from individual vocations the average value of total cash income earned per household was not statistically different across the villages. This suggested that in terms of cash income an average household in any one village was neither better off nor worse off in comparison with households in other villages.

On the other hand, there were significant differences in non-cash income earned by the households in different villages. Non-cash income is a sum of estimated value of home consumption (or use) of crops, livestock, unprocessed forest products, processed forest products, non-forest environmental products and fish. The value of crops consumed at home was the highest in Pungue and the lowest in Nhambita. On average, households in Mbalawa used the maximum value of unprocessed forest products, while those in Munhanganha used the minimum. On average, the value of processed forest products used at home was the highest in Bue Maria and lowest in Munhanganha. Households in Pungue consumed the maximum amount of fish, while households in Nhambita consumed the lowest. It may be noted that Nhambita does not have access to any perennial source of water other than a well within the village, and therefore has very limited fishing opportunities unlike households in Pungue or Bue Maria. Non-cash income earned by households in Mbalawa and Pungue was significantly higher than that earned by households in Nhambita. The cash ratio, which is the proportion of cash income in the gross income of households, in Nhambita was significantly higher (63%) when compared to that in either Mbalawa (46%) or Pungue (49%).

Table 2-4 summarized the forest income of households by villages. There were significant differences between the villages with respect to household use of many products. The average value of pole used at home was the highest in Bue Maria and lowest in Munhanganha. Sale of pole was reported in Nhambita, Mbalawa and Pungue. The average value of pole sale was highest in Nhambita and lowest in Mbalawa. The average value of fuel use was the highest in Mbalawa and lowest in Nhambita. While bamboo use was reported from households in all the villages, the average household use was the highest in Mbalawa and lowest in Nhambita. Bamboo is relatively more abundant around Mbalawa and parts of Pungue, and that is why widespread use of bamboo and sale were reported from Mbalawa and Pungue. The average value of forest food, which is the sum total of estimated values of fruits, tubers, vegetables, mushroom, animals, birds and insects consumed at home, was higher in Bue Maria compared to Pungue.

Table 2-4: Mean forest income by village (MTS)

Forest income source (MTS)	Nhambita	Bue Maria	Munhanganha	Mbalawa	Pungue	Prob > F
Timber use	0	23,333	0	21,304	25,992	0.8162
Timber sale	0	10,000	0	21,739	0	0.8352
Pole use	93,056	177,333	38,125	207,261	84,087	0.0000***
pole sale	20,833	0	0	1,087	2,738	0.0006***
Fuel use	296,666	330,000	364,375	419,391	355,873	0.0000***
Bark use	13,333	11,333	8,750	24,261	2,698	0.0001***
Bamboo use	5,000	7,000	20,625	303,261	264,404	0.0362**
Bamboo sale	0	0	0	23,478	13,214	0.8688
Fruit use	96,000	103,300	938	22,708	26,536	0.0000***
Mushroom use	0	0	625	3,043	4,305	0.8952
Tuber use	61,944	70,000	0	61,217	12,996	0.0018***
Use of greens	167,056	223,333	150,125	95,496	97,040	0.0000***
Use of medicinal herbs	12,500	9,633	1,813	8,165	1,746	0.0000***
Broom use	12,056	19,133	16,094	17,043	11,833	0.0000***
Thatch use	45,444	106,267	80,625	82,157	133,063	0.0034***
Animal use	94,444	133,000	174,688	237,217	154,167	0.0023***
Bird use	2,500	1,333	0	27,261	6,111	0.0000***
Insect use	21,111	8,000	156	50,370	11,857	0.0000***
Forest food	443,056	538,967	326,531	497,313	313,012	0.0000***
Forest use income	964,444	1,838,000	879,438	1,994,157	1,293,544	0.0000***
Forest cash income	20,833	1,165,000	0	1,918,000	170,357	0.0000***
Forest income	985,278	3,003,000	879,438	3,912,157	1,463,901	0.0000***

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

In terms of individual products, the average value of fruit consumed was the highest in Bue Maria and lowest in Munhanganha. The average values of tuber and wild vegetables consumed were also the highest in Bue Maria. The average value of medicinal herbs used was the highest in Nhambita and lowest in Pungue. Nhambita had no access to health care facility. A health centre is located in Pungue. The average value of broom used at home was the highest in Bue Maria and lowest in Pungue. The average value of thatch used was the highest in Pungue and lowest in Nhambita. The average value of animals consumed was the highest in Mbalawa and lowest in Nhambita. The value of birds consumed was also highest in Mbalawa. Households in Munhanganha did not report catching and consuming birds. The average value of insect consumed was the highest in Mbalawa and lowest in Munhanganha. The average forest income (sum of forest use and forest cash incomes) by the households in Mbalawa was significantly higher than the households in Nhambita, Munhanganha or Pungue, and so was the forest use income. Our results provided an indication of the extent of livelihood diversification by the households, which is in line with other studies in Africa (Barrett et al. 2002; Fisher 2002).

Village level comparison showed some interesting differences, both in terms of household socio-economic characteristics, livelihood choices and forest resource use. For instance, it was observed that on average the households in Nhambita were living there for a longer time compared to the households in Bue Maria or Munhanganha which had moved there more recently. In spite of livelihood diversification across all the villages, each village had a dominant vocation for cash income generation. For instance, Nhambita had predominantly wage employment. The carbon project employed around 100 persons on a full time basis, most of who resided in Nhambita. It also provided some seasonal employment opportunities in fire suppression and control and so on. Some people who worked in the GNP resided in Nhambita.

Agriculture and fishing were predominant sources of livelihood in Pungue. Taking advantage of fertile soil and moisture on the river bank in the post-rainy season, many households cultivated commercial crops like tobacco, cotton, sesame, vegetables and so on. It may be recalled that these crops were introduced during the colonial time in Mozambique, and they continue to be grown in a few pockets where favourable conditions exist. The households were also involved in fishing in Pungue. Bue Maria also generated higher cash income from sale of commercial crops mentioned above for the same reason. However, being located on the GNP side of the river Pungue, the households were unable to sell their fish unlike their counterparts in village Pungue. The households in other villages, in contrast, cultivated mainly subsistence food crops like corn,

sorghum, etc. Munhanganha earned significantly higher cash income from sale of livestock. Sale of forestry and non-forestry environmental products was a major source of livelihood in Mbalawa, where households generated greatest value of cash income from sale of both forest and non-forest environmental products and also consumed and used unprocessed forest products. Sale of processed forest products (mainly charcoal) and gold panning were major activities in Mbalawa. As indicated earlier, Mbalawa is located outside the Park boundary where these activities are allowed. In spite of the diversified vocations, the level of cash income remained the same across the villages, although non-cash income was higher in Pungue and Mbalawa for the reasons described above. This analysis demonstrates the importance of environmental resources, particularly those derived from the *miombo* woodland resources, for the households, with about half of the gross income being generated in kind.

The type of forest resource use differed from village to village. This is partly due to patchy availability of forest resources, resource access and availability of markets. For instance, the value of pole use was the highest in Mbalawa, while the households in Nhambita earned more from sale of pole. Poles are primarily used in thatched buildings. Several thatched buildings were erected within the carbon project premises and also in the premises of other smaller projects (e.g. Food for Hungry). Nhambita being the closest to these project sites when compared to other villages, the households had an opportunity to collect and sell poles. This shows that markets can create supply even in a remote place such as Nhambita. Bamboo has a patchy distribution, mainly concentrated in Mbalawa and Pungue. As a result, bamboo use was reported in these two villages. The thatched buildings mentioned above also use bamboo. However, since no bamboo grows around Nhambita, most of it comes from Mbalawa. Use of plant based forest food, such as fruits, tubers, wild vegetables and mushrooms, was higher in Bue Maria followed by Nhambita, both of which were within GNP. On the other hand, use of meat i.e. animals, birds and insects, was higher in Mbalawa which is located outside the Park. Government legislation prohibits hunting in the buffer zone, and that may be the reason for the lower consumption in the villages within the Park (i.e. Nhambita, Bue Maria and Munhanganha). Although one would think that the difference could be due to underreporting in the villages within the Park, we believe that since our enumerators were based in the same villages the information collected closely reflected the realities.

2.3.2 Income levels and environmental resource use

Are poor households more dependent on environmental resources than the rich? To answer this question, we provide data in terms of per capita income. Table 2-5 presents a summary by income groups comparing[24] the socio-economic characteristics and income composition in four income quartiles (households in a block of 25%).

Table 2-5: Socio-economic summary (mean values) of households by income groups

Variables	Income quartiles				
	First	Second	Third	Fourth	Prob > F
Size	4.25	5.58	6.2	7.32	0.0000***
Education of head (year)	3.71	3.12	2.63	2.47	0.0072***
Agricultural land (ha)	2.13	2.31	2.34	2.21	0.7300
Fallow land (ha)	1.31	1.21	1.42	1.14	0.5500
Value of asset s (MTS)	944,306	661,597	525,685	396,438	0.1000*
Age (year)	36.18	39.65	43.1	46.55	0.0001***
Household head born in the village (1/0)	0.6111	0.5555	0.589	0.4384	0.1578
Duration of household formation (year)	12.29	18.22	20.05	22.1	0.0000***
Woman headed household (1/0)	0.08	0.19	0.18	0.3	0.0098***
Cash per capita (MTS)	4,909,950	2,409,859	1,532,308	752,418	0.0000***
Gross income per capita (MTS)	8,103,260	4,625,739	3,604,641	2,376,013	0.0000***
Cash ratio (%)	63	55	47	33	0.0000***
No. of households	72	72	73	73	

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

The first quartile denotes the highest income group and the fourth quartile denotes the lowest income group. Interestingly, there were significant differences between the households with respect to socio-economic characteristics. The highest income groups had smaller family compared to the lowest income groups. Also the household head in the first quartile households was younger and had higher level of education compared to the household head in the fourth quartile households. It also followed that the first quartile households were more recently formed than the households in fourth quartile. About 8% of the households in the first quartile were women headed where as the figure for the fourth quartile was about 30%. Cash income per capita of first quartile was almost six times higher than that of fourth income quartile.

We notice from the Table 2-6 that cash income earned from sale of crops was highest in the second quartile and lowest in the fourth quartile. Income from sale of processed forest products,

[24] Bonferroni, Sidak and Scheffe pair-wise comparisons were used.

sale of non-forestry environmental products, wage employment, business and carbon sale were significantly higher in the first quartile households. Income earned from other sources (including remittances, help received from friends and relatives, etc.) was highest in the second quartile and lowest in the third quartile. Among non-cash income, use of unprocessed forest products and fish was highest in the fourth quartile and lowest in the fourth quartile.

Table 2-6: Mean household income by income groups (MTS)

Income source (MTS)	Income quartiles				
	First	Second	Third	Fourth	Prob > F
Sale of crops	743,167	1,108,923	564,267	281,966	0.0180**
Livestock sale	838,333	843,056	875,616	616,164	0.7211
Sale of unprocessed forest products	34,167	130,833	130,274	32,877	0.5690
Sale of processed forest products	1,407,778	1,195,486	572,466	312,329	0.0218**
Non-forestry environmental products sale	2,921,458	966,375	485,137	434,384	0.0000***
Fish sale	1,821,215	838,056	440,137	309,452	0.0054***
Wage employment	6,668,958	5,684,875	4,845,397	2,096,658	0.0000***
Business	2,591,652	616,194	511,438	124,521	0.0000***
Carbon sale	943,918	567,539	345,649	134,799	0.0016***
Other income	719,792	1,379,597	640,548	718,082	0.0378**
Cash income	18,686,818	13,330,879	9,410,047	5,062,363	0.0000***
Crop used at home	4,705,708	5,222,583	5,320,349	5,428,054	0.3825
Livestock use	510,833	623,611	469,589	491,781	0.6923
Use of unprocessed forest products	4,493,826	3,844,951	3,956,849	3,459,103	0.0898*
Use of processed forest products	168,750	260,417	196,233	348,699	0.4609
Non-forestry environmental products used	7,083	14,458	115,890	24,575	0.3061
Fish use	1,197,604	844,931	778,562	419,486	0.0558*
Non-cash income	11,083,806	10,810,951	10,837,473	10,171,699	0.6394
Gross income	29,768,500	24,143,574	20,246,427	15,234,538	0.0000***
Cash ratio (%)	63	55	47	33	0.0000***

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

Table 2-7 shows the forest income composition of the income quartiles. There were few significant differences between the income quartiles. The average value of fuelwood used by the households in the first quartile was significantly lower than that of the third quartile households. On the other hand, the value of medicinal herbs used by the households in the first quartile was significantly higher than the households in the fourth quartile. The households in the third quartile

used more thatch compared to the households in the second income quartile. The value of animals used by the households in the first quartile was significantly higher than the households in the fourth quartile. Interestingly, forest use income did not vary across the income quartiles, but forest cash income did. The average forest cash income and forest income (sum of use and cash incomes) earned by the households in the first quartile were significantly higher than that earned by the households in quartile 4. The cash ratio progressively declined from first quartile (63%) to fourth quartile (33%).

Table 2-7: Forest income (mean values) by income groups (MTS)

Forest income sources (MTS)	Income quartiles				
	First	Second	Third	Fourth	Prob > F
Timber use	14,583	45,139	7,192	17,123	0.1600
Timber sale	0	2,083	34,247	0	0.4163
Pole use	165,000	130,139	139,726	108,562	0.2229
Pole sale	6,181	2,778	0	2,739	0.2437
Fuel use	354,861	366,389	398,356	386,027	0.0624*
Bark use	5,417	13,333	13,562	18,356	0.1816
Bamboo use	376,250	202,292	188,836	181,849	0.1045
Bamboo sale	5,208	38,750	8,219	8,219	0.3235
Fruit use	47,188	29,250	30,658	20,630	0.5308
Mushroom use	173	486	5,000	5,171	0.5308
Tuber use	47,361	37,708	35,514	29,110	0.7783
Use of greens	115,069	107,319	107,466	111,110	0.8906
Use of medicinal herbs	7,917	5,993	4,356	3,260	0.0423**
Use of broom	13,896	15,792	13,507	14,918	0.4493
Thatch use	92,472	91,167	136,082	92,602	0.0692*
Animal use	206,181	196,875	199,110	132,055	0.0762*
Bird use	15,972	15,486	16,644	6,712	0.3421
Insect use	33,736	24,514	23,322	25,925	0.5441
Forest use income (MTS)	1,666,389	1,542,299	1,515,562	1,502,110	0.8425
Forest cash income (MTS)	1,419,167	1,239,097	614,932	323,288	0.0213**
Total forest income (MTS)	3,085,556	2,781,396	2,130,493	1,825,397	0.0358**

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

The analysis showed that forest resource use varied with income levels. The high income households (first quartile i.e. top 25% households) derived greater amount of cash income from almost all vocations namely, sale of processed forest products, sale of non-forestry environmental products, fish sale, wage employment, business and carbon sale. The households in the upper middle income group (second quartile) earned highest income from sale of crops and other income category (which included remittances, assistance from relatives and friends, pension, etc.). The lower middle income (third income quartile) and low income (bottom quartile) households earned lesser amount of cash income. The non-cash income derived from crops,

livestock, non-forestry environmental resources and so on, did not show significant difference across income levels. However, the high income households consumed significantly larger value of unprocessed forest products (significant at 10% level of significance) and fish compared to the households in lower quartiles. On the whole, our results showed an interesting pattern. There was a tendency for the poor households to use both forestry and non-forestry environmental products for own use, while the rich households extracted these resources for cash income. As evidenced by the analysis, with a rise in income level, the pattern of resource use changed from subsistence to commercial products.

This finding is in conformity with other studies (Hegde and Enters 2000; Cavendish 2000). We expected that the low income households would gather a significantly larger amount of forest resources to supplement their low level of cash income. However, there was no evidence supporting this hypothesis. One possible explanation would be that there was no difference among the income groups with respect to non-cash income, which meant the low income households earned the same level of subsistence income as the high income households from crops, livestock, processed forest products, non-forestry environmental products and most of the individual forest products. This level of subsistence income was adequate to meet the subsistence needs of the households, and therefore, the low income households did not have to collect additional products to augment their subsistence income. On the other hand, the high income households did not substitute their cash income in the place of subsistence income which is why their subsistence income was same as that of the low income households.

2.3.3 Gender and environmental resource use

This section examines whether environmental resource use varies with gender, by comparing male and female headed households (Tables 2-8, 2-9 and 2-10).

Table 2-8: Socio-economic summary of households by gender

Variables	Male-headed households	Female-headed households	P > |t|
Household size (number)	6.1	4.78	0.0008***
Age (year)	40.18	46.58	0.0025***
Head's education (year)	3.49	0.8	0.0000***
Agri land (ha)	2.35	1.78	0.0014***
Value of assets (MTS)	704,170	317,455	0.0622*
Head born in the village (1/0)	0.57	0.45	0.1200

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

The female headed households tended to be smaller in size and older compared to their male headed counterparts. They also had smaller agricultural holdings, lower educational levels of the household head and lower value of assets (Table 2-8).

Table 2-9 compares cash and non-cash income composition of the male and female headed households. The male headed households earned significantly higher amount of cash income from sale of crops and fish, and also from carbon and wage employment. The amount of cash income and gross income earned by the male headed households were significantly higher than that earned by the female headed households. Among the non-cash income it was observed that the male headed households consumed significantly greater value of crops, unprocessed forest products, processed forest products and fish compared to female headed households. Cash income made up of 51% of gross income of male headed households as against 42% for the female headed households.

Table 2-9: Household income by gender (MTS)

Income source (MTS)	Male headed households	Female headed households	P > |t|
Cash income			
Sale of crops	769,926	258,055	0.0343**
Livestock sale	852,255	539,636	0.1700
Sale of unprocessed forest products	101,234	0	0.2451
Sale of processed forest products	928,383	615,546	0.3956
Non-forestry environmental products sale	1,300,468	753,436	0.2770
Fish sale	1,015,436	137,455	0.0394**
Wage	5,110,038	3,552,491	0.0116**
Business	1,088,532	392,455	0.1151
Carbon	567,669	190,823	0.0554*
Others	878,357	798,582	0.7662
Total cash income	12,600,000	7,236,689	0.0000***
Crop used at home	5,312,987	4,562,155	0.0624*
Livestock use	556,936	381,455	0.1603
Use of unprocessed forest products	4,071,621	3,362,282	0.0555*
Use of processed forest products	282,830	76,636	0.0604*
Non-forestry environmental products used	47,681	10,909	0.5342
Fish use	935,053	268,772	0.0092***
Total non-cash income	11,200,000	8,662,209	0.0001***
Gross income	23,800,000	15,900,000	0.0000***
Cash ratio (%)	51	42	0.0005***

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

Table 2-10 indicates that although there was no difference between the two groups with respect to cash income from forest, there were few significant differences in forest use income and gross income from forest due to differences in the use of some individual products. For instance, the value of pole used by the male headed households was significantly higher than that of the female headed households, whereas value of fuelwood used by the female headed households was higher than the male headed households. The male headed households earned more medicinal herbs and thatching grass than did the female headed households. Interestingly, the value of forest food gathered, such as fruits, tubers, vegetables, animals, birds and insects was not significantly different between the two groups. However, the average forest use income (sum of use values of timber, pole, fuelwood, bark, bamboo, fruits, mushrooms, tubers, greens, medicinal herbs, broom thatch, animals, birds and insects) and forest income (sum of forest cash income and forest use income) by the male headed households were significantly higher than that of the female headed households.

Table 2-10: Forest income by gender (MTS)

Forest income source (MTS)	Male headed households	Female headed households	P > |t|
Timber use	20,106	24,545	0.7838
Timber sale	11,277	0	0.6095
Pole use	147,000	87,818	0.0162**
Pole sale	3,596	0	0.1890
Fuel use	370,426	402,546	0.0437**
Bark use	13,191	10,545	0.6224
Bamboo use	259,660	139,909	0.1482
Bamboo sale	18,574	0	0.3208
Fruit use	31,934	31,691	0.9753
Mushroom use	3,723	500	0.3565
Tuber use	37,096	38,636	0.9230
Greens	109,081	115,164	0.5510
Medicinal herbs	5,866	3,255	0.0963*
Broom use	14,155	16,109	0.1621
Thatch use	116,528	46,036	0.0001***
Animal use	185,532	174,455	0.7055
Bird use	15,234	7,091	0.1512
Insect use	27,826	22,727	0.4713
Forest food	410,426	390,264	0.6664
Forest use income (MTS)	1,640,187	1,197,664	0.0143**
Forest cash income (MTS)	961,830	615,546	0.3468
Forest income (MTS)	2,602,017	1,813,209	0.0720*

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

Our analysis showed that there were some significant differences between the male and female headed households. The male headed households were more resourceful compared to the female headed households: they were larger in size and younger, had larger agricultural holding and held greater value of assets, with head of household having greater level of education.

The amount of cash income earned by the male headed households was significantly higher than that of the female headed households. This difference was attributed to cash income earned from crop sale, fish sale, wage employment and carbon sale. On average, the value of crops produced, both for consumption and sale, by the male headed households was significantly higher than that of the female headed households. It was observed that the male headed households had larger land holding and had possibly had more labor (due to larger family size), which helped them produce more crops than female headed households. Fishing was predominantly carried out by men. Added to the risks of water, there was an additional hazard fishermen had to face. The river Pungue was inhabited by crocodiles, and there were instances of crocodiles attacking people. This could be another factor that may have influenced the choice of this vocation by men. Wage employment was also predominantly taken up by men.

Interestingly, there was no difference in cash income either forest based or non-forestry environment based, earned by the male and female headed households. This shows that the female headed households put in as much labor as did the male headed households in forestry and environmental vocations that generated cash income. The value of forest resources used for own-consumption by the male headed households was significantly higher than the female headed households. This difference was mainly due to increased quantities of poles, thatch and medicinal herbs collected by the male headed households, and there was no difference with respect to consumption of forest food which consisted of fruits, tubers, mushrooms, vegetables, animals and insects.

2.4 Conclusion

Environmental resources from the *miombo* woodlands make significant contributions to household economies in rural Africa. Our results demonstrate that households collected a variety of products from the *miombo* woodlands both for their own consumption and for cash income generation. Evidently, forest use income surpassed forest cash income across all the villages, income groups and gender. It was noted that the *miombo* woodland use is determined by, inter alia, resource availability, market access and access rights as determined by government policies.

We observed specialization of vocations in villages. Particularly, forestry and environmental products sale was major source of cash income in Mbalawa which was located outside the Park boundaries which also had highest use of animal based products; Nhambita, which was inside the park but had a development project, was specialized in wage employment; and Pungue, which was on river bank, was specialized in commercial farming and fishing. We also observed that poorer households tend to use the *miombo* resources for subsistence, while richer households use them for cash income. Finally, we observe that the female headed households which had lower level of asset base and cash income compared to the male headed households consumed (or used) as much forest resource as did the male headed households.

This highlights the need for incorporating the *miombo* woodlands as part of poverty reduction strategies in Africa. As we said at the outset, we hope that the results here will be helpful in crafting public policies aimed at both poverty alleviation and the *miombo* woodlands conservation.

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3 INCOME SHOCKS AND *MIOMBO* WOODLAND RESOURCE USE: A HOUSEHOLD LEVEL STUDY IN MOZAMBIQUE[25]

3.1 Introduction

The benefits received by mankind from nature are broadly referred to as ecosystem services. Ecosystem services are classified as provisioning services (e.g. food, water, timber, fibre, etc.), regulatory services (e.g. climate regulation, water quality regulation, flood control, etc.), cultural services (e.g. recreational, aesthetic, scientific and cultural benefits) and supporting services (e.g. photosynthesis, nutrient recycling, soil formation, etc.) (Millennium Ecosystem Assessment; MEA 2005).

The demand for ecosystem services increased significantly between 1960 and 2000 with the doubling of the world population and a six-fold expansion in the world economy, causing nearly two thirds of the ecosystem services are on the decline (MEA, 2005). Poverty has often been blamed for ecosystem degradation with some researchers linking both of them in a downward spiral in which poor people are seen both as the agents as well as victims of ecosystem degradation (Cleaver and Schreiber 1994). Others have questioned the validity of this link arguing that the state of ecosystem health is as much threatened by wealth as by poverty (Angelsen and Wunder 2003; Scherr 2000). The current international development debate has now shifted with a focus on the potential of ecosystems such as forests in alleviating poverty (World Bank 2004).

Tropical forests provide a variety of ecosystem services which include a range of provisioning services (e.g. water, timber, non-timber products) and vital ecological processes such as carbon sequestration, biodiversity conservation, soil and water conservation and scenic beauty (Daily 1997). Forest ecosystems contribute to the wellbeing and at times the very survival of millions of rural poor throughout the world (Byron and Arnold 1999; Campbell et al. 2002; Cavendish 2000; Fisher 2002; Kaimowitz 2002; Neumann and Hirsch 2000; Shackleton et al. 2007; Sunderlin et al. 2005).

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Among the provisioning ecosystem services provided by forests, timber and non-timber forest products (NTFPs) are of primary importance. Timber is commercially the most important forest product. However, timber benefits have largely eluded rural poor. Timber production requires a combination of capital, land tenure, technology, markets and long time horizons. The poor rarely, if ever, have access to any of these inputs. Yet, there may be secondary benefits from timber production that are available to poor, such as employment, local development impacts and economy-wide benefits. Also, wood based fuel (charcoal and fuelwood) could be source of income for smallholder farmers in peri-urban areas, particularly in Africa (Angelsen and Wunder 2003; Sunderlin et al. 2005; Kaimowitz 2002).

NTFPs are an integral part of the livelihoods of the rural poor in the developing world (Byron and Arnold 1999; Campbell et al. 2002; Cavendish 2000; Fisher 2002; Neumann and Hirsch 2000; Shackleton et al. 2007; Sunderlin et al. 2005). The NTFPs play two key roles. First, they meet basic livelihood needs by providing food, shelter, medicinal plants and other commodities, and also serve as income supplements or 'gap fillers' when they are collected to supplement household income (Byron and Arnold 1999; Campbell et al. 2002; Cavendish 2000; Fisher 2002; Hegde and Bull 2008; Neumann and Hirsch 2000; Shackleton et al. 2007; Sunderlin et al. 2005). Their 'gap filling' role implies that they make seasonal, but reasonably predictable, contribution to the household income as a supplement to household earnings. Second, during income shocks and shortfalls caused by adversities such as crop loss, livestock loss, macro-economic crises and the environmental calamities, the NTFPs can have a useful role by serving a reservoir of food as well as source of cash income (McSweeney 2005; Ngaga et al. 2006; Tairo 2007).

When faced with income shocks households choose a variety of strategies to respond to these shocks, including diversifying their income portfolios, stepping up labor supply, using up savings and availing credit (Cameron and Worswick 2003; Paxson 1992; Rose 2001; Rosenzweig and Binswanger 1993). Recently, the role of forests in providing a safety net (or natural insurance) for households faced with income adversities has been emphasised in the literature (Godoy et al. 1998; McSweeney 2005; Shackleton et al. 2007; Wong and Godoy 2003; Pattanayak and Sills 2001).

The safety net function of forests signifies the fact that forest resources perform various forms of self-insurance roles i.e. from serving as sources of emergency food to financial stop gaps (McSweeney 2005). Since the safety net role of forests is temporary and variable, there is no

direct information on this in rural areas (Shackleton et al. 2007). When faced with income shocks, households tend to use forest resources to tide over a shock by using one or more of the following strategies: a) by increasing consumption of the forest products that are normally used and substituting the same in the place of purchased products to save on cash; b) by exploring additional forest products that hitherto were not used; and c) by selling forest products to generate extra cash income required to purchase essential products (Shackleton et al. 2007). The change in the resource use pattern under such circumstances is a shock coping strategy. This 'safety net role' of the NTFPs implies that they smoothen out the change from a good to bad state, and help people cope with the shock. The direct use value of the forest resources used during adverse situations does not reflect their complete value as it does not represent the insurance component resource use (Angelsen and Wunder 2003; McSweeny 2005; Pattanayak and Sills 2002; Shackleton et al. 2007). There is a need for empirical research to capture the safety net role.

The *miombo* woodlands, seasonally dry deciduous woodlands dominated primarily by the genera *Brachystegia*, *Julbernadia* and/or *Isoberlinia*, are the dominant vegetation type in southern Africa (Campbell 1996). The *miombo* woodlands directly contribute to the rural livelihood serving as a source of fuelwood, charcoal, construction timber, bush meat, mushroom, fruits, roots and tuber (Bradley and Dewees 1993; Campbell 1996; Campbell and Luckert 2002; Cavendish 2000; Dewees et al. 2008; Fisher 2002; Kaimowitz 2002; McSweeney 2005; Sale 1981; Syampungani et al. 2009). Due to low per capita income and high population growth rates in southern Africa, there is heavy reliance on subsistence slash-and-burn farming within the *miombo* zone (Williams et al 2008). The woodlands also have an important subsistence value for households, as a source of 'famine foods' during adversities (Ngaga et al. 2006; Tairo 2007).

This research examines how smallholder farmers in the Gorongosa National Park (GNP) buffer zone in Sofala Province in Mozambique used the *miombo* woodland products when faced with income shocks. The Gorongosa National Park was the heart of armed conflicts during the civil war in Mozambique, including the laying of anti-personnel mines[26] which continue to present huge risks. The environmental hazards such as fire, flood and drought are rampant in the area. Also, there are human health issues such as bouts of cerebral malaria, diarrhoea and other waterborne diseases. Using household data collected through questionnaire based surveys as the basis, the current analysis aims to answer the question: Do the *miombo* woodlands act as safety

[26] We were warned about ongoing de-mining operation during field work, and were advised not to deviate from the beaten tracks while on foot.

net against income shocks? The answer could be helpful in crafting better public policies that aim to both alleviate poverty and conserve the *miombo* woodlands.

3.2 Methods

3.2.1 Study area

The study was undertaken in Chicale *Regulado*[27], located in the buffer zone of the Gorongosa National Park in the Sofala Province, Mozambique (Fig. 3-1). Chicale *Regulado* covers an area of 20 km^2, with over 1,100 households spread over five villages, namely Nhambita, Bue Maria, Munhanganha, Pungue and Mbulawa. Nhambita village, where the *Regulo* Chicale family resides, is considered the centre of the study area. Three villages, Nhambita, Bue Maria and Munhanganha, are located close to each other within the buffer zone of the GNP. On the other hand, Mbulawa village is located outside the GNP boundary, and Pungue is situated on the GNP boundary such that a part of the village is inside and a part outside. Key characteristics of the villages are shown in Table 3-1.

Figure 3-1: Study area location

[27] Traditional authority.

The villages also differed in terms of farming systems and the environmental resource use patterns. While farming in the first two villages was mainly subsistence; Bue Maria had a mix of traditional and commercial agriculture (limited area was under vegetable, cotton and sesame cultivation); and Pungue, being located on the bank of the river Pungue, had relatively more commercial farming systems (tobacco and vegetables). While the first three villages had households gathering more traditional environmental products predominantly for subsistence, households in Mbalawa and Pungue had a mix of both subsistence and commercial products. Mbalawa had households producing charcoal for sale and gold panning (for sale), besides gathering subsistence products, while households in Pungue undertook fishing (both subsistence and sale) and gold panning, besides gathering subsistence environmental products.

Table 3-1: Key characteristics of study 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 in the sample	18	13	11	38	25

3.2.2 Research design

The main source of data used in the research was from quarterly based household surveys (Appendix 6). They explicitly integrated quantitative environmental resource use data with household income data. They also recorded additional shock-related incidents such as crop loss,

livestock loss, illness to family members, death of a household member, etc. (Hegde and Bull 2008).

3.2.3 Sampling

Since no official household census was available, we updated the household rosters with village headmen (*Nfumo*'s) by listing all the households under their responsibility (Cavendish 2000). These households were then arranged alphabetically, and then a sample was chosen using a random number table. Where the selected household was not available for interviews, either due to multiple-listing[28] or its inability to participate due to sickness or old age, the immediate next household on the list was chosen. Sample size depends on population heterogeneity, required level of precision and availability of resources (Singleton et al. 1993). Considering the heterogeneity in the area, we decided to draw a large sample.

The initial sample consisted of 335 households. However, 45 households were excluded from the analysis, for two primary reasons. First, five households migrated in the middle of the research missing at least two rounds of survey, and were excluded from the sample. Second, another 40 households were temporarily away during survey months, thereby missing one round of survey; they were also excluded[29]. The remaining 290 households were used for the analysis.

3.2.4 Income definition

We used cash income as the measure of overall household welfare[30], defined as the sum of cash income from sale of crops, livestock, forest products (both unprocessed and processed), wage, environmental products, fish, net gifts/transfers, business and commerce and, PES. Incomes were reported in local currency metical (plural *meticais*; MTS[31]).

[28] There were cases where households were listed in more than one village.

[29] Households missing one round of survey could have been included for analysis by substituting sample average values for missing round. However, the decision to drop all the missed out households was made on the premise that the missing information on specific household response strategies to income shocks can not be bridged by substitution of sample averages.

[30] Consumption is often preferred to income as a measure of welfare (Deaton, 1980), but in rural Africa consumption and income are not dissimilar (Cavendish 2000). We also measured consumption in this study; it will be examined in subsequent analyses.

[31] All calculations in this study are based on old currency; under the currency reforms, the last three digits in the currency have been removed. The exchange rate fluctuated throughout the study period; however, we use a constant exchange rate of 1US$ = 26,500 MTS.

3.2.5 Income shocks

Only idiosyncratic income shocks are considered in our analysis. For the purpose of this research, a household was said to have witnessed an income shock when an event from the list[32] indicated below resulted either in direct cash expenditure and/or wage income loss. Almost every household reported crop loss, and therefore, we excluded this from our analysis. Loss of employment was not an issue reported by the respondents, and also, there was no case of reported theft. Therefore, we consider the following shocks: 1) illness to family members, 2) livestock loss, 3) death of a family member, 4) fire. We also used estimated quantity of food grains in store as an additional variable. In response to these shocks, we examine the role of five risk coping mechanisms reported by the households: a) use of woodland resources, b) sale of farm produce, c) sale of livestock, d) wage employment by a second (additional) member, and e) "other strategies" which included remittances and assistance from friends and relatives.

We classify the woodland resources into two types: 1. roots and tubers[33] (also included are fruits, roots and tubers and mushroom.) and 2. forest meat (i.e. animals, birds, insects, etc.). This classification stems from the fact that while the plant based products are 'immobile', they could be collected with minimum efforts and without the need of any skills. On the other hand, animals and birds being 'mobile', their capture involved some efforts and skills either in trapping them or hunting them, which were not uniformly available to all households.

The sale of crops was straight forward but sale of livestock is a more complex issue. Households reported selling livestock (including poultry birds, sheep, etc) both to tide over liquidity problem and also to prevent further loss in the face of disease outbreak and mortality. In the case of wage employment, we considered the second (and subsequent) member taking up wage employment. There were limited wage employment opportunities in the area, and whenever an opportunity appeared either the household head or most active member of the household took up the same. Only when there was a need for additional cash income, a second member (or subsequent members) participated in wage employment.

[32] Verified during village focus group discussions.
[33] Forest greens were not included as all households collected greens either from the field, fallow lands or forest on a regular basis.

3.2.6 Field work

Field work was undertaken from January to December, 2006. Eight enumerators[34] were recruited and trained, and they conducted the interviews in the local language (*Sena*), under the supervision of the researcher (Hegde and Bull 2008).

3.2.7 Conceptual framework

The safety net role of environmental resources can be examined in several ways. First, a household might respond to a shock by cutting down on its own consumption of food items and cash expenses. Second, households may also respond to shocks by increasing consumption of the environment resources (say, wild food) due to lack of food supply or paucity of cash income to buy food. Third, some households may expand the supply of labor in the labor market. Fourth, some households may also sell assets such as livestock.

The literature covers a range of models on diversification and risk coping mechanisms (Cameron and Worswick 2003; Fisher and Shively 2005; Pattanayak and Sills 2001; Paxson 1992; Rose 2001; Rosenzweig and Binswanger 1993). Following Rose (2001), the theoretical framework underlying the empirical analysis is based on a two period model of household labor supply decision. The 2-period model allows inclusion of *ex ante*[35] and *ex post* decisions, and consideration of economic shocks. The household is assumed to make both production and labor supply decisions in each period. The first period is the one prior to the occurrence of a shock (such as illness, death or fire), and the second period is the period subsequent to the shock occurrence.

Let "ξ" be a random variable representing the shock that adversely affects the household income. In period 1, i.e. the period prior to the actual realization of a shock adversely affecting the household budget, a household does not know the actual occurrence of ξ, but knows the probability of its occurrence (μ) and variability of intensity (ρ). A household's production and labor supply decisions in the first period, L_1, depend on μ and ρ, and also factors such as wage rate, wealth and the parameters in production technology.

$$L_1 = L_1(\mu, \rho, w, A, \theta) \quad \text{---------- (1)}$$

[34] Enumerators had varying educational qualification, with diploma (highest), certification course and high school (lowest).

[35] Rose (2001) considered both *ex ante* and *ex post* decisions, however the current research considers only the *ex post* decisions.

Let A be the wealth level (including cash in hand, stored food grains, etc.) in period 1; w be the off-farm income; θ be a vector of parameters describing environmental resource extraction. We expect the ρ to affect L_1 in two ways. First, through a "portfolio" effect i.e. given the off-farm income and wealth level, the household may be assumed to adjust the composition of its income earning portfolios towards less risky source or it may sell a part of its liquid assets (i.e. stored food grain or livestock) for cash income. Second, there may be a "precautionary effect" whereby the household might cut down on leisure before the realization of the shock in order to minimize the impact of the shock, i.e. collect more environmental resources and deploy a second member into labor market to top up its granary. Both of the above will generate positive effects of ρ on response strategies.

In period 2, the household knows the value of ξ and ρ, and responds to them directly. Therefore, the production and labor supply decision in period 2, L_2, is conditional on decision in the Period 1 is

$$L_2 = L_2(L_1(.), \varepsilon, \mu, A, \theta) \quad \text{---------- (2)}$$

where $\varepsilon = \xi - \mu$ i.e. the "shock".

We would expect ε to affect L_2 through income and substitution effects. When ε is low (high), income shortfalls are low (high) and the household will reduce (increase) the labor supply to smooth income.

Total labor supply for a season L_T is the sum of L_1 and L_2 i.e.

$$L_T = L_T(\mu, \rho, \varepsilon, w, A, \theta)$$

$$L_T = L_1(\mu, \rho, w, A, \theta) + L_2(L_1(\mu, \rho, w, A, \theta), \varepsilon, \mu, w, A, \theta)) \quad \text{---------- (3)}$$

The presence of ex post responses to shock can be tested from the above equation (3), using the test of: $\partial L_T / \partial \varepsilon \neq 0$ [36].

Empirical strategy

[36] However, as Rose (2001) argued, there could be factors other than shocks considered here which bring about uncertainties in resource use. The test mentioned above cannot be considered as the response to risk. If responses are not correlated, then it could be a response; if there is correlation among the risks then the response may be considered as the net response to all sources of risks, which will lead to a potential omitted variable bias that needs to be addressed.

The response strategies are represented as dichotomous variables (taking a value of 1 when used; zero otherwise), and so are the four shocks. Consider the following model:

$$P(C_{it}) = f(\varpi_i + \beta_1 X_{it} + \beta_2 Y_i + \varepsilon_{it})$$

Let C_{it} be a dichotomous variable taking a value of 1 if household 'i' chooses a given response strategy at time t (zero otherwise), X_{it} represents a vector of time varying household level characteristics (i.e. shocks); Y_i represents a vector of fixed household factors that do not vary over time; ϖ_i represents vector of unobserved household characteristics; and ε_{it} represents a random disturbance term that is assumed to be uncorrelated with the independent variables in the model.

When unobserved factors that are correlated with independent variables the coefficient estimates will be biased (Green, 2003), the omitted variable bias originating from the fact that the unobserved factors were not included in the model. Since our data is available on a quarterly basis, where each observation serves as a panel, the omitted variable bias can be controlled by using the fixed effect estimator. Since C_{it} is dichotomous we use a fixed effect logit model to determine the factors influencing the choice of a given strategy (Chamberlain 1980).

The advantage of the fixed effects model is that it yields consistent estimates. However, there are disadvantages. First, the model uses only the observations that have changes in the value of the dependent variable over time. Therefore, time-invariant factors get dropped out of the model. Second, the fixed effects estimator tends to exacerbate the bias due to measurement error. Finally, results from fixed effects estimation are conditional on the sample used in the study, which makes out of sample predictions difficult (Hotchkiss et al. 1999).

Descriptions of the variables used and the expected sign of the coefficients are indicated in Table 3-5. The models were estimated using Stata (Version 8.0; StataCorp, 2003).

3.3 Results

The results are organized into three sections: The first section provides descriptive statistics and the second section covers the results of the conditional logit analysis.

3.3.1 Descriptive analysis

Table 3-2 presents household statistics by the four quarters. Significant differences across quarters were observed. The table indicates that the lowest stored food and the highest consumption of roots and tubers were reported in the December-February period. Livestock sale and slaughter were also the highest in the same period. The mean consumption was the highest in

the June-August period. This is the winter period when the trees shed leaves and visibility in the forest becomes good. The sample households responded during the surveys that animals normally come out in this period and can be trapped or hunted relatively easily. Finally, the crop sale was the highest in the September-November period.

Table 3-2: Comparison of quarterly data

Variables	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Prob > F
	Dec-Feb	Mar-May	Jun-Aug	Sept-Nov	
Root-tubers (kg)	3.29	1.33	2.94	1.45	0.000***
Forest meat (kg)	2.35	2.32	5.96	3.92	0.000***
Stored food (kg)	27.77	99.43	97.43	54.89	0.000***
Livestock sale (number)	2.44	0.74	0.97	1.47	0.000***
Livestock slaughter (1/0)	1.50	0.40	0.52	0.82	0.000***
Crop sale (MTS)	49,586	129,031	184,140	262,860	0.0007***
Livestock loss (number)	1.821	0.272	0.721	0.686	0.000***
Sick (1/0)	0.641	0.445	0.345	0.676	0.000***
Death (1/0)	0.031	0.014	0.010	0.021	0.274
Fire (1/0)	0.024	0.093	0.048	0.021	0.0001***

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

In terms of the idiosyncratic income shocks, most livestock loss was reported in the December-February period. The definition of livestock used in this research covered sheep and poultry and other birds. With livestock related pests and diseases being rampant in the area (Tsetse fly, *Glossina* spp, is a major impediment for cattle), cattle was not kept. Even sheep and poultry birds were frequently infected with diseases resulting in high mortality, particularly in summer months. Many respondents reported selling their healthy birds and animals fearing disease outbreak, and those who could not sell on time reportedly slaughtered (and consumed) their birds and animals. For these reasons, the highest amounts of livestock loss, livestock sale and slaughtering were recorded during this period. The highest incidents of sickness were reported during the September-November and December-February periods. While the number of deaths recorded did not show any pattern, the highest number of fires was reported during the March-May period when fields are burnt after harvest.

Tables 3-3 and 3-4 contain a summary of shock patterns and the choice of two shock coping strategies, namely bush-meat collection and roots and tubers collection[37].

[37] Similar tables are constructed for others, but not included here.

Table 3-3: Patterns of shock (sickness) and coping strategy (bush-meat collection)

		Average quantity of forest meat collected (kg)				Count
SN	Sickness pattern[38]	Quarter 1	Quarter 2	Quarter 3	Quarter 4	
1	0,0,0,0	0.154	0.231	0.308	0.731	26
2	1,0,0,0	0.333	0.444	0.667	0.667	18
3	0,1,0,0	0.500	1.000	1.000	1.000	2
4	0,0,1,0	0.333	0.667	1.000	0.333	3
5	0,0,0,1	0.289	0.316	0.421	0.579	38
6	1,1,0,0	0.353	0.647	0.706	0.412	17
7	1,0,1,0	0.375	0.250	0.750	0.375	8
8	1,0,0,1	0.326	0.391	0.522	0.630	46
9	0,1,1,0	0.400	0.400	0.600	0.800	5
10	0,1,0,1	0.333	0.500	0.833	0.917	12
11	0,0,1,1	0.500	0.000	0.500	0.833	6
12	1,1,1,0	0.400	0.333	0.467	0.400	15
13	1,1,0,1	0.484	0.581	0.548	0.548	31
14	1,0,1,1	0.375	0.375	0.625	0.563	16
15	0,1,1,1	0.417	0.417	0.833	0.583	12
16	1,1,1,1	0.400	0.429	0.514	0.371	35

A comparison of meat collection across the quarters provides an indication that the average quantity of meat collected tended to be higher in the quarters when sickness was reported compared to the quarters when no sickness was reported (Table 3-3). A similar pattern was observed in the roots and tubers collection (Table 3-4). This has an interesting implication when the above tables are read in conjunction with Table 3-2. Sickness incidence was high in quarter 1, while meat collection was highest in quarter 3. However, when sickness was present in quarter 4, significant amount of roots and tubers collection was reported in many cases.

[38] Four entries represent the four quarters; 1 denotes presence and zero absence of the shock in that quarter.

Table 3-4: Patterns of shock (sickness) and coping strategy (roots and tubers collection)

		Average quantity of roots and tubers collected (kg)				
SN	Sickness pattern	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Count
1	0,0,0,0	0.647	0.077	0.308	0.654	26
2	1,0,0,0	2.017	0.875	0.333	0.611	18
3	0,1,0,0	4.500	4.250	6.000	0.000	2
4	0,0,1,0	3.000	3.500	8.000	0.500	3
5	0,0,0,1	2.379	0.500	1.026	2.132	38
6	1,1,0,0	2.771	2.235	1.882	0.588	17
7	1,0,1,0	4.275	0.625	1.250	0.313	8
8	1,0,0,1	2.614	0.522	2.572	1.304	46
9	0,1,1,0	1.683	2.133	2.000	0.900	5
10	0,1,0,1	4.458	4.667	6.792	2.083	12
11	0,0,1,1	6.375	1.889	5.167	0.333	6
12	1,1,1,0	3.000	0.800	1.333	0.333	15
13	1,1,0,1	3.586	1.102	3.839	3.446	31
14	1,0,1,1	7.460	0.906	2.125	3.042	16
15	0,1,1,1	5.271	2.875	9.042	1.083	12
16	1,1,1,1	4.342	2.524	5.671	0.914	35

3.3.2 Conditional logit analysis

Definitions of variables used in the analysis and the expected sign of coefficients are provided in Table 3-5. The results of the conditional logit analysis are presented in Table 3-6.

The results of the conditional logit show that in most cases the variables have the expected signs. The probability of collecting roots and tubers was higher following sickness and death in the family, and that of collecting forest meat was higher following sickness. This suggests that when either a household member died or fell sick, the households resorted to bush-food as a means of survival. When a member falls sick the households incur cash expenses for treatment, for the local traditional healer (*Corendeiro*) or for travel to the nearest hospital at Gorongosa town (30 km away). If the sick member is also a wage earner, there will be loss of wage income for the household. Similarly, following death, a household would incur expenses for burial and traditional ceremonies, and in some cases, the household moves to a different (new) house abandoning the old house. The results above probably suggest that under these circumstances a household would gather plant-food from forest for survival.

Crop sale (Model 3) was also used as a shock coping strategy by the households which experienced sickness. Food grains are one of the most liquid assets in rural economy in Africa. Households tend to sell off their produce to tide over liquidity problem. The significant positive

relationship between crop sale and stored grain is only suggesting that higher the quantity of food grain in store, higher was the probability of sale.

Table 3-5: Description of the explanatory variables

Variable	Explanation	Expected sign
Dependent variables		
Forest meat	Dummy variable if a household reported collecting animals or birds or insects from forest in the 30-day period prior to the survey	
Forest plants	Dummy variable if a household reported collecting fruits or tubers or mushrooms, from forest in the in the 30-day period prior to the survey	
Livestock slaughtering	Dummy variable if a household reported slaughtering livestock or poultry in the in the 3-month period prior to the survey	
Crop sale	Dummy variable if a household reported selling crop produce in the in the 3-month period prior to the survey	
2nd member wage work	Dummy variable if a second household member engaged in wage employment in the 3-month period prior to the survey	
Others	Dummy variable if a household reported receiving any assistance from other family members or relatives or friends in the 3-month period prior to the survey	
Explanatory variables		
Stored food	Per capita quantity of estimated food grains (rice, corn and sorghum) in store (kg)	-
Death	Dummy variable if a household reported death of any household member in the 3-month period prior to the survey	+
Livestock loss	Dummy variable if a household reported losing livestock or poultry in the in the 3-month period prior to the survey	+
Sickness	Dummy variable if a member of the household fell sick in the 3-month period prior to the survey	+
Fire	Dummy variable if the household experienced a fire in the 3-month period prior to the survey	+

Livestock slaughter increased following sickness, livestock loss and with a decline in quantity of grain stored. The above results show that the households used livestock as a means of shock coping mechanism both by slaughtering for own consumption and selling livestock (Models 4 and 5). This is confirmed by the results of Model 4 in which a strong positive relationship was seen between livestock slaughter and livestock loss. The negative relationship between livestock slaughter and grain stored probably suggests that when faced with severe food shortages, households tend to slaughter their livestock.

Table 3-6: Results of fixed effects logit analysis

Variables	Coefficients	std err	P>|z|
Model 1: Roots and tubers (n = 676)			
Sickness	0.325	0.183	0.076*
Fire	0.243	0.370	0.512
Death	0.975	0.558	0.081*
Livestock loss	0.025	0.026	0.343
Stored grain	-0.002	0.001	0.252
Model 2: Forest meat (n =848)			
Sickness	0.406	0.167	0.015**
Fire	-0.341	0.361	0.344
Death	0.739	0.617	0.231
Livestock loss	0.005	0.025	0.841
Stored grain	0.002	0.001	0.103
Model 3: Sale of crops (n = 728)			
Sickness	0.389	0.184	0.035**
Fire	0.280	0.361	0.438
Death	-0.858	0.361	0.303
Livestock loss	-0.054	0.033	0.107
Stored grain	0.009	0.002	0.000
Model 4: Livestock slaughtering (n = 540)			
Sickness	0.491	0.252	0.051*
Fire	-0.063	0.555	0.909
Death	0.737	0.850	0.386
Livestock loss	0.461	0.074	0.000***
Stored grain	-0.004	0.002	0.018**
Model 5: Livestock sale (n = 584)			
Sickness	0.533	0.195	0.006***
Fire	-0.184	0.412	0.655
Death	0.717	0.643	0.265
Livestock loss	-	-	-
Stored grain	-0.001	0.001	0.255

Variables	Coefficients	std err	P>|z|
Model 6: 2nd member wage work (n = 356)			
Sickness	1.031	0.291	0.000***
Fire	-0.582	0.676	0.390
Death	1.624	1.345	0.227
Livestock loss	0.054	0.051	0.289
Stored grain	-0.006	0.003	0.015**
Model 7: Other strategies (n = 372)			
Sickness	0.142	0.262	0.588
Fire	0.729	0.494	0.140
Death	1.935	1.260	0.125
Livestock loss	0.003	0.031	0.916
Stored grain	-0.002	0.002	0.176

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

Livestock sale (Model 5) increased with sickness in the family. Livestock is another liquid asset in the study area. It may be noted that as the livestock sale and livestock loss are strongly co-related[39]. The households also mitigated the shocks caused by sickness by taking up additional wage employment (Model 6). The statistically significant relationship between wage employment and grain stored may also be suggesting that the households stepped up their labor supply for precautionary purposes i.e. with the family granary was going empty the household took up additional wage employment by cutting down on leisure for the purpose of building up cash reserves.

The model 7 dealt with 'other strategies' (i.e. receiving remittances and assistance). Although not statistically significant, the coefficients on all the shock variables have the expected signs implying that households tended to receive assistance when faced with shocks and when household food supply was in short supply.

3.4 Discussion

This paper explored the safety net role of the *miombo* woodlands for the households living near the Gorongosa National Park in Mozambique. The household reliance on tropical forests to

[39] The variable livestock loss was dropped by Stata.

mitigate risks associated with subsistence has been discussed in literature (Godoy et al. 1998; McSweeney 2005; Shackleton et al. 2007; Wong and Godoy 2003). The consensus view is that the natural insurance for forest dwellers is important because life in the forest fringes is full of risks and uncertainties caused by the environmental, agricultural, epidemiological and market conditions, and also because forest fringes are remote where residents do not have means of securing alternate reliable and institutionalized insurance (McSweeney 2005). The safety net role of forests is often under-appreciated, and provides the most important argument for conservation of forests (Byron and Arnold 1999; Wunder 2001) while the question of whether forests form safety net or poverty trap is being investigated (Angelsen and Wunder 2003).

The use of forests as safety net has been interpreted in two forms, first as a diversification strategy (or portfolio strategy) and second as a coping strategy (Delacote 2007). A diversification strategy may explain a situation where the forest products are used as risk free assets as households extract wild-food to save on stored grains. A coping strategy is a situation when a household extracts wild-products to tide over a crisis. In the study villages, forests were used as part of both diversification and coping strategies; however, this part of analysis focuses on coping strategies.

Our results demonstrate that rural households devise a variety of strategies used in conjunction with one another, to deal with the income shocks. First, a sharp seasonality both in extraction of wild-products (roots and tuber and wild-meat) and occurrence of shocks was observed. Second, the *miombo* woodlands were used as safety nets against idiosyncratic shocks, particularly by providing alternate means of survival. Importantly, while crop sale and livestock sale and remittances were available only to the relatively better off households in the community, forest food was available to every household. Since the above model did not treat wealth status of the household in its entirety (although food grain in store is meant to partly capture wealth), it is possible that resource poor households that did not have either livestock or surplus crop produce to sell would resort to forest-food to cope with income shocks.

A number of features make wild-products extraction an attractive risk coping strategy. First, they do not have a strong correlation with most other shocks or among themselves i.e. a crop loss does not necessarily mean that less wild-products. Second, they are accessible to all (as a common pool resource) and extractable with limited use of capital (i.e. capital and labour) and skills. Third, they are renewable and annually re-occurring, and therefore reliable.

3.5 Conclusion

There is relatively a large body of literature on the direct contributions of forests to the household economy, but evidence on the safety net role of forests is limited. This analysis provides both a conceptual framework and empirical evidence on the role of the *miombo* woodlands in rural Africa. By making use of qualitative data on the presence or absence of shocks, rather than their intensity, it helped provide a first evidence of the safety net role of the *miombo* woodlands. This can be particularly useful when resources are not available for intensive data collection, and where only qualitative information exists.

The results provide some key policy implications. First, the forests are by no means a guarantee of poverty alleviation; nor are most of the vocations that are available to forest fringe communities. The safety net role of forests is often undervalued in academic and policy circles. The critical role the woodlands play is that they act as a "cushion" by preventing deepening of poverty among the communities (Shackleton et al. 2007). On this account, the remaining *miombo* woodlands are critical for the survival of millions in Africa. Second, alleviating risk is a policy concern throughout the developing world, as risk limits development, increases inequality among communities, impedes technology adoption and accelerates natural resource degradation. Policy intervention to address risk through institutionalized insurance is necessary.

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4 HOUSEHOLD PARTICIPATION IN A PAYMENTS-FOR-ECOSYSTEM-SERVICES PROGRAM: A HOUSEHOLD LEVEL STUDY FROM MOZAMBIQUE[40]

4.1 Introduction

Human society receives a variety of goods and services from the ecosystems which vary along a wide spectrum ranging from natural to managed (Tilman et al. 2002). One way to classify the goods and services is to make a distinction between provisioning services, regulation services and cultural services. Provisioning services include production of food, fibre and fuel. Regulatory services include regulation of climate (including factors that influence climate such as carbon sequestration), hydrological and biochemical processes and a range of biological processes. Finally, cultural services include education, recreation, social and spiritual values held in ecosystems (Wossink and Swinton 2007; MEA 2005).

Recently, there has been a pronounced increase of interest in the study of ecosystem services (ES). From economics perspective, the identification and measurement of the value of the ES is interesting because most of the ES occur as positive externalities and public goods, and as a result, markets have difficulty in handling their production. For instance, forest and agricultural landowners frequently provide a variety of ecosystem services, but receive little or no benefits from the ES: a consequence is that a variety of the ES are at the risk of irreversible loss (Fisher et al. 2008; MEA 2005).

To counter the above trend, a financial and policy tool for conservation, known as Payments for Ecosystem Services (PES), was created (Jack et al. 2008; Landell Mills 2002; Pagiola et al. 2005; Wunder 2005; Wunder 2007; Zbinden and Lee 2005). Essentially, PES is a voluntary transaction between a ecosystem service buyer and an ecosystem service provider, so that at least part of the benefits received by the buyer are of direct benefits to the ES providers (Jack et al. 2008; Wunder 2007).

Projects based on PES have been used to finance conservation both in developed and developing countries (Fisher et al. 2008; Jindal et al. 2008; Landell Mills and Porass 2002; Pagiola et al.

[40] A version of this manuscript will be submitted for publication. Hegde, R., Bull, G. Q., Kozak, R., Maness, T. and Wunder, S. Household participation in a Payments-for-Ecosystem Services program in Mozambique. 23 pp.

2007). As the use of this approach grows, it is increasingly recognized that there is a need to investigate empirically how the program affects the service providers, particularly resource poor households, and if there are any entry barriers. There has been very little research in the past on household participation in the PES-programs (Kosoy et al. 2008; Miranda et al. 2003; Pagiola et al. 2008), although this addresses who participates in, and who benefits from, the PES program.

The present paper's objectives are to determine: (a) the extent to which the resource poor people participate in the PES scheme as sellers of the ES; and, (b) the critical socio-economic factors which influence household decision to participate in the PES-program.

4.1.1 PES program in Mozambique

A small scale agro-forestry based carbon sequestration project has been implemented in Nhambita *Regulado* (community) in Sofala Province in Mozambique (Fig 4-1) (Hegde et al. 2009a). The *miombo* woodlands provide the critical livelihood support to the rural households in Mozambique (Hegde and Bull 2008). Nhambita community, being located in the buffer zone of the Gorongosa National Park, depends heavily on the *miombo* woodlands. Traditionally, households practice slash-and-burn agriculture (also known as shifting cultivation) where they clear the *miombo* woodland and burn the biomass to start their *mashamba* (farm), following which they grow mainly subsistence crops including corn, sorghum, peas, cucumber and other vegetables. After 3-4 years, they clear land in another place leaving the old *mashamba* site for regeneration for 20-25 years. This is legally allowed even in the Park buffer zone. A household needs to take the permission from the *Regulo* (traditional chief) to clear any fresh forest, in some cases with payment of a nominal fee. However, when this regulation is not strictly enforced, the households skip this step and continue with land clearing episodes, and the cycle continues (Fig. 4-2).

In the Park buffer zone, the communities are also allowed to collect fuelwood from dead and fallen trees, gather wild products for own use, and hunt animals using bow and arrow for subsistence. In the community land outside the Park boundaries, some households also produce charcoal. The charcoal producers generally cut and burn trees to produce charcoal, while some households cut trees to produce head-loads of fuelwood for sale along roadside. These households keep moving from place to place normally when trees from an accessible distance are exhausted. The PES project in Nhambita aims to conserve the *miombo* woodlands by halting land clearing and burning.

The smallholder farm households have signed voluntary contracts with the project implementing agency[41] to plant indigenous and fruit tree plants on their *mashamba* (either on farm boundaries or in mixed rows along with crops) and manage the same for 25 years in return for conditional cash payments. The conditions for the payments include that the participating household must ensure a minimum seedling survival rate of 80% in the first year, 90% in the second year and 100% in the third year; that no clearing and burning of forest land is carried out during the project period, over and above what has been recorded in the map attached to the contract. This eliminates the practices of production of charcoal and fuelwood.

Figure 4-1: Study area location

[41] A consortium of partners, consisting of EnviroTrade (a private firm based in the UK), University of Edinburgh and Edinburgh Centre for Carbon Management, is implementing the Nhambita Project which is supported by the European Union. EnviroTrade has taken the lead in implementing the project.

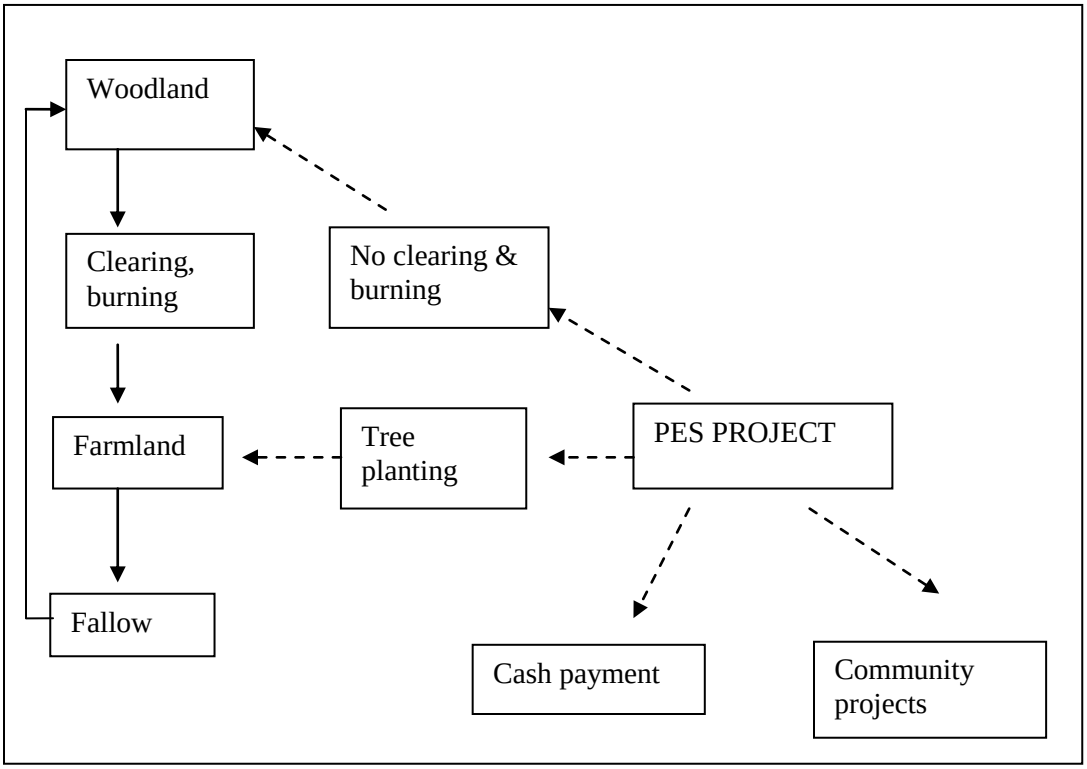

Figure 4-2: Conceptual framework for Nhambita carbon project

The number of trees maintained is used to calculate the amount of carbon going to be fixed, which is the basis for determining the amount of money to be paid to the farmer. The cash payments are split into seven annual instalments: 30% in the first year, 12% for the next five years, and the remaining 10% in the final year. Carbon credits are sold in the international voluntary carbon markets. Part of the sale deeds is deposited in a trust fund which is used for paying the participant farmers, and a part is used to undertake development activities in the villages.

The Carbon Livelihoods Project was started as a Pilot Project in Nhambita in the second half of 2003. The pilot phase of the project was limited to the villages of Nhambita, Bue Maria and Munhanganha. After a series of meetings with the project authority and their own community level meetings, only 60 households in total from the three villages expressed an interest in joining the project. The initial work consisted of preparation of Plan Vivo maps for the smallholder farmers. Although the maps were basic, they contained the necessary information including a map of the existing farm, current fallow and also any abandoned land (by the members of the family during the civil war) which the family may plan to cultivate in the future, with GPS points. Basically, the map captured all the potential land that a family may farm now or in the future.

The farmers went through training in early 2004 on various aspects linking tree planting by the farmers to sequestering carbon emitted on a global scale. They then created firebreaks on their farm and started planting trees along farm boundaries and in mixed rows. There is a choice of species to be planted including commercial fruit crops (e.g. mango, cashew, etc.), local fruit species and indigenous trees.

The technical staff members from the project undertake field monitoring of seedling survival prior to release of the payment to the individual farmers. Monitoring of the practices, e.g. new clearing, use of fire for burning residues, is also done by the technical staff. With the expansion of planting activities, there is a proposal to use remote sensing for field monitoring and verification.

The PES-project also has a menu of other forest based activities for the development of the community, such as a carpentry unit, a bee keeping unit, nursery unit, field demonstration of improved gardening, etc. and provides full time employment for about 100 people. It also provides limited seasonal employment in forest fire prevention and fire watch activities. Besides cash payment and direct employment, the project also distributed guinea fowls for rearing, bee hives for bee keeping and red gram seeds for cultivation to the households on a pilot scale.

The participation rates of the smallholder farmers in the project remain low (around 30%), which raises concerns about the adequacy of the ES provision. The present paper aims to identify the factors affecting the farmers' participation in the PES project.

4.2 Methods

4.2.1 Study area

4.2.1.1 Location

The study was undertaken in Chicale *Regulado*[42], located in the buffer zone of the Gorongosa National Park (GNP) in the Sofala Province, Mozambique.

Chicale *Regulado* covers a total of 20 km^2 area, with over 1,100 households spread over five villages, namely Nhambita, Bue Maria, Munhanganha, Pungue and Mbulawa (Table 4-1). Nhambita village, where the *Regulo* Chicale family resides, is considered as the centre of the study area. Three villages, Nhambita, Bue Maria and Munhanganha, are located close to each

[42] Traditional authority.

other within the buffer zone of the GNP. On the other hand, Mbulawa village is located outside the GNP boundary, and Pungue is situated on the GNP boundary such that a part of the village is inside and a part outside. Key characteristics of the villages are shown in Table 4-1.

Table 4-1: 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

The villages also differed in terms of farming systems and environmental resource use patterns. While farming in the first two villages was mainly subsistence; Bue Maria village had a mix of traditional and commercial agriculture (limited area was under vegetable, cotton and sesame cultivation); while Pungue, being located on the bank of the river Pungue, had relatively more commercial farming systems (with tobacco; vegetables). While the first three villages had households gathering more traditional environmental products predominantly for subsistence, the households in Mbalawa and Pungue had a mix of both subsistence and commercial products.

Mbalawa had households producing charcoal and fuelwood for sale and undertaking gold panning (for sale), besides gathering subsistence products, while the households in Pungue undertook fishing (both subsistence and sale) and gold panning, besides gathering subsistence environmental products. Because of the proximity of the three villages, Nhambita, Bue Maria and Munhanganha, for the purpose of the present research, are considered as one village henceforth (Hegde and Bull 2008).

4.2.1.2 Brief historical background

The Nhambita community land was legalized in 2003 after a claim was made under the new Land Act (No. 19/97) which permits communities' ownership of their ancestral land and management of its resources for the benefit of the entire community as per a pre-approved management plan. Part of the community land was taken over by the National Park Authority when the then Hunting Reserve was upgraded to the National Park in 1965. To minimize the poaching pressures inside the GNP during its rehabilitation, a buffer zone strategy was used that envisaged involvement of the local community in the management of the GNP (Zolho 2005b).

4.2.1.3 Climate and geography

The climate is subtropical with alternating cool and dry winters (April-October) and hot wet summers (November-March), with May being the coolest and October being the hottest month. The area lies within the 600 mm and 800 mm per annum rainfall isohyets, and is generally influenced by the Gorongosa Mountain. Most of the rain is received between November to March, with July to September being the driest months (Zolho 2005b).

Geographically, the land in Gorongosa consists of eroded surfaces of granite and basaltic gneiss complex of Precambrian times, which, after heavy weathering, result in sandy soils that are generally unsuitable for any form of intensive farming (Tinley 1977). The vegetation is dry *miombo*, interspersed with evergreen thickets on the deeper alluvial sands. There are a few narrow patches of thick riverine forest along the seasonal streams, such as Lupice, and the river Pungue (Zolho 2005b).

4.2.1.4 Land use

Land use in the GNP and surroundings consists of three types: protected area; buffer zone and community land. The protected area is under the State administration. The buffer zone, the land immediately adjacent to the GNP boundary, is jointly managed by the government, communities and other stakeholders. While subsistence farming is allowed in the buffer zone, no other

commercial activity, including hunting or extraction of forest products for commercial production, is allowed. The community land is managed by the communities under the Land Act. Activities in the community land include subsistence farming, charcoal production, fishing, hunting, etc.

4.2.2 Research design

Questionnaire-based quarterly household surveys (Appendix 6), which explicitly integrated quantitative environmental resource use data with household income data and tree planting data for PES participant households, were the main source of data used in the research. In addition to the four quarterly surveys, two annual household surveys (Appendix 4-5) and two village surveys (Appendix 2-3) – one each at the beginning of the research and one at the end – were undertaken (Hegde and Bull 2008).

4.2.2.1 Sampling

Since official household census was not available, we updated the household rosters with village headmen (*Nfumo*'s) by listing all the households under their responsibility (Cavendish 2000a). These households were then arranged alphabetically, and then a sample was chosen using a random number table. Where the selected household was not available for interviews, either due to multiple-listing[43] or its inability to participate due to sickness or old age, the immediate next household on the list was chosen. Sample size would depend on population heterogeneity, required level of precision and availability of resources (Singleton et al. 1993). Considering the heterogeneity in the area, we decided to draw a large sample.

The initial sample consisted of 335 households. However, 45 households were excluded from the analysis, for two primary reasons. First, five households migrated in the middle of the research missing at least two rounds of survey, and were excluded from the sample. Second, another 40 households were temporarily away during survey months, thereby missing one round of survey; they were also excluded[44]. The remaining 290 households were used for the analysis.

[43] There were cases where households were listed in more than one village.

[44] Households missing one round of survey could have been included for analysis by substituting sample average values for missing round. However, the decision to drop all the missed out households was made on the premise that the missing information on specific household response strategies to income shocks can not be bridged by substitution of sample averages.

4.2.2.2 Income definition

We used cash income as the measure of overall household welfare[45], defined as the sum of cash income from sale of crops, livestock, forest products (both unprocessed and processed), wage, environmental products, fish, net gifts/transfers, business and commerce and, PES. Incomes were reported in local currency metical (plural *meticais*; MTS[46]).

4.2.2.3 Field work

Field work was undertaken from January to December, 2006. Eight enumerators[47] were recruited and trained, who conducted the interviews in the local language (*Sena*), under the supervision of the researcher (Hegde and Bull 2008).

4.2.3 Analytical framework

We use the analytical framework developed by (Jumbe and Angelson, 2007). For convenience, the same notations are retained.

The economic theory behind agricultural household behaviour has been extensively covered in the literature (Singh et al. 1986). The research question we would like to answer is how do the households decide to participate in the PES program in Mozambique. The literature shows that the costs and benefits of participating in any program are the key where each household will weigh the net benefits of participation against that of non-participation (Jumbe and Angelsen 2007; Ostrom 1999). Motivated by the above work, we put the cost-benefit framework into the agricultural household modelling framework which helps understand how the different household characteristics and context specific factors influence the household participation decision.

The main costs and benefits relevant for our field conditions are as follows. The PES participants are bound by the contract not to slash and burn the forests. Therefore, household participation may be perceived to limit the access to forest resources, at least to charcoal and fuelwood producers and shifting cultivators. The project participation involves costs, particularly additional labour for planting, tending, etc, which may discourage the smaller particularly, woman headed

[45] Consumption is often preferred to income as a measure of welfare (Deaton, 1980), but in rural Africa consumption and income are not dissimilar (Cavendish 2000). We also measured consumption in this study; it will be examined in subsequent analyses.

[46] All calculations in this study are based on old currency; under the currency reforms, the last three digits in the currency have been removed. The exchange rate fluctuated throughout the study period; however, we use a constant exchange rate of 1US$ = 26,500 MTS.

[47] Enumerators had varying educational qualification, with diploma (highest), certification course and high school (lowest).

households. In terms of benefits, the project participation is expected to improve the overall household wellbeing by cash payments to the households, by providing employment opportunities to many and generating community level benefits.

The model is static as it does not involve any feedback effect. The following assumptions are made which were relevant for the field conditions and which make the model more tractable. We assume imperfect labour market in that a household may rent out a labour, but does not hire in labour which is common in much of Africa. We also assume that the markets for agricultural and forest products function perfectly (there were markets for these products even in remote places). These assumptions allow us to focus on income and consumption rather than individual goods (Jumbe and Angelsen 2007).

The household maximises a twice differentiable quasi-concave utility function which depends on total consumption[48] (C) and leisure (L_H), of the following form.

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

Where H is a vector of household characteristics that affect household preferences.

Following are the technological, time and budget constraints facing the households.

$$Q^F = Q^F(L_F, D; R, \Omega) \text{ ---------- (2)}$$

$$Q^G = Q^G(L_G; M, \phi) \text{ ---------- (3)}$$

$$D = D(P; H, V, R) \text{ ---------- (4)}$$

$$S = S(P; H, V); S(1) > S(0) = 0 \text{ ---------- (5)}$$

$$L = L_F + L_G + L_W + L_P + L_H \text{ ---------- (6)}$$

$$pFQ^F + pGQ^G + wL_W + E = C \text{ ---------- (7)}$$

$$L_F, L_G, L_W, L_H, Q^F, Q^G, C \geq 0 \text{ ---------- (8)}$$

Equation (2) captures a production function for a composite forest commodity. It implies that the commodity production depends on labour invested in forest products collection (L_F) and forest access (D). Production also depends on a technology parameter Ω and a vector of exogenous

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

forest resource characteristics (R). Equation (3) is agricultural production function which depends on family labour (L_G), land area (M) and an exogenous production technology (ϕ).

Equation (4) describes how the access to forest resources (D) is affected by household participation in the PES program (P). Participation is a binary variable taking the value of one (1) for participation and zero (0) for non-participation. Access is broadly defined as both legal access and its degree of enforcement. The access also depends on household (H), village (V) and resource characteristics (R). According to the PES program, a household participating in the project cannot clear and burn the forest (either for agricultural production or charcoal production)[49].

Equation (5) is the social capital function. It gives social good as a function of participation. Participation requires that a household perceives the community as friendly, helpful and trustworthy.

Equation (6) gives the total labour endowment (L) which is allocated among forest collection (L_F), agriculture (L_G), off-farm wage labour, (L_W), labour allocation on tree planting and maintenance (L_P) and leisure (L_H). It is obvious that L_P is zero (0) if a household does not participate in the program. Equation (7) says that the household income, which includes the value of agricultural commodities (Q^G) and forest commodities (Q^F) valued at their respective market prices[50] and wage income, cannot exceed the consumption. Equation (8) represents the non-negativity constraints.

The choice variables are L_F, L_G, L_W, L_H, Q^F, Q^G, C and P. Since P is a discrete variable, the optimisation strategy is first to optimise labour allocation for given P. We then compare the utility outcomes of the two values of P and choose the P which maximises utility. We open up for corner solutions for both forest production ($L_F = 0$) and off-farm labour $(L_W = 0)$. Leaving out equations 4 and 5, the Lagrangian for the Kuhn-Tucker problem is given by:

$$l = U(C, L_H, S; H) + \lambda_1[Q^F - Q^F(L_F, D; R, \Omega)] + \lambda_2[Q^G - Q^G(L_G, M; \phi)] + \lambda_3[L - L_F - L_G - L_W - L_P] + \lambda_4[pFQ^F + pGQ^G + \omega L_W + E - C] \text{ ---------- (9)}$$

[49] In this case, participation is assumed to limit access to forest resources, while Jumbe and Angelson (2007) assumed participation in community management improves access.
[50] See Hegde and Bull (2008) for a detailed account of how valuation was done.

The first order conditions can be summarised as follows, together with 2, 3, 6 and 7:

$$pFQ_{L_F}^{F} \leq pGQ_{L_G}^{G} = \frac{UL_H}{U_C} = \frac{\lambda_3}{\lambda_4} \geq \omega \text{ ---------- (10)}$$

When a household is involved in forest collection, an equality sign replaces the first inequality sign. Similarly, labour market participation implies the replacement of second inequality sign with equality sign. When the household participates in both activities, then equation (10) implies that the value of marginal labour productivity in agriculture and forestry should be equal to the market wage rate, which again is equal to the marginal rate of substitution between leisure and consumption. Where household does not participate in the labour market, the household's shadow wage rate is given by $\lambda_3/\lambda_4 = \omega$. When the market wage is below ω, a household prefers working in agriculture, leisure and possibly forestry.

We are interested in the household participation decision, and for this problem we write the model in a semi-structural form (almost reduced form, as P is an endogenous variable):

$$U = U^*(P; P_F, P_G, \omega, \mathrm{E}, \Omega, \phi, L_p, H, V, R), P = 0,1 \text{ --------- (11)}$$

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

$$B = U^*(1) - U^*(0) = B(P_F, P_G, \omega, \mathrm{E}, \Omega, \phi, L_p, H, V, R) \text{ ---------- (12)}$$

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 $B < 0$ ---------- (13)

In this model, participation is assumed to affect utility in three ways. First, as explained earlier participation limits the access to forests i.e. D(1) < D(0). Higher prices of forest products (charcoal, fuelwood and timber) will reduce benefits from the participation. In general, we can expect that households that are involved in fuelwood and charcoal production have less incentive to participate in the PES project. Factors such as small landholdings (M), low agricultural prices (P_G), access to off-farm employment with low wages and poor technologies (ϕ) will increase the value of B.

Second, there is a labour cost for participation (L_p). Other things being constant, the higher this labour requirement the lower is B. For the households participating in the labour market the opportunity costs of time is given by the market wage rate (ω) and the participation cost increases as the wage rate increases. For those households that do not participate in the labour market, we can expect the poor households to have a lower shadow wage, and hence be more likely to participate, *ceteris paribus*.

Third, we assume that social capital influences the participation. Migration is a common phenomenon in rural Africa. Households migrate for various reasons. We noticed during field work that some households migrated for reasons best known to them, leaving behind standing crops nearly ready for harvest. Therefore, we probed on household's perception of the community as a liveable place, which will influence their long term decision such as PES planting.

4.2.4 Empirical model

The decision to participate in the PES program depends, *inter alia*, n whether participation will provide cash income, maintain the resource access, not adversely impact the crop production and will involve less labor requirement. The key model is the probit participation equation which is a function of factors including forest dependence. However, forest dependence is endogenous, and is, therefore, estimated first. Since not all households earn cash income from the woodlands there is a potential selection bias which is corrected using the Heckman procedure.

The model is thus specified as a system of equations to account for the interrelationships among forest use, forest dependence and PES participation as follows.

$A_i = Z_i\gamma + \varepsilon_i$ (forest use) ---------- (14)

$y_i = x_i\beta + u_i$ (forest dependence) ---------- (15)

$P_i = W_i\zeta + \phi y_i + e_i$ (participation) ---------- (16)

Where, Ai is forest use (or access) for the cash income generation which is a dummy variable indicating whether an individual derive income or not.

y_i denotes forest dependence defined as the ratio of forest cash income (sum of cash income earned from sale of forest products) to the household income; Pi is a dummy variable for the

participation; i =1,.....N denotes households; Z_i, x_i and W_i are vectors of exogenous variables that determine forest use, forest dependence and participation, respectively; γ, β, and ζ are unknown parameters and ε_i, u_i and e_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 (16).

We consider forest income from sale of forest products. Consequently, y_i is observed for a household i together with covariates x_i and Z_i if A_i =1. We make the following distributional assumptions about the error terms u_i, ε_i and e_i.

$u_i \sim N(0, \sigma_u^2)$, $\varepsilon_i \sim N(0,1)$, $e_i \sim N(0, \sigma_e^2)$ and $E(u_i|Z_i\varepsilon_i) = E(u_i|\varepsilon_i) = \rho$, where ρ is the correlation between u_i and ε_i. σ_u^2 and σ_e^2 are respective variances of $u_i$and e_i while variance of error term in (14) is reduced to unity.

4.2.5 Model estimation

4.2.5.1 The three step estimation

The model is estimated in three systematic steps: the first two steps being the part of Heckman's two-step sample selection correction procedure (Heckman 1979) while the purpose of the third step is to correct for the endogeneity. In the first step, the inverse Mills' ratio is obtained to correct the selection bias in the estimates of the share of forest income (forest dependence). From equation (14) we specify the following reduced form of forest use model:

$$Ai = \begin{cases} 1 & if Zi\zeta + Xi\beta + vi \geq 0 \\ 0 & otherwise \end{cases} \text{ ---------- (17)}$$

Where

The associated log likelihood function is

$$logL(\alpha, \beta) = \sum_{A_i=1} \log\left(\Phi\left(\frac{Zi\zeta + Xi\beta}{\sigma_v}\right)\right) + \sum_{A_i=0} \log\left(1 - \Phi\left(\frac{Zi\zeta + Xi\beta}{\sigma_v}\right)\right) \text{ ---------- (18)}$$

Where $\Phi(.)$ is the cumulative function of the standard normal distribution. By the normality assumption, we optimise this log likelihood function by maximum likelihood to estimate parameters of the model. The dependent variable for forest use equation (14) was computed from

the information given by a respondent if a household collects forest products coded as one (1) and zero for the yes and no responses.

We obtain the predicted estimates of the forest income share (forest dependence) corrected for the sample selection bias in the second step. Applying the ordinary least squares to equation (15) produces inconsistent estimates of the share of forest income since the expected value of the error term conditional on forest use is non-zero (Maddala 1983). The conditional mean of the share of forest income in Equation (15) is

$$E(y_i|A_i = 1) = x_i\beta + E(u_i|Z_i,\varepsilon_i) = x_i\beta + E(u_i|\varepsilon_i) \quad \text{---------- (19)}$$

such that $E(u_i|\varepsilon_i) \neq 0$. The conditional expectation of the error term u_i and ε_i is:

$$E(u_i|\varepsilon_i) = E(u_i|\varepsilon_i \leq Z_i\gamma) = E(\sigma_u, \rho|\varepsilon_i) = \rho\sigma_u \frac{\phi(Z_i\gamma)}{\Phi(Z_i\gamma)} \quad \text{-------- (20)}$$

Where $\phi(.)$ and $\Phi(.)$ are the standard normal density and cumulative distribution functions, respectively. The ratio $\lambda_i = \frac{\phi(.)}{\Phi(.)}$ is defined as the inverse Mills' ratio which is the covariance between residuals of the selection (forest use) and the outcome (forest dependence) equations estimated from equation (18). Replacing $E(u_i|\varepsilon_i)$ by the inverse Mills' ratio λ_i as a sample selection bias correction term in (15) we respecify the forest dependence equation as:

$$y_i = x_i\beta + \theta\lambda_i + \eta_i \quad \text{---------- (21)}$$

Where η_i is the error term that is assumed to have the conditional mean zero and variance σ_η^2, while θ is an unknown parameter. The statistical significance of the coefficient for the inverse Mills' ratio (θ) gives evidence of sample selection bias.

The dependent variable in equation (21) (forest dependence) was computed as the ratio of forest income to the total household income. Forest income includes cash income from sales of forest products.

As noted above, the third step addresses the problem of endogeneity in estimating the impact of forest dependence on participation Equation (16). From equation (21), we derive the predicted estimates of share of forest income, denoted as $\hat{y}i$. We then re-specify our participation equation (16) with predicted estimates of the share of forest income included as one of the explanatory variables as:

$$Pi = \begin{cases} 1 & if Wi\zeta + \delta\hat{y}i + ki \geq 0 \\ 0 & otherwise \end{cases} \text{ ---------- (22)}$$

Where $k_i \sim N(0, \sigma_k^2)$, δ is our parameter of interest. We estimate the model using maximum likelihood by optimising the following likelihood function:

$$logL(\tau, \delta) = \sum_{Ti=1} \log\left(\Phi\left(\frac{Wi\tau + \delta\hat{y}i}{\sigma_k}\right)\right) + \sum_{Ti=0} \log\left(1 - \Phi\left(\frac{Wi\tau + \delta\hat{y}i}{\sigma_k}\right)\right) \text{ ------- (23)}$$

The dependent variable in equation (23) is dichotomous (1,0) indicating whether or not a household participates in PES program.

4.3 Results

4.3.1 Comparison of participant and non-participant households

The summary statistics for the participant and non-participant households are presented in Table 4-2. The participant households were significantly larger in size than the non-participant households. The average level of education of the household head of the PES-participant household was higher compared to that of the non-PES participant household head. The average agricultural land area held by the PES-participant households was significantly larger than the non-PES participant households. The value of assets owned by the PES-participant households was also significantly higher compared to the non-PES participant households. There was no difference between the participant and non-participant households with respect to household annual cash income earned.

Table 4-2: Descriptive statistics

Variables	Non-participant	Participant	P > |t|
Household size (number)	5.65 (2.63)	6.26 (2.61)	0.069*
Age of head (years)	41.09 (14.33)	42.03 (13.95)	0.601
Head's education (years)	2.71 (2.25)	3.55 (2.59)	0.005***
Gender (woman headed = 1)	0.21 (0.41)	0.15 (0.36)	0.245
Ethnicity (Household from major ethnic group = 1)	0.26 (0.44)	0.32 (0.47)	0.261
Head born in the village (1/0)	0.55 (0.49)	0.54 (0.50)	0.803
Duration of household residence (years)	27.29 (18.35)	29.11 (17.81)	0.427
Agricultural land (ha)	2.08 (1.05)	2.61 (1.43)	0.000***
Value of assets (MTS)	515,000 (675,599)	876,183 (2227,965)	0.041**
Cash income (MTS)	5,037,858 (5,629,881)	5,249,423 (2,951,265)	0.734

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively; values in parentheses are standard deviations).

4.3.2 Factors influencing program participation

As was shown in the theoretical modelling, the participation decision depends, *inter alia*, on the effect of participation on access to the *miombo* woodland resources (e.g. charcoal making, land clearing) which determines income generation. This section describes the results of 3-step procedure as discussed in the theoretical modelling. The variable definitions are provided in Table 4-3, and the results are indicated in Table 4-4.

The results from the three step estimation (Table 4-4) indicate that the education level of the household head, household size, duration of residence of the household head in the community and trust positively influenced the household participation decision. The variable forest dependence had a negative influence on the participation. The coefficient on Site1 variable implied that project participation was likely to be higher in the areas where the project was first introduced on a pilot scale and where cash payments have been made at least once.

Table 4-3: Definitions of variables used in 3-step estimation

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		
Age	Age of household head (years)	-ve
Education	Education level of head of household (years)	+ve
Size	Number of members in a household	+ve / -ve
Woman	Dummy variable taking a value of 1 if household head is a woman; zero otherwise	-ve
Residence	Refers to the number of years the head has been living in the village. If the head is born in the same village it represents head's age, if the head is not born in the village then it refers to the number of years the head has been living in the village (year).	+ve
Agland	Area of agricultural land (ha)	+ve
Forest dependence	Predicted income share from sale of forest products (%)	
Good	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 on a scale of 3 that it finds that the fellow villagers can be trusted in general.	+ve
Site1	Dummy variable (1,0) indicating whether the household is located in either Nhambita, Mbalawa or Munhanganha where the pilot project was first introduced.	+ve

Table 4-4: Determinants of participation by 3-step estimation

Variable	Coefficient	Standard Error	z-value	P>|z|
Age	-0.0050854	0.0086511	-0.59	0.557
Education	0.1526008	0.0474	3.22***	0.001
Size	0.0809533	0.0384171	2.11**	0.035
Woman	0.1431027	0.2849579	0.50	0.616
Residence	0.0116197	0.0056298	2.06**	0.039
Agland	0 .0459233	0 .0888681	0.52	0.605
Forest dependence	-4.993779	2.208752	-2.26**	0.024
Good	0. 2633743	0.2683408	0.98	0.326
Trust	0 .5893189	0.2026571	2.91***	0.004
Site1	1.323818	0.2946496	4.40***	0.000
Constant	-2.174663	0.5822	-3.78	0.000

(*, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels respectively)

4.4 Discussion

The household participation rates were low in the PES project, which raises concerns about the adequacy of ES provision. The PES-programs have generally been administered in a top-down approach to begin with, where ensuring stakeholder participation and enhancing the efficiency and effectiveness evolve depending on the program design and implementation (Kosoy et al. 2008). Therefore, it is not realistic for them to make strong claims about the stakeholder participation at the beginning. The PES-program development approach contrasts with the participatory approach evolved in the 1980s and 1990s, in response to the failure of the top-down approach (Cooke and Kothari 2001). The Nhambita PES program could be an example of this phenomenon. When the program is external and where the participation is voluntary, participation rates are unlikely to be high.

The analysis identified several factors influencing the household participation decision. The positive relationship between family size and project participation and between education and participation is consistent with the literature (Zbinden and Lee 2005). During the fieldwork it was noticed that tree planting and maintenance required significant labour inputs. Larger households have larger amount of labor available, which is necessary for tree planting and maintenance tasks. The positive relationship between education of the household head and household participation confirms the conventional knowledge on the relationship between education and technology adoption (Pattanayak et al. 2003). Education is known to improve the knowledge, skills and attitude of an individual which makes them more receptive to new technology.

The PES participation was influenced by the duration of residence of the household head. If the household head is staying longer in the village implies that the head intends to stay in longer in the village, a key decision for long term investments such as the PES-planting. The households that are involved in charcoal production constantly move from place to place, have shorter duration of residence and therefore are less likely to participate in PES-programme.

Household participation in the PES project was positively influenced by the perceived trust the household placed in the fellow community members. The variables ‘good’ and ‘trust’ reflect social capital and kinship within the community. The greater a household perceives the community as a good place to live and perceives the fellow-members as trustworthy there are greater likelihoods of it staying longer and deciding to participate in the PES-programme. It may be noted that the coefficient on ‘good’ also has the expected positive sign although it is not

statistically significant. PES is a long term programme, and the participation decision reflects the long term perspective of a household. As many community members explained during the fieldwork, the very notion of the cash payments being made annually for planting trees on their farm wasn't convincing to begin with, particularly when such a claim was made by 'outsiders' to the community. It may be expected that these concerns are assuaged with time and awareness.

The variable forest dependence had a negative influence on the participation. Forest dependence is defined as the share of cash income earned from sale of forest products (timber, bamboo, fuelwood, charcoal, etc.) in the total household income. During interviews, some households indicated that they didn't join the project because their livelihood depends on the forests and the project does not offer them any alternative livelihood. Farmers do not trust any idea when introduced, but when they see the benefits they tend to adopt the idea, which explains why the households in the pilot project area (Site1) are more likely adopt than those outside the area.

We had expected that the woman headed households are less likely to participate in the project. Although not statistically significant, our results show that they had a greater likelihood of participating in the PES-project. Our expectation of negative relationship between woman headed households and participation was based on the fact that woman headed households are likely to have lesser labour resource required for tree planting and maintenance. Further, there is also the perceived risk of yield reduction and other uncertainties associated with PES-planting. Land tenure is said to have been a key determinant in the PES project participation elsewhere (Grieg-Gran et al. 2005), but was not an issue in the Nhambita PES project.

Planting trees on farm and homesteads is a common practice in rural Africa. Since tree planting on farm boundaries and in mixed rows on farm as required by the PES-project does not involve any complex operation, technology is not likely to be a limitation for participation (Pagiola et al. 2008). The economic incentive could be the key factor influencing the participation. The actual amount of cash payment made to the participating households was not significant (about MTS 1,498,933; US$ 60). Yet by accounting for about 10% of cash income, the carbon income was an important part of the household cash income (Hegde and Bull 2008; Hegde and Bull 2009). This was smaller compared to the PES-schemes in Latin America where the PES-come contributed up to 30% of the household income (Kosoy et al. 2008; Miranda et al. 2003). By paying 30% of the carbon payment upfront (in year 1), the project seeks to cover the bulk of the labour costs upfront

and is beneficial for the smallholder farmers. The tree species planted were beneficial for the farm households beyond the project period.

Transaction cost is an area that the project can improve upon. Currently, with about 2/3rds of the revenue from the carbon sales being spent on overheads and transaction costs, the farmers' share in the carbon dollar is small. Strategies are already in place to address the transaction costs, by bundling practices for enhancing environmental services (UOE 2008). If the project succeeds in paying the farmers with a larger proportion of the revenue from carbon sales, which means that more cash income per tree planted (and maintained), that will provide even greater incentive for participation.

4.5 Conclusion

There are a number of PES projects all over the world, but mainly concentrated in Latin America (Kosoy et al. 2008) and Africa (Jindal et al. 2008), which are expected to be replicated in other countries (Wunder 2007). The foregoing analysis addresses household level factors that influence participation in the PES-project. Although the analysis is based on the household level data, it addresses community level issues that are a key to the PES-projects, which are relevant for designing the PES-projects anywhere. The PES project targeted forest clearing and burning, including charcoal and fuelwood production which are the threats to the *miombo* woodlands and excluded those who indulge in these practices, which was inevitable.

The underlying assumption behind PES is the existence of a system for internalising externalities created by public good nature of the ecosystem services. While the monetary compensation is the key incentive, an effective incentive system should be responsive to the needs and aspirations of the members. An effective incentive system should not only ensure that the cash payment is made, but it is utilised properly. For instance, it was noticed during fieldwork that alcoholism was an issue within the community, and a significant amount of cash income was being spent on liquor consumption. The project needs to educate the non-participants on the importance of the *miombo* woodlands conservation and ensure their participation. There should also be investment on social capital, participants' network to support traditional leadership, to promote self-help and articulate collective voice of people for investing in the long term future of the residents.

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5 PERFORMANCE OF AN AGRO-FORESTRY BASED PAYMENTS-FOR-ECOSYSTEM-SERVICES PROJECT IN MOZAMBIQUE: A HOUSEHOLD LEVEL ANALYSIS[51]

5.1 Introduction

5.1.1 General overview

Forests and farm lands provide a variety of ecosystem services including watershed conservation, regulation of hydrological flows, biodiversity conservation and carbon sequestration. However, most of these benefits are realised "offsite", and land users typically receive no rewards for the services they provide. As a result, land uses that provide ecosystem services, such as forests, are rapidly being lost. To help remedy this problem the concept of Payments-for-Ecosystem-Services (PES) emerged (Engel et al. 2008; Fisher et al. 2008; Heal 2000; Pagiola et al. 2005; Wunder 2005; Zbinden and Lee 2005). The PES model is based on the principle that those who provide the ecosystem services (ES) be compensated and those who derive the benefits should pay for them. Recent years have seen the growing use of the PES schemes to finance conservation both in developed and developing countries (Fisher et al. 2008; Jack et al. 2008; Pagiola et al. 2008; Landell Mills and Porass 2002).

The PES model is claimed to be more efficient than the traditional command-and-control approach on the ground that as a market based approach the PES helps target areas where conservation costs are lowest. Further, since the PES program directly links the ES providers with the ES users through compensation, it provides a feedback to the ES users on the level and quality of the service they receive vis-à-vis the cost of the service, serving as an effective quality check (Pagiola et al. 2005; Wunder 2007).

Although the PES model was designed to increase the conservation outcome, it is also perceived to be a poverty reduction instrument. The beneficial impacts of the PES schemes are supposedly either through direct cash payments to the households and/or through the program activities that are designed to target poor landowners. The PES can also produce negative impacts of at least two types. First, a PES scheme may curtail the resource access to the low income population (Kerr 2002). Second, a PES scheme can target the marginal lands where land tenure is insecure,

[51] A version of this manuscript will be submitted for publication. Hegde, R. and Bull, G. Q. Performance of a Payments-for-Ecosystem Services program in Mozambique: A household level analysis. 23 pp.

which may give the 'elites' the opportunity to take control (Landell Mills and Porass 2002). Evaluation of a PES scheme should take into account the full range of impacts the scheme has had on the participants. Given the potential for negative impacts, there is a need to investigate empirically how the PES program affects the service providers, particularly the resource poor households.

Using household data collected from household surveys in Mozambique, this paper will address the following questions: (1) Do people benefit from participating in the PES project? (2) Are there any biases in the distribution of the PES-project benefits among the participants?

Answer to these questions helps to: a) assess the economic impacts and effectiveness of the PES-project as a strategy for addressing the environment and development linkages; b) analyze the social equity issues, i.e. whether the poorest and the most vulnerable households benefit from participating in the program; and, c) provide some useful insights for designing interventions in the future. The paper focuses on the poor households and the woman headed households as they are economically more vulnerable and are the focus of policy interventions for economic development.

5.1.2 Nhambita PES-Project, Mozambique

A small scale agro-forestry based carbon sequestration project is under implementation in Nhambita *Regulado* in Sofala Province in Mozambique. The smallholder farmers have voluntarily signed contracts with the project implementing agency[52] to plant indigenous and fruit plants on their farm (either on farm boundaries or in mixed rows along with crops) and manage the same for 25 years in return for conditional cash payments. The cash payment is split into seven annual instalments: 30% in the first year, 12% for the next five years, and the remaining 10% in the final year. The carbon sequestered is monitored under a Plan Vivo system (i.e. the number of trees maintained in a plot is used to calculate the amount of carbon going to be fixed, which in turn forms the basis for determining the amount of money to be paid to the farmer). The carbon credits generated are sold in the international voluntary carbon markets. Part of the sale deeds is deposited in a trust fund which is used for paying the participant farmers and for undertaking development activities (e.g. building school, construction wells for providing potable water, etc.) in the villages (Hegde et al. 2009a; Hegde et al. 2009c; Jindal 2004; UOE 2008).

[52] A consortium of partners, consisting of EnviroTrade (a private company based in the UK), University of Edinburgh and Edinburgh Centre for Carbon Management, is implementing the Nhambita Project which is supported by the European Union. EnviroTrade has taken the lead in implementing the project.

The Carbon Livelihoods Project was started as Nhambita Pilot Project in the second half of 2003. The pilot phase of the project was limited to the villages of Nhambita, Bue Maria and Munhanganha. After a series of meetings with the project authority and their own community level meetings, only 60 households in total from the three villages expressed an interest in joining the project.

The initial work consisted of preparation of the Plan Vivo maps for the farmers. Although the maps were basic, they contained the necessary information including a map showing the location of the existing farm, current fallow land and also the abandoned land (by the members of the family during the civil war) which the family may plan to cultivate in the future, with GPS points. Basically, the map captured all the potential land that a family may farm now or in the future.

The participant farmers went through a training program on various aspects linking tree planting to sequestering carbon to remedy carbon dioxide concentration in the environment. They then created firebreaks on the farm and started planting trees along the farm boundaries and in mixed rows. A choice of species including commercial fruit crops (e.g. mango, cashew, etc.), local fruit species and indigenous timber trees was given to the farmers for planting.

The project technical staff members undertake the field monitoring of seedling survival prior to release of payment to individual farmers. Monitoring of practices, e.g. new clearing, use of fire for burning residues, is also done by the monitoring staff. There is a proposal to use remote sensing for field monitoring and verification through annual visual inspection of Modis NDVI (Normalised Difference Vegetation Index) for the project area and its surrounding landscape, for an assessment of integrity of the woodlands in the area and detect any forest degradation (UOE 2008).

Besides carbon, the project also has a menu of other forest based activities for the development of the community, such as a carpentry unit, a bee keeping unit, nursery development, field demonstration of improved gardening, etc. and provides full time employment for about 100 people. It also provides limited seasonal employment in forest fire prevention and fire watch activities. Besides cash payments and employment, the project also distributed to smallholder households guinea fowls for rearing, bee hives for bee keeping and red gram seeds for cultivation,

on a pilot scale. Notwithstanding the benefits, farmers' participation rates in the project remain around 30% (Hegde et al. 2009c).

5.2 Methods

5.2.1 Study area

The study was undertaken in Chicale *Regulado*[53], located in the buffer zone of the Gorongosa National Park (GNP) in the Sofala Province, Mozambique (Fig. 5-1). Chicale *Regulado* covers a total of 20 km^2 area, with over 1,100 households spread over five villages, namely Nhambita, Bue Maria, Munhanganha, Pungue and Mbulawa (Table 5-1). Nhambita village, where the *Regulo* Chicale family resides, is considered as the centre of the study area. Three villages, Nhambita, Bue Maria and Munhanganha, are located close to each other within the buffer zone of the GNP. On the other hand, Mbulawa village is located outside the GNP boundary, and Pungue is situated on the GNP boundary such that a part of the village is inside and a part outside. Key characteristics of the villages are shown in Table 5-1.

Figure 5-1: Study area location

[53] Traditional authority.

The villages also differed in terms of the farming systems and the environmental resource use patterns. While farming in the first two villages was mainly subsistence; Bue Maria village had a mix of both traditional and commercial agriculture (limited area was under vegetable, cotton and sesame cultivation); while Pungue village, being located on the bank of the river Pungue, had relatively more commercial farming systems (with tobacco and vegetables). While the first three villages had households gathering more traditional environmental products predominantly for subsistence, households in Mbalawa and Pungue had a mix of both subsistence and commercial products. Mbalawa had households producing charcoal for sale and undertaking gold panning (for sale), besides gathering subsistence products, while households in Pungue undertook fishing (both subsistence and sale) and gold panning, besides gathering subsistence environmental products. Because of the proximity of the three villages, Nhambita, Bue Maria and Munhanganha, they are considered as one village for this research (Hegde and Bull 2008).

Table 5-1: 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

5.2.2 Research design

Questionnaire-based quarterly household surveys, which explicitly integrated quantitative environmental resource use data with household income data and tree planting data for PES participant households, were the main source of data used in the research. In addition to the four quarterly surveys (Appendix 6), two annual household surveys (Appendix 4-5) and two village surveys (Appendix 2-3) – one each at the beginning of the research and one at the end – were undertaken (Hegde and Bull 2008). Questionnaires developed by CIFOR-PEN[54] were adapted and expanded to suit the objectives of the research.

5.2.3 Sampling

Since official household census was not available, we updated the household rosters with village headmen (*Nfumo*'s) by listing all the households under their responsibility. These households were then arranged alphabetically, and then a sample was chosen using a random number table. Where the selected household was not available for interviews, either due to multiple-listing[55] or inability to participate due to sickness or old age, the immediate next household on the list was chosen. Sample size would depend on population heterogeneity, required level of precision and availability of resources. Considering the heterogeneity in the area, we decided to draw a large sample.

The initial sample consisted of 335 households. Due to attrition, a final sample consisting of 290 households was used for this analysis (Hegde and Bull 2008).

5.2.4 Analytical framework

5.2.4.1 Assessing the PES-project impacts

The evaluation framework used for analysis here considers whether PES program leads to an increase in household welfare as shown in Figure 5-2.

There are three types of PES impacts[56]: First, the PES project helps sequester carbon by tree planting, while switch from slash-and-burn cultivation to settled cultivation helps conserve woodlands, both of which contribute to household welfare (not measured here). Second, the main economic benefits from the project include direct cash payments to farmers and employment opportunities (both full time and part time) on the project, which are direct and measurable.

[54] Details can be seen at (http://www.cifor.cgiar.org/pen/_ref/home/index.htm).
[55] There were cases where households were listed in more than one village.
[56] Impacts in solid lines are the ones measured here; those in dotted lines were not measured.

Third, the potential impact on crop yields caused by interaction between trees and crops, affects the household welfare.

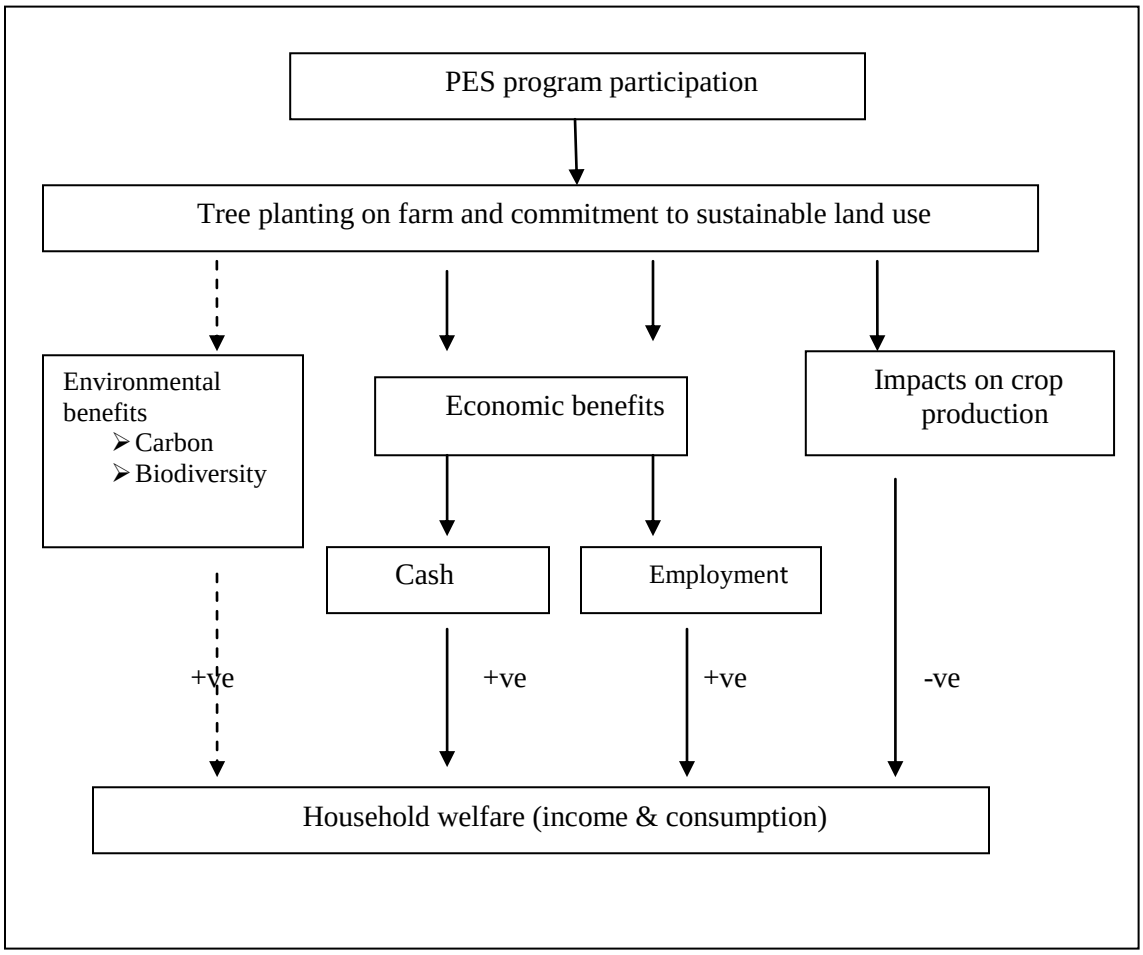

Figure 5-2: Evaluation framework

The manuscript focuses on the economic impacts of the PES project. We postulate that the household consumption and income are the measures of household welfare, and therefore are important measures in evaluating the PES program participation. One question we seek to answer is: Will the PES project participation lead to an increase in the household consumption and cash income? The estimates of crop yields were recorded as reported by the households during interviews, which is also used as an additional outcome indicator for analyzing the project's impacts. However, we are of the opinion that the impact of PES-planting on the agricultural yields will be best addressed by field experiments. The measurement of carbon sequestration and biodiversity conservation benefits fall beyond the scope of this study.

We observe both the outcome of a household participating in the project and that of a non-participant household. To understand the true effect of the household participation, we need to compare the observed outcome of participation with the outcome that would have resulted had the household not participated in the project. As widely noted, the outcome that would have resulted had the household not participated i.e. the 'counterfactual' is not observed, which is known as the 'evaluation problem'(Vandenberghe and Robin 2004). Nevertheless, available information on the non-participants can be used to derive the counterfactuals.

One specific parameter of interest in this study is what is known as the average treatment effect on the treated (ATT) i.e. the impact that the PES project has on the people who actually participated in the project. In theory, Instrumental Variables (IV) regression and Heckman Estimation can be used to derive the ATT. However, their major limitation is that they impose a linear form on the outcome equation, i.e. it needs to be assumed that the PES project impact is uniform across the distribution of the covariates and will be adequately captured by the (constant) coefficient on the dummy variable representing the participation (Vandenberghe and Robin 2004). There is no justification in economic theory why they should be linear.

We, therefore, decided to use the non-parametric matching approach (Rosenbaum and Rubin 1983; Rosenbaum and Rubin 1985). The underlying principle consists of matching a treatment with the comparison units (i.e. the PES participant households with non-participant households) that are similar in terms of their observable characteristics (Vandenberghe & Robin, 2004). While this approach has an intuitive appeal, it does have an assumption that any selection on unobserved variables is trivial, i.e. the latter do not affect outcomes in the absence of treatment. This identifying assumption for matching, which is also the assumption for Ordinary Least Squares regression, is known as the Conditional Independence Assumption (CIA).

When the CIA holds, the estimators depending on the matching techniques can yield unbiased estimates of the ATT. They allow the counterfactual outcome for the treatment group to be inferred, and therefore, for any difference between the treated and the un-treated to be attributed to the treatment.

The matching techniques are commonly applied in evaluating social programs and job training (Baker 2000; Daheja and Wabha 2002; Faltermeier and Abdulai 2009; Gilligan and Hoddinott

2007; Heckman 1997; Heckman and Smith 2002; Heckman et al. 1997; Himaz 2008; Hope 2007; Jumbe and Angelsen 2006). Some researchers believe that the propensity score matching generally replicates experimental results reasonably well (Daheja and Wabha, 1998), while others disagree (Smith and Todd, 2003).

Matching the households based on their vectors of co-variates is computationally demanding, particularly when the number of co-variates is large. Rosenbausm and Rubin (1983, 1985) demonstrate a way to overcome this problem, which is to match on a single index variable known as the propensity score, which considerably reduces the dimensionality as the matching is done on a scalar rather than a vector.

Propensity score is defined as:

$$Prob(X) \equiv \Pr(D = 1|X) = E(D|X) \text{ --------- (1)}$$

$D = (0,1)$ is the indicator of exposure to treatment and X is the multidimensional vector of pre-treatment characteristics. Rosenbaum and Rubin (1983, 1985) show that exposure to the treatment is random within cells defined by the values of the mono-dimensional variable $p(X)$. As a result, given a population of units denoted by i, if the propensity $p(X_i)$ is known, the Average effect of Treatment on the Treated (ATT) can be estimated as follows:

$$\tau \equiv E\{Y_{1i} - Y_{0i}|D_i = 1\} \text{ ---------- (2)}$$

$$= E\{E\{Y_{1i} - Y_{0i}|D_i = 1, p(X_i)\}\} \text{-------- (3)}$$

$$= E\{E\{Y_{1i}|D_i = 1, p(X_i)\} - E\{Y_{0i}|D_i = 1, p(X_i)\}|D_i = 1\} \text{-------- (4)}$$

Where the outer expectation is over the distribution of $(p(X_i)|D_i = 1)$ and Y_{1i} and Y_{0i} are the potential outcomes in the two counterfactual situations of treatment and non-treatment, respectively.

The propensity score must verify the balancing property, i.e. the individuals with the same propensity score must have the same distribution of observed co-variates. In other words, the

function used to compute the propensity score should be such that the individuals with a similar propensity score have, on average, similar values of Xi.

The propensity score matching (PSM) accounts for sample selection bias due to observable differences between treatment and comparison groups (Daheja and Wabha 2002). The PSM controls for the self-selection bias by creating the counterfactual for the group of participants. It constructs a statistical comparison group by matching every individual observation on the participants with individual observation on the non-participants with similar characteristics. Consequently, the matching procedure creates the conditions of a randomised experiment for evaluating a causal effect as in a controlled experiment (Faltermeier and Abdulai 2009; Rosenbaum and Rubin 1983). To achieve this outcome, the matching approach employs the CIA as discussed above (Faltermeier and Abdulai 2009).

The PSM method, however, has the following limitations (Vandenberghe & Robin, 2004). First, during matching it may happen that for a particular individual in the treatment group no matching may be found in the untreated group, which is known as common support problem. One way of addressing this is to drop those treatment observations whose propensity score is higher than the maximum or lower than the minimum of the untreated ones. This may be helpful for matching, but on the downside, it can cause loss of a significant number of treated observations as for these discarded individuals the program effect cannot be computed. Second, even within the common support region, the probability of observing two individuals with exactly the same value of $\Pr(D = 1|X)$ is in principle zero. Various matching methods have been developed to overcome this problem, namely Nearest Neighbour Matching, Radius Matching, Kernel Matching and Stratification Matching (Becker and Ichino 2002).

The nearest neighbour method uses algorithm that matches a participant household with a non-participant household having the nearest propensity score. The advantage of this is that it minimises the biases in matching treatment with comparison group. Its limitation is that: a) it disregards potentially useful observations; and b) its over-reliance on a limited number of nearest neighbours can result in ATT with large standard errors. In the radius matching, each treated unit is matched only with the control units whose propensity score lies within a predefined neighbourhood of propensity score of the treated unit. But, there is a trade-off between the size of the neighbourhood and the quality of matching (i.e. if the dimension of the neighbourhood is small, quality of matching will be better, but some of the units may not find a match and vice

versa). In the kernel matching, all members of the comparison group are used to build a match for each member of the treatment group. The kernel is a function that weights the contribution of each non-treated group member based on the distance of propensity scores (exact matches are assigned larger weight and poor matches are given smaller weight). The stratified matching consists of dividing the range of propensity score in intervals such that the treated and the control units have on average the same propensity score within each interval.

5.2.4.2 Assessing the impact of discrimination

Traditionally, decomposition techniques are used to assess the impact of discrimination in labor market or wage rates of different groups defined by gender, race or union membership (Andrews et al. 1998; Arbache and Carneiro 1999; Blinder 1973; Jolliffe and Compos 2005; Jumbe and Angelsen 2006; Liu et al. 2004; Oaxaca 1973; Trejo 1997). A few studies have borrowed this technique to assess the distribution of benefits in social development programs (Jumbe and Angelsen 2006). We decided to employ the decomposition technique following literature (Reimers 1983; Oaxaca 1973; Jumbe and Angelsen, 2006) to assess whether different groups of participants benefit equally from program participation. We compare the male and the female headed households and the rich[57] and the poor households to detect any discrimination. Using Heckman's sample selection correction procedure, the estimates for different groups are adjusted (Jumbe and Angelsen, 2006).

The estimates of variable of interest are derived for the comparison groups which are then used in decomposition analysis. Suppressing the index for households' equations for the comparison groups can be expressed as:

High privileged group: $\hat{y}_H = \bar{x}\hat{\beta}_H + \hat{\theta}_H\hat{\lambda}_H$---------- (5)

Low privileged group: $\hat{y}_L = \bar{x}\hat{\beta}_L + \hat{\theta}_L\hat{\lambda}_L$---------- (6)

Our parameter of interest is: $\bar{\pi}(D) \equiv \bar{y}_H - \bar{y}_L = E(y_H - y_L | j = 1)$ --------- (7)

[57] For the purpose of this paper, households whose income is more than or equal to sample average income are classified as rich; households with below average income are classified as poor. Sofala is the poorest province in Mozambique. If we use the national poverty line personal income of 1.9 million MTS as cut off, that would leave over three quarters of households in *poor* group.

Where $\bar{\pi}(D)$ is the income differential between two groups, H indexes the high privileged group defined as those with higher PES-income relative to their counterparts (i.e. the male headed households or the high income PES-participant households), and L indexes the low-privileged group, thus, those who are expected to obtain lower PES-income from the program (i.e. female headed households or low-income participants). The terms $\hat{\theta}_H\hat{\lambda}_H$ and $\hat{\theta}_L\hat{\lambda}_L$ are the sample selection correction terms, respective, where $\hat{\lambda}_H$ and $\hat{\lambda}_L$ are the inverse Mills' ratios while $\hat{\theta}_H$ and $\hat{\theta}_L$ are their respective parameters.

We use the PES-income of high-privileged group as our non-discriminatory benchmark. Our non-discriminatory income differential can be decomposed as

$$\bar{\pi}(D) = \left(\bar{x}\hat{\beta}_H + \hat{\theta}_H\hat{\lambda}_H\right) - \left(\bar{x}\hat{\beta}_L + \hat{\theta}_L\hat{\lambda}_L\right) \text{ ---------- (8)}$$

$$\bar{\pi}(D) = \bar{x}_H(\hat{\beta}_H - \hat{\beta}_L) + \hat{\beta}_L\,(\bar{x}_H - \bar{x}_L) + (\hat{\theta}_H\hat{\lambda}_H - \hat{\theta}_L\hat{\lambda}_L) \text{ ---------- (9)}$$

(Discrimination + Endowments + Sample selectivity)

The first part on the right hand side of equation (9) measures the proportion of income differential due to discrimination. It measures how much of the income gap is due to differences in the returns to endowments (coefficients), and how it would change for the low-privileged group. The second part measures the proportion of income gap due to inter-group differences in average group characteristics such as age, experiences, education, or assets. The last part measures the proportion due to sample selection correction. Following Reimers (1983), we subtract the mean of the selection correction term from the left side of equation in order to derive income differentials corrected for sample selection bias which can be decomposed as

$$\hat{\bar{\pi}}(D) = \bar{x}_H(\hat{\beta}_H - \hat{\beta}_L) + (\hat{\beta}_L\,(\bar{x}_H - \bar{x}_L) \text{ ---------- (10)}$$

Where $\hat{\bar{\pi}}(D) \equiv (\bar{y}_H - \bar{y}_L) - (\hat{\theta}_H\hat{\lambda}_H - \hat{\theta}_L\hat{\lambda}_L)$ represents sample selection bias-adjusted estimates of the income differential.

Stata 8.0 package (Stata Corp, 2003) was used for the aforementioned analysis.

5.3 Results

5.3.1 Descriptive statistics

Table 5-2 presents a summary of the key variables used in the analysis.

Table 5-2: Descriptive statistics

Variables	Participants	Non-participants	Male headed	Female headed	High income	Low income
Sample size	96	194	235	55	142	148
Family size	6.20*	5.68	6.9***	4.78	6.06*	5.65
Age of household head (years)	42.23	40.98	40.18***	46.58	40.75	42.02
Head's education level (years)	3.50***	2.72	3.49***	0.8	3.46***	2.52
Agricultural land (ha)	2.56***	2.09	2.36***	1.78	2.53***	1.97
Value of assets (MTS)	870,469***	512,242	704,170*	317,455	842,07 8***	428,142
Unprocessed forest products used (MTS[58])	263,766	252,369	266,204*	213,146	260,423	252,033
Sale of processed forest products (MTS)	189,677	336,980	309,532	205,182	343,275	238,378
Value of crops (MTS)	5,478,188	6,017,282	6,084,104***	4,820,209	6,640,102 ***	5,080,956
Wage income (MTS)	2,242,677 ***	1,288,778	1,703,030***	1,183,782	2,043,570 ***	1,183,331
PES-income/year (MTS)	1,498,933	-	567,669***	190,824	877,347***	130,502
Cash income per capita (MTS)	7,184,881	5,012,907	1,191,818	1,041,578	1,669,885 ***	677,300

(Asterisks indicate P > |t|. *** - 1% significance; ** - 5% significance; * - 10% significance)

There are some statistically significant differences between the participants and the non-participants, in respect of household size, level of education, asset ownership and wage income earned. The participant households were larger in size; heads of the participant households had longer years of schooling (i.e. higher education) compared to the heads of the non-participant households; the participant households had larger agricultural land holding compared to the non-

[58] 1 US$ = MTS 26,500 (November 2006).

participant households; and the participant households earned a higher wage compared to the non-participant households. Similarly, the female headed households were smaller in size and had smaller land holding compared to the male headed households. Heads of the female headed households were older and had lower level of education. The value of crops produced, value of unprocessed non-timber products consumed and amount of PES-income received by the female headed households was lesser compared to the male headed households. The low income households had smaller family size, lower level of education, smaller agricultural holding, lower asset values, lower value of crops, lower wage income and lower PES-income compared to the high income households.

Clearly, the female headed and the low income households had fewer resources and were economically weak and vulnerable.

5.3.2 Overall PES-project impacts

Table 5-3 contains the bias-adjusted estimates of the Average Treatment effect on the Treated (ATT) generated from the four matching methods discussed above. It is recognised that the estimates from different matching methods vary as the methods are sensitive to the set of variables used in the propensity score and the sample size used to measure the program impact (Smith and Todd 2005). This was evident in our case.

Table 5-3: Matching estimates of PES impacts

Bias adjusted ATT	Nearest Neighbour Matching	Stratified Matching	Radius Matching	Kernel Matching
Full sample				
Expenditure per capita (MTS)	89,784***	70,762***	66,409***	53,202**
Cash income per capita (MTS)	323,000***	249,000***	277,000***	266,000***
Crop value (MTS)	-126,000	-186,000***	-278,000***	-299,000***
Forest products (MTS)	-34,000	-7,715	-30,700	-24,500
Woman headed households				
Expenditure per capita (MTS)	80,494	4,888	-57,000	-77,200
Cash income per capita (MTS)	564,000	239,000	305,000	190,000
Crop value (MTS)	80,624	-414,000***	-448,000***	-510,000***
Forest products (MTS)	39,006	28,936	15,668	-4,937
Poor households				
Expenditure per capita (MTS)	-3,524	32,896	16,566	9,793
Cash income per capita (MTS)	53,024	135,000	116,000	109,000
Crop value (MTS)	-222,000	-210,000***	-235,000***	-231,000***
Forest products (MTS)	-101,000**	-38,400*	-46,000**	-48,000***

(Asterisks represent t values of mean difference between treated and control; *, ** and *** imply significance at the 0.1, 0.05 and 0.01 probability levels, respectively)

The estimates of the project impact on the consumption expenditure (i.e. total of expense on food-grains, vegetables, meat, oil, etc.) per capita, which is a proxy for income, are positive and statistically significant across all the methods used and very close to each other. This means that the participant households incurred more consumption expenditure than what they would have, had they not participated in the project. The estimates of the impact on cash income showed a similar pattern as well. This means that in overall the PES-project impacts were positive resulting in increased cash income and consumption.

The PES-project's net impact on crop yield produced a negative estimate across all the matching methods. The results from stratification, radius and kernel matching were statistically significant. This means that the project impact on crop yields was negative. It is to be expected that tree planting in the field either along the boundaries and/or in mixed rows with crops will negatively affect crop growth, causing yield decline. Such impacts would generally be expected after the trees attain some growth. Interestingly, our estimates from all the four matching methods point to a decline in crop yields early in the project.

The project impact in terms of forest use (total value of forest products used[59]) is interesting. All four matching methods produced negative, but statistically non-significant estimates. In view of the consistency of the sign across all methods, therefore, one is tempted to conclude that the Nhambita PES-project helped reduce forest use by households.

5.3.3 Project impacts on vulnerable households

Results from Table 5-3 seem to suggest that the PES-project impacts on the woman headed households and the poor households were inconclusive. In the case of the woman headed households, the estimate on consumption expenditure was positive under nearest neighbour and stratification methods, but negative under radius and kernel matching methods, although none of them was statistically significant. On the other hand, the estimate on cash income was positive but statistically non-significant. The estimates on the value of crops were negative and significant under three of the four matching methods, probably pointing to yield decline caused by the tree planting. The estimate on the value of forest products used was positive although non-significant under three of the four methods. This means that the woman headed participant households consumed more forest resources than what they would have had they not participated.

[59] Forest products were valued by asking households to report the price of products collected and sold. (Hegde and Bull, 2008). Since wild vegetables and fuelwood are regularly consumed by all households, they were excluded in estimating the forest use.

Similarly, for the poorer households, the estimates on consumption expenditure and value of crop yields were mixed. The estimates on cash income were positive but not significant. However, the value of forest products consumed was negative under all the matching methods used and was statistically significant under radius and kernel matching methods.

5.3.4 Impact of discrimination

Table 5-4 contains the summary results from the decomposition analysis, after correcting for the sample selection bias. Between the male and the female headed households we find that 54% of the differential was due to endowments and 46% of differential was due to discrimination. Similarly, in the case of the rich and the poor households, there was discrimination in favour of the rich households. It was clear that the PES project tended to favour the male headed and the richer households.

Table 5-4: Summary of PES-income decomposition

	Bias adjusted estimates	
	Male (H) and Female (L)	Rich (H) and poor (L)
Mean prediction high (H):	14.23	13.96
Mean prediction low (L):	13.93	13.80
Raw differential (R) {H-L}	0.30	0.16
due to endowments (E)	-0.49	-0.48
due to coefficients (C):	0.04	-0.05
due to interaction (CE):	0.74	0.69
Unexplained (U)	0.137	0.104
Explained (V)	0.161	0.059
% unexplained {U/R}	46	63.8
% explained (V/R):	54	36.2

H: High privileged and non-discriminated group
L: Low privileged, discriminated group

5.4 Discussion

The PES approach emerged as a mechanism to improve the efficiency of managing natural resources, but not as a means of reducing poverty, although many proponents argued that PES-can address both conservation and development objectives (Landell Mills and Porass 2002; Pagiola et al. 2005). The PES-payments to the participants (i.e. ecosystem service providers) are said to be the main mechanism by which the PES model would contribute to poverty reduction objectives (Wunder 2008). One of the reasons for interest in using the PES model as a poverty reduction strategy includes the high incidence of poverty in rural areas and household dependence on the natural resources, where paying the poor to improve their environmental management could generate benefits to these households and to others in the form of local and global

environmental goods and services (Bulte et al. 2008). Implementing the PES-projects targeting poverty reduction needs to address two basic questions: a) do payments make poor households better off; and b) to what extent is the PES model compatible with an economically viable development trajectory for the economies as a whole (Wunder 2008). If the former is addressed adequately, it is likely to bring about the later eventually.

Our results demonstrate that the PES-project generated economic benefits. The main financial benefit in the PES-project was the cash payment. The amount of cash payment received by households was not significant (on average about MTS 1,498,933 for participating households, which is equivalent to US$60 per year), but it accounted for about 10% of total cash income of the participating household, which made carbon income quite 'visible', given the limited cash income opportunities (Hegde et al. 2009a). The project is designed in such a way that a third of the carbon sales revenue goes into a community trust fund which is used for, besides paying participating households, setting up community level enterprises. They include a carpentry unit, a saw-mill, a non-timber forest product enterprise unit, a plant-nursery and a demonstration farm. They provide employment to about 100 community members in total. Although the wage-rates offered in the project employment are generally about the same as the local wage market, the project employment serves as a regular source of salaried employment to the households that are otherwise dependent on seasonal wage work which is highly erratic. The regular salary income may be the main contributor to the increased household consumption.

How does the PES-income in the Nhambita project compare with payment in other PES-schemes? Studies suggest that the PES-payments in Latin America contributed up to 30% of total income (Kosoy et al. 2008; Miranda et al. 2003). Wunder (2008) reports that the PES-income formed over 10% of household income for over a quarter of participants in Costa Rica; PES-like schemes in Bolivia generated an annual income of US$77 to US$640 per household. Another study noted that in the Virlilla watershed in Costa Rica the PES-payment was about 16% of cash income, three quarters of households earned more than $820 per month and thereby moved out of poverty (Miranda et al. 2003). In most of the cases reported here, these are the gross PES-income estimates, without a clear picture of the returns foregone from the PES-induced restrictions, and yet, there was a net gain from PES-projects (Wunder 2008).

Our analysis suggests that the project may have resulted in a reduction in forest resource used for subsistence. This reduction is not likely to be an outcome of the rules of the PES-project since the

project did not target subsistence use of forest products. The main focus of the project was a shift from the slash-and-burn farming to settled cultivation, and thereby conservation of the *miombo* woodlands by supporting secondary growth. Therefore, the decline in forest use should not be attributed to the PES-project regulations, and this project should not be compared to those reported elsewhere that restricted access to resource use, affecting livelihoods of residents (Kerr 2002). It is possible that since the household members were engaged in the project related full time employment, they did not venture into forest in search of wild-food, which reduced the value of the forest products used.

Another impact brought out by the analysis was in the form of decline in the value of crops grown. As suggested earlier, although the precise nature and magnitude of this impact is best addressed through field experiments, the possibility of a reduction in crop-yields as a result of the tree planting is worth highlighting. The project being in early years of implementation, the participants may not have started experiencing the livelihood impacts as yet. However, during field work, households wondered about the impact of trees on their crop-yields. As long as the PES-payments at least cover the additional labour costs and the value of crop yields reduced as a result of tree planting, and the households are able to buy the food-grains using the payment, there will be incentive for participation. Given that the trees planted under the PES-scheme are such that they produce some benefits (i.e. fruits, timber, etc.) after seven to eight years (when the cash payments stop), the households are likely to find it worthwhile maintaining the trees. As long as the benefits exceed the costs, households are likely to continue their participation. Bennett (2008) recounts that some participating farmers in China's Slopping land Conversion Program experienced that tree planting on their land produced lesser benefits than what they received in their previous land use with the public payments being inadequate to cover the gap.

The results also pointed to biases in the flow of benefits in favour of the rich and the male headed households. The PES-participation was open to all the households in the Nhambita project. There was no deliberate attempt to restrict participation to better-off households. It could be possible that the economically weaker households were still waiting to see how the PES-project turned out, and delayed their participation, or they decided not to participate because of their old age, sickness or lack of labour resource as in case of single member or single parent households (Hegde et al. 2009c).

The division between the cash payments, community enterprises and community development in the Nhambita PES-project may dilute the concept of conditional incentives to participating households, but it will help an inclusive development of the community. To be effective, mode of PES-payment should be mutually agreed upon between participant households and the project implementing agency to be in cash, in-kind and technical assistance, although a more effective incentive would be in the form of small but frequent cash payments mimicking regular cash income (Wunder 2007). It is said that the impact of PES-schemes on non-participants is likely to be neutral in most cases, and in some, they may be adversely impacted due to restricted access to resources, and changes in land, labor and output markets (Wunder 2008). Considering all the factors described above, the net effects of the PES-project appear to be positive.

There were few non-monetary impacts that are not covered in the analysis. The project appeared to have contributed to technical knowledge, improvement in social capital, increased propaganda and improved community visibility. Before starting the project, the participants went through a training course on PES-planting, and thereby gained significant awareness of the environmental benefits of the project. The project also resulted in increased social and institutional networking within the community through a community association that works with the project implementing agency in prioritising the community development needs. A village development fund was created to address the broader community level needs. The project also contributed to other community development activities such as building school, construction of well, etc., and thereby indirectly benefited even non-participant households. The Nhambita project has featured in the Stern Review and received international attention. It also received several dignitaries that enhanced the visibility of the community. All of the above helped raise the profile of the project and that of the community.

5.5 Conclusion

The PES-model is currently experiencing widespread adoption in the developing world; it aims to improve ecosystem conservation while contributing to household welfare. Yet, its performance has not been widely studied, particularly in Africa.

This analysis demonstrates the welfare impacts of PES-project in a subsistence village economy in Mozambique. Particularly, it is seen that the PES-project participation resulted in higher cash income and consumption expenditure of the participant households. The vulnerable sections of the community, particularly the woman headed households and the poor households, did not

appear to have had much impact from the project. Therefore, the project implementing agency may want to pay extra attention on these aspects.

The PES-participant households may be made outright worse off by one or more of the following factors: participants being forced into participation; participants being misled through false promises; participants underestimating the opportunity costs associated with their decision and the macro-level effects; or participants making irrational decisions (Wunder 2008). As far as this research is concerned, these factors have been taken into account. Household participation was voluntary and there were no reports of breached promises or fraudulent practices concerning the project. Households did express concerns around the timing and delay in payments, which seems to be a common issue in the developing world.

It was obvious that the PES project had high growth potential. During the fieldwork, discussion was held with the project implementing agency on how the project can be further developed taking advantage of the emerging international opportunities (i.e. then avoided deforestation, which later became Reducing Emissions from Deforestation in Developing Countries; REDD) by bundling additional ecosystem services (e.g. forest fire control and improved woodland management) and expansion into new geographical areas. Subsequently, it was learnt that the Nhambita project has undergone further developments and expansion since the completion of the initial fieldwork. Paying for activities that serve to protect and conserve the *miombo* woodlands (i.e. providing fire protection during fire season) is now a part of the project under avoided deforestation. The Nhambita project idea is being replicated in new geographical areas in Mozambique and other countries.

In spite of the progress achieved so far, there were few issues worth considering as the project is on an expansion path. First, the option of enterprise-based activities and associated employment generation that exists in Nhambita may be difficult to replicate in all the new communities, given the complexities in managing these systems. The project management needs to consider an appropriate incentive mix, consisting of cash payments and community benefits, for the new communities. Second, there was a high incidence of alcoholism in Nhambita community. If unchecked, the new stream of carbon income could be spent on unproductive purposes rather than contributing to livelihood improvement. Third, with many project staff members coming from regions outside Nhambita, the project has resulted in an 'emigrant community' in Nhambita village. The emigration has resulted in an increase in the number of shops selling grocery and

non-grocery items like cloths and liquor in the village. Careful planning is required to ensure that proper hygiene is maintained and environmental problems (e.g sewage disposal) are minimised.

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6 CONCLUSION

6.1 Overview

The concept of Payments-for-Ecosystem-Services (PES) emerged as a policy tool for realigning the private and social benefits that result from decisions relating to ecosystem resource management. The PES is an incentive based approach which seeks to compensate individuals for undertaking actions that increase levels of desired ecosystem services (Jack et al. 2008). There have been calls for increased and quality research on the contribution of ecosystem services in alleviating poverty, which can guide pro-poor policy decisions that safeguard or enhance the benefits that poor people receive from forests in a sustainable manner (Angelsen and Wunder 2003; Sunderlin et al. 2005).

Literature highlights research gaps mainly in quantification of the contribution (both subsistence and cash income) of ecosystem services to the household economy and evaluation of the PES model as a policy tool to address both conservation and poverty reduction (Angelsen and Wunder 2003; Sunderlin et al. 2005). This dissertation, while investigating a range of ecosystem services accruing to the households, undertakes an evaluation of a PES project in the buffer zone of the Gorongosa National Park in Sofala Province in Mozambique.

The central research question investigated in the thesis was: Do economic incentives to smallholder farmers result in improved ecosystem services provision and improved household welfare as measured by increased household cash income and consumption? The data used in the research was generated from quarterly surveys of 290 randomly chosen households.

The dissertation consists of four manuscript chapters which address different aspects of this question. The first manuscript (Chapter 2) assessed the contribution of the *miombo* woodlands to the household economy and identified the critical socio-economic factors, such as the level of income and gender, which influence woodland resource use, through tabular analysis. The second manuscript (Chapter 3) investigated whether the *miombo* woodlands act as a safety net to the households faced with economic adversities. Based on quarterly household data on the presence or absence of shocks, it provides the first empirical evidence on the safety net role of the *miombo* woodlands, through use of conditional logit analysis. The third manuscript (Chapter 4) investigated the critical socio-economic factors influencing the household decision to participate

in the PES-program, using 3-stage estimation. The fourth manuscript (Chapter 5) empirically investigated whether the households benefitted from participating in the PES project, and also whether there were any biases in the distribution of PES-project benefits among the participants. It utilized the propensity score matching technique to assess the PES-impacts on the household cash income, consumption expenditure, forest resource use and crop yields, and decomposition analysis to identify any biases in the flow of benefits.

The first two manuscripts assess the contribution of the *miombo* woodlands ecosystem services to the household economy. They also link the smallholder households' dependence on the woodlands with their decision to participate in the PES-project, which is addressed in the third manuscript. The third manuscript investigated the determinants of household participation in the PES-project. The fourth and the final manuscript evaluated how the PES-project participation impacted the household cash income, consumption expenditure, forest resource use and crop yields.

6.2 Discussion

The *miombo* woodlands are critical for the household livelihoods in Africa (Campbell 1996; Campbell and Luckert 2002; Cavendish 2000; Dewees et al. 2008; Fisher 2002; Kaimowitz 2002; McSweeney 2002; Sale 1981; Syampungani et al. 2009). Yet, relatively little is known about the contribution of the *miombo* woodlands to the households living in the forest margins. In the earlier studies in the *miombo* regions in Zimbabwe and Malawi, the woodlands contributed about 30%-40% of the total household income (Cavendish 2000; Fisher 2002).

My findings suggest that the *miombo* woodlands contribute about 25% of total household income in Mozambique. I found that the *miombo* ecosystem provides a range of products including considerable variety of foods; a number of non-food direct uses such as medicines; a large number of wood uses including timber, fuelwood, construction material and utensils; uses of grasses, reeds, canes, etc. for thatch, mats, baskets, fodder and so on. However, the *miombo* products' collection generated relatively little cash income in the study area, and therefore had little potential to lift people out of poverty.

My research observed that the resource use varied by villages, by the income groups and by gender of the household head. Forestry and environmental products' sale and animal husbandry were the major sources of cash income in Mbalawa which was located outside the Park

boundaries; wage employment was a major source of income in Nhambita which was inside the park boundary but had a development project; and farming and fishing were the major sources of income in Pungue which was located on the river bank.

The value of the *miombo* woodland resource used by the rich households was higher than that of the poor households in absolute terms, but the income share of the woodland resources was higher for the poor households, which was similar to the pattern described in the literature (Byron and Arnold 1999; Cavendish 2000). It was observed that the rich households earned greater amount of cash income from trade of the *miombo* woodlands products than the poor households, which was also consistent with the findings reported in the literature (Shackleton et al. 2007). Finally, the research found that the female headed households, which had lower level of asset base and cash income compared to the male headed households, consumed (or used) as much forest resource as did the male headed households.

The *miombo* woodlands also help the households cope with income shocks or sudden changes in economic, social or climatic environment surrounding the household, such as death of a family member, sickness in the family, drought, flood, etc. When faced with shocks, households may search for newer forest products or increase the consumption of the products already in use and substitute them for the purchased products: this may be reflected in increased collection trips (Pattanayak and Sills 2001) or increased quantities of collection (Shackleton et al. 2007). These benefits from forests are qualitative and are difficult to quantify by estimating their direct use values (Angelsen and Wunder 2003; Shackleton et al. 2007). Using conditional logit analysis, the second manuscript (Chapter 3) provided the first empirical evidence of the safety net role of the *miombo* woodlands.

Given the low income generation potential of the non-timber resources, there is increased attention to using PES (Angelsen and Wunder 2003; Landell Mills and Porass 2002; Sunderlin et al. 2005; Pagiola et al. 2005). The Nhambita PES project, in which the household participation was voluntary, had low participation rates which raised concerns about the adequacy of PES. Although there were no specific entry barriers to participation in the PES project, certain sections of the community, particularly those practising slash-and-burn farming and charcoal and fuelwood production had little incentive to participate in the project. The empirical analysis indicated that the variable forest dependence, defined as the ratio of cash income earned from sale of forest products to the household income, was negative and significant, meaning that higher the

forest dependence the lower was the participation. Other household level factors, namely the size of household and level of education of the household head, had positive influence on participation, which is consistent with other studies (Miranda et al. 2003; Zbinden and Lee 2005).

Could the PES project act as an income generation tool, given that conditional payments are made for the provision of ecosystem services, as claimed by the PES-proponents? The results from the propensity score matching technique (Chapter 5) suggest that the participant households earned more cash income than what they would have earned without the PES project participation, and also incurred more consumption expenditure than what they would have incurred without the project participation. This suggests that the project participants were made better-off, a finding consistent with the arguments made by the PES-proponents (Landell Mills and Porass 2002; Pagiola et al. 2005; Wunder 2008). The amount of cash payment received by the participant households was modest, but it accounted for about 10% of the total cash income of the participating household, and thereby the PES project made a useful contribution given the limited cash income opportunities (Hegde et al. 2009a). The PES project is designed in such a way that a third of the carbon sales revenue goes into a community trust fund which is used for, besides paying participating households, setting up community level enterprises. The community enterprise unit, which consists of a carpentry unit, a saw-mill, a non-timber forest product enterprise unit, a plant-nursery and a demonstration farm, employs about 100 community members and provides steady wage income to households that are otherwise dependent on seasonal wage employment which is erratic. The regular wage income is likely to be the main driver behind the increased household consumption.

There were additional impacts of the PES-project. First, the analysis pointed out that the introduced tree planting may have resulted in a decline in the agricultural production (Hegde and Bull 2009). Although the precise nature and magnitude of the tree crop interaction is best addressed through agronomic experiments, the possibility of a reduction in crop-yields as a result of tree planting is noteworthy. As long as the PES-payments cover the costs of tree planting and the benefits foregone, there will be an incentive for the households to participate. Given that the trees planted under the PES-scheme are beneficial (i.e. provide green-manure, fruits, timber, etc.), households are likely to find it worthwhile maintaining the trees.

Second, although statistically not significant, the analysis suggests that the project participation may have resulted in reduced forest resource used for subsistence. This reduction is unlikely to

have been an outcome of the PES-project regulations since the project did not target subsistence use of the *miombo* woodlands. It is possible that since the household members were engaged in the project related full time employment, they did not venture into the forest in search of wild-food.

Third, in the Nhambita PES-project, splitting the revenue from carbon sales into a combination of cash payments, community enterprises development and overall community development may dilute the concept of conditional incentives to the participating households, but it does help with the community development. To be more effective, the mode of PES-payment should be mutually agreed between the participant households and the project implementing agency.

Fourth, the results indicate a bias in the benefit flow to richer and the male headed households, even though the participation was open to all the households in the Nhambita project. It may be possible that the economically weaker households were still waiting to see how the PES-project turned out, and delayed their participation, or they decided not to participate because of their old age, sickness or lack of labour resource as in the case of single member or single parent households (Hegde et al. 2009b).

Fifth, transaction cost is an important factor in the PES project. According to the literature, the Plan Vivo system, which has been adopted in the Nhambita PES project, is cost effective while working with a large number of small scale farmers and rural communities (Cacho et al. 2005). Currently, with about 2/3 of the revenue from the carbon sales spent on the project overheads and transaction costs, the farmers' share in the carbon dollar is small. Strategies are already in place to address the transaction costs problem, primarily by bundling the practices for enhancing the ecosystem services (Hegde et al. 2009b). The Nhambita project has undergone further developments and expansion since the completion of the initial fieldwork. Paying for the activities that serve to protect and conserve the *miombo* woodlands (i.e. providing fire protection during fire season) is now a part of the project. If the project succeeds in paying the farmers a larger proportion of the revenue earned from carbon sales, that will provide even greater incentive for the participation.

Finally, there were few other non-monetary impacts associated with the project. The project resulted in an improvement in technical knowledge, social capital and community visibility. Before taking up the project, the participants went through a training course on the PES-planting,

and thereby gained significant awareness of the environmental benefits. The project also led to the formation of a community association to help identify development priorities and guide developmental activities in the community. The Nhambita project has featured in the Stern Review and received the international attention.

6.3 Strengths and weaknesses

To my knowledge this is the first field research that comprehensively covers the issue of PES and household livelihoods in Africa. The research used long term (12-month), high quality data collected through survey of a large sample of respondents. The short time interval between the two rounds of surveys improved respondents' ability to recall and report on their production and consumption. The fact that the interviews were conducted in the local language by the enumerators from the same community further enhanced the credibility and quality of the information.

The research utilized data collected through questionnaire based surveys. As in any surveys, the quality of the information collected is determined by the respondent's ability to recall information. Low literacy status of the respondents further challenged their ability to recall and report. Due to lack of knowledge of the local language, I had to rely on translated information, which may have further affected the information. In the absence of standardized conversion rules, I devised rough rules for converting local units into metric units which may have influenced the quantity and value of the items reported.

Household attrition led to a significant reduction in the sample size (i.e. 45 households were dropped from a sample of 335 households). Households did drop off in different rounds of the surveys, but I have no reason to believe that the attrition was systematic (Hegde and Bull 2008).

This evaluation takes a narrow view of the PES-project, by focusing on the PES-payments and consumption patterns of households, while impacts of a PES-project, in this instance, are multidimensional. PES is generally a long term project; therefore, it requires long term observation on the household behavior.

Finally, the interrelationship between tree planting and agricultural production is a key factor that can make or break the deal in terms of continued household participation. It needs to be precisely established through field experiments.

6.4 Contributions of the research

The thesis evaluates the role of ecosystem services in household livelihoods. The first two manuscripts evaluate the contribution of broader ecosystem services to the household economy both quantitatively as well as qualitatively. The third manuscript examined the determinants of household participation in the PES program. It demonstrated that forest dependence, measured as a ratio of income from sale of forest products to total household income, was an important factor influencing the household participation. The household participation in the PES-project is important because it examines if there are any entry barriers to participation. The fourth and final manuscript evaluates the impacts of the PES project participation on the household cash income, consumption, forest use and agricultural production. It also investigates the presence of any discrimination in the flow of project benefits.

This research broadly contributes to the literature linking forest ecosystem resources with household livelihoods. The research was conducted using the data from a large sample of households in remote villages on the *miombo* woodlands resource use, income generation from different vocations, household income shocks and shock coping strategies. The data generated was amenable to analysis using a range of advanced analytical techniques. The research demonstrated that the woodlands made significant contribution to the household income and consumption. The household participation in PES-projects is influenced by both obvious factors (such as education; length of residence, etc.) and also complex factors (such as resource dependence; trust and networking). The PES-project led to an improvement in household welfare by increasing household cash income and consumption.

The specific contributions include (a) a rigorous estimation of the forest resource use by the households in the forest frontier; (b) a comprehensive household income and expenditure account recorded on a quarterly basis; (c) a novel empirical technique that demonstrated the role of forest ecosystem services as safety net; (d) an assessment of the socio-economic drivers of household participation in the PES project; and (e) an evaluation of the PES project impacts on the household welfare.

6.5 Policy recommendations

The main application of the research findings would be in formulating the forestry and environmental policies and how they relate to household livelihoods and socio-economic development plans for the forests. The research findings on the potential of the PES projects in

addressing both conservation and poverty would be useful in PES-based policy and program development, including improving household participation, resource access and incentive design.

The research provides the following policy recommendations.

1) There is a need to incorporate the *miombo* woodlands as part of the broader poverty alleviation strategies. The *miombo* woodlands make significant contribution to household economy by providing a variety of products for consumption and cash income and also by acting as a "cushion" which prevents the deepening of poverty among the communities.
2) There is need for investment in rural enterprises to enhance the value of the woodlands products through local value-addition and new products development (e.g. bee keeping, bamboo based enterprises, etc). It was found that the NTFPs currently generated very little cash income in the study area.
3) There is a need for expanding the PES-model to other geographical areas. The field evidence in this research suggests that the PES projects can serve both as a conservation and poverty reduction tool.
4) There is a need for an incentive mechanism that ensures that the PES payment compensates for the welfare loss to the participant households. The research points out that PES participation may involve significant welfare loss (i.e. leading to a decline in agricultural productivity, increase in labor costs etc.).
5) There is a need for an effective community organization that relies on transparent information flows and is empowered to effectively monitor the PES-project impact on agricultural production, local livelihoods (including the pattern of PES-income utilization by the participant households) and overall woodland conservation, and communicate the same with the project implementing agency to ensure that appropriate remedial measures are taken to mitigate any adverse impacts.

6.6 Future research

Due to paucity of time and resources, the field research was limited to 12-month duration. To capture the full impacts, this research should be repeated at regular intervals using a larger sample and in different PES-project sites. Since the PES-project impacts are multi-dimensional, its evaluation should have a multi-pronged strategy, focusing on households, communities and landscape. The PES-project impacts could be of long term nature. The following areas need consideration in the future.

a) Evaluation of the PES-payments and their utilization over a longer term in multiple locations.
b) Evaluation of PES planting impacts on the agricultural production. The analysis could focus on measuring the changes in yields under different planting systems.
c) Evaluation of permanence, additionality and leakage under the PES project over a longer term.
d) Evaluation of the landscape level impacts of the PES project.

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APPENDICES

Appendix 1: Country and survey information (C1)

1. Please provide the following information about the study area.

Name of the country	
Name of region(s) (province, state, etc.)	
Name of district(s)	

2. Please provide the following information about the timing of the surveys.

Survey	**Date** (yyyymmdd)
Start of surveys	
Completion of all surveys	
Start of VS1	
Start of VS2	
Start of HS1	
Start of HS2	
Start of QS1	
Start of QS2	
Start of QS3	
Start of QS4	

Appendix 2: Village survey 1 (V1)

Control information

Task	**Date(s)**	**By who?**	**Status OK? If not, give comments**
Meeting with officials			
Village/focus group meetings			
Other interviews			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Geographic and climate variables

What is the name of the village?	1. (name)	2. (village ##)
What are the GPS coordinates of the centre of the village? (UTM format)		
What is the latitude of the village?		degrees
What is the longitude of the village?		degrees
What is the altitude (masl) of the village?		masl
What has been the average annual rainfall (mm/year) in the district during the past 20 years (or less, see guidelines)?		mm/year
What is the coefficient of variation in rainfall for the past 20 years? (Note: To be filled in if data are readily available.)		

B. Demographics

In what year was the village established?	
What is the current population of the village?	persons
How many households live currently in this village?	households
What was the total population of the village 10 years ago?	persons
How many households lived in the village 10 years ago?	households
How many persons (approx.) living here now have moved to the village in the past 10 years (in-migration)?	persons
How many persons (approx.) have left the village over the past 10 years (out-migration)?	persons
How many different groups (ethnic groups, tribes or castes) are living in the village?	

C. Infrastructure

How many households (approx.) in the village have access to electricity (from public or private suppliers)?	households
How many households (approx.) in the village have access to (= use) piped tap water?	households
How many households (approx.) have access to formal credit (government or private bank operating in the village)?	households
Are informal credit institutions such as savings clubs and money lenders present in the village?	(1-0)
Is there any health centre in the village?	(1-0)
A. Are there any primary schools in the village?	(1-0)

Does the village have at least one road useable by cars during all seasons? If 'yes', go to 8.		(1-0)		
If 'no': what is the distance in kilometers to the nearest road usable during all seasons?		Km		
Is there a river within the village boundaries that is navigable during all seasons? If 'yes', go to 10.		(1-0)		
If 'no': what is the distance to the nearest river that is navigable during all seasons?		Km		
What is the distance from the village centre to the nearest … (in km and in minutes by most common means of transport)		**1. km**	**2. min**	**3. code-transport**
	district market			
	market for major consumption goods			
	market where agric. products are sold			
	market where forest products are sold			

D. Forest and land cover/use

1. Land categories in the village (approx. area in hectares).

Land category	**1. Total area (ha)**	**Ownership (ha)**			
		2. State	**3. Community**	**4. Private**	**5. Open access (de facto)**
Forest:					
Natural forest					
Managed forests					
Plantations					
Agricultural land:					
Cropland					
Pasture (natural or planted)					
Agroforestry					
Silvipasture					
Fallow					
Other land categories:					
Shrubs					
Grassland					
Residential areas, infrastructure					
Wetland					
Other, specify:					
Total land					

2. What are the main forest types, users and products in the village?

1.Type of forest (code-forest)	**2.Ownership** (code-tenure)	**3.Approx. area** (ha)	**Main users[1] (max. 3)**			**Main products (max. 3)** (code-product)		
			4.Rank 1	**5.Rank2**	**6.Rank 3**	**7.Rank1**	**8.Rank2**	**9.Rank3**

By "main users" is meant those who have acquired the highest value of forest products (subsistence and cash) from a given forest type in the past 12 months.
Codes: Choose the most appropriate among the following groups (as some do overlap):
villagers that are members of FUG;
villagers not members of FUG;
subsistence oriented users in the village;
small-scale commercial users in the village;
large-scale commercial users in the village;
subsistence oriented users from outside the village;
small-scale commercial users from outside the village;
large-scale commercial users from outside the village;
other, specify:

3. Does the village practice any form of active and deliberate forest management?

Type of management	**Code[1]**
Planting of trees	
Cutting down undesired (competing) trees	
Protecting certain desired (patches of) trees in the forest to promote the natural regeneration of these species	
Protecting areas of forest for particular environmental services, like water catchment	
Establishing clear use rights for a limited number of people to particular forest products (e.g., honey trees)	
9. Other, specify:	

1) Codes: 0=no, not at all; 1=yes, but only to a limited extent; 2=yes, they are common.

DA. Food aid.

Has the village (as a community or individuals in the village) received any food aid over the past 12 months? Codes: 0=no; 1=yes, directly to households; 2=yes, directly to village; 3=yes, both to household and village	

E. Forest resource base

		1. Fire-wood or charcoal	2. Timber or other wood	3. Food from the forest	4. Medicine from the forest	5. Forage from the forest	6. Other[1)]
1. What is the most important product (MIP) for the livelihood of the people in the village (in this category)? [2)] (name)							
2. (code-product)							
3. How has availability of the MIP changed over the past 5 years? Codes: 1=declined; 2=about the same; 3=increased							
4. If the availability of the MIP in this category has **declined**, what are the reasons? Please rank the most important reasons, max. 3 (leave rest blank).	**Reason**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**
	Reduced forest area due to small-scale clearing for agriculture						
	Reduced forest area due to large-scale projects (plantations, new settlements, etc.)						
	Reduced forest area due to people from outside buying land and restricting access						
	Increased use of MIP due to more local (village) people collecting more						

		1. Fire-wood or charcoal	2. Timber or other wood	3. Food from the forest	4. Medicine from the forest	5. Forage from the forest	6. Other[1)]
	Increased use of MIP due to more people from other villages collecting more						
	Restrictions on use by central or state government (e.g., for forest conservation)						
	Local restrictions on forest use (e.g., community rules)						
	Climatic changes, e.g., drought and less rainfall						
	9. Other, specify:						
5. If the availability of the MIP in this category has **increased**, what are the reasons? Please rank the most important reasons, max. 3.	**Reason**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**
	Less clearing of forests for agriculture (incl. pastoralism)						
	Fewer local (village) people collecting less						
	Fewer people from other villages collecting less						
	Reduced use from large-scale commercial users/projects						

		1. Fire-wood or charcoal	2. Timber or other wood	3. Food from the forest	4. Medicine from the forest	5. Forage from the forest	6. Other[1)]
	Changes in management of forests						
	Climatic changes, e.g., more rainfall						
	Other, specify:						
6. What would be most important to increase the benefits (use or income) from the MIP? Please rank the most important reasons, max. 3.	**Action**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**
	Better access to the forest/MIP, i.e., more use rights to village						
	Better protection of forest/MIP (avoid overuse)						
	Better skills and knowledge on how to collect/use it						
	Better access to credit/capital and equipment/technology						
	Better access to markets and reduced price risk						
	9. Other, specify:						

1) Select the most important product for the village that do not fall into any of the other five categories.
2) "Most important" is defined as the most important for the wellbeing of the village, whether it be through direct use in the home, or through sale for cash, or both.

F. Forest institutions

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	1. Fire-wood or charcoal	**2. Timber or other wood**	**3. Food from the forest**	**4. Medicine from the forest**	**5. Forage from the forest**	**6. Other[1)]**
What is the most important product (MIP) for the livelihood of the people in the village (in this category)? (name)						
(code-product)						
In what type of forest do you get the MIP? (code-forest)						
What is the ownership status of this forest (code-tenure)						
Are there customary rules regulating the use of the MIP in the village? Codes: 0=none/very few; 1=yes, but vague/unclear; 2=yes, clear rules exist If code '0', go to 7.						
If 'yes': are the customary rules regarding forest use enforced /respected by the population of the village?[1)]						
Are there government rules that regulate forest use? Codes: 0=none/very few; 1=yes, but vague/unclear; 2=yes, clear rules exist If code '0', go to 9.						
If 'yes' (code '1' or '2' above): are the government rules enforced/respected by the members in the village?[1)]						
Do the villagers require any permission to harvest the MIP? Codes: 0=no; 1=yes, users have to inform the authorities; 2=yes, written permission needed If code '0', go to next section.						
If 'yes' (code '1' or '2' above): does the user have to pay for the permission?	(1-0)	(1-0)	(1-0)	(1-0)	(1-0)	(1-0)
If 'yes': who issues this permit? Codes: 1=village head; 2=FUG; 3=forest officer (forest departments); 4=other government official; 9=other, specify:						

1) Codes: 0=no/very little; 1=to a certain extent by some groups of villagers; 2=to a certain extent by everyone; 3=yes, but only by some groups of villagers; 4=yes, by everyone; 9=no particular rules exist.

Appendix 3: Village survey 2 (V2)

Control information

Task	Date(s)	By who?	Status OK? If not, give comments
Meeting with officials			
Village/focus group meetings			
Other interviews			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Geographic and climate variables

What is the name of the village?	*(name)	(village ##)
What was the total rainfall in the village for the past 12 months?		mm/year
If rainfall data not available (question 2): How was the rainfall past 12 months compared with a normal year (=average last 20 years)? Codes: 1=well below normal (< 50 %); 2=below normal (50-90%); 3=normal (90-110%); 4=above normal (110-150%); 5=well above normal (> 150%)		

B. Risk

Has the village faced any of the following crises over the past 12 months? Codes: 0=no; 1=yes, moderate crisis; 2=yes, severe crisis	Flood and/or excess rain	
	Drought	
	Wild fire (in crops/ forest/grasslands etc)	
	Widespread crop pest/disease and or animal disease	
	Human epidemics (disease)	
	Political/civil unrest	
	Macro-economic crisis	
	Refugee or migration infusion	
	Other, specify:	

C. Wages and prices

What was the typical daily wage rate for unskilled agricultural/casual adult **male/female** labour during the **peak/slack** season in this village over the past 12 months? (Lc$/day)		**Male**	**Female**
	Peak	1.	2.
	Slack	3.	4.
What is the main staple food in the village? (code-product)			
What was the price of a kg of the main staple food during the past 12 months **before** and **after** the main agricultural harvest? (Lc$/kg)		**1. Before harvest**	**2. After harvest**
What is the sales value of one hectare of good agricultural land in the village (i.e., not degraded, not too steep, and suitable for common crops, and within 1km of the main road or settlement) (Lc$/hectare)			

D. Forest services

Has the village (as a community or individuals in the village) received any direct benefits (in kin or in cash) related to forest services over the past 12 months? Codes: 0=no; 1=yes, directly to households; 2=yes, directly to village (e.g., development project); 3=yes, both to household and village		
If the village has received payment (code 2 or 3 above), please indicate the amount the village has received.	**Payments related to:**	**Amount**
	1. Tourism	
	2. Carbon sequestration	
	3. Water catchment	
	4. Biodiversity conservation	
	9. Other, specify:	
Has the village received any forestry-related external support (technical assistance, free inputs, etc.) from government, donors, NGOs) over the past 12 months?	(1-0)	

Note: If any such payment or assistance has been received it should be elaborated in the village narrative.

E. Food aid.

Has the village (as a community or individuals in the village) received any food aid over the past 12 months? Codes: 0=no; 1=yes, directly to households; 2=yes, directly to village; 3=yes, both to household and village	

Appendix 4: Annual household survey 1 (A1)

Control information

Task	**Date(s)**	**By who?**	**Status OK? If not, give comments**
Interview			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Identification

1. Identification and location of household.

Household number		
Village	*(name)	(village ##)
District		
Name and PID (see B. below) of primary respondent	*(name)	(PID)
Name and PID (see B. below) of secondary respondent	*(name)	(PID)
GPS reference point of household (UTM format)		
Distance of the household from the centre of village (in minutes of walking and in km)	1. min	2. km

B. Household composition

1. Who are the members of the household?

1. Personal Identification number (PID)	*** Name of household member**	**2. Relation to household head[1)]**	**3. Year born** (yyyy)	**4. Sex** (0=male 1=female)	**5. Education** (number of years completed)
1		Household head			
2					
3					
4					

1) Codes: 1=spouse; 2 son/daughter; 3=son/daughter in law; 4=grandchild; 5=mother/father; 6=mother/father in law; 7=brother or sister; 8=brother/sister in law; 9=uncle/aunt; 10=nephew/niece; 11=step/foster child; 12=other family; 13=not related.

2. We would like to ask some questions regarding the head of this household.

What is the marital status of household head? Codes: 1=married and living together; 2=married but spouse working away; 3=widow/widower; 4=divorced;; 5=never married; 9=other, specify:	
How long ago was this household formed (see definition of household)	years
Was the household head born in this village? If 'yes', go to 5.	(1-0)
If 'no': how long has the household head lived in the village?	years
Does the household head belong to the largest ethnic group/caste in the village?	(1-0)

What is the source of water (tick as appropriate):

Well/open well
Borehole
Stream
Rainwater tank

How far is the water source (tick as appropriate):

Less than 100m
Between 100m and 500m
Between 500m and 1 km
More than 1 km

Who in the household fetches water (prompt for up to three persons)

Mention	Name of the person	PID	Average number of trips per day	How long does each round trip take (including waiting time)	Quantity of water each trip (liter)
First					
Second					
Third					

What is the source of energy: (tick as appropriate)

Source	Cooking	Lighting	Space heating
Wood			
Charcoal			
Kerosene			
Electricity			
Others			

C. Land

1. Please indicate the amount of land (in hectares) that you currently own and have rented in/out.

Note: See definitions of land categories in the Technical Guidelines.

Category	**1. Area** (ha)	**2. Ownership** (code-tenure)	**Main crops grown/harvested in the past 12 months** **Max 3** (code-product)		
			3. Rank1	**4. Rank2**	**5. Rank3**
Natural forest					
Managed forests					
Plantations					
Cropland					
Pasture (natural or planted)					
Agroforestry					
Silvipasture					
Fallow					
Other vegetation types/land uses (residential, bush, grassland, wetland, etc.)					
Total land owned (1+2+3+…+9)					
Land rented out (included in 1-9)					
Land rented in (not included in 1-9)					

Note: During RRA exercises at village level we will identify the most common crop species

2. Land value

What is the average sales value of one hectare of agricultural crop land that you own?	

D. Assets and savings

1. Please indicate the type of house you have?

1. Do you have your own house? [1)]	
2. What is the type of material of (most of) the walls? [2)]	
3. What is the type of material of (most of) the roof ? [3)]	
4. How many m^2 approx. is the house?	m^2

1) Codes: 0=no; 1=own the house on their own; 2=own the house together with other household(s); 3=renting the house alone; 4=renting the house with other household(s); 9=other, specify:

2) Codes: 1=mud/soil; 2=wooden (boards); 3=iron (or other metal) sheets; 4=bricks or concrete; 9=other, specify:

3) Codes: 1=thatch; 2=wooden (boards); 3=iron or other metal sheets; 4=tiles; 9=other, specify:

2. Please indicate the number and value of implements and other large household items that are owned by the household.

	1. No. of units owned	**2. Total value (current sales value of all units, not purchasing price)** (Lc$. If asset not owned, put '0')
Car/truck		
Tractor		
Motorcycle		
Bicycle		
Handphone/phone		
TV		
Radio		
Cassette/CD/ VHS/VCD/DVD/ player		
Stove for cooking (gas or electric only)		
Refrigerator/freezer		
Fishing boat and boat engine		
Chainsaw		
Plough		
Scotch cart		
Shotgun/rifle		
Others (worth more than approx. 50 USD purchasing price)		

3. Please indicate the savings and debt the household has.

How much does the household have in savings in banks, credit associations or savings clubs?	Lc$
How much does the household have in savings in non-productive assets such as gold and jewelry?	Lc$
How much does the household have in outstanding debt?	Lc$

DA. Variability of agricultural production

1. What has been the production output for the most important agricultural crops over the last 5 years - in terms of bad, normal and good years?

Agricultural crop	Bad year		Normal year (total production)		Good year (total production)	
	Total production	Year	Total production	Year	Total production	Year

E. Forest resource base

How far is it from the house/homestead to the edge of the nearest natural or managed forest that you have access to and can use?	1. … measured in terms of distance (straight line)?	km
	2. … measured in terms of time (in minutes of walking)?	min
Does your household collect firewood? If 'no', go to 8.		(1-0)

If 'yes': how many hours per week do the members of your household spend on collecting firewood for family use?		(hours)
Does your household now spend more or less time on getting firewood than you did 5 years ago? Codes: 1=more; 2=about the same; 3=less		
How has availability of firewood changed over the past 5 years? Codes: 1=declined; 2=about the same; 3=increased If code '2' or' 3', go to 7.		
If declined (code '1' on the question above), how has the household responded to the decline in the availability of firewood? Please rank the most important responses, max 3.	**Response**	**Rank 1-3**
	Increased collection time (e.g., from further away from house)	
	Planting of trees on private land	
	Increased use of agricultural residues as fuel	
	Buying (more) fuelwood and/or charcoal	
	Buying (more) commercial fuels (kerosene, gas or electricity)	
	Reduced the need for use of fuels, such as using improved stove	
	Reduced fuelwood consumption	
	9. Other, specify:	
Has your household planted any woodlots or trees on farm over the past 5 years? If 'no', go to next section.		(1-0)
If yes: what are the main purpose(s) of the trees planted? Please rank the most important purposes, max 3.	**Purpose**	**Rank 1-3**
	Firewood for domestic use	
	Firewood for sale	
	Fodder for own use	
	Fodder for sale	
	Timber/poles for own use	
	Timber/poles for sale	
	Other domestic uses	
	Other products for sale	
	9. Carbon sequestration	
	10. Other environmental services	
	19. Other, specify:	

EA. Trees on farm

1. Does the household have any trees on farm land? (1/0):

If 1, please provide the following information:

SN	Species	Number of trees	Location	Planted or natural	Age of tree	Source of seedling	Purpose of planting

(Codes: 1=Timber; 2= Fruits; 3= Fodder; 4= Manure; 5= PES; 6= to claim ownership of land, 7=other, specify)

2. If trees are combined with crops, what is the combination (please tick as appropriate):

Crops in the center of the field with trees planted along the border
Trees and crops mixed in the field
Crops planted only in the initial stages of trees, with only trees later on
Any other (specify):

3. For how many years have you been following this system (years)?

4. Is the household involved in PES (carbon project) ? (1/0)

4. If the household is involved in PES (carbon) project, please provide the following information:

Which year did the household get involved in the project:

Did you sign any contract with the project management ?

Did you plant any trees ? IF yes, please provide the following information

Year of planting	Species	Number of seedlings planted	Who decided on the species to be planted (use codes)[1] 1= household members 2 = project management	System of planting (use codes)[2]

Codes
1 = planting on the fallow land
2 = planting on crop land along the bunds
3 = planting in the field along crops
4 = Other, specify

5. If the trees are planted by the household, did the household clear the land prior to planting?
No (0) Yes(1) Land was already cleared (2)

6. If yes (1), please indicate:

SN	Member (PID)	No of days worked in clearing	Number of hours worked per day

7. Did your household plough the land or dig holes before planting seedlings ? (1/0)

8. In which season, did you plough/dig holes

Dry Wet

9. Which member of the household was involved in plowing / digging holes

SN	Member (PID)	Species	No of days worked in plowing/digging	Number of hours worked per day

10. Did you water your seedlings (1/0)

11. In which year of planting did you water the seedlings (tick as appropriate)

1st year 2nd year 3rd year beyond 3rd year

12. How many times did you water the plants during the last year:

Year	Species	Frequency of watering
First year		
Second year		
Third year		
Beyond third year		

13. How many buckets/ containers of water were required for one round of watering ?

14. Which member of the household was involved in watering:

SN	Member (PID)	Species	No of days worked in watering	Number of hours worked per day

15. Did your household add any organic matter to the seedlings ? (1/0)

16. In which year did you add the organic matter (tick as appropriate):

First Second Third Beyond third year

17. What did you use as organic matter (tick as appropriate):

Manure Leaf litter Other (specify)

18. In which season, did you add the organic matter (tick as appropriate):

Dry Wet

19. Which member of the household was involved in adding organic matter

SN	Member (PID)	Species	No of days worked in adding organic matter	Number of hours worked per day	

20. Did your household do any weeding around the planted seedlings ? (1/0)

21. In which year did you add the clear the weeds (tick as appropriate):

First Second Third Beyond third year

22. In which season, did you add the organic matter (tick as appropriate):

Dry Wet

23. Which member of the household was involved in weeding

SN	Member (PID)	Species	No of days worked in weeding	Number of hours worked per day	

24. Did your household replace any dead seedlings (1/0)

25. In which year did you replace the seedlings (tick as appropriate):

First Second Third Beyond third year

26. Which member of the household was involved in weeding

SN	Member (PID)	Species	Source of seedlings	Price of seedlings	No of days worked in re-planting	Number of hours worked per day

27. Did your household apply any plant protection chemicals to these plants (1/0):

28. Did you build any fire breaks around the plants (1/0)

29. Did you build any fence around the plants (1/0)

30. Did any member of your household receive any other benefits by participating in the carbon project?

Benefits	Description	Income or saving	Cash / kind	Monetary income/ equivalent	Frequency of receipt
Income					
Direct employment					
Training					
Tools/ implements					
Fruits / nuts					
Timber					
Fuelwood					
Fodder					
Increased crop yield					
Honey					
Bank account					
Other					

31. Did your household ever harvest the trees or tree products in the past: (1/0)

SN	Species	Main product	Total quantity harvested	Quantity consumed at home	Quantity sold	Revenue obtained

32. Did you ever hire any labor for managing the trees: (1/0)

SN	Species	# Hired labor			Wage paid
		M	F	C	

33. Wage rate:

Male: Female: Child:

34. Do you have bee-boxes underneath the trees: (1/0):

35. If yes, have you harvested honey in the last one year (1-0):

36. If yes, please provide the following information:

Quantity harvested:

Quantity consumed at home:

Quantity sold:

Revenue earned:

37. In your experience, what is the impact of trees on crop yields (tick as appropriate):

Crop yields decline
Crop yields increase
No effect

Appendix 5: Annual household survey 2 (A2)

Control information

Task	**Date(s)**	**By who?**	**Status OK? If not, give comments**
Interview			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Identification

Household number		
Village	*(name)	(village ##)
District		
Name and PID of primary respondent	*(name)	(PID)
Name and PID of secondary respondent	*(name)	(PID)

B. Crisis and unexpected expenditures

1. Has the household faced any major income shortfalls or unexpectedly large expenditures during the past 12 months?

Event	**1. Code[1)]**	**2. Estimated income loss or costs**	**How did you cope with the income loss or costs?** Rank max. 3[2)]		
			3.Rank1	**4.Rank2**	**4.Rank3**
1. Serious crop failure					
2. Serious illness in family (productive age-group adult unable to work for more than one month during past 12 months, due to illness, or to taking care of ill person)					
3. Death of productive age-group adult					
4. Land loss (expropriation, etc.)					
5. Major livestock loss (theft, drought, etc.)					
6. Other major asset loss (fire, theft, flood, etc.)					
7. Lost wage employment					
8. Wedding					
9. Other, specify:					

1) Codes: 0=no; 1=yes, moderate crisis; 2=yes, severe crisis. See Technical Guidelines for definitions.

2) Codes:

1. Harvest more forest products; 2. Harvest more wild products not in the forest; 3. Harvest more agricultural products; 4. Spend cash savings; 5. Sell assets (land, livestock, etc.); 6. Do extra casual labour work; 7. Assistance from friends and relatives; 8. Assistance from NGO, community org., religious org. or similar; 9. Get loan from money lender, credit association, bank etc.; 10. Tried to reduce household spending; 11. Did nothing in particular; 19. Other, specify:

C. Forest services

1. Has the household over the past 12 months received any cash or in kind payments related to the following forest services?

Principal purpose	**1. Have received?** (1-0)	**2. If yes, amounts (values) received** (Lc$) (if nothing, put '0')
Tourism		
Carbon projects		
Water catchments projects		
Biodiversity conservation		
Others, specify:		

CA. Trees on farm

1. Does the household have any trees on farm land? (1/0):

If 1, please provide the following information:

SN	Species	Number of trees	Location	Planted or natural	Age of tree	Source of seedling	Purpose of planting

(Codes: 1=Timber; 2= Fruits; 3= Fodder; 4= Manure; 5= PES; 6= to claim ownership of land, 7=other, specify)

2. If trees are combined with crops, what is the combination (please tick as appropriate):

1. Crops in the center of the field with trees planted along the border
2. Trees and crops mixed in the field
3. Crops planted only in the initial stages of trees, with only trees later on
4. Any other (specify):

3. For how many years have you been following this system (years)?

4. Is the household involved in PES (carbon project) ? (1/0)

4. If the household is involved in PES (carbon) project, please provide the following information:

Which year did the household get involved in the project:

Did you sign any contract with the project management ?

Did you plant any trees ? IF yes, please provide the following information

Year of planting	Species	Number of seedlings planted	Who decided on the species to be planted (use codes)[1] 1= household members 2 = project management	System of planting (use codes)[2]

Codes
1 = planting on the fallow land
2 = planting on crop land along the bunds
3 = planting in the field along crops
4 = Other, specify

5. If the trees are planted by the household, did the household clear the land prior to planting?
No (0) Yes(1) Land was already cleared (2)

6. If yes (1), please indicate:

SN	Member (PID)	No of days worked in clearing	Number of hours worked per day	

7. Did your household plough the land or dig holes before planting seedlings ? (1/0)

8. In which season, did you plough/dig holes

Dry Wet

9. Which member of the household was involved in plowing / digging holes

SN	Member (PID)	Species	No of days worked in plowing/digging	Number of hours worked per day

10. Did you water your seedlings (1/0)

11. In which year of planting did you water the seedlings (tick as appropriate)

1st year 2nd year 3rd year beyond 3rd year

12. How many times did you water the plants during the last year:

Year	Species	Frequency of watering
First year		
Second year		
Third year		
Beyond third year		

13. How many buckets/ containers of water were required for one round of watering ?

14. Which member of the household was involved in watering:

SN	Member (PID)	Species	No of days worked in watering	Number of hours worked per day

15. Did your household add any organic matter to the seedlings ? (1/0)

16. In which year did you add the organic matter (tick as appropriate):

First Second Third Beyond third year

17. What did you use as organic matter (tick as appropriate):

Manure Leaf litter Other (specify)

18. In which season, did you add the organic matter (tick as appropriate):

Dry Wet

19. Which member of the household was involved in adding organic matter

SN	Member (PID)	Species	No of days worked in adding organic matter	Number of hours worked per day

20. Did your household do any weeding around the planted seedlings ? (1/0)

21. In which year did you add the clear the weeds (tick as appropriate):

First Second Third Beyond third year

22. In which season, did you add the organic matter (tick as appropriate):

Dry Wet

23. Which member of the household was involved in weeding

SN	Member (PID)	Species	No of days worked in weeding	Number of hours worked per day

24. Did your household replace any dead seedlings (1/0)

25. In which year did you replace the seedlings (tick as appropriate):

First Second Third Beyond third year

26. Which member of the household was involved in weeding

SN	Member (PID)	Species	Source of seedlings	Price of seedlings	No of days worked in re-planting	Number of hours worked per day

27. Did your household apply any plant protection chemicals to these plants (1/0):

28. Did you build any fire breaks around the plants (1/0)

29. Did you build any fence around the plants (1/0)

30. Did any member of your household receive any other benefits by participating in the carbon project?

SN	Benefits	Description	Income or saving	Cash / kind	Monetary income/ equivalent	Frequency of receipt
	Direct employment					
	Training					
	Tools/ implements					
	Fruits / nuts					
	Timber					
	Fuelwood					
	Fodder					
	Increased crop yield					
	Honey					
	Bank account					
	Other					

31. Did your household ever harvest the trees or tree products in the past: (1/0)

SN	Species	Main product	Total quantity harvested	Quantity consumed at home	Quantity sold	Revenue obtained

32. Did you ever hire any labor for managing the trees: (1/0)

SN	Species	# Hired labor			Wage paid
		M	F	C	

33. Wage rate:

Male: Female: Child:

34. Do you have bee-boxes underneath the trees: (1/0):

35. If yes, have you harvested honey in the last one year (1-0):

36. If yes, please provide the following information:

Quantity harvested:

Quantity consumed at home:

Quantity sold:

Revenue earned:

37. In your experience, what is the impact of trees on crop yields (tick as appropriate):

Crop yields decline
Crop yields increase
No effect

D. Forest clearing

Did the household clear any forest during the past 12 months? If 'no', go to 9.		(1-0)		
If YES:	How much land was cleared?	Ha		
	What was the cleared land used for? Codes: 1=cropping; 2=tree plantation; 3=pasture; 4=non-agric uses (Rank max 3)	1.Rank1	2.Rank2	3.Rank3
	If used for crops (code '1' in question above), which principal crop was grown? (code-product) Rank max 3	1.Rank1	2.Rank2	3.Rank3
	What type of forest did you clear? (code-forest)			
	If secondary forest, what was the age of the forest?	Years		
	What was the ownership status of the forest cleared? (code tenure)			
	How far from the house was the land cleared located?	Km		
Has the household over the last 5 years cleared forest? If 'no', go to 11.		1-0		
If 'yes': how much land (approx.) has been cleared over the last 5 years?		Ha		
How much land used by the household has over the last 5 years been abandoned (left to convert to natural re-vegetation)?		Ha		

E. Total household consumption on non-food occasional

In the past one year, how much was spent on:

	Items	Amount
A	**Household**	
1	Kitchen equipment	
2	House maintenance & repair	
3	Furniture	
4	Bedding, etc.	
B	**Clothing & footwear**	
1	Shoes for adults and children	
	Clothes for adults and children	
	Clothing material	
C	**Healthcare**	
1	Hospital and doctors' fees	
2	Dentists	
3	Medical supplies	
4	Traditional healers	
D.	**Luxury items**	
1	Holidays, jewelry, etc.	
E.	**Schooling**	
	School fees	
	School uniforms	
	School books	
	Other school costs	

Appendix 6: Quarterly household surveys (Q1-Q4)

Control information

Task	**Date(s)**	**By who?**	**Status OK? If not, give comments**
Interview			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Identification

Household number		
Village	*(name)	(village ##)
District		
Name and PID of primary respondent	*(name)	(PID)
Name and PID of secondary respondent	*(name)	(PID)

B. Direct forest income (income from unprocessed forest products)

1. What are the quantities and values of raw-material forest products the members of your household collected for both own use and sale over **the past month**?

Note: Answers in columns 3 and 4 should be consistent with land categories reported in village questionnaire (V1D01) and in the annual household questionnaire (A1C).

1. Forest product (code-product)	**2. Collected by whom?[1)]**	**Collected where?**		**5. Quantity collec-ted (7+8)**	**6. Unit**	**7. Own use (incl. gifts)**	**8. Sold (incl. barter)**	**9. Price per unit**	**10. Type of market** (code-market)	**11. Gross value (5*9)**	**12. Tran-sport/ marketing costs (total)**	**13. Purch. inputs & hired labour**	**14. Net income (11-12-13)**
		3. Land type (code-land)	**4. Ownership** (code-tenure)										

1) Codes: 1=only/mainly by wife and adult female household members; 2=both adult males and adult females participate about equally; 3=only/mainly by the husband and adult male household members; 4=only/mainly by girls (<15 years); 5=only/mainly by boys (<15 years); 6=only/mainly by children (<15 years), and boys and girls participate about equally; 7=all members of household participate equally; 8=none of the above alternatives.

C. Forest-derived income (income from processed forest products)

1. What are the quantities and values of processed forest products that the members of your household produced during **the past month?**

1. Product (code-product)	**2. Who in the household did the work?[1)]**	**3. Quantity produced (5+6)**	**4. Unit**	**5. Own use (incl. gifts)**	**6. Sold (incl. barter)**	**7. Price per unit**	**8. Type of market** (code-market	**9. Gross value (3*7)**	**10. Purchased inputs & hired labour**	**11. Transport/ marketing costs**	**12. Net income excl. costs of forest inputs (9-10-11)**

1) Codes: 1=only/mainly by wife and adult female household members; 2=both adult males and adult females participate about equally; 3=only/mainly by the husband and adult male household members; 4=only/mainly by girls (<15 years); 5=only/mainly by boys (<15 years); 6=only/mainly by children (<15 years), and boys and girls participate about equally; 7=all members of household participate equally; 8=none of the above alternatives.

2. What are the quantities and values of unprocessed forest products used as inputs to produce the processed forest products in the table above?

Note: The products in column 1 should be exactly the same as those in column 1 in the table above.

1. Processed (final) products (code-product)	**2. Unprocessed forest product used as input** (code-product)	**3. Quantity used (5+6)**	**4. Unit**	**5. Quantity purchased**	**6. Quantity collected by household**	**Collected where?**		**9. Who in the household collected the forest product?[1)]**	**10. Price per unit**	**11. Value (3*10)**
						7. Land type (code-land)	**8. Ownership** (code-tenure)			

1) Codes as in the table above.

Note: Columns 7,8,9 should be left blank if no collection by household. Column 10 (price) should be asked even if only from collection, but if not available, see the Technical Guidelines on valuation.

Note: Answers in columns 7 and 8 should be consistent with land categories reported in village questionnaire (V1D01) and in the annual household questionnaire (A1C).

D. Fishing and aquaculture

1. How much fish did your household catch **exclusively from the wild** (rivers, lake, sea) during **the past month**?

***Type of fish (list local names)**	**Collected where?**		**3. Total catch (kg) (4+5)**	**4. Own use (incl. gifts)**	**5. Sold (incl. barter)**	**6. Price per kg**	**7. Gross value (3*6)**	**8. Costs (inputs, hired labour, marketing)**	**9. Net income (7-8)**
	2. Land type (code-land)	**3. Owner-ship** (code-tenure)							

Note: Answers in columns 7 and 8 should be consistent with land categories reported in the village questionnaire (V1D01) and in the annual household questionnaire (A1C).

2. How much fish did your household catch **from ponds (aquaculture)** in **the past month**?

*** Type of fish (list local names)**	**1. From where? [1)]**	**2. Total catch (kg) (3+4)**	**3. Own use (incl. gifts)**	**4. Sold (incl. barter)**	**5. Price per kg**	**6. Gross value (2*5)**	**7. Costs (inputs, hired labour, marketing, etc.)**	**8. Net income (6-7)**

1) Codes: 1=Pond owned by households; 2=Pond owned by group of which household is a member; 3=Pond owned by community/village; 4=Pond owned by others and persons can buy fishing rights (include costs in column 7); 9=Other, specify:

E. Non-forest environmental income

1. In addition to forest products and fish included in the previous tables, how much of **other wild products** (e.g., from grasslands, fallows, etc.) did your household collect **in the past month**?

1. Type of product (code-product)	**Collected where?**		**4. Quantity collected (6+7)**	**5. Unit**	**6. Own use (incl. gifts)**	**7. Sold (incl. barter)**	**8. Price per unit**	**9. Gross value (4*8)**	**10. Costs (inputs, hired labour, marketing, etc.)**	**11. Net income (9-10)**
	2. Land type (code-land)	**3. Owner-ship** (code-tenure)								

Note: Answers in columns 2 and 3 should be consistent with land categories reported in the village questionnaire (V1D01) and in the annual household questionnaire (A1C).

F. Wage income

1. Has any member of the household had paid work over **the past month**?

Note: One person can be listed more than once for different jobs.

1. Household member (PID)	**2. Type of work** (code-work)	**3. Days worked past month**	**4. Daily wage rate**	**5. Total wage income (3*4)**

G. Income from own business (not forest or agriculture)

1. Are you involved in any types of business, and if so, what are the gross income and costs related to that business over **the past month?**

Note: If the household is involved in several different types of business, you should fill in one column for each business.

	1. Business 1	2. Business 2	3. Business 3
What is your type of business?[1)]			
Gross income (sales)			
Costs:			
Purchased inputs			
Own non-labour inputs (equivalent market value)			
Hired labour			
Transport and marketing cost			
Capital costs (repair, maintenance, etc.)			
Other costs			
Net income (2 - items 3-8)			
Current value of capital stock			

1) Codes: 1=shop/trade; 2=agric. processing; 3=handicraft; 4=carpentry; 5=other forest based; 6=other skilled labour; 7=transport (car, boat,…); 8=lodging/restaurant; 19=other, specify:

H. Income from agriculture – crops

1. What are the quantities and values of crops that household has harvested during **the past 3 months**?

1.Crops (code-product)	**2. Area of production** (m^2)	**3. Total production (5+6)**	**4. Unit (for production)**	**5.Own use (incl. gifts)**	**6. Sold (incl. barter)**	**7. Price per unit**	**8.Total value (3*7)**

2. What are the quantities and values of inputs used in crop production over **the past 3 months** (this refers to agricultural cash expenditures)?

Inputs	**1. Quantity**	**2. Unit**	**3. Price per unit**	**4. Total costs (1*3)**
Seeds				
Fertilizers				
Pesticides/herbicides				
Manure				
Draught power				
Hired labour				
Hired machinery				
Transport/marketing				
Other, specify:				
Payment for land rental				

HA. Stock of agricultural products

1. At present, what is your present stock of different agricultural products?

Product name	Number of units	Unit of measurement

I. Income from livestock

1. What is the number of ADULT animals your household has now, and how many have you sold, bought, slaughtered or lost during **the past 3 months**?

2. What are the quantities and values of animal products and services that you have produced during **the past 3 months**?

Product/service	**1. Production (3+4)**	**2. Unit**	**3. Own use (incl. gifts)**	**4. Sold (incl. barter)**	**5. Price per unit**	**6. Total value (1*5)**
Meat [1)]						
Milk						
Butter						
Cheese						
Ghee						
Eggs						
Hides and skin						
Wool						
Manure						
Draught power						
Other, specify						

1) Make sure this corresponds with the above table on sale and consumption of animals.

3. What are the quantities and values of inputs used in livestock production during **the past 3 months** (cash expenditures)?

Inputs	**1. Unit**	**2. Quantity**	**3. Price per unit**	**4. Total costs (2*3)**
Feed/fodder				
Rental of grazing land				
Medicines, vaccination and other veterinary services				
Costs of maintaining barns, enclosures, pens, etc.				
Hired labour				
Other, specify:				

4. Please indicate approx. share of fodder, either grazed by your animals or brought to the farm by household members.

Type of grazing land or source of fodder		**3. Approx. share** (%)
1. Land type (code-land)	**2. Ownership** (code-tenure)	
Total		100%

J. Other income sources

1. Please list any other income that the household has received during **the past 3 months**.

Type of income	**Total amount received past 3 months**
Remittances	
Support from government, NGO, organization or similar	
Gifts/support from friends and relatives	
Pension	
Payment for forest services	
Payment for renting out land (if in kind, state the equivalent in cash)	
Other, specify:	

L. Risks and crisis

2. Has the household faced any major income shortfalls or unexpectedly large expenditures during the past three months?

Event	**1. Code[1)]**	**2. Estimated income loss or costs (see guidelines)**	**How did you cope with the income loss or costs? Rank max. 3[2)]**		
			3.Rank1	**4.Rank2**	**4.Rank3**
1. Serious crop failure					
2. Serious illness in family (productive age-group adult unable to work for more than one month during the year, due to illness, or to taking care of ill person)					
3. Death of productive age-group adult					
4. Land loss (expropriation, etc.)					
5. Major livestock loss (theft, drought, etc.)					
6. Other major asset loss (fire, theft, flood, etc.)					
7. Lost wage employment					
8. Wedding					
A. Unusual high price fluctuations/inflation on goods (e.g. prices on agricultural products)					
9. Other: _____					

1) For each event, use the following codes: 0 = no; 1 = yes, moderate crisis; 2 = yes, severe crisis. See the Technical Guidelines for definitions.

2) Codes for how coped with crisis:

1. Harvest more forest products
2. Harvest more wild products not in the forest
3. Harvest more agricultural products
4. Spend cash savings
5. Sell assets (land, livestock, etc.)
6. Do extra casual labour work
7. Assistance from friends and relatives
8. Assistance from NGO, community org., religious org. or similar
9. Get loan from money lender, credit association, bank etc.
10. Receive food aid or other help from government
11. Tried to reduce household spending
12. We did nothing in particular

19. Others: _____

M. Total household consumption on regular food

What was the total household consumption of food during the last 30 days?

Code	Item	Consumed: 1/0	Bought: 0/1	How much was consumed during the last month	How much was from own production	If bought, what was the amount spent OR quantity purchased during the last month	How much was received as a gift or as a payment during the last month
Stables	Rice						
	Maize						
	Wheat						
	Barley						
	Millet						
	Sorghum						
	Cassava/manioc						
	Potato						
	Sweet potato						
	Yam						
	Groundnut						
	Cabbage						
	Carrot						
	Cauliflower						
	Groundnut						
Vegetable	Cabbage						
	Carrot						
	Cauliflower						
	Cucumber						
	Squash						
Fruit	Tomato						
	Avocado						
	Banana						
	Coconut						
	Mango						
Meat	Chicken						
	Goat meat						
	Cow meat						
Animal products	Vegetable oil						
Other	Sugar						
	Eggs						
	Bread						
	Meals outside home						
	Meals given to guests						
	Other food expenditure						

N. Total household consumption on non-food regular

In the past one month, how much, if any, did the household spend on the following non-food items:

	Items	Amount
A	**Personal items**	
1	Personal care items (soap, shampoo, toothpaste, etc.)	
2	Cigarette, tobacco	
3	Alcohol, spirits	
4	Other items	
B	**Transportation**	
C	**Miscellaneous**	
1	Washing powder	
2	Electricity/ kerosene	
3	Other items	

Appendix 7: Certificate of approval from UBC Behavioural Research Ethics Board

The University of British Columbia
Office of Research Services and Administration
Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Bull, G.Q.	Forest Resources Mgt	**B05-1188**

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

CO-INVESTIGATORS:

Hegde, Ravi, Forest Resources Mgt

SPONSORING AGENCIES

Centre for International Forestry Research

TITLE:

Payments for Environmental Services and Rural Household Behavior: The Case of Carbon in Mozambique's Agro-Forests

APPROVAL DATE	TERM (YEARS)	DOCUMENTS INCLUDED IN THIS APPROVAL:
FEB 2 0 2006	1	Feb. 7, 2006, Consent form (Portuguese & English) / Dec. 14, 2005, Advertisement / Conatct letter / Questionnaires

CERTIFICATION:

The application for ethical review of the above-named project has been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approved on behalf of the Behavioural Research Ethics Board
by one of the following:
Dr. Peter Suedfeld, Chair,
Dr. Susan Rowley, Associate Chair
Dr. Jim Rupert, Associate Chair
Dr. Arminee Kazanjian, Associate Chair

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures