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Trade-offs between carbon sequestration and rural incomes in the N'hambita Community Carbon Project, Mozambique

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ABSTRACT

This paper presents a preliminary assessment of trade-offs between carbon sequestration and farmers' incomes from land-use systems implemented in a community-based project, in Mozambique. Systems either focus on carbon sequestration or combine sequestration with cash crop cultivation. The latter provide carbon payments with potential income from cash crop sales. Uncertainty about the future costs and benefits of maintaining and utilizing the land-use systems over time is addressed via application of Monte Carlo simulations. Our results show that compared with sequestration-only systems those that combine sequestration and cash crop production have higher net benefits, although they have less carbon-sequestration potential. Homestead planting provides the most attractive balance among competing policy goals. Carbon payments contribute to cash income and may enable smallholders to overcome initial project investment costs.

Introduction

Changes in the management of agricultural and forest lands could potentially lead to substantial climate benefits from carbon-sequestrating activities (Niles et al., 2002). Under the Kyoto Protocol, the Clean Development Mechanism (CDM) allows for afforestation/reforestation (AR) projects that can be implemented by low-income communities in developing countries. To date, however, very few CDM projects are engaged in AR activities (Thomas et al., 2010). Meanwhile outside the CDM, a parallel market for voluntary CO_2 emission reductions has grown rapidly in recent years.[1] A number of projects have been established in developing countries, which sequester carbon by putting in place incentives for afforestation, reforestation and agroforestry activities in rural communities (Chomitz et al., 1999; Asquith et al., 2002; Nelson and de Jong, 2003). While the Verified Emissions Reductions (VERs) produced are not currently eligible for the CDM, they may be eligible in the future should projects fulfil CDM criteria.

AR projects, whether participating in the CDM or not, can potentially combine cost-effective carbon sequestration with a significant contribution to sustainable development (Pearce, 2000; Landell-Mills and Porras, 2002).[2] Although the potential of such projects to serve as important carbon sinks has been demonstrated (Montagnini and Nair, 2004; de Jong et al., 2005; Olschewski and Benítez, 2005), doubts remain about their economic viability and potential to deliver sustainable development benefits to local communities (Minang et al., 2007; Perez et al., 2007; Pfaff et al., 2007). In particular, there are concerns about possible trade-offs between sequestration and developmental objectives.[3]

Smith and Scherr (2003) assessed trade-offs between the social benefits of a project and its attractiveness to potential investors. While large-scale plantations and protected areas are economically viable, they pose risks for local people such as the risk of losing access to land. Community-based projects, on the other hand, provide potentially the highest benefits and the lowest risks to local people but have higher transactions costs (Cacho et al., 2005). Yet, trade-offs also exist among different types of community-based projects. In this paper, we quantify trade-offs between the potential for carbon sequestration and income generation in the N'hambita

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[1] The traded volume of Verified Emissions Reductions (VER) was 23.7 $MtCO_2e$ (million tonnes of carbon dioxide equivalent) in 2006, of which around a third were forestry-related (Hamilton et al., 2007).

[2] Note that the official objective of the CDM is to achieve cost-effective reductions of GHG emissions while enabling sustainable economic development in host countries. See text of the Kyoto Protocol, particularly Article 12.2 under http://unfccc.int/essential_background/kyoto_protocol/items/1678.php, retrieved on 26 June 2008.

[3] More broadly, possible trade-offs between poverty alleviation and the provision of environmental services by the poor in developing countries has been examined, for example by Pagiola et al. (2005).

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Community Carbon Project, central Mozambique. Implemented in 2003 by the University of Edinburgh, Envirotrade and the Edinburgh Centre for Carbon Management (ECCM), this pilot project follows Plan Vivo[4] management guidelines for the production of VERs.

In this paper, we focus on trade-offs in AR schemes and the role of carbon payments in encouraging farmers to adopt carbon-sequestrating land uses. In particular, the ex ante net present value (NPV) of seven different land-use systems are estimated for the N'hambita project using survey data collected during project implementation. Some systems focus on carbon sequestration, while others combine sequestration with the cultivation of cash crops. The latter provide carbon payments in the early years of the project with the prospect of income from cash crop sales in later years thus allowing for a differentiation in benefits received by farmers over time. Uncertainty about our assumptions for values of inputs to the estimation of NPV is addressed via application of Monte Carlo simulations to project data. This paper joins a growing literature that assesses the possible trade-offs in carbon sequestration, specifically AR, projects in low-income communities. For example, Tschakert (2004) estimated a wide range of net benefits for local people participating in different land management options in Senegal, while Aune et al. (2005) and Coomes et al. (2008) found projects to be economically unviable in Nepal, Uganda and Tanzania, and Panama, respectively.

Our study contributes to the existing literature in two ways. Firstly, this is the first in-depth study of a land-use project located in Africa that incorporates cash crops into the carbon sequestration strategy in addition to the usual forestry options. It also uses data for payments received by farmers. Given that many African countries are among the poorest in the world, the benefits from such projects could have a relatively greater economic impact than in other developing regions. However, few carbon sequestration projects are located in Africa (Nanasta, 2007). As the international community slowly moves towards a post-Kyoto climate agreement, the UNFCCC has expressed concern at this lack of projects and is keen to explore ways of enhancing the continent's role in climate change mitigation (Jindal et al., 2008). Mozambique, a country with a Human Development Index (HDI) of 0.384, the sixth lowest in the world (UNDP, 2007)[5] is keen to scale-up carbon offset schemes. Hence, our results have direct policy relevance in terms of identifying those land-use activities that not only efficiently sequester carbon but also enhance incomes in a particularly poor part of the world. Second, our study is the first to our knowledge that assesses the inter-temporal sequence of farmers' costs and benefits (and the uncertainties associated with these) from carbon project participation, in Mozambique. Strategies to subsidise initial investment costs before carbon benefits are realised may reduce farmers' risks from participation (Coomes et al., 2008).[6] We find that carbon payments can potentially contribute significantly to cash income and may enable smallholders to overcome initial costs in investments that have uncertain future returns.

In section Background to the N'hambita Community Carbon Project, we present the background to the project followed by methods and results in sections Methods and data and Results, respectively. In section Discussion, we discuss our results and conclude in section Conclusion.

Fig. 1. Location of the N'hambita community in Mozambique (denoted by star). *Source*: Maps.com and authors.

Background to the N'hambita Community Carbon Project

N'hambita community is located in the province of Sofala in central Mozambique (see Fig. 1) within miombo woodlands in the buffer zone of the Gorongosa National Park.[7] In this relatively low-lying area, the climate is characterised as sub-tropical with dry (May to October) and wet (October to April) seasons (University of Edinburgh, 2008). The soils in the area are generally poor, highly weathered and freely draining sandy loams on higher ridges, with sandy silt loams found along streams and river margins.

In 2004, the community consisted of over 1000 households (Hegde and Bull, 2008). Based on a very small sample of households, Jindal (2004) estimated an average annual cash income of US$ 9 per household. Despite relatively high levels of poverty, it is unlikely that this low figure is representative of the community as a whole. As is common in much of Mozambique, the local economy is dominated by traditional, subsistence agriculture, which includes crop rotation and slash-and-burn. Two different types of agricultural fields dominate, *dimbas* and *machambas*. *Dimbas* are located in flood plains while *machambas* are established around homesteads. Both are typically planted with multiple crop plants including maize, sorghum, pigeon pea and cassava with little or no use of manure or fertilizer.

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[4] See: www.planvivo.org.

[5] The Human Development Index (HDI) gives a relatively complete picture of the level of development of a country. It includes live expectancy, illiteracy and gross domestic income (GDI) per capita. At 0.384, Mozambique's HDI is well below the mean of least developed countries (LDC), at 0.488 (UNDP, 2007).

[6] Nevertheless, it was also noted that such strategies may also lead to new problems and risks for project investors (see Coomes et al., 2008).

[7] Named after the Swahili word for the dominating genus of *Brachystegia* and spread over large parts of Southern Africa, miombo woodland consists of seasonally dry deciduous woodland (Williams et al., 2008). The canopy in the dry Eastern Miombo woodlands in Mozambique is smaller than 15 m and can be described as 'a kind of closed-canopy savanna' (Sambane, 2005).

The N'hambita Community Carbon Project[8] is a pilot project of 5 years duration organised by Envirotrade, an Edinburgh-based company, which is assisted by the University of Edinburgh and the ECCM. Core funding was partially provided by the European Union and there is a close cooperation with NGOs such as the World Wildlife Fund and the German aid organisation *Gesellschaft für Internationale Zusammenarbeit* (GIZ).[9] Project aims include the implementation of sustainable land-use practices to promote sustainable development and diversify farmers' income sources.

Land-use activities were set up in 2001 with an official project launch in 2003. The project includes the production and sale of VERs under Plan Vivo, a management plan originally developed for a similar project in Mexico and also used in Uganda and Mozambique (see Orrego, 2005). VERs are produced via the establishment of seven land-use systems. Between 2005 and 2007, VERs were sold, e.g., to the MAN Group and the International Institute for Environment and Development (IIED). Seedlings were provided by a local, project-built nursery. The expected amount of sequestered carbon is modelled and, on the basis of these results, carbon payments are paid out to the farmers via a carbon trust established in 2007. These payments are the farmers' only direct cash income source related to the project. Some land-use systems also encourage the development of cash crops (see below). Other products from the plots can be consumed by households, such as sustainably produced timber and fodder. Additionally, the project attempts to implement new income sources for the community by promoting activities such as beekeeping. To improve local education, GTZ supported the construction of a school in N'hambita. The pilot project is intended to be spread nationally and even globally later on; the project may eventually be nominated as a CDM measure if the requirements are fulfilled (Sambane, 2005).

Of the seven different land-use systems, five (two types of fruit orchard, woodlot and two types of dispersed interplanting) typically involve the establishment of new plots on existing agricultural land while boundary planting involves the planting of trees around the boundaries of existing *machambas*. The latter system provides timber, fruit, shade and nitrogen fixation, and should not affect crop yields significantly. In utilizing the otherwise less productive edge of the *machambas*, this option is ideal if little space is available. Table 1 lists the tree species planted, the density of planting and the planting systems adopted. The planting systems are used to model the quantities of sequestered carbon for each land use.

With the homestead planting option, trees are planted around the house, providing shade, fruits and timber. This option is typically undertaken on land not previously used for agriculture. Major species include mango and cashew, alongside lemon, orange and avocado, ziziphus and tamarind. While not as high as the woodlot option, homestead planting has a relatively high tree density (850 trees/ha) in contrast to the other options. By including mango and cashew trees, the homestead system could potentially provide cash income from fruit sales. Under the fruit orchard system, the area under contract is planted with trees of mango or cashew. Trees can be planted on existing *machambas*. Produced fruits are intended for commercial sale. After 50 years, the harvest will decline, and the plot is supposed to be re-established sequentially. The two fruit orchard systems are listed as distinct options, 'fruit orchard (mango)' and 'fruit orchard (cashew)', respectively.

On old *machambas* which have not been used for several years, miombo woodland is re-established on fallow ground under the woodlot system. In the agroforestry system, dispersed interplanting, nitrogen-fixing trees are planted throughout existing *machambas*. One of two species, *Faidherbia albidia* or *Gliricidia sepium* can be chosen. Dispersed interplanting removes the need to change the *machamba* via slash-and-burn agriculture and enables farmers to grow on the same plot for a longer period. *G. sepium* is harvested every 30 years, while *F. albidia* is only thinned once after about 20 years and then grown to full maturity, which can take more than 100 years. The two agroforestry systems are classified as 'dispersed interplanting (*gliricidia*)' and 'dispersed interplanting (*faidherbia*)', respectively.

As of 2007, over 70% of the community was involved in project activities (University of Edinburgh, 2007). Households were allowed to enrol for multiple contracts at the same time, with each contract typically covering 0.25–1.50 ha of *machamba* land for 100 years (Jindal, 2008). While data on the amount of land enrolled in each land-use system are currently unavailable, 1,073 contracts were negotiated by 852 households as of 2008. The dominant land uses contracted are boundary planting (56.3% of all contracts), homestead planting (15.4%), and fruit orchards (13.8%) (University of Edinburgh, 2008).

Methods and data

Survey data provided by the ECCM, consists of 'technical specifications' of the different land-use systems, which were collected during project implementation. These include technical details (e.g. tree species and number, sequestered carbon, expected harvest, etc.) as well as values for the investments required for plot establishment. Data sources, also containing the methods of collection, are listed in the following sub-sections. The analysis only includes financial incentives implemented in the project. Some non-financial benefits produced from the plots but consumed domestically, in particular fruits, are excluded due to a lack of data. Before describing the data, the cost–benefit framework used in this paper is described first.

In order to compare the costs and benefits of the seven land-use systems, we adapt a formula used by de Jong et al. (2000) to estimate the costs of carbon sequestration in another Plan Vivo project established in Chiapas, Mexico. In our formulation these costs are equivalent to the revenues received by farmers in year t from the sale of VERs on the world market, and are denoted $B_C(t)$. Thus, the net benefits from land use for an individual farmer per ha in year t are given as:

$$NB(t) = B_C(t) + B_P(t) + B_T(t) - C_E(t) - C_M(t) - C_O(t) \tag{1}$$

where $B_P(t)$ denotes revenues from the sale of agricultural products; $B_T(t)$, benefits from timber harvesting, i.e. for fuelwood and construction; $C_E(t)$, costs of establishment of land-use activities; $C_M(t)$, costs of maintenance, i.e. labour and other inputs, of the plot; and, $C_O(t)$, opportunity costs. de Jong et al. (2000) include project monitoring in the implementation and management costs, which we exclude since these are not considered by farmers. Similarly, other transactions costs such as certifying sequestered carbon are also excluded from our analysis, although these will also impact on overall system cost-effectiveness (see van Kooten et al., 2002; Cacho et al., 2005).

The opportunity cost is the net benefit that is expected from an alternative land use, which in the case of all land-use systems in the N'hambita community is assumed to be a *machamba* commonly cultivated with maize intercropped with sorghum (see Jindal, 2004). This can be calculated as the annual revenues from a hectare of crop production net of labour and other input costs (e.g. seeds, tools, etc.). Due to a lack of data for alternative land-use costs, we assume that labour and other input costs in a given year are equivalent to land-use maintenance costs under the project activ-

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[8] See: http://www.envirotrade.co.uk/Pages/mozambique_sustdevel.htm and www.miombo.org.uk.

[9] Please note that GIZ was formerly known as the *Deutsche Gesellschaft für Technische Zusammenarbeit* (GTZ).

Table 1
Land-use planting systems, tree species and potential timber products.

Land-use system	Suggested proportions of planting	Spacing	Tree density	Timber Products	First expected major thinning in year
Boundary planting	*Pterocarpus angolensis* 20% *Khaya naysica* 10% *Sclerocarya birrea* 15% *Millettia stuhlmanii* 15% *Strychnos innocua* 10% *Ziziphus mauritania* 10% +(first 25 years) *Albizia lebbeck* 36%	One row, 4 m apart	25 trees/100 m	P. a.: high value, durable K.n.: furniture S.b.: furniture & crafts M.s.: apiculture S.i.: fuelwood, fodder Z.m.: construction, fuelwood, furniture A.l.: fuelwood and poles	5 (Albizia lebbeck), 60 (other)
Homestead planting	*Mangifera indica* (Mango) 40% *Anarcadium accidentale* (Cashew) 40% *Ziziphus mauritania* 10% *Tamarindus indica* 10%	Larger trees: 4 m × 4 m Smaller trees: 3 m × 3 m	Approx. 850 trees/ha	Z.m.: construction, fuelwood, furniture T.i.: furniture, crafts	60
Fruit orchard (cashew)	*Anarcadium accidentale* 100% Potentially some minor species	5 m × 3 m	666 trees/ha	Some fuelwood	60
Fruit orchard (mango)	*Mangifera indica* 100% Potentially some minor species	4 m × 4 m	625 trees/ha	Some fuelwood	60
Woodlot	*Khaya nyasica* 20% *Sclerocarya birrea* 25% *Millettia stuhlmanii* 25% *Brachistegia boehmii* 15% *Julbernadia globiflora* 15% + (first 25 years) *Albizia lebbeck*: 64%	3 m × 3 m	1100 trees/ha	K.n.: furniture S.b.: furniture & crafts M.s.: apiculture B.b.: durable bark rope J.g.: poles A.l.: fuelwood and poles	5 (Albizia lebbeck), 60 (other)
Dispersed interplanting (*gliricidia*)	*Gliricidia sepium* + crops	10 m × 5 m	200 trees/ha	g.s.: fodder, fuelwood, furniture, apiculture	5
Dispersed interplanting (*faidherbia*)	*Faidherbia albidia* + crops	10 m × 5 m	200 trees/ha	F.a.: fodder, fuelwood, poles, furniture, apiculture	20

Source: University of Edinburgh (2008).

ity in the same year.[10] This strong assumption is one of a number in our analysis that is subject to uncertainty, which we address in section Uncertainty analysis. As a result, (1) is reduced to:

$$NB(t) = B_C(t) + B_P(t) + B_T(t) - C_E(t) - B_O(t) \tag{2}$$

where $B_O(t)$ are simply the revenues from the alternative land use. Data for the various components in (2), which are used to estimate the net benefits of adopting each land-use system, are described in the following subsections.

Calculation of the NPV for each system is a particularly useful tool for comparing activities that include benefits and costs at different points in time (Graves, 2007). This is the case for the N'hambita project where benefits from the sale of carbon certificates and from cash crops do not occur synchronously. To allow for comparability over time, costs and benefits are discounted into a present value according to the following formula:

$$\text{NPV} = \sum \frac{B(t)}{(1+i)^t} - \sum \frac{C(t)}{(1+i)^t} = \sum \frac{NB(t)}{(1+i)^t}$$

where the summations $\sum$ run from $t = 0$ to $t = T$, and i is the discount rate. Benefit cost ratios, BCR, are calculated using the following:

$$\text{BCR} = \frac{\sum (B(t)/(1+i)^t)}{\sum (C(t)/(1+i)^t)}$$

The discount rate represents the opportunity costs of the investment (Niles et al., 2002), which is closely related to the local rate of interest. Regarding individual decision-making, the discount rate can also be interpreted as the individual's inter-temporal preferences. These tend to be higher for Least Developed Countries (LDC) than for industrialised ones (Poulos and Whittington, 1999). In the literature, related studies show a wide range of discount rates, from 3% (Niles et al., 2002), 5% (DTZ Pieda Consulting, 2000), over 10% (de Jong et al., 2000), 15% (Tomich et al., 2002; Aune et al., 2005) to 20% (Cacho et al., 2003). We assume a moderate discount rate of 10%.

Benefits from the sale of carbon certificates (B_C)

The ECCM provided data on carbon storage in biomass and products based on a model called CO_2Fix-V3.1. This model was originally developed by the Modelling Carbon Sequestration in Forested Landscapes (CASFOR) project (see Schelhaas et al., 2004). Important parameters in the model include wood-carbon content, timber production, product allocation for thinnings and expected lifetime of products. The average storage over 100 years serves as the baseline used by the project developers for the calculation of the carbon payments to farmers. This implies in turn, that buyers of VERs pay for carbon sequestration over a period of 100 years, an important assumption we return to in section Discussion.

The baseline of a plot is the amount of carbon stored in biomass at the time the project activity begins, excluding carbon stored in crop plants (ECCM, 2007). The longer a plot has been fallow, the higher the baseline. Data for the accumulation of carbon in fallow plots is provided by Sambane (2005), who measured carbon sequestration on 28 sample plots within the N'hambita community. While measures on agricultural land such as boundary planting and

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[10] We observe that the inputs and practices used in the land-use systems adopted in the project are designed to closely resemble those used in *machamba* cultivation. For example, fertilizers are used neither in *machamba* cultivation nor in project land-use systems.

interplanting have a baseline of zero, the ECCM assumes that fruit orchards are established on land that has been fallow for between one and 10 years. For the woodlot system, the land is assumed fallow for 11–30 years.

In order to be able to react to unforeseen damages to the plots, which could reduce their ability to store carbon (e.g. due to fire), a risk buffer of 15% is subtracted from the calculated amounts of stored carbon. In case of no damages, this money is to be paid out to the farmers at a later stage. Within our framework, such payments are excluded for two reasons. Firstly, it is not clear when these additional payments would be made, and secondly, it is difficult to estimate to what extent the risk buffer will be used to compensate any potential damages.

The tradable amount of carbon per ha is calculated as the sequestered amount of carbon due to project activity subtracted by buffer and baseline (see Table 2).

Carbon payments received by individual farmers are dependent on the carbon purchase price paid by carbon buyers along with the transactions costs of scheme management and the monies allocated to community funds. Mean carbon payments to farmers from six transactions (carbon sales) that took place from 2005 to 2007 are US$ 6.72/tonne CO_2, respectively US$ 24.63/tonne carbon (or C) (University of Edinburgh, 2008).[11] Total carbon payments to the farmers per ha are shown in Table 2, with the woodlot and homestead options providing the highest payments. Payments are paid out by the carbon trust in annual instalments over the first 7 years of land-use implementation, and are supposed to reflect farmers' establishment costs. In the first year, 30% of the total payment is made followed by 12% in each successive year between years 2 and 6. In the 7th year, the final 10% is paid to the farmer.

Benefits from the sale of cash crops (B_P)

Three out of seven land-use systems include the cultivation of cash crops, namely mango or cashew. For the homestead planting option, the project planners suggest that 40% of all planted trees could be mango with another 40% allocated to cashew trees (see Table 1). The remaining 20% could be a mixture of other species, e.g. guava, orange, tamarind. The two fruit orchard options include either the cultivation of mango or cashew.

Project data show cashew trees to achieve a mature yield starting from the 10th year. A different source, however, suggests an average mature yield beginning from the 7th year and an average annual yield of seven to 11 kg per tree (Azam-Ali and Judge, 2004). For this analysis, the first harvest is assumed in year 7 with a linear increase to the mature yield in year 10. Project yield data are not yet available. Instead, based on Azam-Ali and Judge (ibid), a yield of 700 kg/ha is assumed for small-scale production. The market value for cashew nuts, at US$ 0.49/kg in 2005, is provided by the project developers. The potential income generated by sale cash crops in three of the land-use systems is shown in Table 3.

Mango trees bear fruit for the first time, from 4 to 7 years after planting (Griesbach, 2003). We assume a first harvest in year 7. Dirou (2004) reports a mature yield between 8 and 10 years. Thus, similar to the cashew orchard system year 10 is taken as maturity. Further incomplete data meant that data from other sources are used in order to calculate yield in the study area. Coughlin (2006) reports an average mango yield of 10,000 kg/ha in Mozambique, while an online agroforestry database established by the Traditional Tree Initiative[12] suggests that yield is often as small as 5000 kg/ha. The lower-yield estimate of 5000 kg/ha is used for this analysis. The market value of mango assumed by the project organisers is US$ 0.21/kg, as recorded in 2005. In the homestead system, 80% of the area is divided equally between cashew and mango trees.

Costs of establishment (C_E)

The costs for establishment of the plots were estimated by the ECCM. These, shown in Table 4, include the time the farmers spend working on the plots[13] and the purchase of seedlings from the nursery, although these are provided for free during the pilot phase. In addition, farmers are expected to maintain the plots on their own without the need for additional hired labour.

Benefits from timber harvesting (B_T)

In the absence of harvest data, we use estimates of dry biomass and predicted volumes of poles (for construction) and fuelwood for each system along with the year of harvest in order to calculate the systems' projected timber benefits. Mean price data are extracted from estimates collected from different rural areas of Mozambique by Mlay et al. (2003). Prices for fuelwood and poles of, respectively, US$ 3.06 and 5/m^3, are assumed.

Benefits from crop production under alternative land uses (B_O)

An alternative land-use option for all project activities, a *machamba*, is assumed based on a field survey in the project area undertaken by Jindal (2004). Although maize is commonly intercropped with sorghum, we assume for simplicity that only maize is grown on plots with an average yield of 261 kg/ha. A rotation of 6.7 years crop production followed by 15 years fallow is also assumed.[14] Retail-level price data collected in Gorongosa region, and provided by the *Sistema De Informação De Mercados Agrícolas De Moçambique* (SIMA),[15] are used to estimate maize values. Thus, maize output that is either sold or consumed domestically is valued using market prices. Jeje et al. (1998) report huge differences in returns from the sale of maize immediately after the harvest in June and after storage from June until December. Thus, an average price of US$ 0.26/kg is calculated from the June and December prices reported in 2010. The expected annual income from the production of maize on a plot (averaged over productive and fallow years) is estimated as US$ 30.68/ha.

Table 4 shows the annual revenues received from the alternative land use for each system. Homestead planting, both fruit orchard varieties and woodlot, are assumed to be installed on plots that would otherwise be used as *machambas*. For boundary planting, 400 m surround 1 ha, which are assumed to cover 20% of the area in line with assumptions made by the project developers (University of Edinburgh, 2008). For the two dispersed interplanting variations, no loss in production compared to the alternative land-use option is expected by the developers. Thus, revenues from the alternative land use, B_O, are assumed zero.

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[11] Between 2005 and 2007, 79,658 tonne of CO_2 were sold in the form of VER certificates for a total of US$ 639,374 of which US$ 339,059 were recovered as costs by Envirotrade including certification costs (University of Edinburgh, 2008). Thus, transactions costs accounted for over 50% of carbon sale revenues.

[12] See: www.agroforestry.net/tti, retrieved on 05 January 2008.

[13] Labour costs are estimated using standard day rates for the project area in 2006 (W. Garrett, personal communication, 05 June 2008).

[14] The average age of *machambas* reported by Jindal (2004) is 6.7 years, followed by a fallow time of 10–20 years.

[15] Established by the Mozambican Ministry of Agriculture, the SIMA provides data for different agricultural products at different trade levels and in different locations within Mozambique on a weekly basis. Available online at: http://www.sima.minag.org.mz/, retrieved on 01 May 2011.

Table 2
Average carbon storage, baseline, buffer, tradable carbon and total carbon payments of the seven land-use systems.

Land-use system	Average carbon storage over 100 years (tC/ha)	Baseline (tC/ha)	Buffer (tC/ha)	Tradable carbon credits (tC/ha)	Total carbon payments (US$/ha)
Boundary planting	12.92	0.00	1.94	10.98	270.49
Homestead planting	42.05	0.00	6.31	35.74	880.34
Fruit orchard (cashew)	40.2	2.80	5.61	31.8	782.99
Fruit orchard (mango)	34.00	2.80	4.68	26.52	653.19
Woodlot	61.30	11.30	7.50	42.50	1,047
Dispersed interplanting (*gliricidia*)	10.00	0.00	1.50	8.50	209.36
Dispersed interplanting (*faidherbia*)	31.9	0.00	4.79	27.12	667.84

Source: Authors' calculations based on information provided by the Edinburgh Centre for Carbon Management (ECCM).

Table 3
Potential annual yields and generated income in the three land-use systems with commercial fruit production.

	Year after planting	1–6	7	8	9	≥10
Fruit orchard (cashew)	Yield relative to mature yield	0%	25%	50%	75%	100%
	Absolute yield (kg/ha)	0	175	350	525	700
	Income (US$/ha)	0	85.75	171.5	257.25	343
Fruit orchard (mango)	Yield relative to mature yield	0%	25%	50%	75%	100%
	Absolute yield (kg/ha)	0	1250	2,500	3,750	5000
	Income (US$/ha)	0	262.5	525	787.5	1050
Homestead planting	Income (US$/ha)	0	139.30	278.60	417.90	557.20

Source: Azam-Ali and Judge (2004), Traditional Tree Initiative (see footnote 12), University of Edinburgh (2008), authors' calculations.

Table 4
Costs for establishment and maintenance ('costs') and annual benefits from crop production under the alternative land use B_0 for the different land-use systems.

Land-use system	Costs in year 1 (US$/ha × year)	Costs in years 2–5 (US$/ha × year)	B_0 (US$/ha)
Boundary planting	100	40	6.14
Homestead planting	480	200	30.68
Fruit orchard (cashew)	480	200	30.68
Fruit orchard (mango)	520	200	30.68
Woodlot	1100	430	30.68
Dispersed interplanting (*gliricidia*)	145	62.5	0
Dispersed interplanting (*faidherbia*)	145	62.5	0

Source: Edinburgh Centre for Carbon Management (ECCM) and authors' calculations.

Uncertainty analysis

Obviously, considerable uncertainty is linked to the input data feeding into our analysis. This is addressed using standard Monte Carlo simulations. Ten input variables are varied, namely: discount rate; prices for mango and cashew, respectively; benefits from alternative land uses (maize prices); establishment costs; prices for fuelwood and poles, respectively; and, yields for timber, mango and cashew, respectively. The carbon price was not varied, as it was derived directly from carbon transactions and hence, will remain fixed throughout the duration of the land-use contracts. All variables were varied over 100,000 simulations, using latin-hypercube sampling (LHS). The uncertainty analysis was implemented using the R software (version 2.9.2; see R Development Core Team, 2009).

Different uncertainty levels for the input variables are applied. For mango and cashew prices, as well as for maize, FAOSTAT data are used to estimate the uncertainty level.[16] The levels for the discount rate, establishment costs and yield quantities are chosen relatively arbitrarily and on the basis of our literature review while fuelwood and pole price-level uncertainties are based on recent African timber price data.[17] Table 5 shows the uncertainty levels applied to each of the ten input variables. In the simulations all uncertainties are accounted for simultaneously.

In the Monte Carlo simulations, the input variables are varied according to a uniform probability function around the standard values described above.

Results

Net present values and carbon sequestration potential of land-use activities

The NPV over a 100-year planning horizon for the seven land-use systems are summarized along with key parameters in Table 6. This time horizon is chosen to value these systems over the same period for which carbon credits have been quantified and sold. It also allows for the inclusion of the costs and benefits of sequential harvests.

Median values of the NPV of the seven land-use systems range from a net loss of about US$ 1700 to positive returns of US$ 4100/ha, which suggests a greater range of discounted benefits compared with, for example, the Scolel Té project in Mexico (DTZ Pieda Consulting, 2000). Note also the variation in confidence intervals due to uncertainty over the input values. The fruit orchard options along with homestead planting show the highest NPV, while only one of the other systems has a positive, median NPV, namely dispersed interplanting (*faidherbia*). Moreover, three of these four land-use options have positive, lower-bound confidence intervals. Those of homestead planting and mango orchard also compare favourably with median NPV for many of the other options, although note that the latter has the widest interval of all.

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[16] http://faostat.fao.org, retrieved 01 May 2011.

[17] http://www.itto.int retrieved 15 February 2011.

Table 5
Uncertainty levels applied to seven input variables for the Monte Carlo-based uncertainty analysis.

Input variable	Level of uncertainty	Source
Discount rate	±50%	Arbitrary, based on literature
Mango price	±50%	FAOSTAT
Cashew price	±40%	FAOSTAT
Benefit from alternative land uses	±40%	FAOSTAT
Establishment costs	±40%	Arbitrary, based on literature
Fuelwood price	±40%	ITTO
Pole price	±40%	ITTO
Timber yield	±40%	Arbitrary, based on literature
Mango yield	±40%	Arbitrary, based on literature
Cashew yield	±40%	Arbitrary, based on literature

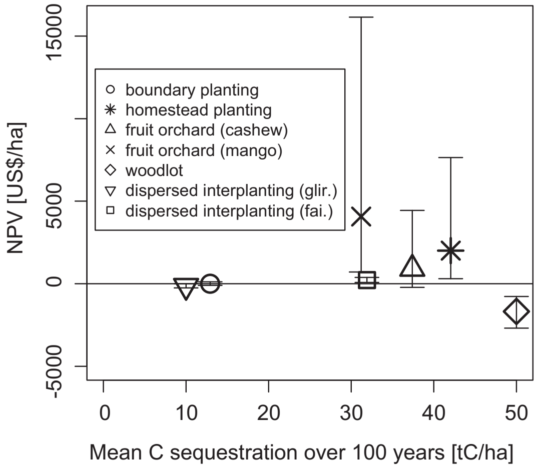

Fig. 2. Comparison of mean carbon sequestration potential (tC/ha) vs. NPV over 100 years after the establishment of the land-use systems in US$/ha median values of Monte Carlo simulations. Error bars show 95% confidence intervals.

Due to high costs of establishment and no additional income from cash-crop production, the reforestation option (woodlot) has the lowest NPV despite comprising the largest carbon payment of all systems. Moreover, reforestation, along with dispersed interplanting (*gliricidia*), have negative, higher-bound confidence intervals.

Fig. 2 compares the mean quantity of carbon sequestered per ha for each land-use system over a 100-year planning horizon, and the median NPV per ha, including the 95% interval. From the perspective of carbon sequestration efficiency, i.e. the quantities of carbon sequestered in a single ha, the most favourable option appears to be reforestation on old *machambas* (woodlot) and homestead planting. But the most attractive options from a farmer's perspective are the fruit orchard options and homestead planting. These provide the highest NPV to the farmers and hence, may contribute most to improving farmers' incomes. They also have the highest cost–benefit ratios (see Table 6). Homestead planting thus appears to provide both relatively high levels of carbon sequestered per ha and net benefits to farmers, followed by the fruit orchard options.

Temporal distribution of costs and benefits

Fig. 3 shows the annual net benefits of the seven land-use systems over the first 20 years. Until year 5, only dispersed interplanting with *F. albidia* provides an annual positive net benefit to the farmer. By years 6 and 7, all options show positive net benefits. After year 7 the three cash crop options show net benefits that rise until year 10, while the other four options show low net benefits of around zero. Income from harvesting timber occurring in years

Table 6
Key parameters of the seven land-use options: costs for establishment, total carbon payments, total revenues from the sale of cash crops, timber revenues, and NPV over 100 years: median values of Monte Carlo simulations with 95% confidence intervals.

Land use system	Total costs for establishment (US$/ha)	Total carbon payments (US$/ha)	Total revenues from sale of cash crops over 100 years (US$/ha)	Total revenues from timber over 100 years (US$/ha)	Median NPV over 100 years (US$/ha) (lower and upper 95% quantiles)	BCR over 100 years
Boundary planting	260	270	0	1142	−2 (−100 to 113)	0.982
Homestead planting	1280	880	51,541	175	2004 (305 to 7640)	2.570
Fruit orchard (cashew)	1280	783	31,728	232	903 (−224 to 4441)	1.717
Fruit orchard (mango)	1320	653	97,125	198	4065 (714 to 16,150)	4.166
Woodlot	2820	1047	0	1035	−1678 (−2691 to −776)	0.346
Dispersed interplanting (*gliricidia*)	395	209	0	653	−130 (−251 to −2)	0.567
Dispersed interplanting (*faidherbia*)	395	668	0	218	217 (78 to 385)	1.683

Source: Edinburgh Centre for Carbon Management (ECCM) and authors' calculations.
Note: BCR denotes benefit cost ratio.

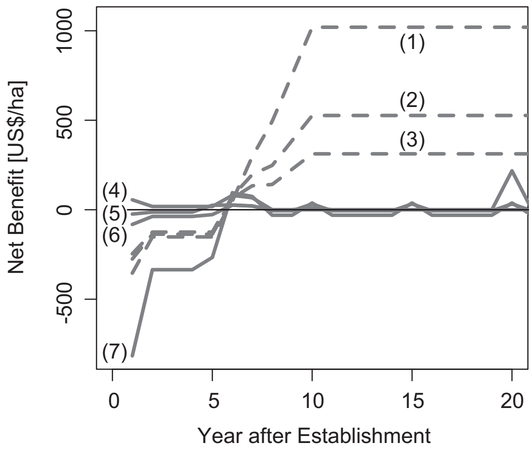

Fig. 3. Annual net benefit for farmers of the seven land-use systems in US$/ha over the first 20 years. (1) fruit orchard (mango); (2) homestead planting; (3) fruit orchard (cashew); (4) dispersed interplanting (*faidherbia*); (5) boundary planting, (6) dispersed interplanting (*gliricidia*); (7) woodlot. *Note*: Dotted lines represent systems including the cultivation of cash crops. The focus is on the first 20 years in order to distinguish the balance of costs and benefits for each land-use system.

5, 10 and 15 is relatively small compared to that from cash crops. However, it is relatively larger for the land-use options providing no income from cash crop production.

Regarding the inter-temporal distribution of costs and benefits for each land-use option, two groups can be identified: with and without cash crop production. First consider activities without cash crop production, for example, the woodlot option. The annual net benefit in the first 5 years is dominated by establishment costs as the carbon payments are not high enough to offset these. By years 6 and 7, no more establishment investments are necessary, and the carbon payments dominate. As of year 8 onwards, carbon payments cease and annual net benefits are close to zero, sometimes rising due to timber benefits. The second group consists of the cash crop systems (denoted by the dotted lines in Fig. 3), for example, the homestead planting system. Here, establishment costs again dominate annual net benefits in the first 5 years. By year 6 investments are complete and by year 7, the first crops can be harvested. The mature yield is reached in year 10. From year 7 onwards, annual net benefits are dominated by the income generated from fruit sales.

Sensitivity analysis: discount rates and carbon prices

In subsections Net present values and carbon sequestration potential of land-use activities and Temporal distribution of costs and benefits, we presented results based on assumptions of uncertainty for ten input variables. In particular, we assumed an uncertainty level of 50% for the discount rate, which at an initial assumed rate of 10% allows it to vary between five and 15%. In this subsection, we focus on the sensitivity of our results to a greater range of discount rates in order to better understand how this affects the levels of costs and benefits over time. We also investigate the role of carbon payments by relaxing the assumption of a fixed carbon price. First fixing nine of the inputs at their median values (prices of cashew, mango, fuelwood, and poles; establishment costs; opportunity costs; yields of timber, mango and cashew), we first vary the discount rate (between three and 35%) while keeping the carbon price constant at US$ 24.63/tonne C, and second, elicit the break-even carbon price in order to obtain a non-negative NPV. The latter is also undertaken at varying discount rates.

Keeping the carbon price constant while increasing discount rates shows NPV to be increasing only for the woodlot option (Table 7). NPV, however, remains negative at all rates. As rates increase, i.e. with farmers who prefer present over future consumption, NPV declines for all the other options. The exception is dispersed interplanting (*gliricidia*), which begins increasing after 20%. Fruit orchard (mango) NPV remains positive until rates hit around 30% while cashew and boundary planting remain positive until 20% and 10%, respectively. Dispersed interplanting (*faidherbia*) is the only option showing a positive NPV at all rates. With increasing discount rates, farmers value short-term benefits such as the carbon payments over those that might be realised after seven to 10 years. At the same time, costs borne by farmers in the first few years are also magnified at higher discount rates. Our results show that potential long-term benefits from the sale of cash crops are still attractive even for quite poor farmers, although the only option that would be attractive for those with rates of 30% or higher is dispersed interplanting (*faidherbia*). We infer that this is due to the carbon payments received in the first 7 years.

Further policy implications can be seen with the estimation of the lowest break-even carbon prices in order for NPV to remain non-negative, in Table 8. At relatively low discount rates, homestead planting, and both fruit orchard systems are all profitable even if carbon prices are zero. In other words, we would expect less-poor farmers to adopt these land-use systems even if they do not receive carbon payments, i.e. in the absence of project intervention. Hence, there are implications in terms of whether the carbon sequestered can be considered additional or not (also see Aune et al., 2005). However, the spontaneous adoption of these systems is not observed in non-participating households. One obvious reason might be that there are particularly poor farmers in the project area who strongly prefer present to future consumption. If this were the case, i.e. with discount rates of 20–25% or higher, then additionality of carbon sequestered would be less of a problem according to our results. The most expensive carbon sequestration system is woodlot at around US$ 80/tonne C. At higher discount rates of around 25%, fruit orchard (mango) is competitive due to high mango revenues in later years, although dispersed interplanting (*faidherbia*) is the cheapest option when rates reach 30%.

Discussion

In this paper, we quantify trade-offs for seven land-use systems in the N'hambita Community Carbon Project, central Mozambique. Using project survey data, we estimate the carbon-sequestration potential and income generated for each system, the latter using Monte Carlo simulations in order to account for uncertainties in the assumptions made for input variables. For the cash crop options, the ranking of NPV correlates with the magnitude of income potentially generated by fruit sales. These systems generally have higher NPV compared with the four other options. Regarding the latter systems, the carbon payments and establishment costs determine their relative attractiveness to farmers. We find that carbon payments only offset the costs for dispersed interplanting (*faidherbia*). In terms of the efficiency of the land-use systems to sequester carbon on a per ha basis, woodlot is the most favourable option followed by homestead planting.

In summary, our results show mild trade-offs between farmers' incomes and carbon sequestration potential, with homestead planting demonstrating the most favourable combination of income and carbon sequestration benefits. Even when accounting for uncertainty, NPV remains positive, i.e. at the lower-bound confidence interval. This is despite inclusion of the opportunity costs of *machamba*, which we could justifiably exclude given that much land used for homestead planting was not previously used for agriculture. Our analysis also reveals that those land-use systems that provide higher net benefits to farmers may not provide

Table 7
NPV at carbon price of US$ 24.63/tC at different discount rates (dr), calculated using fixed median values.

NPV over 100 years (US$/ha)	dr: 3%	dr: 5%	dr: 10%	dr: 15%	dr: 20%	dr: 25%	dr: 30%	dr: 35%
Boundary planting	108	36	−5	−14	−18	−21	−22	−23
Homestead planting	12,583	6669	2071	770	248	4	−119	−182
Fruit orchard (cashew)	7146	3644	946	201	−87	−213	−269	−292
Fruit orchard (mango)	24,651	13,208	4292	1754	724	235	−17	−153
Woodlot	−2278	−1990	−1664	−1482	−1348	−1238	−1146	−1067
Dispersed interplanting (*gliricidia*)	−26	−96	−135	−135	−128	−121	−113	−107
Dispersed interplanting (*faidherbia*)	359	302	213	165	135	115	100	89

Source: Authors.

additional carbon benefits at discount rates of up to 15%. Thus, we might expect the same land uses to be adopted in the absence of the project intervention. That this is not observed probably reflects the fact that around 85% of the local population live below the poverty line (see Jindal, 2008). Farmers with discount rates of 25% may benefit from participating in homestead planting, fruit orchard (mango) or dispersed interplanting (*faidherbia*). At higher rates, homestead planting ceases to provide net benefits.

Similar to Aune et al. (2005) we find that the proportion of income due to the carbon payments is relatively small compared with non-carbon income. However unlike Aune et al. who dismiss the potential of carbon payments to contribute to farmers' incomes due to their small size (and high transactions costs of scheme implementation), we caution that there may be additional benefits in helping farmers overcome investment risks during the early years of the project. In N'hambita, the carbon payments are paid out over the first 7 years, whereas fruit sales do not begin until year 7. The former occur within a critical phase of the land-use systems when the plots are initially established. Moreover, the size of carbon payments along with the payment schedule is known with certainty by the farmers unlike the future returns from commodities such as cashew. As there is relatively little cash in the community, with land mostly used for subsistence, carbon payments might play a key role in enabling farmers to invest in plots that could *potentially* generate more income later on. Following Coomes et al. (2008), our results indicate that substantial carbon sequestration gains should be considered in light of the high economic costs and risks from participation, namely those resulting from the need for up-front project financing before carbon benefits are realised.

Despite a slightly negative NPV, one that is far lower than either of the fruit orchard options or homestead planting, boundary planting comprises 56% of all contracts in the project. There are a number of possible reasons for this outcome. Boundary planting, similar to homestead planting, requires relatively little commitment on the part of farmers due to the utilisation of land not previously used for agriculture. Farming on other land can thus continue as before. Potential timber benefits may be another reason for the adoption of boundary planting. From Table 6, this, along with the woodlot option, provides higher timber benefits compared with the other options. In particular, the possibility to grow and harvest *Albizia lebbeck* for fuelwood within 5 years (see Table 1) may have provided an incentive for farmers to enrol in this land use. Homestead planting was the second most-popular option, and has the second-highest NPV. Its lack of dependence on timber-producing tree species, however, implies fewer timber benefits compared with boundary planting.

Participation in the other land-use options was relatively low. One reason could be the need to adopt new agricultural and land-use practices, e.g. for interplanting. These may have been perceived as too risky and perhaps unattractive when set against a 'safer' option such as boundary planting. Further research is necessary, however, to clarify what might determine adoption of the different land uses, including the role of farmers' time and risk preferences. Fruit orchards require constant crop maintenance, investments in skills and other inputs, and a supporting infrastructure for getting products to market. It is likely that maintenance costs for the fruit orchard, interplanting and woodlot options will be high and differentiated.

Use of secondary market data necessitated numerous assumptions in our analysis. To address uncertainty, we established uncertainty levels and ran Monte Carlo simulations. Despite relatively large uncertainty, reflected in the confidence intervals described in Table 6, our results are broadly categorical in terms of differentiating between incomes from the different land uses. For example, the best two income-generating land uses, mango orchards and homestead planting, return positive NPV even when the lower-bound values in the uncertainty analysis are considered. Other potential income sources, including non-timber-forest-products (NTFPs), bee-keeping, and new, off-farm employment opportunities in other enterprises associated to the project are also not considered due to missing data. However, data are missing because the costs and benefits necessary to estimate more accurate NPV have yet to materialise in the N'hambita project. Our estimates can and should be updated once new data comes to light in the future. For example, when timber and cash crops are harvested, prices received by farmers along with their costs of harvesting, storing, transporting and selling the products should be surveyed.

We note from Table 4 that there are high establishment costs for all land-use options, at least relative to average incomes in the project area. These were included in the cost–benefit calculations in order to give an idea of how these might be traded-off with respect to expected future benefits. In reality, these costs were covered by core project funding provided, for example, by the EU. This raises the crucial question of whether or not such projects can realistically

Table 8
Break-even prices (US$) at different discount rates (dr).

Break-even carbon price for $NPV_{100} = 0$ (US$/tC)	dr: 3%	dr: 5%	dr: 10%	dr: 15%	dr: 20%	dr: 25%	dr: 30%	dr: 35%
Boundary planting	13.76	20.80	25.21	26.57	27.53	28.31	28.95	29.48
Homestead planting	0	0	0	0	12.62	24.43	31.68	36.40
Fruit orchard (cashew)	0	0	0	14.90	29.38	37.52	42.56	45.89
Fruit orchard (mango)	0	0	0	0	0	7.56	25.99	37.96
Woodlot	83.79	79.61	77.71	78.43	79.59	80.75	81.82	82.77
Dispersed interplanting (*gliricidia*)	27.95	37.88	46.20	49.14	50.81	52.00	52.94	53.70
Dispersed interplanting (*faidherbia*)	10.00	11.57	13.98	15.24	15.98	16.45	16.78	17.02

Source: Authors.

be scaled up in the absence of external funds. Unless establishment costs can be minimised and sufficiently covered by participating communities this seems very unlikely indeed.

Estimation of the systems' carbon sequestration potential along with the calculation of NPV adopt a 100-year time horizon. *Faidherbia albida*, for example, has a high carbon potential over 100 years, although it can take around 50 years to reach maturity. The project developers therefore assume that the land-use systems will continue well into the future with livelihoods and incomes dependent on continued production of cash crops and other commodities. There is, of course, no guarantee that farmers will continue the land-use options in a sustainable manner with repercussions for carbon sequestration. Long-term time horizons used for calculating the quantities of carbon sequestered are only credible if appropriate protocols, including monitoring and enforcement of farmers' contracts, are established to ensure that farmers do not switch land use leading to carbon reversals. We note that the 15% risk buffer described in section Methods and data may not be adequate to cover all potential risks to carbon sequestered over such a long time period. Hence, we share the concerns of Jindal (2008) that there remain considerable risks in providing, in the first 7 years of the project, the entire value of payments for carbon expected to be sequestered over a 100 year period. After these payments are made, the economic viability of the land uses is dependent on the successful production and sale of other commodities, the yields and prices of which are all subject to uncertainty. Whether considering the production of timber within a few years or cashew production further into the future, insurance, perhaps subsidised, could be purchased by farmers to mitigate the potential risk of losses.

Given that the project is a pilot that officially finished in 2008, there are concerns about the long-run sustainability of such projects in Africa, particularly regarding the ability of communities to maintain carbon stocks over time (see Minang et al., 2007; Perez et al., 2007). Specifically in N'hambita, there are concerns about the impact of a seven-fold rise in population between 1997 and 2008, primarily due to in-migration, on project outcomes (Jindal, 2008). In addition to increased pressure on land resources, migrants who bring in distinct notions of land tenure may create tension with non-migrants. This could be difficult to resolve due to pluralism, defined as a situation where no single authority is seen as legitimate and able to implement rules regarding evidence of claim, and one that is common across the continent (see Unruh, 2008). Tenure-related complexities may have long-run repercussions for the project's sustainability.

Finally, the use of NPV assumes that farmers will respond rationally to price signals. Unlike, for example, the study of Mexican farmers by de Jong et al. (2000), it is not clear that this is the case for farmers in Mozambique. One way to investigate this is to assess participation rates of farmers in each land-use activity. While still early days for the project, a study by Jindal (2008) found that larger households and those with more farmland had a higher probability of participation. Given high levels of poverty among the local population, the study could not assess how participation varies according to differences in wealth nor the project's impacts on reducing poverty. For a better understanding of what drives land-use behaviour and the project's impacts on poverty in the area, a follow-up study should be undertaken in the coming years. In addition, an econometric analysis using panel data might enable the project developers to gauge the relative environmental effectiveness of each land-use system with respect to carbon sequestration.

Conclusion

In this paper, we presented a preliminary assessment of the N'hambita Community Carbon Project in Mozambique, which was officially launched in 2003. Since project launch, there has been high interest among farmers in participating in the project. For seven land-use systems, we quantified the trade-offs between raising farmers' incomes and carbon sequestration. Given uncertainties over the data and the assumptions made, homestead planting appears to provide the most attractive balance among competing policy goals. We have also shown that carbon payments have some potential to encourage rural development. Specifically, carbon payments may provide much-needed cash for investments in generating income in the long-run, e.g. from cash crops.

The danger, of course, then lies in creating a dependency on incomes derived from volatile cash crop markets. Mozambique was once a global leader in cashew production, for example, a situation that changed from the 1970s onwards due to a combination of civil war and increased global competition (see, for example, Horn-Welch et al., 2002). In order to minimise the risk of exposure to these markets, the project developers have implemented a range of other income-generating opportunities, including beekeeping, carving, and limited timber production alongside investments in local infrastructure. It is still to be shown, however, whether or not these are sufficient for long-run project sustainability. As noted, further research on farmer participation and actual rather than potential benefits received by farmers alongside the environmental effectiveness of the project is needed in the future.

The project is being used as a template for similar projects in Mozambique and possibly other countries. Including N'hambita, Envirotrade currently has three carbon projects in Mozambique. Given that the long-term impacts of the project will not be known for some time, this paper provides only limited guidance on how other projects might be implemented. Three issues, in particular, should be considered for N'hambita and similar projects. First, given that carbon buyers have paid for the potential carbon sequestered over a period of 100 years, robust systems need to be in place to ensure the long-term viability of carbon sinks. New investors of AR projects in a post-2012 climate framework may need more assurances that their investment will endure beyond a time-frame of a few years. Second, the project suffers from relatively high transactions costs of around 50%, which would need to be reduced if future projects are to attract new investors and provide more carbon benefits to farmers. Given that N'hambita has benefited from intense support from outside organisations such as the EU, scaling-up thus raises the question of who should bear the up-front cost, e.g. of 'core funding', of projects. Should these costs be borne by organisations such as Envirotrade then this implies taking on a large amount of risk in the event of project failure. Third and finally, there is a need to assess the impacts of in-migration and potential tensions over land tenure since reasonably clear and enforceable property rights are a necessary condition for the effectiveness of such land-use policy interventions.

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