Ecological Economics 93 (2013) 94–103

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Assessing sustainable forest management under REDD+: A community-based labour perspective

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ARTICLE INFO

Article history:
Received 18 January 2013
Received in revised form 25 April 2013
Accepted 7 May 2013
Available online xxxx

Keywords:
REDD+
Deforestation
Sustainable forest management
Amazon
Labour input
Bolivia

ABSTRACT

Reducing emissions from deforestation and forest degradation plus (REDD+) encourages economic support for reducing deforestation and conserving or increasing existing forest carbon stocks. The way in which incentives are structured affects trade-offs between local livelihoods, carbon emission reduction, and the cost-effectiveness of a REDD + programme. Looking at first-hand empirical data from 208 farming households in the Bolivian Amazon from a household economy perspective, our study explores two policy options: 1) compensated reduction of emissions from old-growth forest clearing for agriculture, and 2) direct payments for labour input into sustainable forest management combined with a commitment not to clear old-growth forest. Our results indicate that direct payments for sustainable forest management – an approach that focuses on valuing farmers' labour input – can be more cost-effective than compensated reduction and in some cases is the most appropriate choice for achieving improved household incomes, permanence of changes, avoidance of leakages, and community-based institutional enforcement for sustainable forest management.

1. Introduction

A decision taken by the United Nations Framework Convention on Climate Change (UNFCCC) at the Copenhagen Conference of Parties in 2009 highlights "the importance of reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forest and enhancement of forest carbon stocks in developing countries" (Decision 4/CP.15). By taking this decision concerning the Reducing Emissions from Deforestation and Forest Degradation plus (REDD+) mechanism, the UNFCCC intended to make available economic support not only for reducing deforestation rates, but also for conserving or increasing existing forest carbon stocks using sustainable forest management (UNFCCC, 2010). At the same time, the convention also recognized "the need for full and effective engagement of indigenous peoples and local communities in, and the potential contribution of their knowledge to, monitoring and reporting of activities" (Decision 4/CP.15). These decisions are particularly important with a view to supporting multifunctional community- or family-based forest management in situations where individuals are highly dependent on forest for their livelihoods (Sunderlin et al., 2008). Focusing on sustainable forest management means going beyond mere compensation for emission reductions and also thinking about economic activities with co-benefits that can viably link conservation strategies with local livelihoods.

However, linking REDD + schemes to sustainable forest management poses methodological challenges associated to baseline definition, implementation, and monitoring, especially regarding counterfactual scenarios for establishing socio-economic impacts (Caplow et al., 2011). In this regard, Skutsch et al. (2011) suggest considering at least the following two types of REDD + design: 1) payments to compensate the management of carbon outputs, that is, fixed payments to a forest managing unit based on the amount of carbon fixed compared to a baseline value and on an assessment of opportunity costs; 2) payments to compensate the management of inputs, such as agreeing to meet certain specific norms of sustainable forest management.

In the first type of REDD + design – output-based compensated reduction – compensation payments are based on verified reductions of carbon emissions (Bellassen and Gitz, 2008; Börner et al., 2010; Milne and Adams, 2012; Sandker et al., 2010). Payments generally compensate at least the opportunity costs of not converting forest into other, more profitable land use categories (e.g. agriculture, pasture, perennial crops). Forest users are expected to respect the emission reduction agreement; compliance has to be monitored and assessed on a regular basis (Skutsch et al., 2011). Compensated reduction models

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http://dx.doi.org/10.1016/j.ecolecon.2013.05.003

are oriented strictly towards conservation and hence do not require labour inputs. Consequently, they are potentially less beneficial to poor and landless labourers (Grieg-Gran et al., 2005). Indeed, they can trigger migration from rural to urban areas or lead to high carbon leakage and difficulties in ensuring the permanence of carbon sequestration (Dargusch et al., 2010; Wunder et al., 2008). High transaction costs and unequal benefit sharing due to insecure land rights and systemic effects on local market prices for basic food products have also been mentioned as problematic aspects of compensated reduction approaches (Grieg-Gran et al., 2005; Peskett et al., 2008). Furthermore, designing compensated reduction approaches across multiple scales poses methodological challenges (Cattaneo, 2011). More importantly, however, valuing forests based on a utilitarian strategy that focuses exclusively on conservation leads to the commodification of forests; this, in turn, can have counterproductive effects and might even increase environmental degradation in the long run (Gómez-Baggethun and Ruiz-Pérez, 2011; Muradian et al., 2013). Market mechanisms for compensating differential opportunity costs through carbon offset trading have been presented by some as a new mechanism of wealth redistribution from poorer to wealthier classes (McAfee, 2012).

These issues are particularly relevant in Bolivia, where President Evo Morales has condemned the "commodification of nature" promoted by the REDD + programme.[1] The main argument, also shared by a number of scholars (McAfee, 2012), is that Western countries must reduce their own emissions before implementing global mechanisms that constrain the development options of forest users in poor countries. Seeking to reorient forest policies away from the commodification of ecological services, the Bolivian government has practically paralyzed all ongoing REDD + programmes.

The second type of REDD + design – input-based sustainable forest management — relies on radically opposite principles. The basic idea is to reduce CO_2 emissions by improving forest management techniques, for example by establishing certification mechanisms and legal commodity chains in order to make forestry more sustainable economically and ecologically. In addition, achieving these goals requires improving local capacity, institutions and forest management techniques by means of adequate publicly funded incentives in a first step. In this sense, input-based sustainable forest management schemes are closely related to the widely known framework of integrated conservation and development projects (ICDPs), whose limits have long been assessed and which were criticized mainly for their low cost-effectiveness (Blom et al., 2010; García-Amado et al., 2013; Wunder and Albán, 2008).

In view of the drawbacks of both compensated reduction and sustainable forest management approaches, the question arises whether it would be possible to merge or combine them to create a more balanced mechanism, and whether this could be done taking advantage of the REDD + debate and the related international mobilization and funding opportunities (García-Amado et al., 2013). This second aspect in particular calls for more knowledge about whether the financial means currently available to 'buy' carbon emission reductions could be used more efficiently to support and redirect local forest users' labour input into sustainable forest management.

Currently Evo Morales' government seems to be more inclined towards an input-based sustainable forest management approach than compensated reduction (PSB, 2012:13). The problem is, however, that Bolivia's current forest regime has a very low capacity for management due to its institutional and financial situation (Pacheco et al., 2010). A recent evaluation has shown that only 5% of Bolivia's potential for sustainable forest management has been realized so far, and that 50% of the extracted timber is still cut illegally (Pellegrini and Dasgupta, 2011). During the last decade, the government's main policies focused on a redistributive land reform influenced by the corporative interests of Evo Morales' political basis (Bottazzi and Rist, 2012). Concrete solutions are certainly needed in the forestry sector, which is characterized by a lack of clear policies, disintegrating forest management mechanisms, and accelerating deforestation and forest degradation (Pacheco et al., 2010; Pellegrini and Dasgupta, 2011; Redo et al., 2011).

The idea of reorienting REDD + instruments towards sustainable forest management opens a new field of research that is relevant not only to Bolivia, but to most tropical forest countries, and that centres around the following question: What are the potentials and constraints of converting REDD + mechanisms into an instrument for enhancing community and family forestry? Such an approach could help to prevent REDD + interventions from unilaterally benefitting large-scale forest owners and related national or transnational private corporations (Barr and Sayer, 2012; Börner et al., 2010; Tienhaara, 2012). Refocusing REDD + on the needs and particularities of sustainable community and family forestry also resonates better with equity- and rights-based definitions of sustainable development (Jaung and Bae, 2012).

However, in order to enable the selection of an appropriate mechanism to support community forestry, it is necessary to first solve a number of pending methodological questions, especially regarding the estimation of opportunity costs. In some cases, opportunity costs in REDD + projects are calculated considering only the net revenue from agriculture (profit). Such approaches presuppose an ideal labour market that would allow farmers to compensate the reduction in work brought about by the project by finding alternative wage labour or independent activities in areas nearby (Bellassen and Gitz, 2008). This assumption is highly problematic, given that alternative employment opportunities are often scarce at the forest frontier. Displacing labour by giving up agriculture means further constraining farmers' opportunities to find another job (Grieg-Gran et al., 2005; Peskett et al., 2008). Under such circumstances, assuming farmers' interest in participating in a payment for environmental services (PES) scheme without considering their future employment options can lead to low participation once the programme is implemented. For this reason, the opportunity cost of foregone labour should be taken into consideration when assessing potential REDD + mechanisms. This means considering the value of farmers' labour inputs into their land in baseline assessments and including it in incentives for carbon sequestration. This is the reasoning followed by Skutsch et al. (2011), who propose a "system in which communities are paid for their services in measuring and monitoring carbon stock, combined either with conditionalities for forest management, or with a supplementary payment related to carbon performance" (Skutsch et al., 2011: 150). Indeed, this proposition is very provocative, but also challenging, and further empirical and conceptual modelling is required in order to test its feasibility.

The present study explores the practical implications of leveraging incentives for sustainable forest management to obtain reductions in deforestation, as opposed to a financial incentive directly compensating reductions. The main difference between the two approaches is that an incentive for sustainable forest management subject to a cross-compliance condition regarding deforestation lends itself better to integrating the fundamental aspect of community-based labour requirements. The study is based on empirical data on trade-offs and synergies between agriculture, forestry, carbon emissions, and local land users' labour investments in the concrete case of eleven community forests in the lowlands of Bolivia. This article focuses on the modelling of two scenarios: 1) an output-oriented scenario of compensated reduction of emissions from old-growth forest clearing based on a flat rate payment; and 2) an input-oriented scenario of payment for labour required for sustainable forest management

[1] http://pwccc.wordpress.com/2010/10/07/presidents-letter-to-the-indigenous-peoplesnature-forests-and-indigenous-peoples-are-not-for-sale/ (accessed on 20 December 2012).

combined with a commitment not to clear old-growth forest. In order to enable comparison of the two scenarios, the underlying economic and ecological model must be based on first-hand agronomic and forestry data.

2. Material and Methods

2.1. Data Collection

This paper results from a two-year research project on community-based sustainable forest management in indigenous Tsimane and Andean migrant settlements located in the buffer zone of the Pilón Lajas Biosphere Reserve and Indigenous Territory in the Beni department of Bolivia, 350 km north of La Paz. Fieldwork was carried out from February to July 2011, by an interdisciplinary team composed of 3 socio-anthropologists, 2 forestry scientists, 1 spatial analyst (remote sensing), and 1 agronomist. An economist provided additional expertise for the analysis and interpretation of the field data. Data collection for this article included a household survey (N = 209) among Tsimane' Amerindians (N = 61) and Andean settlers (N = 148), as well as participatory forest measurements (N = 337) carried out with the communities involved (N = 11). More specifically, data were collected by the following methods:

1. Focus group and interviews: In each community, research started with a focus group consisting of community members in order to understand the main social, institutional, and historical characteristics of each settlement. Based on interviews with key persons we also established a precise model of productive activities in the village, including costs, labour requirements, and level of commercialization for the most important marketable products of the area, which are rice, maize, cassava, plantain, cattle, and timber (N = 40). Information about inputs, wage labour, and product market prices collected during these interviews was then cross-checked against secondary data provided by relevant stakeholders, NGOs, and government services.
2. Household surveys: Farmers were asked to draw their parcels and mark the location of each specific crop and mixed crops, indicating cultivation periods, the surface cultivated, and yields. Farmers were also asked what proportions of the land they had cleared for crop cultivation had previously been old-growth forest and fallow land, respectively. The focus was on the surface cleared in 2010, looking back on the one-and-a-half years preceding the survey. In 20% of the cases, we visited the parcels to observe the crops and asked more specific questions about agricultural techniques, cropping calendars, and uses of products. This enabled us to assess the surfaces cleared by each household for each crop or combination of crops. Farmers' estimations of their cleared surfaces correspond closely to direct physical measurements carried out by researchers in this area (Reyes-García et al., 2003). Farmers' perceptions of the importance of each source of income (e.g. agriculture, forestry, wage labour) within the household economy were also recorded in the survey. Household representatives were asked to weight images depicting the various sources of income by distributing 25 tokens among them. The same method was used to determine the proportions of time invested in each productive activity and the importance of each activity in terms of direct consumption (or subsistence use).
3. Forest measurement: A forest measurement inspired by International Forestry Resources and Institutions (IFRI)[2] methodology was conducted to assess above-ground biomass, species diversity, and carbon sequestration. We first used recent SPOT images provided by the Planet Action programme[3] to divide the forest surface into two categories for each community: old-growth and young-regrowth forests. Then we randomly selected 30 to 90 forest plots in each settlement using the automatic function of the ArcMap software. Each plot consisted of a circular area with a radius of 10 m, in which we measured the diameter at breast height of all trees and saplings. In a smaller circle of 1 m radius at the centre of each plot, we additionally recorded all natural regeneration and individual herbaceous plants. Most plots were located in old-growth forests, where forestry activities are usually possible and for which we wanted to obtain comparative results (N = 330). When an automatically defined plot was in an area where the forest was not accessible on foot, we redefined the plot by moving it 100 m to the west. Forest sampling was carried out in direct collaboration with hired villagers. During this process, we gathered useful information about forest use and the value of products on the local market.

2.2. Data Analysis

The agronomic and forestry data collected were then used to calculate 3 classes of interrelated variables.

First, on the basis of agronomic variables, we defined scenarios of agricultural production for each community depending on their current practices. Each scenario was constructed taking into account the given community's preferences for mixed crops and successional crops, according to a methodology that had already been applied in similar areas (Malky et al., 2012; Pagiola, 2009). Depending on these scenarios, we calculated the net present value of agricultural production per hectare in each community.

Second, we used the forestry data collected to characterize each community forest based on 3 main indicators: species diversity (H'), above-ground biomass, and the amount of carbon stored in each forest. We calculated species diversity (H') using the Shannon–Wiener index (Önal, 1997). Above-ground biomass was estimated based on the calculation of stem biomass and a biomass expansion factor for branches and leaves using Brown's methodology (Brown, 1997). The total carbon stored in the total above-ground biomass was calculated using a correspondence factor provided by a relevant model in this field of research (Brown and Lugo, 1992; IPCC, 2003). In this way, we obtained a precise estimation of annual carbon emissions per hectare deforested for agricultural purposes.

Third, we used forest data to assess the timber production capacity of each forest that would be placed under a rotational forest extraction regime (Pattie et al., 2003). On this basis, we calculated the forest's commercial volume per hectare, its annual trade volume, net annual revenue from forest extraction, and the total labour required for sustainable management activities per hectare.

Finally, we entered relevant variables – such as the area deforested for agriculture, carbon emissions per hectare, net present value of agriculture, and forest productivity – in an enterprise budget model (Gittinger, 1982) to assess the trade-offs related to the compensated reduction and the sustainable forest management scenarios that are detailed in Sections 3.3. and 3.4. In this article, we focus on profits and implicit wages as two separate components of opportunity costs, and examine the implications of different REDD + designs for these two components from a smallholder's perspective. Based on the size and productive capacity of their community forests, settlements were classified into two categories: those with more than 1000 ha of old-growth forest and hence a higher potential for forestry, labelled "forestry settlements" (N = 5); and those with less than 1000 ha of old-growth forest but sufficient young-regrowth forest and agricultural land, and hence a higher potential for agriculture, labelled "agricultural settlements" (N = 6). This division was based on the hypothesis that villages with insufficient

[2] http://www.ifriresearch.net/.
[3] http://www.planet-action.org/.

Table 1
Average demographic and basic land cover characteristics of the forestry settlements (N = 5) and agricultural settlements (N = 6) studied for 2010.

	Forestry settlements (N = 5)	Agricultural settlements (N = 6)	Standard deviation (N = 11)
Social data			
Year of establishment	1974	1981	12
Number of families	19	19	4.8
Land cover (ha)			
Old-growth forest	2284	485	1495
Fallow and grazing land	198	198	151
Permanent crops and young regrowth	346	461	147
Other land use	96	212	119
Total	2924	1355	1451
Forest data			
Forest species diversity H'	3.51	3.31	0.33
Biomass density, old-growth forest (tC/ha)	342	262	103
Carbon density, old-growth forest (tC/ha)	171	131	52
Cropland (ha per family)			
Annual crops	1.4	1.8	0.6
Semi-perennial crops (plantain)	1.2	1.3	0.8
Perennial crops (cocoa, citrus fruits)	0.7	0.9	0.7
Total average cropland	1.1	1.3	0.4

forest size should not present great potentialities for sustainable forest management scenario.

2.3. Case Study: the Pilón Lajas Biosphere Reserve

The Pilón Lajas Biosphere Reserve and Indigenous Territory is located 350 km north of La Paz in the outer limits between the western cordillera of the Andes and the plains of the Beni department. The area is characteristic of tropical rainforest ecosystems, which are found in several parts of the world, including South and Central America, Southeast Asia, and sub-Saharan Africa. Despite the dense vegetation and high level of biodiversity in rainforests, soil quality is often poor; once the land has been cleared and used for agriculture, it takes about 5 to 10 years for the soil to recover its productive capacity (Lieth and Werger, 1989). Tropical rainforests play a major role in carbon sequestration and have become the main target of REDD + programmes. The selected eleven communities are inhabited by a mix of indigenous people and Andean migrants. The latter moved to the area in the 1980s from the highlands. Similar population mixes can be found in the Andean piedmont in Ecuador, Peru, Bolivia, and northern Argentina (Rudel et al., 2002).

The statute of the Pilón Lajas Biosphere Reserve – which was established in 1992 – permits managed and moderated timber extraction in the reserve's buffer zone. This is where the studied communities are located. Timber may be extracted for commercial purposes under the condition that the community follows a forestry management plan procedure as stipulated by the national forestry law; this plan must include a polycyclic rotation of harvesting areas.[4] This condition is hard for local users to fulfil. Their main problem is that management plans are costly and hard to manage efficiently without external assessments, appropriate monitoring procedures, and an adequate infrastructure. In view of these difficulties, most local users prefer to bypass the formal rules and extract timber illegally, selling it on the black market, before converting the land into cropland and pastures (Bottazzi, 2009).

[4] Forestry law N°1700 of 1996.

3. Results

3.1. Local Productive Strategies in Forestry and Agricultural Settlements

The data on land cover, forests, and agriculture indicated in Table 1 reflect the categorization of villages into "forestry settlements" and "agricultural settlements": forestry settlements have a higher potential for sustainable forest management than agricultural settlements, based on larger forest surfaces (averaging 2284 ha), higher biomass density (342 t/ha), and greater species diversity (H' = 3.51) in old-growth forests. Forestry settlements are generally involved in sporadic timber extraction activities under informal institutional arrangements with other commodity chain actors. These activities typically yield extremely low profits. In some cases, standing trees are directly sold to external forest operators, without any labour input from the community. In such cases, the price per tree is below US$ 20, and sometimes the trees are not sold, but bartered for merchandise or alcohol. In other cases, community members decide to invest their own labour in timber extraction. Money to cover the costs of inputs – such as chainsaw rental, oil, and food supply – is often advanced by illegal timber traders, keeping the net benefit to the community very low. Timber prices on the black market in the area range between US$ 0.10 and 0.30 per cubic metre, depending on wood quality, whereas prices on the certified market are considerably higher, ranging between US$ 0.25 and 0.52 per cubic metre (own observations). The absence of technical capacity to fulfil the formal requirements of certified extraction also clearly shows in the quality of the final product, which fails to meet international standards for export, reducing prices by another 50% (Hjortsø et al., 2006). According to our survey, income from timber extraction in forest settlements represent only 8% of total household incomes, while agriculture and cattle account for 41%. Revenues from the sale of timber are invested in agricultural inputs, such as seedlings or cattle, or spent on consumption. Families complement the limited profit from unsustainable logging activities by converting forest into more profitable agricultural land, leading to the area's high average annual deforestation rate of 1.3% between 1987 to 2006 (Bottazzi and Dao, 2013). Inhabitants of agricultural settlements generally rely very little on forest extraction (5% of household incomes); this is due to the reduced forest surface in their villages (485 ha on average). Their household productive strategies are mainly based on annual (1.8 ha), semi-perennial (1.3 ha), and perennial (0.9 ha) crops, as well as on small-scale cattle ranching. These activities together account for 55% of household incomes.

The slightly greater size of surfaces cleared in agricultural settlements is reflected in their focus on agriculture, and particularly rice cultivation. After the rice is harvested, it is followed by maize, cassava, and plantain, which are often planted on the same plots originally cleared for rice. Once these annual crops are harvested, the plantains remain in production for 2–3 more years, followed by 5–10 years of fallow with natural forest regeneration. Due to its high nutrient requirements, rice is often planted in areas cleared from old-growth forest, where soils contain more nutrients than on plots previously used for agriculture and then left fallow. For this reason, rice has the highest impact on deforestation (Vadez et al., 2008). Each year, families also plant a few perennial crops, such as cocoa and citrus fruits, mainly for their own consumption.

Revenue from agriculture and other activities are sometimes invested in cattle, which are kept on agricultural plots after harvesting, impeding forest regrowth. After several years of cattle grazing, the land becomes unproductive and is abandoned, and new forest areas are cleared. This leads to substantial deforestation and forest degradation. These processes cause environmental damage through carbon emission and loss of biodiversity, and they are also unsustainable for farmers themselves, who are forced to constantly find new forested areas to clear for their crops.

Table 2
Average productive features and carbon-emission data of agricultural and forestry settlements under current conditions (calculated by family based on data for 2010).

	Forestry settlements	Agricultural settlements	Overall average[a]	Standard deviation
Cleared surface in fallow land and young regrowth (ha)	0.97	1.00	0.99	0.39
Cleared surface in old-growth forest (ha)	0.41	0.68	0.56	0.43
Total surface cleared for agriculture (ha)	1.38	1.68	1.55	0.41
Labour input into agriculture (days)	135	178	159	46
Labour input into timber (days)	17	13	15	7
Total labour input in land use (days)	152	192	174	48
Carbon emission from forest clearing (tCO_2)	449	494	474	205
NPV[b] of agriculture (US$)	628	991	826	293
NPV of agricultural labour (US$)	1156	1528	1359	396
NPV of timber (US$)	172	135	152	73
Net income from land use (US$)	1956	2653	2336	657

[a] The average was calculated by dividing the sum of all community values by the total number of communities (N = 11).
[b] NPV = Net Present Value.

3.2. Opportunity Cost of Emission Reduction Based on Current Land Use

In Bolivia, very few studies have estimated the opportunity cost of agricultural land use; their results vary depending on the areas affected by deforestation and the type of counterfactual scenario used in the PES schemes studied (Grieg-Gran, 2006; Silva-Chavez, 2005). Table 2 presents the average socioecological outcomes per family of one year of agriculture and forestry in the settlements studied, based on primary data from each community for 2010. The average surface each family cleared for new crops in 2010 was 1.55 ha, which corresponds to a net present value per family of approximately US$ 991 in agricultural settlements and US$ 628 in forestry settlements. This is almost half of the values that Grieg–Gran obtained for large-scale agriculture in the area of Santa Cruz (2006). Two thirds of the total cleared surface was cleared from fallow land and one third from old-growth forest, resulting in an average annual emission of 474 tCO_2 per household. Agriculture and forestry require an average labour input of 174 days per family, which represents one third of the total labour investment in all livelihood activities (including also wage labour on other agricultural farms, domestic activities, and production of small-livestock). Only the labour inputs in agriculture and forestry were considered in this study. Based on the above values, we calculated an average opportunity cost of forgone profit from agriculture of US$ 1.94 per ton of CO_2 not emitted (Fig. 1).

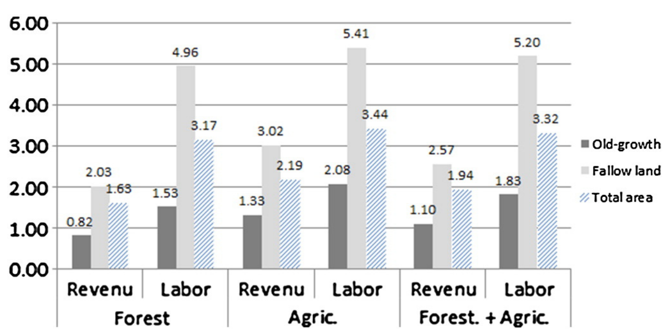

Fig. 1. Comparison of opportunity costs of forgone profits and labour inputs (both in US$) of reducing carbon emissions from clearing old-growth forest and fallow land by 1tCO_2 in forestry and agricultural settlements.

This result corresponds well with similar work carried out in a nearby area (Malky et al., 2012)[5] but remains extremely low compared to estimates for the region of Santa Cruz (Grieg-Gran, 2006). The average opportunity cost of labour is almost double that of profits. If we add up both components and include transaction and implementation costs, we get a total cost of reducing carbon emissions of around 6.3 US$/$tCO_2$; on this basis, reducing carbon emissions by 100% in 2010 would have cost each settlement an average of US$ 53,200.

Fig. 1 presents the calculated average opportunity costs of reducing emissions from clearing old-growth forest and fallow land by 1 tCO_2 for both forestry and agricultural settlements. The opportunity cost of emission reduction per ton of CO_2 is much lower for old-growth forest because its carbon density is considerably higher than that of fallow land. Fig. 1 also clearly shows that the labour component of opportunity costs is almost twice as high as the profit component (inputs without labour) both for old-growth forest and fallow land.

The following sections present the trade-offs between household incomes, carbon emission reduction, and the cost-effectiveness of an output-oriented and an input-oriented REDD + payment scheme, respectively. The first scenario follows an output-based PES approach, compensating the reduction of emissions from clearing old-growth forest with a flat-rate payment (5 US$/$tCO_2$) (Bellassen and Gitz, 2008). The second scenario explores the option of providing payment for the labour input required for more sustainable forest management, based on the implementation of a sustainable forest management plan. This payment is additionally conditioned by a commitment to stop deforestation in old-growth forest (Fig. 2).

3.3. Scenario 1: Compensated Reduction of Emissions from Old-Growth Forest Clearing

Scenario 1 takes present land use patterns as a business-as-usual baseline, using the empirical data collected (Table 2). The scenario assumes that villagers conclude an agreement with the state to stop clearing old-growth forest, while maintaining agricultural production on previous fallow land and young-regrowth forest. As an incentive for farmers to conserve their old-growth forests we hypothetically defined a compensation payment of US$ 5 per additional ton of CO_2 stored in their forest compared to business as usual. This amount corresponds approximately to the opportunity cost calculated for the study area. Based on previous studies and preliminary data from our survey, we assumed that limiting crop production to previous fallow land would entail a 20% reduction of average yields (Pascual, 2005; Vadez et al., 2008). We calculated the expected values of the system's main input and output variables, notably changes in farmers' labour inputs, the reduction of carbon emissions, the net present value of agricultural production, and the total amount of net cash payments for carbon sequestration based on the compensated reduction scheme.

The data presented in Table 3 indicate that a complete avoidance of old-growth forest clearing represents a 59% reduction of carbon emissions compared to business as usual as calculated in the previous section. As one would expect, if incentives compensate the opportunity cost, the benefits for communities, especially for agricultural settlements, are higher than with business as usual: their income increases by 20% compared to opportunity costs due to the additional benefit from the carbon offset price (5 US$/$tCO_2$) and the high concentration of carbon in old-growth forest. This model also releases almost 40% of farmers' labour while maintaining two thirds of the total agricultural production (the part implemented on fallow land). The cost

[5] This study, carried out by the NGO Conservation International, found an opportunity cost value of 2.3 US$/$tCO_2$ (1.298 US$/ha) based on a similar methodology.

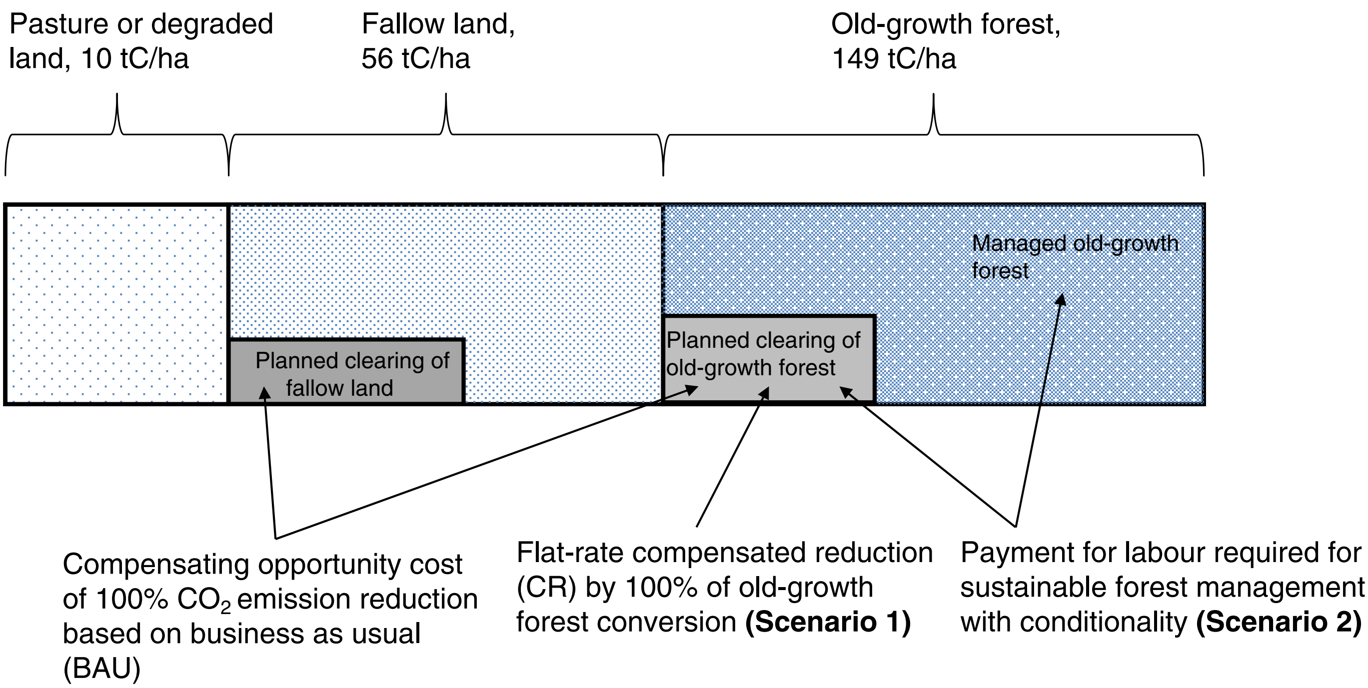

Fig. 2. Current land clearing and possible reduction scenarios under different REDD + designs (arrows indicate activities to which funds are being targeted).

Table 3
Average productive features and carbon-emission data of agricultural and forestry settlements under compensated reduction (Scenario 1), calculated by family.

	Forestry settlements	Agricultural settlements	Overall average	Standard deviation
Cleared surface, fallow land (ha)	0.97	1.00	0.99	0.39
Cleared surface, old-growth forest (ha)	–	–	–	–
Total surface cleared for agriculture (ha)	0.97	1.00	0.99	0.39
Labour input into agriculture (days)	88	88	88	30
Labour input into timber (days)	17	13	15	7
Labour input into managing CR (days)	4.1	4.6	4.4	3.1
Total labour input in land use (days)	110	106	108	27
Carbon emission from forest clearing (tCO_2)	164	169	167	66
Emission reduction (tCO_2)	285	325	307	219
NPV[a] of agriculture (US$)	321	476	406	157
NPV of agricultural labour (US$)	819	907	867	340
NPV of timber extraction	172	135	152	73
Net cash payment for CR (5 US$/$tCO_2$)	1425	1625	1534	1093
Total revenue from land use and CR[b] (US$)	2737	3143	2958	1053
Total annual cost of CR (+20% TIC[c]) (US$)	1709	1951	1841	1311
Emission reduction compared to BAU[d] (%)	57	61	59	24
Total annual cost of CR per settlements (US$)	37,029	39,414	38,330	34,032

[a] Net present value.
[b] Compensated reduction.
[c] Transaction and implementation costs; these were estimated using the methodology proposed by Pagiola (2009).
[d] Business as usual.

for Scenario 1 averages US$ 1841 per family. It is slightly higher for agricultural settlements (US$ 1951) than for forestry settlements (US$ 1709).

3.4. Scenario 2: Payment for Labour Inputs into Sustainable Forest Management

Under Scenario 2, each land user is paid for labour invested in sustainable forest management, provided that they commit to stop clearing old-growth forest. Paid activities include establishment of a management plan for the community forest, sustainable forest extraction, and monitoring. All of these activities are to be implemented in old-growth forests and must be strictly in line with the principles of sustainable forest management as defined for sustainable commercial forestry, as well as with a previously established management plan. Restrictions regarding diameter size must be respected and the production of tree seedlings for forest regeneration must be guaranteed as stipulated by the latest legislation in this field (MDSP, 1998). Agricultural activities are the same as under Scenario 1, allowing for a 59% reduction of carbon emissions based on communities' commitment not to clear old-growth forest for agriculture. Labour released due to the reduction in agricultural activities is invested in sustainable forest management in exchange for a financial compensation (Table 4).

Communities have a variable potential for investing in forestry labour, depending on the size of their forests. Forestry labour is compensated with US$ 15 per day[6] and includes the implementation of an old-growth forest management plan and annual forest monitoring. Scenario 2 results in a considerable increase in work invested in land

[6] This amount corresponds to the upper limit of standard wages, which vary from US$ 8 to 15 per day.

Table 4
Average productive features and carbon-emission data of agricultural and forestry settlements under sustainable forest management (Scenario 2), calculated by family.

	Forestry settlements	Agricultural settlements	Overall average	Standard deviation
Cleared surface, fallow land (ha)	0.97	1.00	0.99	0.39
Cleared surface, old-growth forest (ha)	–	–	–	–
Total surface cleared for agriculture (ha)	0.97	1.00	0.99	0.39
Labour input into agriculture (days)	88	88	88	30
Labour input into SFM[a] (days)	91	14	49	49
Total labour input (days)	179	102	137	48
Carbon emission from forest clearing (tCO_2)	164	169	167	66
Emission reduction (tCO_2)	285	325	307	219
NPV[b] of SFM (US$)	242	26	124	133
NPV of agricultural labour (US$)	819	907	867	340
NPV of agriculture (US$)	321	476	406	157
Payment for labour input into SFM (US$)	1365	203	731	745
Total revenue from land use (US$)	2747	1612	2128	752
Additional cost of implementation (US$)	103	14	54	62
Total annual cost of SFM (+20% TIC[c]) (US$)	1468	217	785	795
Emission reduction compared to BAU[d] (%)	57	61	59	24
Total annual cost of SFM incentives per settlement (US$)	29983	4351	16002	17732

[a] Sustainable forest management.
[b] Net present value.
[c] Transaction and implementation costs.
[d] Business as usual.

use, since it promotes labour inputs into more sustainable forest management practices rather than off-farm activities. Villagers receive part of their income from a REDD + incentive that pays them for specific inputs into sustainable forest management. Depending on the size of their forests and available human resources, communities will invest variable amounts of work in sustainable forestry. In forestry settlements, the additional work to be invested in sustainable forest management would equal current labour inputs into agriculture on previous fallow land and would complement their revenue. In total, households in forestry settlements would have to invest an average of 179 working days, which should be bearable for a family of 2 to 4 persons capable of forest and farm work. Smaller households could always consider hiring an external wage labourer. At US$ 2747, the household revenue under Scenario 2 is higher than under both business as usual and Scenario 1 for forestry settlements due to their high potential for generating income from timber and the high payment for forestry labour. The total cost of financial incentives for sustainable forest management averages US$ 16,002 per village, which is less than half the cost of Scenario 1. For agricultural settlements, however, family incomes are lower under Scenario 2 than under Scenario 1 or business as usual.

4. Comparing Compensated Reduction and Sustainable Forest Management Models

Trade-offs and synergies between household incomes, carbon emission reduction, and relative costs of different REDD + designs are a determining factor in selecting the optimal approach in different situations. Fig. 3 shows that under the flat-rate compensated reduction scheme of Scenario 1 (left), there is, by construction, a linear relationship

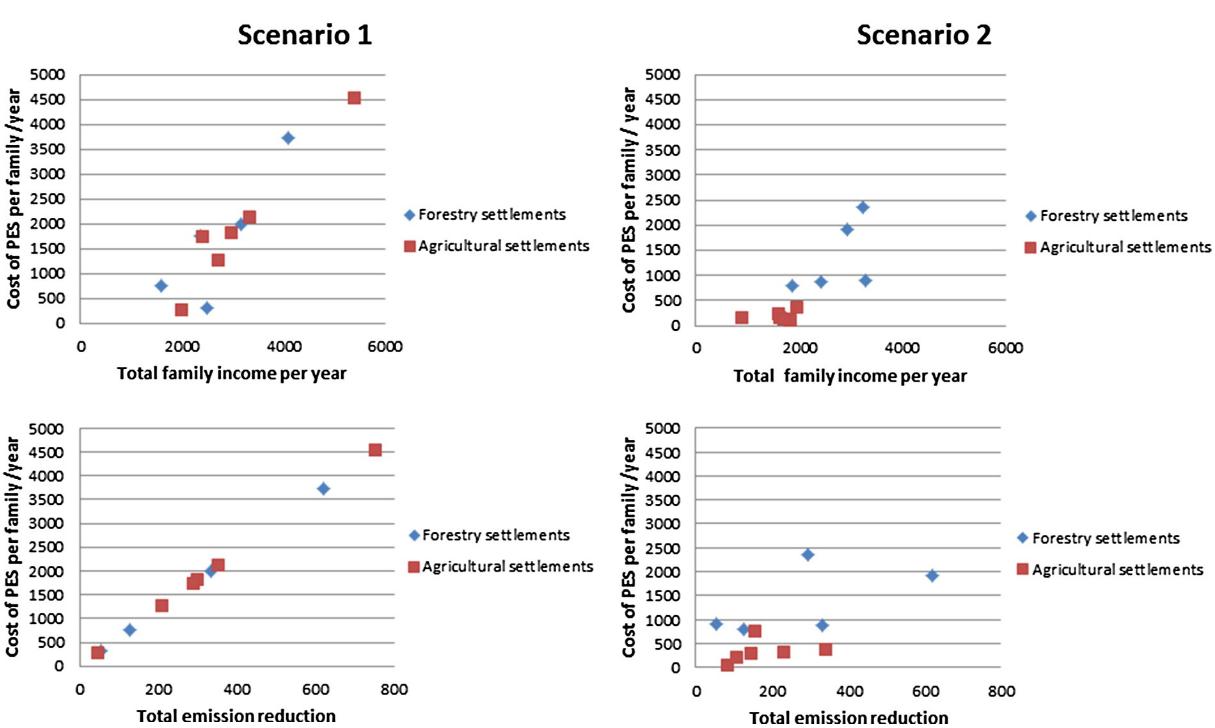

Fig. 3. Costs of PES schemes under scenarios 1 and 2 in relation to family incomes and emission reductions in forestry and agricultural settlements.

between compensation payments and emission reduction for both agricultural and forest communities. As a result, under Scenario 1, family incomes increase in accordance with payments (reflecting the fact that the incentive payment rate exceeds opportunity costs).

Differences between forestry and agricultural settlements under Scenario 1 depend essentially on the basic productive characteristics of each community (forest size, biomass, structure, and timber species' market value).

Under Scenario 2, which involves cross-compliance, emission reductions in agricultural settlements cost less than under Scenario 1, as the largest share of families' income is based on farming activities. However, the possibilities for households in agricultural settlements to increase their income under Scenario 2 are extremely limited due to the lack of forest resources. For forestry settlements, the trade-offs are substantial: Fig. 3 illustrates the positive relationship between sustainable forest management incentives and both family incomes and emission reduction.

Table 5 compares average family incomes and the payments made per family and tCO_2 emission reduction under the two scenarios. In the case of forestry settlements, both scenarios result in the same family income of about 9.6 US$/$tCO_2$, but the cost of Scenario 2 (4.81 US$/$tCO_2$) is considerably lower than that of Scenario 1 (6.00 US$/$tCO_2$). In forestry settlements, therefore, Scenario 2 is more cost-effective than Scenario 1. In the case of agricultural settlements, the situation is different. The external costs of incentives are extremely low due to the lack of forestry potential and corresponding potential labour inputs into sustainable forest management. At 4.96 US$/$tCO_2$, however, family incomes are almost half of what they are under Scenario 1. Such a small potential benefit would hardly suffice to incentivize agricultural communities to participate in sustainable forest management.

5. Discussion

The empirical findings from our systematic comparison of compensated reduction and sustainable forest management scenarios as possible types of REDD + programme design support the preference of Evo Morales' government for input-based schemes and offer concrete guidance for implementing this policy. Table 6 summarizes trade-offs and synergies under each scenario considering the multiple requirements made in the context of REDD + implementation policy, such as carbon emission reduction, cost-effectiveness, incentives for sustainable land management, household incomes, permanence of changes, avoidance of leakages, and community-based institutional enforcement for sustainable forest management.

The compensated reduction scenario (Scenario 1) would be more attractive than sustainable forest management (Scenario 2) in agricultural settlements and would have the highest positive impact on family incomes, especially in communities that have already cleared large surfaces of old-growth forest and lack forestry alternatives within their settlement. The substantial margin derived from an emission reduction incentive of 5 US$/$tCO_2$ arises from the low opportunity cost in old-growth forest, which can lead to higher benefits for those participating in the programme. Forestry settlements, which have maintained a higher proportion of forest, have a great potential for sustainable forest

Table 6
Comparative assessment of scenarios 1 and 2.

	Scenario 1		Scenario 2	
	Agricultural villages	Forestry villages	Agricultural villages	Forestry villages
Substantial carbon emission reduction	x	x	x	x
Cost-effectiveness			x	x
Incentives for sustainable land management	x	x		x
High household incomes	x	x		x
Permanence				x
Avoidance of leakage				x
Incentives for sustainable forest management				x
Community participation in REDD+				x

management and would benefit more under Scenario 2 — at lower implementation costs than for a compensated reduction programme. Under Scenario 2, the largest proportion of income is generated by the direct payment for investing labour in sustainable forest management. Adequate accompaniment of payments by regular monitoring and capacity building would represent an additional outcome of the sustainable forest management option and a good opportunity for knowledge sharing among communities and external technicians.

Compensating the reduction of emissions from clearing old-growth forest can indirectly incentivize land users to improve the efficiency of land use by developing sustainable management practices on fallow land. Labour released by the compensated reduction scheme would allow for greater investments in sustainable land management practices. Indeed, some land users have already begun to use such practices, especially in settlements where both old-growth forest and agricultural land have become critically scarce. As a result, the studied communities grew about 75% of their crops on previous fallow land in 2010. They made this possible by intensifying their production using adapted soil management technologies (rotation with high-nitrogen crop, mixed crops, higher labour inputs, perennial crops, and, in certain cases, complex agroforestry systems). One community has completely prohibited cattle grazing in order to protect fallow areas from land compaction and allow for secondary forest regrowth. However, under both scenarios considered in this article, more sustainable land management remains uncertain; this is mainly because neither scenario includes any direct incentives for farmers to change their cultivation habits. Many farmers who “finished their land” – as people in the area commonly refer to the situation where land has become unsuitable for agriculture – have bought another parcel in a nearby settlement to pursue the same unsustainable practices. Moreover, it is difficult for local land users to cope with the shortages that occur during several years following an investment into a more intensive and long-term productive system, for example an agroforestry system. The available fallow land and young-regrowth forest in the area is sufficient to enable larger communities to establish sustainable rotational and intensified agricultural systems without extending cropland into old-growth forest; this has been shown in closed areas (Milz, 2010). However, this transition to more

Table 5
Cost-effectiveness of a carbon emission reduction by one ton of CO_2 in forestry and agricultural settlements under scenarios 1 and 2.

	Forestry settlements		Agricultural settlements		Overall average	
	Scenarios		Scenarios		Scenarios	
	1	2	1	2	1	2
Overall family income (US$/$tCO_2$)[a]	9.61	9.64	9.67	4.96	9.64	6.94
Cost of PES per family (US$/$tCO_2$)[b]	6.00	4.81	6.00	0.55	6.00	2.35
Total emission reduction per settlement (%)	57		61		59	

[a] This value represents the total income per family divided by the total emission reduction per family.
[b] This value represents the total REDD+ direct payments and implementation cost per family divided by the total emission reduction per family.

efficient land use can only be achieved if farmers are given adequate financial support and technical assistance.

In the case of forestry settlements, Scenario 2 (sustainable forest management) offers clear advantages in terms of community participation. By including local villagers and valuing their forestry work it increases the likelihood of project permanence — depending, of course, on international funding availability. It also increases the chances of avoiding leakage, since it leads to concrete labour investments by the local population, enhances their knowledge and capacity, and values their personal involvement. It can also provide a medium-term incentive for the development of more sustainable forest management practices outside the project area, based on knowledge transfer and the progressive establishment of fair trade in timber, as well as higher prices paid to local producers on the legal market. Cost-effectiveness is a further significant asset of Scenario 2, as it reduces the budgetary cost of the same level of deforestation reduction considerably and increases household incomes more compared to Scenario 1 or business as usual.

6. Conclusions

Our approach builds on recent criticisms of output-based carbon trade mechanisms voiced in Bolivia as well as more generally by the scientific community (Gómez-Baggethun and Ruiz-Pérez, 2011; McAfee, 2012), and assesses possible alternatives with a view to meeting stakeholders' multiple requirements of effectiveness, efficiency, and equity. Our results suggest that the input-oriented sustainable forest management scenario combined with the conditionality not to clear old-growth forests presents a greater opportunity for efficiently reconciling carbon sequestration, forest conservation, and household incomes at a lower cost, both in tropical rainforest areas such as the Bolivian Amazon and in other socioecologically similar areas. Our results, therefore, empirically support Skutsch's proposition of combining several REDD + mechanisms focusing on both input and output schemes, and suggest that it is a viable and positive alternative to current practices in terms of its socioecological outcomes. Nevertheless, the results also stress the importance of flexible mechanisms that make it possible to respond to context-specific situations. The selection of appropriate mechanisms depends on multiple factors:

First, our estimates of the opportunity costs of reducing emissions from agriculture are higher for fallow land and young-regrowth forest than for old-growth forest. Therefore, we suggest that PES schemes should primarily focus on avoiding emissions from clearing old-growth forest, while maintaining agricultural production on previous fallow land and young-regrowth forest. This makes sense also against the background that agricultural activities absorb and value labour inputs, translating them into livelihood gains and food security. Under both scenarios, the avoidance of agriculture in old-growth forest leads to a significant and cost-effective emission reduction (around 60% compared to business as usual), while ensuring maintenance of agricultural production on previous fallow land.

Second, the size and structure of forests, as well as a community's capacity for forest management are paramount factors in successfully implementing sustainable forest management or compensated reduction schemes. As our empirical data show, compensated reduction presents advantages in communities where forestry is of low spatial and economic importance and livelihoods were previously based on agriculture. It remains unclear, however, whether in these cases compensated reduction could progressively be transformed to include sustainable land management as a means for reducing pressure on existing forests by intensifying the agroecological systems. Conversely, sustainable forest management subject to cross-compliance measures stands a better chance of being successfully implemented in settlements with sufficient forest resources as well as social and institutional capacity for sustainable forest management. Such settlements are most probably the ones targeted by REDD + programmes. Our model suggests that in these cases, sustainable forest management would provide better household incomes while maintaining low carbon emission, all at a lower budgetary cost than for a flat-rate compensated reduction scheme.

Third, our results also clearly show that the value of labour input in agriculture as well as in forestry is, in most cases, higher than the profit generated by the activity. This important aspect underlines that valuing labour is highly critical from the farmers' point of view and also illustrates why a standard PES scheme strictly based on compensating forgone profits would be risky in a context where off-farm employment is difficult to find.

Therefore, the main finding of our study concerns the need to place local institutional structures and the related livelihoods at the centre of interventions to reduce deforestation. In many contexts where deforestation is occurring, ecological services are intertwined with human activity; whether this is recognized and valued or not, services are often the result of co-production through direct labour input. Our findings show that a scheme that involves sustainable forest management incentives based on a logic of rewarding local labour input is an efficient way of putting the large amount of public funding provided by the REDD + programme to work for reducing carbon emissions, conserving forests, and at the same time improving local forest users' livelihoods.

Acknowledgements

The authors acknowledge support from the Swiss Network of International Studies (SNIS) and the Swiss National Centre of Competence in Research (NCCR) North–south: Research Partnerships for Mitigating Syndromes of Global Change, co-funded by the Swiss National Science Foundation (SNSF), the Swiss Agency for Development and Cooperation (SDC), and the participating institutions. We would also like to thank the anonymous referees for their helpful comments on an earlier draft of this paper, as well as Marlène Thibault for editing the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ecolecon.2013.05.003.

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