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Reducing Poverty Through Carbon Forestry? Impacts of the N'hambita Community Carbon Project in Mozambique

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Summary. — Debates about the potential poverty alleviation impacts of global carbon markets are far from settled. We extend this debate by examining the impacts of a project in Mozambique that pays local people for carbon forestry activities. We conduct before-and-after project comparison using household data from project and non-project villages. Even though the poorest households participate widely in the project, the impact on incomes is small despite generous carbon accounting and contract terms. Leakage and impermanence remain strong concerns. Development activities under the project unrelated to carbon sequestration have a much bigger impact, albeit on a smaller number of households.

Key words — Africa, Mozambique, PES, carbon, REDD, impacts

1. INTRODUCTION

This paper examines the local impacts of the N'hambita Community Carbon Project in Mozambique. We situate our analysis in the context of literature on payments for environmental services (PES) that has long commented on the potential of such environmental payments to alleviate poverty in developing countries (Grieg-Gran, Porras, & Wunder, 2005; Pagiola, Arcenas, & Platais, 2005; Wunder & Alban, 2008). Out of the various types of environmental service schemes (e.g., watershed protection and biodiversity conservation), forestry carbon projects are the most mature, both in terms of size and extent (Ecosystem Marketplace, 2007; Landell-Mills & Porras, 2002). These projects pay local land users for planting new forests and for protecting existing ones, both of which help in mitigating climate change (Metz, Davidson, Bosch, Dave, & Meyer, 2007; Miles & Kapos, 2008). Ecosystem Marketplace estimates that there are more than 220 forestry carbon projects around the globe that have together sold carbon services worth about US$150 million (Hamilton, Peters-Stanley, & Marcello, 2010). With many of these projects located in developing countries, hope arises that such carbon mitigation projects will also benefit the poor (Perez, Roncoli, Neely, & Steiner, 2007; UNEP, 2002).

In one of the first studies on local impacts of forest carbon projects, Tipper (2002) suggested that the Scolel Te project in Mexico had a positive effect on household incomes in the project area. Similarly, Wunder and Alban (2008) found that the PROFAFOR carbon project in Ecuador had increased household incomes in addition to investing in educational and development infrastructure in the area. An important drawback of the project, however, was that in order to limit transaction costs, individual carbon contracts were signed only with farmers owning at least 50 hectares of land. A more recent study on the Humbo project in Ethiopia, registered under Kyoto Protocol's Clean Development Mechanism (CDM), suggested that local communities were benefitting from the project activities, and anticipated that there would be a significant influx of capital into the area in the form of carbon payments over the next 10 years (Brown, Dettmann, Rinaudo, Tefera, & Tofu, 2011). In contrast, May, Boyd, Veiga, and Chang (2004) studied four carbon projects—Plantar, Peugeot, and Bananal in Brazil, and Noel Kempff in Bolivia, and concluded that even though these projects had generated some development benefits, the top-down approach and slow adoption of appropriate land use systems also led to negative impacts in the area. Similar views were echoed by Asquith, Vargas Ríos, and Smith (2002) who found that the Noel Kempff project had a mixed effect, with some stakeholders benefitting from the carbon activities but a large proportion of community members expressing dissatis-

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faction with the project due to its negative impact on their livelihoods.

These studies show that so far carbon mitigation projects have had a mixed effect on local populations and that the debate on whether or not they help alleviate poverty is far from settled. Indeed, there are concerns regarding the extent to which local poor and smallholders are actually able to participate in such projects (Pagiola, Rios, & Arcenas, 2008; Uchida, Xu, Xu, & Rozelle, 2007). Poor households may be unable to participate in PES due to insecure tenure, insufficient land to set aside for PES activities, high transaction costs, or high upfront investments needed to adopt new land use practices (Jindal, Swallow, & Kerr, 2008; Smith & Scherr, 2003). Also relevant for agroforestry PES projects are the factors that affect smallholders' adoption of new agricultural technology: secure tenure, access to technical assistance, and availability of savings to meet investment and maintenance costs (Mercer, 2004). In some PES studies, researchers have found that poor households are able to participate (e.g., see Pagiola *et al.,* 2008), while in others, participation seems to have been limited to relatively well-off landowners (Miranda, Porras, & Moreno, 2003). Scholars therefore have pointed out a strong need to conduct more research on welfare effects of carbon mitigation projects beyond the provision of environmental payments alone (Corbera, González Soberanis, & Brown, 2009; Engel, Pagiola, & Wunder, 2008).

An important constraint in existing impact studies is that many of them rely on anecdotal evidence or on information gathered only from participating households that may be biased (e.g., Tipper, 2002; Brown *et al.,* 2011). Instead, impact studies should include both participants and non-participants for a more complete assessment of environmental service projects (Pagiola *et al.,* 2005). In addition, while many PES projects including carbon mitigation projects combine development activities with conditional environmental service payments (Engel *et al.,* 2008), most studies do not differentiate the PES component from the development component when measuring impacts of these projects (e.g., Asquith *et al.,* 2002). The resultant impact estimates may thus overstate what PES can achieve on its own. Moreover, while concerns regarding impermanence and leakage in carbon forestry projects have been expressed widely in environmental literature (Wunder, 2005), documentation on actual field experience is limited (e.g., see Jindal, Kerr, & Nagar, 2007; Wunder & Alban, 2008). These gaps are disconcerting given the rapid increase in the number of carbon mitigation projects and plans to invest billions of dollars in activities aimed at Reducing Emissions from Deforestation and Forest Degradation (REDD) in developing countries (Miles & Kapos, 2008).

We attempt to address some of these research gaps through a detailed investigation of the N'hambita Community Carbon Project, located in a remote part of Mozambique, which pays local households for carbon mitigation through agroforestry and avoided deforestation activities. We combine the conceptual framework suggested by Grieg-Gran *et al.* (2005) with that of Pagiola *et al.* (2005) to focus on five key issues: (i) the extent to which poor people participate in the project, (ii) impacts on participants' livelihoods, (iii) impacts on non-participants, (iv) spillover effects in the community, and (v) environmental impacts including a closer look at the issues of leakage and permanence of carbon mitigation activities. Our most novel contribution is differentiating the impact of the PES component of the project that makes conditional carbon payments, from the development component that extends employment and other development benefits to the local households. Our main limitation is the non-experimental nature of our field data, which restricts us from drawing stronger conclusions. We deal with this limitation by using the statistical approach of difference-in-difference, and by using multiple modes of enquiry in which we combine quantitative data gathered through a household survey with qualitative data collected through focus groups and open-ended discussions with farmers. We focus less on the specific numbers that come out of our analysis and more on their direction and magnitude. We start by providing a brief introduction to the project, followed by a discussion on our data collection and analysis techniques. We conclude by presenting our results and their significance for climate change mitigation through community based forestry projects.

2. THE N'HAMBITA COMMUNITY CARBON PROJECT, MOZAMBIQUE

The N'hambita Community Carbon Project [1] is located along the periphery of Gorongosa National Park (GNP) in Sofala province. Mozambique's long civil war from 1975 to 1992 displaced thousands of local families to urban centers. However, when many of these families came back after the end of the war, they had few livelihood options (Howell & Convery, 1997)The area's 88% poverty rate was among the highest in the country (Simler, Mukherjee, Dava, & Datt, 2004). The N'hambita project was initiated to provide income to these families through improved forest-based land use practices while also producing carbon mitigation services for international carbon markets (Grace, 2008). As part of the Plan Vivo system, the project follows the approach of using international carbon payments to compensate low-income farmers for transforming their land use to sustainable agroforestry systems that meet local needs (Plan Vivo, 2011). In fact, the project was highlighted in the Stern Review as an example of a carbon mitigation project that also helps to alleviate poverty among local communities (Stern, 2007). The project began its field activities in 2003, making it the first forest-based carbon mitigation project in Mozambique. It was initially funded by the European Union, but since the end of the pilot phase in 2008 it has operated on revenue from the sale of carbon offsets (each offset equals one ton of carbon dioxide or tCO_2 sequestered by the project) to international buyers such as the MAN group and the Carbon Neutral Company.

The project area lies between the rainfall isohyets of 600 and 800 mm/year, with the average annual rainfall from 2000 to 2007 recorded at 749 mm (Grace, 2008). The average elevation in the area varies from 40 m in the valley to 400 m along the escarpment. The project operates in all six villages of the Chicale *regulado* (a traditional administrative unit measuring about 20,000 hectares managed by a local chief or *regulo*). Five of the six villages—Bue Maria, Mbulawa, Munhanganha, Mutiambamba, and N'hambita—are located deep inside the forest, while the sixth, Pungue, is situated on the road to the town of Gorongosa. None of the villages is electrified and there is only one primary health center for the entire area. Three of the villages have small grocery shops, but the main market for the area is in Gorongosa, about 60 km away. Five of six villages have a primary school, but the nearest secondary school is in Gorongosa. According to Hegde and Bull (2008), there are 1,026 households in the area; the most populous village has 414 households. Subsistence farming and hunting and gathering are major sources of livelihoods in the area.

(a) *PES component of the N'hambita project*

The PES component relates to activities that produce carbon offsets. The project offers regular payments to the local

Table 1. *Important components of the N'hambita project*

PES component	Development component
1. Payments for carbon sequestration	1. Jobs in microenterprises (ME)
• Agroforestry on HH farms • Payments to HH for 7 years (based on rates for 100 years) • Avg price \$4.50/tCO_2 • Payment: \$400–\$800/ha	• Various microenterprises promoted by the project • Carpentry shop • Tree nurseries • Salary \$50–\$100 per month
2. Payments for REDD	2. Project and extension staff
• Protection of 11,000 ha forest block • Payment to community trust fund	• From local community • Salary \$50–\$600 per month

Source: Authors' fieldwork, 2008; and project documents

community with the amount determined by the nature of the activity and the number of carbon offsets it yields. This includes carbon sequestration through adoption of agroforestry on private farms and REDD activities on community woodlands (Table 1).

(i) *Carbon sequestration through agroforestry*

The project invites local households to choose from a menu of agroforestry systems that result in sequestration of atmospheric carbon. Some systems are for planting throughout a plot: mango (*Mangifera indica*) and cashew (*Anacardium occidentale*) orchards to generate food and cash, woodlots with siris (*Albizia lebbeck*), and African mahogany (*Khaya nyasica*) to support charcoal production and timber requirements, intercropping with acacia (*Faidherbia albida*) to fix nitrogen and thus raise crop yields. Other systems options include native hardwoods such as panga panga (*Millettia stuhlmannii*) along the boundary of the *m'shambas* (farmers' fields), or fruit trees such as tamarind (*Tamarindus indica*) within the homestead. The specific carbon sequestration rates of different systems were estimated by carbon experts from the Edinburgh Centre for Carbon Management and the University of Edinburgh using a mix of field measurements and computer models. Depending on planting density and the choice of tree species, they project that the carbon sequestration potential for different agroforestry systems varies from 10 to 181 tCO_2/ha over a period of 100 years (for details see technical appendices in Grace (2008)).[2]

Once enrolled, households receive free seedlings and technical assistance on how to plant and manage the new trees. Each agroforestry system is designated as a separate contract and generally covers about 0.25–1.5 ha of a household's *m'shamba* land. A household can enter multiple contracts, either by adopting the same agroforestry activity on multiple plots or combining different agroforestry activities on the same plot (e.g., boundary planting with fruit orchards). The contract also specifies that the household should not clear additional *m'shamba* land. In return, the project pays the contracted household for the carbon offsets that its agroforestry systems generate. It is important to note that while carbon offsets are generated over 100 years, farmers receive their entire payment during the first 7 years of the contract. The logic of frontloading the payments is to facilitate adoption; after the payments have been disbursed over 7 years the new agroforestry systems are intended to provide their own livelihood benefits. From this perspective, the carbon payments are intended to facilitate the transition to a productive and more sustainable land use system.

By May 2008, the project operated 1234 agroforestry/carbon contracts covering about 1000 ha. The project team estimates that during the previous 5 years, local farmers had planted more than 500,000 trees, expected to generate total offsets of 82,056 tCO_2.

(ii) *Reducing emissions from deforestation and degradation (REDD)*

In addition to carbon sequestration, the local community also receives carbon payments for REDD activities in communally owned miombo woodlands (open canopy dry deciduous forests common to southern Africa) around Gorongosa National Park. Major drivers of deforestation in these forests include clearance for agriculture, tree felling for charcoal production, and spread of fire from agricultural fields (Herd, 2007). Timber logging is no longer a major issue in the area (Hegde & Bull, 2008). Remote sensing images show a 2.4% annual rate of deforestation from 1999 to 2007 (Tipper, 2008).

To reduce this deforestation, the N'hambita project has introduced two main activities: a total ban on tree felling, and formation of fire patrols in the forests. The project allows non-destructive harvest of other forest produce such as grass and wild food. The REDD activities began in 2006 in a selected block of 5000 ha and since then have expanded to 11,071 ha. The project team has estimated that over 10 years, these REDD activities will generate carbon offsets totaling 7.8 tC/ha (i.e., 28.6 tCO_2/ha), based on a net reduction in biomass loss in the area (Tipper, 2008). This estimate assumes that in the absence of a project intervention, the current annual area of deforestation of 1185 ha, or 3.3% of the forest area in 2008, will continue until the forest has disappeared within 33 years. We believe this estimate of deforestation is too high because it assumes away the possibility of endogenous conservation in response to growing scarcity. Using such a high baseline deforestation rate increases the number of carbon offsets the project can claim.

The N'hambita project combines offsets from agroforestry and REDD activities and sells them as one lot in international voluntary carbon markets. Out of the total carbon offsets that the project produces, 15% are withheld as a buffer against leakage and other unexpected carbon losses while the remaining 85% are sold in the international market. During the last few years the project has sold 116,807 tCO_2 worth more than \$900,000, an important achievement considering that these offsets have been sold mainly in the voluntary market, which absorbs a smaller volume of carbon offsets than the Kyoto market.

Grace (2008) estimated that by 2007, the project had paid a total of \$223,750 to the local community for agroforestry and REDD activities, with more payments expected shortly. However, the actual flow of money into the community varies by activity. The project has tried to address many of the concerns

Table 2. *Determinants of participation in agroforestry contracts*

	(1) Dependent variable = probability of participation Logit Model	(2) Dependent variable = number of contracts Tobit Model
Gender of household head (male = 1)	−0.17 (0.43)	0.07 (0.17)
Migration into the area within past 5 years (dummy)	−1.32 (0.55)***	−0.53(0.27)**
Number of people in the household	0.29 (0.15)**	0.14(0.06)**
Number of literates in the household	0.12 (0.27)	0.07 (0.099)
Age of the household head	−0.002 (0.015)	−0.00 (0.006)
Number of *m'shambas* per household	0.15 (0.31)	0.14 (0.13)
Number of livestock per household	−0.03 (0.04)	0.002 (0.127)
Total annual cash income of the household	−0.0008 (0.0002)***	−0.0003 (0.0001)**
Household Income from a regular job and/or a business	0.0009 (0.0004)***	0.0004 (0.0002)***
Bue Maria (dummy = 1)	−17.85 (1.29)***	−0.19 (0.416)
Mbulawa (dummy = 1)	−19.45 (0.81)***	0.56 (0.32)**
Munhanganha (dummy = 1)	−19.36 (0.79)***	0.07 (0.28)
Mutiambamba (dummy = 1)	−18.64 (0.80)***	−0.07 (0.32)
Nhambita (dummy = 1)	−19.76 (0.82)***	−0.46(0.35)
Constant	20.28	0.64 (0.36)*
LR Chi sq	32.68	42.41
Prob > Chi sq	0.0032	0.0001
Pseudo R sq	0.1532	0.1682
Log likelihood	−90.311	−334.1915
Number of sampled households	334	

Notes: Figures in parentheses are standard errors.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

raised in the literature regarding the challenges of including the poor. REDD payments, for instance, go to a community trust fund managed by a democratically elected executive committee and are used for the benefit of the entire community. A proportion of REDD payments is also used for paying wages to people who patrol the forest block against fire outbreak. In contrast, for agroforestry-led carbon sequestration activities, most of the money is paid directly to individual contract holders, while a small proportion goes into a community trust fund. The project thus far has paid farmers an average of \$4.50 per tCO_2, which is much higher than the carbon price in most voluntary carbon markets (Hamilton *et al.,* 2010). Depending on the agroforestry system, households receive an average of \$400–\$800 over 7 years, 30% of which is paid in the first year.

(b) *Development component*

The development component consists of various microenterprises that the project runs to promote alternate livelihoods. In addition, most project staff has been hired from the local community and since their monthly salaries contribute significant cash inflows for the community, we also categorize this as part of the development component.

(i) *Promotion of microenterprises*

Project-supported microenterprises include nurseries, a community sawmill, a carpentry shop, beekeeping, and a vegetable garden. Project employment, whether as staff or in a microenterprise, is not conditional on participation in carbon mitigation activities though people who are employed also hold agroforestry contracts for carbon sequestration. While the microenterprises and project jobs were initially supported from donor funding, the project team aims to make them self-sustaining by linking them with the local market.

(ii) *Project staff*

Most of the staff is located on site, drawn from the local community. This includes agroforestry extension workers, administrative staff, drivers, and mechanics for project vehicles, and other casual staff. Project staff receive a regular monthly wage, bringing additional cash into the community. In all, microenterprises and the project employ about 170 people with wages ranging from MTN 1200 per month (\$49.50) for a forest nursery worker to MTN 15,000 per month (\$619.10) for a senior extension worker. [3]

3. DATA

The main data for this study were collected through a household survey conducted in May 2008. Based on the census compiled by Hegde and Bull (2008), we divided the local population in the project villages into three strata and randomly sampled about 25% of households from each stratum: (i) households with agroforestry contracts and at least one member employed ($n = 54$), (ii) households with only agroforestry contracts ($n = 170$), and (iii) non-participating households with neither agroforestry contracts nor employment ($n = 46$). We also conducted the same survey with 64 randomly selected households in six control villages from the neighboring area of Cudzu where the project did not take place. The total sample size for the household survey was 334 households that lived in the area in 2008. Only 238 of these households existed in the area in 2001; the others were more recent migrants or young families. We use the full set of data to analyze the determinants of participation in the project and the smaller set to analyze its impacts.

The survey focused on important demographic and socioeconomic variables related to project participation and impact such as the number of people in the household, their

Table 3. *Cross-sectional analysis of sampled households before (2001) and after (2008) project*

Variables	Before project (2001) (household mean values)				After project (2008) (household mean values)			
	(1) non-participants	(2) agroforestry contracts	(3) agroforestry contracts and employment	(4) F-value from one-way ANOVA	(1) non-participants	(2) agroforestry contracts	(3) agroforestry contracts and employment	(4) F-value from one-way ANOVA
Number of literates per household	0.88 (0.98)	0.96 (0.96)	1.1 (0.99)	0.59	1.44 (1.37)	1.7 (1.42)	1.98 (1.58)	1.49
Households with no literates (%)	41.2 (0.49)	35.9 (0.48)	22.9 (0.43)	1.83	32.4 (0.48)	21.8 (0.41)	12.5 (0.33)	2.36*
Number of *m'shambas* per household	1.4 (0.67)	1.36 (0.55)	1.6 (0.96)	2.47*	1.8 (0.87)	1.87 (0.78)	2.2 (1.1)	3.08**
Households with access to wage labor in the village (%)	55.9 (0.50)	38.5 (0.49)	39.6 (0.49)	1.78	44.1 (0.50)	40.4 (0.49)	37.5 (48.9)	0.18
Household with at least one permanent job or a small business (%)	23.5 (0.43)	26.3 (0.44)	14.6 (0.36)	1.39	17.6 (0.39)	30.8 (0.46)	100 (0)	61.9***
Household's annual cash income (MTN)	918 (937)	1013(1517)	783(1570)	0.47	1184 (1525)	1502(1794)	2820(2961)	8.95***
Asset ownership per household (number)	2.2 (1.37)	2.39 (1.22)	2.35 (1.31)	0.30	2.2 (1.34)	2.39 (1.34)	2.79 (1.15)	2.22*
Number of sampled households	34	156	48		34	156	48	

Notes: Households.
Figures in parentheses are standard deviations.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

educational status, their agricultural profile including livestock ownership, and extent of participation in the project. We collected these data for both 2008 (after-project) and 2001 (before-project) using the recall method.[4] As is often the case in program evaluation (Patton, 1997), this work was commissioned without baseline data that would provide a stronger foundation for assessing impact.[5] We discuss this further below. Researchers have used recall extensively to study the impacts of an external intervention (e.g., Mullan, Kontoleon, Swanson, & Zhang, 2010; Uchida *et al.,* 2007). To minimize errors associated with recall, we selected 2001 as the reference year since it was vivid in people's memory as the year when the local river last flooded. At the same time, choice of the flood year does not affect our results since the study villages were located away from the river and did not seem to be affected greatly by the floods. As we explain below, we focus on variables that are easier to remember and less prone to recall error.

To measure the impact of the N'hambita project on participating households, ideally we would like to compare their household well-being in terms of health and nutrition status and consumption of goods and services. Lacking the resources to obtain such data, income from goods and services sold is often used as a proxy (Grosh & Glewwe, 2000). However, considering that most households in the area directly consume the goods that they produce (e.g., agricultural crops and non-timber forest products), income alone is a weak and partial indicator of household well-being. Therefore, we include additional variables that indicate different aspects of household socio-economic status—access to a permanent job or a small business (which translates into a regular source of cash income), asset ownership (indicating household financial status), and average literacy in the household (indicating the social well-being of the household based on how well it is able to access educational services). Change in access to wage labor is an important variable in PES projects especially for non-participating households that may have only limited means to earn livelihoods (Pagiola *et al.,* 2005).

Most questions in the survey were about household characteristics that do not change rapidly and are easy to recall, such as the number of literates in the household, the characteristics of one's dwelling, and the number of *m'shambas* that the household farms. We also use cash income as an indicator of household well-being because the N'hambita project uses cash payments and because in open-ended discussions, respondents indicated that access to cash and ownership of durable goods are the only important factors for distinguishing between the welfare of one household and another.[6]

We acknowledge limitations to the use of recall data for cash income because respondents cannot realistically recall specific numbers over 8 years. Despite this error, we use this variable for a number of reasons. First, considering the remote location of study villages and the near absence of opportunities to earn cash, we expect respondents to remember at least roughly any important chunks of cash that they managed to earn.[7] Second, we have no *prima facie* reason to assume that one group of households (say project participants) would report more erroneous data than other groups in our sample. Third, we are only interested in the directional change and rough magnitude of this variable during the study period rather than its specific value. Finally, reported cash income is closely correlated to ownership of durable assets, which respondents mentioned as being a good indicator of household well-being and which are easier to recall because there are few of them and they do not change much.

Table 4. *Impacts of the N'hambita community carbon project. Difference in difference for the project area from 2001 to 2008*

Impact variables	(1) Mean change for non-participating HH	(2) Mean change for HH with only agroforestry contracts	(3) Mean change for HH with both agro- forestry contracts and employment	(4) F-value from one-way analysis of variance
Number of literates per household	0.56 (0.17)***	0.69 (0.09)***	0.88 (0.17)***	0.74
Households with no literates (%)	−8.8 (0.05)**	−14.1 (0.3)***	−10.4 (0.05)**	0.37
Number of *m'shambas* per household	0.56 (0.14)***	0.56 (0.06)***	0.79 (0.17)***	1.35
Households with access to wage labor in the village (%)	−11.8 (0.06)***	1.9 (0.03)	−2.1 (0.07)	1.99
Household with at least one permanent job or a small business (%)	−5.9 (0.07)	4.5 (0.03)	85.4 (0.05)***	76.97***
Household's annual cash income (MTN)	265 (275)	489 (106)***	2037 (392)***	16.34***
Asset ownership per household (number)	0.03 (0.23)	0.01 (0.09)	0.44 (0.18)**	2.57**
Number of sampled households	34	156	48	

Notes: HH Households.
Figures in parentheses are standard errors.
Columns 1, 2, and 3 represent intra-group differences during 2001–08.
Column 4 represents *F*-values for difference-in-difference for each variable.
** Significant at 5%.
*** Significant at 1%.

Table 5. *Comparison of the project and control areas: Difference in difference during 2001–08*

	Project villages ($n = 238$)			Control villages ($n = 53$)			(7) Difference in difference (6) − (3)
	(1) Mean in 2001	(2) Mean in 2008	(3) Difference in mean (2) − (1)	(4) Mean in 2001	(5) Mean in 2008	(6) Difference in mean (5) − (1)	
Number of literates per Household	0.98	1.7	0.7*** (0.07)	0.81	1.6	0.8*** (0.15)	0.1 (0.18)
Households with no literates (%)	34.03	21.4	−12.6*** (0.03)	43.4	24.5	−18.9*** (0.05)	−6.3 (0.06)
Number of *m'shambas* per Household	1.42	1.93	0.51*** (0.05)	1.5	2.2	0.7*** (0.14)	0.19 (0.13)
Households with access to wage labor in the village (%)	41.2	40.3	−0.09 (0.02)	9.4	13.2	3.8 (0.05)	3.89 (0.06)
Household with at least one permanent job or a small business (%)	23.5	42.9	19.3*** (0.03)	11.3	13.2	1.9 (0.05)	−17.4** (0.08)
Household's annual cash income (MTN)	953	1723	770*** (119.3)	2526	9501	6974.8***(2069.6)	6205.3*** (2073.02)
Asset ownership per household (number)	2.4	2.5	0.1 (0.08)	2.2	2.4	0.2 (0.13)	0.1 (0.17)

Notes: Standard errors in parentheses.
** Significant at 5%.
*** Significant at 1%.

Overall, our results remain the same even when we do not use recall data; the cross-sectional analysis shown on the right hand side of Table 3 indicates that the group of project participants with both jobs in the local microenterprises and agroforestry contracts has benefitted much more than the group with only agroforestry contracts for carbon sequestration. However, using recall data helps us to further sharpen this analysis (Tables 4 and 5).

Finally, to triangulate survey data and add analytical depth, we also collected qualitative data through semi-structured discussions with an additional set of respondents in the project villages: (i) respondents employed through the project and also with agroforestry contracts (group size 25), (ii) women, most of whom had only agroforestry contracts (group size 25), (iii) respondents who had neither agroforestry contracts nor employment (group size 14), (iv) new immigrants to the area, most of whom did not have agroforestry contracts (group size 24), and (v) members of the community association (group size 11). In all, 99 people participated in these semi-structured discussions, which helped us to understand their perceptions of the project and enriched our interpretation of survey findings.

4. METHODS

As mentioned, our analysis of the project's impacts focuses on five key issues: (i) the extent to which poor people participate in the project, (ii) impacts on participants' livelihoods, (iii) impacts on non-participants, (iv) spillover effects in the community, and (v) environmental impacts.

(a) *Participation*

Following the approach of Pagiola *et al.* (2008), we first look at participation rates of households in different income categories in our sample, followed by standard regression analysis to identify any systematic barriers or factors that influence participation. We assess these factors using two econometric models, one focused on whether or not a household participates in an agroforestry activity under the project, and a second focused on the number of contracts that a household enters. For the first one, we use the standard binomial Logit regression model with a dichotomous, categorical dependent variable (participates/does not participate). For the second model we measure intensity of participation as the number of contracts the household enrolls in. Since the dependent variable is left-censored (the minimum number of contracts is 0), a Tobit model is appropriate in capturing the marginal effects of various household characteristics on intensity of participation (e.g., Pagiola *et al.,* 2008). [8]

The list of possible explanatory variables was drawn from relevant literature on agroforestry adoption (Franzel, 1999; Mercer, 2004; Nkamleu & Manyong, 2005). In a comprehensive review of such studies, Pattanayak, Mercer, Sills, and Yang (2003) report five categories of factors that were most important in explaining agroforestry adoption: preferences, resource endowments, market incentives, biophysical characteristics, and risk and uncertainty. Based on this work, we included the following variables in our two econometric models, the values for which were derived using the recall data from 2001 (Table 2):

(i) Household characteristics: gender of the household head, age of the household head, educational status of the household, household size, and year of migration into the community;

(ii) Resource endowments: livestock ownership, number of *m'shambas*;

(iii) Off-farm income: any permanent job or wage labor; and

(iv) A village dummy variable to indicate location, the base case being the village of Pungue located on the main road, with all other villages located away from the road.

(b) *Impacts on participants and non-participants*

Two important challenges are (i) differentiating the impact of the PES component (carbon payments on agroforestry contracts) from the development component (wages from employment in various microenterprises), and (ii) isolating project impacts from wider changes in the economy or even climatic variations. As discussed above, to address these challenges, our main estimation strategy was to follow stratified random sampling whereby we distributed local households into three categories: households that participated in both carbon/agroforestry activities and microenterprises (MEs), households that participated in only agroforestry activities, and households that participated neither in agroforestry activities nor in MEs. (A possible fourth category of households with jobs in MEs but not agroforestry contracts did not appear to exist.) Continuing with the household as the unit of analysis, we compared the before-project status of households in each of these categories with the after-project status. Assuming that changes in the wider economy would have had similar effects on all households, we were thus able to differentiate impacts of the project from those of wider changes as well as impacts of the project's PES component from those of the development component. Finally, to estimate project spillover effects on the entire community (e.g., impact of improvements in project-funded educational infrastructure on the community-wide literacy rate) we compared averages across all sampled households in the six project villages with randomly sampled households from six neighboring villages outside the project area.

An important limitation of this approach is the bias introduced by self-selection due to possible non-random assignment of the participants to the project. A useful approach in this case would be the use of propensity score matching where participants and non-participants are matched on an observable set of variables that affect participation in the project before conducting the impact analysis (Rosenbaum & Rubin, 1983). However, a much smaller number of non-participating households in our sample (46) and two levels of participation—households with only agroforestry contracts and households with both jobs and contracts—restricted us from using this approach.

Instead, we followed the difference-in-difference approach (Wooldridge, 2002), using one-way ANOVA to compare the mean values of changes from before the project began to after it had been operating for several years, for each of the three groups of households. We would also like to point out that some of the households in our sample arrived in the area after 2001. These households were therefore omitted from this analysis.

In order to measure the spillover effects of the project in the entire area, we conduct a similar difference-in-difference test between the six project villages and the six neighboring villages where the project was not implemented. We also look at some qualitative impacts such as changes in development infrastructure in the area and increased visibility among national and international development agencies.

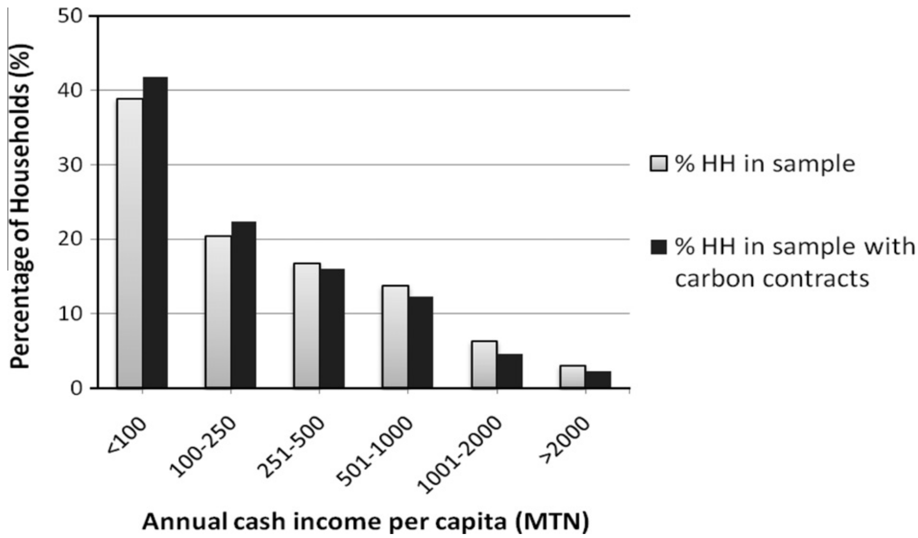

Figure 1. *Distribution of sampled households: Proportion of households in different income categories (2001) and proportion of households with carbon/agroforestry contracts. Source: Authors' survey (2008).*

(c) *Environmental impacts*

Since we treat the carbon offsets produced by the project as given (they have been estimated by carbon experts and are beyond the authors' specialization), we focus on related issues of leakage and permanence of these carbon offsets. We explore leakage by looking at change in number of plots or *m'shambas* owned by different groups of households (households that possess carbon/agroforestry contracts *versus* non-participating households). An increase in number of farm plots indicates that a household has continued to clear forest area to set up new farmland in spite of the moratorium to do so. For permanence, we look at issues arising out of contract length, and at people's perceptions of agroforestry.

5. PARTICIPATION OF THE POOR

The N'hambita project's flexible arrangements contribute to the high demand for agroforestry contracts, and as of 2008, 852 or about 80% of all households in the area had enrolled in the project. Further, all land in Chicale *regulado* is owned by the entire community as communal property and after taking permission from the local chief (the *regulo*), individual households can demarcate a piece of land to set up their own farm. In time, the household gets *de facto* ownership of this farmland. Concerns about tenure insecurity do not appear to apply to the N'hambita project and we did not find any landless households in our field survey.

Even though 80% of households participate in the project, it is useful to investigate whether or not the poorest households are among them. Figure 1 displays the distribution of sampled households in six income classes. About 39% of the households in our sample are in the poorest group with an annual per capita cash income of less than MTN 100, while 20% of the households were between MTN 100 and 250 and so on. Only 4% are in the wealthiest group with more than MTN 2000. Although cash income represents only a small proportion of a household's annual gross income, it is still an important indicator of the household's relative wealth status with a strong positive correlation with the status of asset ownership. Since we did not use income as a variable to stratify our sample, these percentages roughly represent the income distribution for the whole community. Looking at the percentage of sampled households with agroforestry contracts by income category, we find that the poorest households are slightly overrepresented (42%) while the wealthiest are slightly underrepresented (3%). This indicates that the poorest households are participating in agroforestry activities in the N'hambita project.

Table 2 presents the results from regression analysis of the determinants of (1) whether a household participates in a project, and (2) the number of agroforestry contracts in which it enters. The results are similar across the two models.[9] In terms of significance of various explanatory variables, although the gender of the household head is insignificant, similar to Nkamleu and Manyong (2005) and Franzel (1999) we find both household size and off-farm income (from a regular job or a business) to be significant. Other factors that influence participation are as follows. Whether the household migrated into the community in the previous 5 years, total annual cash income of the household, and location of the household in a village away from the paved road all have significantly negative impacts. Household size has a strong positive influence on both the decision to participate and on the number of agroforestry contracts a household entered, once it decided to participate. A larger household helps in supplying additional labor when a new land use practice is adopted, so each additional member improves the chances of participating (coefficient value 0.29) and raises the number of contracts by 0.14. However, if a household migrated into the area within the last 5 years, the likelihood of participating in the project declines (coefficient value −1.32) and the expected number of agroforestry contracts falls by −0.53. This is because recent migrants are still establishing themselves in the community and possibly are unaware of the project or how best to access it. Similar to the findings of Pagiola *et al.* (2008) in Nicaragua, the econometric analysis confirms that poorer households have a slightly higher chance of both participating in the project and slightly more agroforestry contracts. Participation in agroforestry activities ensures a regular source of cash income, which is especially important for poorer households. Households that already have a regular income source in the form of a job or a small business are also slightly more likely to participate in the project and have more agroforestry contracts.

Finally, households in villages away from the paved road have a much lower probability of participating in the project than households in Pungue village, which is closest to the road (column 1). However, once the households start participating in the project, the number of contracts they possess is largely unaffected by their location (column 2). This indicates that remotely located households have difficulty in first accessing the project, but once they join it they have an equal chance of entering additional contracts.

6. PROJECT IMPACTS

According to our household survey, socioeconomic indicators in the area changed rapidly during 2001–08, 5 years after the project began: there were changes in number of literates per household, number of *m'shambas* that a household possessed, non-farm employment, and in asset ownership. Cross-sectional analysis for the three groups of households in our sample (non-participants, households with agroforestry contracts, and households with both jobs and agroforestry contracts) shows that while the three groups were fairly similar before the project, they became quite different after the project interventions (Table 3). Indeed there were significant differences in literacy levels (reduction in households with no literates), access to a permanent job or a small business, household's annual cash income, and its asset ownership.

The left side of Table 3 shows that before the project started the three groups of households in our sample were very similar with relatively few differences, which indicates that they were well matched before the project. In particular, mean values of average annual cash income were very low and did not vary significantly across groups. Asset ownership also did not significantly differ across the groups, suggesting that they had similar pre-project levels of wealth and income. The only exception was that households that eventually gained both project employment and agroforestry contracts owned significantly more *m'shambas*. [10]

(a) *Impacts on project participants*

As introduced above, carbon payments under agroforestry contracts are frontloaded with 30% of the contract value paid in the first year and all payments made within 7 years. By the time of our 2008 field survey, most participating households had received two or three payments; the average payment per household for the previous year (2007–08) was MTN 1923 ($80), equivalent to two to three months of wage labor. In contrast, the average annual salary of an employee during this period was much higher at MTN 12,484 ($519). During group discussions with project participants, many respondents said they used their money to buy roofing material, food and clothes for the family, or books and school stationery for their children. Some people also invested in agricultural seeds, while others bought household durables such as a radio or a bicycle.

The right side of Table 3 shows that after several years of project activities, the situation had changed substantially from 2001 and the households in the three groups were quite different. Table 4 shows the change in the values of all indicators for all categories of households during 2001–08.

The average reported annual cash income increased for all household categories, but for non-participating households the increase (MTN 265) was statistically insignificant. For agroforestry contract holders the increase (MTN 489) was significantly different from zero but not in comparison to a similar increase for non-participating households. Only households with both jobs and agroforestry contracts had an increase (MTN 2037) that was significantly different from non-participants. In percentage terms, the increase in the nominal value of cash income during 2001–08 was 29% for non-participants, 48% for households with agroforestry contracts, and 260% for households with both agroforestry contracts and jobs. [11] Results were qualitatively similar for change in average asset ownership in that households with both jobs and agroforestry contracts increased their ownership of durable assets noticeably (0.44% or 18% on average) compared to virtually no change for non-participants and households with only agroforestry contracts. This indicates that the main economic impacts from the project came from employment as opposed to agroforestry contracts. Indeed, the variable measuring households' access to a regular source of income in the form of a job or a small business is most positive for the group that has both a project job and agroforestry contracts (column 4 in Table 4). [12]

However, it is also important to note that most households had received only two or three rounds of carbon payments by the time of the survey. With more payments in the near future, the impact on participating households may increase until payments end. It is impossible to know what will happen when carbon payments do in fact end. The aim of the project is that when the agroforestry systems mature they will benefit households through production of fruits and small timber, and that as nitrogen-fixing trees mature they will make agriculture more productive. In open-ended discussions, participants stressed the importance of cash payments to their well-being, but they were not able to say much about the expected future production benefits of the agroforestry systems. They also said little about the possibility that mature fruit and timber trees could interfere with cropping systems and create pressure to clear additional forest for new *m'shambas*.

(b) *Impacts on non-participants*

Technically, there are no non-participants in the project area since even these households participate in REDD activities. However, the attempt here is to explore the more direct impact of participation or non-participation in agroforestry activities. Since participation in the project is voluntary, households are not penalized for declining to participate in agroforestry activities. They may however still face some negative impacts due to reduced opportunities to earn wage labor (especially if a large number of households have replaced seasonal crops with more permanent agroforestry crops). Table 3 shows that before the project started, 55.9% of non-participating households earned wage labor locally, mainly by providing seasonal agricultural labor to other households. By 2008, this proportion had dropped to 44.1%. In contrast, households with both agroforestry contracts and jobs, and households with only agroforestry contracts were virtually unchanged in this regard (−2.1% and +1.9% respectively). Project income compensates loss of wage labor for participants, but not for non-participants. There is insufficient data to establish whether or not the loss in wage income has hurt the economic status of non-participant households. Their average asset ownership did not change from 2001 to 2008 while their cash income showed a modest increase (MTN 265.32).

Non-participating households may also face increased hardship from a ban on harvesting from the large tract of miombo forest under REDD activities. However, this ban extends mainly to timber felling while local households are allowed to collect non-timber forest products such as wild food and grass. The project also tries to ensure that benefits from carbon mitigation activities reach everyone. For instance, all REDD payments and a proportion of agroforestry payments go to a community fund that maintains development infrastructure such as school buildings for the benefit of all residents.

(c) *Spillover effects in the area*

In recent years the area has seen impressive growth in public infrastructure, more due to overall improvement in Mozambique's national economy than to project intervention. However, the project does stimulate demand for such infrastructure. The $80 of annual carbon payments that each agroforestry contract holder receives on average aggregates to about $70,000 annually for the area. In addition, most people employed through the project spend a considerable proportion of their income locally. With many households routinely buying household items such as soap and cooking oil, by 2008 many small provision stores and grocery shops had opened in all the six villages when just a few years earlier there were very few.

Another important spillover benefit is the community trust fund that receives half of all REDD payments and a proportion of carbon payments from agroforestry. The local community association, consisting of 24 members from different villages, manages this fund. It managed MTN 65,000 ($2683) in mid-2008 with about $22,942 in additional REDD payments expected shortly. The association has used the trust fund for construction and maintenance of school buildings and a local health clinic, benefiting the entire area. Our qualitative data show that while the N'hambita project has improved the visibility of the area among various development agencies, at the same time, the existence of the community fund and growth in local leadership, has helped households to better articulate their development needs. As a result, within the last few years, many new agencies have started working in the area on health and water management related issues, while a steady stream of international researchers have visited the area to learn from the project.

In terms of these wider or spillover effects, we also explore change in literacy rates in the area. In focus groups, many project participants said they had used their carbon payments for their children's school fees and school supplies. The average number of literates in the area increased from 0.9 to 1.7 per household from 2001 to 2008, and the percentage of households with no literates fell from 34% to 21.4% (Table 5). This change was impressive among all households, though higher for participants than non-participants (Table 4). To check whether the change in literacy rates was a spillover effect of the project, we compared this change between project villages and non-project villages outside the project area [13]. Using the difference-in-difference approach as outlined above, but now comparing the mean change before and after the project for households in project and non-project villages, we do not find a statistically significant difference (Table 5), as control villages experienced very similar improvements. This indicates that literacy attainment is a wider phenomenon in the region (perhaps due to increased educational investment from the government) and cannot be attributed to the N'hambita project. Table 5 also reinforces our previous discussion—increased access to regular cash income is more pronounced in project villages rather than the control villages, mainly due to availability of jobs under the development component of the N'hambita project. Carbon activities on the other hand have not increased cash incomes or asset ownership appreciably.

(d) *Environmental impact*

As mentioned above, during the last several years the project has sold 116,807 tCO_2 from agroforestry and avoided deforestation, worth more than $900,000. In this section we discuss the extent to which the carbon offsets arising from agroforestry and avoided deforestation are threatened by leakage and impermanence.

(i) *Leakage*

Leakage refers to unplanned, additional carbon emissions arising from activities outside the project boundary. For instance, project beneficiaries may plant trees at one site but cut trees in another, resulting in net release of carbon to the atmosphere. The three main drivers of leakage in the area are cutting trees to produce charcoal, burning *m'shambas*, and clearing forest for agriculture. Charcoal production is an important source of livelihood in Mozambique (Food, 2007). In Chicale *regulado*, Herd (2007) estimates that 35 ha of local woodlands are lost every year to charcoal production. Since most charcoal makers in the study area do not have licenses to operate, we could not obtain reliable data regarding the impact of the project activities on them. The project aims to enroll charcoal makers into the project by establishing woodlots that eventually would provide wood for charcoal production, but it will take some time for them to mature and supply the amount that is needed. The project is also trying to provide more efficient kilns to charcoal makers (Herd, 2007) so that they require less wood.

Burning *m'shambas* is an old cultural practice in the area to prepare for cultivation, clear undergrowth around settlements, collect honey, or keep away dangerous animals. This increases the risk of carbon loss especially if the fire escapes to nearby forest areas. Therefore, the project discourages contracted households from burning their *m'shambas*. In our survey, only 16% of agroforestry contract holders confirmed that they had burned their *m'shamba* in the previous year. While many of these respondents had also modified the burning to reduce the risk of wildfire, it is still difficult to end this old cultural practice and the project needs to do much more to reduce the chance of leakage.

The third and probably most important driver of leakage in the area is clearing forests to establish new *m'shambas*. During the 1977–92 civil war, many people were displaced from rural to urban areas (Heltberg, Simler, & Tarp, 2003). Although the influx of people returning to the area after the war and clearing forests to set up farms does not constitute leakage (since this is unrelated to carbon management activities), previously settled residents may also clear forests to set up new farm plots as they see their old plots become less productive with time. According to our survey, the average number of *m'shambas* or plots in the project area increased from 1.4 per household in 2001 to 1.9 in 2008 (Table 5). This number is very close to that in non-project villages (1.5 in 2001 and 2.2 in 2008). This indicates that the project has neither increased nor reduced the pace of forest clearing for expansion of agricultural land. In order to curtail forest clearing, the N'hambita project undertakes regular monitoring and even stops carbon payments if a farmer is reported to have cleared forest area, but apparently enforcement is difficult. The project team hopes that with time, many of the agroforestry systems will enrich the soil and maintain high productivity, thus reducing the need to look for alternate farmland. However, since the carbon emissions due to forest clearing are not factored in the calculations for estimating net sequestration rates from agroforestry activities for the entire area, the resultant carbon payments are quite generous indeed.

(ii) *Permanence*

Permanence of carbon offsets is an important concern due to the temporary nature of forestry carbon stocks: a forest can be cut at any time, eventually releasing most of the sequestered carbon back into the atmosphere (Sedjo, Marland, & Fruit, 2001). For the N'hambita project the most important threat to permanence is the extremely long contract period. The project estimates its carbon offsets based on a 100-year contract period. Assuming such a contract is enforceable, it produces high value long-term offsets but it subjects future generations to a rule they may not agree with. Such long-term contracts are however not unique to the N'hambita project and several others including the PROFAFOR project in Ecuador have used similar contracts (Wunder & Alban, 2008). An alternative is to shorten the contract period, say to 10 years, but that would produce temporary carbon offsets that carry a lower market price (Haites, 2004). This would greatly reduce carbon payments to farmers and perhaps make the project financially unviable. So there is an inherent trade-off between contract duration and the payment that local farmers will receive for carbon offsets.

The timing of carbon payments is a related issue. As mentioned earlier, farmers receive the entire value of carbon offsets from agroforestry over the first 7 years, after which the agroforestry systems are expected to provide sufficient returns in the form of improved soil fertility and timber and non-timber products for farmers to continue managing them well. Indeed mango orchards and homestead planting are expected to yield the highest net benefits over the duration of the project (Palmer & Silber, 2012). However, these benefits have yet to accrue as most trees are still very young. They are expected to begin to yield fruit by the time carbon payments end after 7 years, but it is difficult to predict with certainty whether or not the benefits from fruit trees will satisfy farmers. If some farmers decide to cut their trees or stop caring for them after 7 years, the entire project impact may be jeopardized. The project tries to address this threat by retaining 15% of all carbon offsets as a risk buffer. For instance, if an agroforestry system is estimated to produce 100 tCO_2 as carbon offsets, the project only sells 85 tCO_2, while retaining the balance as a buffer against the risk of impermanence or even leakage of carbon offsets. However, future experience will determine if this risk buffer is sufficient to address concerns about permanence of carbon offsets.

Since PES began to spread rapidly in the late 1990s there has been widespread interest in utilizing it as a means to help poor people in developing countries (e.g., Grieg-Gran *et al*., 2005; Landell-Mills & Porras, 2002). Carbon is the most marketable environmental service, with over 220 projects worldwide as of 2010 (Hamilton *et al.,* 2010). In our analysis of the poverty alleviation impacts of the N'hambita Community Carbon Project in Mozamibique, we find that within a short period of time it penetrated deep within the community with a participation rate of more than 80%. Poor households have been able to access the project and many of them have multiple carbon contracts under which they convert agricultural plots to agroforestry. Carbon payments supplement their household incomes but, despite generous contract terms, liberal carbon accounting, and challenges related to leakage and permanence, the impact on household livelihood is small. In contrast, the project's development component has had a large economic impact, employing many people. However, the project cannot employ everyone in the community and in fact project employment may decline when funds come only from carbon sales rather than donors. Our finding of limited income from carbon sales suggests the need for caution in hopes regarding poverty alleviation from PES. We believe that at the current scale of operations and at current carbon prices, payments for carbon sequestration activities alone are unlikely to move people out of poverty in developing countries.

Two main caveats apply to our conclusion. First, the project does not explicitly aim to pull rural people out of poverty through carbon payments alone. Revenue from carbon sales is intended to help people transition to more sustainable, productive land uses that eventually will generate locally valuable goods. Even so, the N'hambita project offers participants very generous contract terms, concentrating payments for 100 years of carbon sequestration in only 7 years. In addition, the estimate of the number of carbon credits that the project generates is based on a high estimate of without-project deforestation. At the same time, the project does not appear to have succeeded in reducing clearance of forest for agriculture compared to a nearby non-project area. This means that the project offers about the best possible terms to farmers who provide carbon services and yet it still has had limited impact on their incomes. The project has succeeded in getting people to adopt agroforestry, but it is too soon to know whether adoption will be maintained once carbon payments end.[14]

Second, we had to undertake impact analysis of the project in the absence of baseline socioeconomic data. We were required to construct our own baseline data using a survey that asked local people to recall the conditions they faced 7 years earlier, at the time of widespread flooding that affect much of Mozamibique (but not the local villages). We acknowledge major limitations to the data, yet we have no reason to expect that errors in the data varied systematically across the different categories of people we studied. Our main finding is not dependent on the recall data: that whereas the differences in indicators of well being between non-participating households and households with agroforestry contracts are very small, differences between non-participants and households with both agroforestry contracts and project employment are very large. Using recall data to establish a rough baseline helps us to establish that prior to the projects there were no major differences across these groups for important household attributes that do not normally fluctuate and are not difficult to remember. There is no basis for assuming that respondents just quoted average numbers for the recall survey, thus we are confident that our findings do not result from either recall errors or selection bias.

The project offers some useful lessons for the continuing global negotiations on the role of forestry carbon projects in carbon mitigation strategies. Combining carbon sequestration on individual plots with REDD payments on community forests presents an interesting option. This natural complementarity helps reduce transaction costs relative to overall project benefits and it raises the revenue that local people receive. Transaction costs for the N'hambita project are high but would have been much higher if the two activities were not combined. It is important to design such combined projects in ways that ensure that local communities retain flexibility to meet their timber and non-timber needs.

By offering a menu of agroforestry systems the N'hambita project also addresses the issue of flexibility to a certain extent. In contrast to many carbon sequestration projects that allow only one set of land use practices, this menu provides flexibility for individual households to select systems that suit their specific needs. Mixing native trees with other multi-purpose species also ensures that as the trees mature, farmers can fulfill many of their timber and non-timber requirements from their own farmlands, reducing the need to fell forest trees.

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This flexibility comes at a price: higher transaction costs related to monitoring and supervising individual contracts. Even in N'hambita, where a large proportion of carbon offsets comes from REDD activities, one third of all carbon revenue is used to meet local transaction costs and another third is paid to international brokers and commission agents who help sell carbon offsets. Local costs will be high when many small farmers are contracted instead of a few large ones (Wunder, 2005). Similarly, hiring international brokers is a necessary expense especially when projects sell carbon offsets in highly disaggregated voluntary markets. When these costs are unavoidable, projects may not be viable without the support of donor funds, at least in the initial stages of project development before they can raise sufficient carbon revenue from the market.

Finally, in terms of payment mechanisms for REDD, this project distributes payment between wages for forest guards and a community fund. Judicious use of the fund is paramount in giving individual households an incentive to conserve the forest. However, forest use is dynamic and open to many conflicting claims. In the N'hambita project, migration into the area and new migrants' need to create farmlands places heavy pressure on forests, which cannot be addressed only through REDD payments. This issue is not unique to Mozambique and requires a much broader strategy both at national and international levels.

NOTES

1. Project details can also be found at www.miombo.org.uk.

2. Since none of the authors has expertise on carbon estimation, we are unable to independently verify these numbers. However, since these estimation rates are in the public domain and have been verified by international certifiers that have helped the project in selling carbon offsets, we take them as given.

3. In September 2008, $1 = MTN 24.23.

4. It should also be noted that 2008 implied not the end of the project but completion of the first 5 years of implementation and the conclusion of the donor-funded phase. The project was expected to run for many more years, funded by sale of carbon offsets.

5. A baseline survey was conducted in 2004, but the project expanded rapidly thereafter. Villages designated as non-project controls were incorporated into the project and households labeled as nonparticipants in the baseline survey soon joined the project. The baseline data were therefore not useful for analysis in this research.

6. Even the area of m'shamba land per household does not explain household well-being. Households clear forest for mshambas as needed and in our sample the per capita area of m'shamba land does not vary across the three categories.

7. For this reason we expect that reported cash income in the survey approximates a lower bound of overall earned cash.

8. An alternative is to use the two-stage Heckman correction. However, as Mercer (2004) points out, if there is no *prima facie* reason to assume which variables explain the dichotomous decision of whether or not to participate and then the intensity of participation, the use of the Tobit model is more appropriate.

9. Tests for potential multicollinearity using variance inflation factor or *vif* command in STATA is negative, with none of the variables reporting a *vif* of more than 6.1 (usually multicollinearity is a concern only if *vif* values are more than 10).

10. During open-ended discussions people suggested that the difference in the number of *m'shambas* reflects differences in household size and in how well-established a household is locally.

11. We do not have reliable data on rural inflation rates during the project period. National data suggest official annual inflation rates of about 10% during the project period, which would suggest that cash incomes actually declined for nonparticipating households and households with agroforestry contracts. In any case, the proportional difference in income change across households is invariant to the inflation rate and shows a much larger increase for households with both agroforestry contracts and jobs than for nonparticipants and households with only agroforestry contracts, which do not differ greatly.

12. Since the three groups in our sample were well matched before the project (left hand side, Table 3), we are confident that any subsequent changes in income and asset ownership are due to the project and less likely to be biased by the non-random assignment of project treatments. It is hard to imagine that households that have gained the most from the project, i.e. those with both agroforestry contracts and jobs in microenterprises, would have seen such a significant change in their income and asset ownership in the absence of the project. The area is quite remote and the authors did not observe any additional economic activity apart from the project and subsistence agriculture that could have produced such a big change. Similarly, for households that participate in only agroforestry activities and have not seen any significant gains, a biased estimate would imply that these households would have gained much more in absence of the project. Again, given the same state of factors—remote location, lack of economic opportunities—this outcome is highly implausible.

13. Six villages from the neighboring area of Cudzu were selected as non-project villages.

14. The world is littered with discarded technologies that project managers had hoped farmers would maintain after the end of project funds (Easterly 2006).

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