Smallholder REDD+ strategies at the forest–farm frontier: a comparative analysis of options from the Peruvian Amazon

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Background: Involving local populations in developing countries will be key to the success of the REDD+ forest mitigation mechanism. Strategies should therefore be designed to target specific activities, land uses and decision-making at the smallholder level. This article analyzes and compares smallholder land use and livelihood strategies at the forest–farm frontier in the Peruvian Amazon to draw out locally contextualized REDD+ strategies. **Results:** Data were collected through household surveys and interviews. The results point to four central REDD+ strategies: payments for ecosystems services, reduced forest degradation, enhanced carbon production and income diversification. **Conclusion:** Local REDD+ strategies should be contextually informed and allow for the widest conception of potential strategies under the mechanism to maximize implementation flexibility and, thus, participative equity.

In recent years, REDD+ has emerged and gained significant traction as a mechanism with the potential to alleviate poverty and conserve biodiversity while contributing to the mitigation of global climate change [1–3]. The UNFCCC COP16 in Cancun in December 2010 marked an important step forward for REDD+ through the adoption of the Cancun Agreements [4]. Parties agreed upon the scope of the REDD+ mechanism, encompassing five activities (reducing emissions from deforestation, reducing emissions from forest degradation, conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks), thus incorporating considerable flexibility. It was also agreed that developing countries should follow a phased approach to implementation: beginning with capacity building and the development of strategies, policies and measures (Phase 1); followed by the piloting of policies, measures and demonstration activities (Phase 2); and, ultimately, evolving into benefit distribution for measured, reported and verified emissions reductions and removals (Phase 3). The Cancun Agreements also set out a number of safeguards that should be observed throughout the implementation of activities, including respect for the rights of local people, consistency with the conservation of biodiversity and natural forests, the participation of stakeholders, and for actions to reduce the displacement of emissions (leakage) and address the risks of reversals (permanence).

With the majority of participating countries in Phase 1, it is critical that they begin, not only to raise awareness and build technical capacity across structural levels, but also to consider and design strategies for implementation at the local level – where action will ultimately be taken. Essentially, local interventions should be rooted in the principle of making trees more valuable standing than felled. However, it stands to reason that the alteration of the *status quo* path of economic development in tropical forest frontier regions, most often involving considerable deforestation [5], will be complex and necessarily involve a deep understanding of local circumstances [6]. Moreover, the safeguard asserting the need for local participation is supported by the emerging REDD+ literature, in that this approach is necessary not only for the top-down realization of co-benefits [7,8], but also for the environmental effectiveness (for emissions reductions and removals to be additional), cost efficiency (achieving reductions and

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Key terms

REDD+: Policy approaches and positive incentives on issues relating to reducing emissions from deforestation, reducing emissions from forest degradation, conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks. Following UNFCCC guidance (FCCC/TP/2009/1), all five REDD+ activities are covered by the following three categories outlined in the IPCC's guidance and guidelines: forest land converted to other land (deforestation); forest land remaining forest land (includes forest degradation, forest conservation, sustainable forest management and enhancement of carbon stocks); other land converted to forest land (enhancement of forest carbon stocks).

Forest–farm frontier: Interface between anthropogenically managed productive areas (e.g., agriculture, pasture lands) and natural forest. This is a key area for targeting REDD+ interventions, given the potency of agriculture as a driver of deforestation and the forest degradation resulting from human extraction of forest products.

Smallholder: Owners of small-scale farms that usually support a single family, often producing a mixture of cash and subsistence crops. The high levels of private land ownership in the study areas presented here mean that much of the buffer zone forest area belongs to local people, making smallholders the critical local actors to engage in REDD+.

Peruvian Amazon: Largest ecological region in Peru, covering 782,880 km^2: 61% of Peruvian territory and approximately 11% of the whole Amazon Basin. Stretching from the cloud forests of the Andes down into lowland tropical rainforest, it harbors vast biodiversity and is home to 11% of the national population, including people from a number of different indigenous ethnicities and migrants from the highlands, thus forming a socially, as well as ecologically, diverse and unique landscape.

REDD+ safeguards: List of criteria set out in Appendix 1 of UNFCCC Decision 1/CP.16, adopted in Cancun in 2010, which aim to ensure no harm is done by REDD+ activities and that the benefits of REDD+ go beyond climate change mitigation. The decision states that the safeguards should be promoted and supported throughout the implementation of REDD+ activities.

removals at the minimum viable and fair cost) and participative equity (Center for International Forestry Research's '3E' criteria [9]) of initiatives as a whole [10–12]. Given the fundamental premise of the REDD+ mechanism lying in its ability to achieve cheap emissions reductions [13], careful thought is needed for the design of REDD+ strategies to maximize participation while ensuring cost efficiency and environmental effectiveness.

A further consideration on the emergence of REDD+ and its surrounding guidance is that local implementation efforts can learn from and build on previous experience with existing initiatives that (aim to) achieve similar objectives. A prime example of this is payments for ecosystem services (PES). An approach well covered in the literature over the past two decades [14], PES involve the direct financial compensation for forest carbon gains and losses. This approach was pioneered by Costa Rica in 1997, through a national program where farmers sign contracts covering a specified number of hectares of their land and are paid by the government for the ecosystem services they produce by adopting management practices that conserve forest, allow secondary forest growth and reforest degraded lands and pastures [15,16].

The **forest–farm frontier** occupied by **smallholders** is a key area for REDD+: it represents an interface where predominantly poor rural populations sustain (and seek to enhance) their livelihoods through the progressive encroachment into, and often collateral degradation of, forest ecosystems [17,18]. The effective application of REDD+ here potentially offers an opportunity to slow, halt or even reverse the patterns of deforestation, while alleviating poverty and safeguarding biodiversity and other ecosystem services. The current period of REDD+ piloting and lesson-learning is a key time to enhance knowledge surrounding the integration of REDD+ at the forest–farm interface to maximize participation and equity of opportunity for local populations, in whose hands the fate of the forest ultimately lies.

This article analyzes and compares the ways in which REDD+ can be grounded at the local level at two conservation-priority sites by posing the central research question: how can local populations participate in REDD+ at the forest–farm frontier in the **Peruvian Amazon**? This is addressed through three subquestions:

- Does REDD+ provide a viable economic alternative to current land use practices?
- What drives forestry decision-making?
- Which alternative livelihood sources could be promoted to support the objectives of REDD+?

These questions are explored through a comparative analysis of smallholders inhabiting protected area buffer zones. By addressing REDD+ strategies at the smallholder level, this study aims to inform the development of locally contextualized approaches that will maximize adoption and, thus, promote permanence of emissions reductions and removals. The analysis of REDD+ options places particular emphasis on aspects relating to cost efficiency and environmental effectiveness, with an ultimate view to evaluating the extent to which strategies could or should differ at the local level at the two study sites. Based on the findings, the discussion sets out four broad options for integrating REDD+ at the local level.

Experimental

Study sites

Forests cover approximately 72 million ha in Peru (53% of the country), and were lost at a rate of 0.15% per year, representing 108,200 ha, between 1990 and 2010 [19]. Although Peru's network of Amazonian-protected areas is providing moderate protection for core areas [20], human activity threatens to increasingly isolate these pockets and exhaust the forest resources available to local populations. To counter this effect, and attempt to limit human interference in conservation objectives, buffer zones surround all protected areas in Peru, although they are granted no formal protection status to achieve these ends. This raises important questions as to the strategic role REDD+ could play in promoting buffer zone objectives while supporting local livelihoods and the **REDD+ safeguards** on the conservation of natural forests. This justification supported the selection of case studies for this research to be taken from the buffer zones of two Amazonian protected areas.

The first site is the western buffer zone of the Yanachaga–Chemillen National Park (YChNP) (Figure 1) in Peru's 'Selva Central' (Central Jungle), the closest forested region to the capital, Lima, at a distance of 250 km. The park lies on the eastern slopes of the Andean highlands between 10°15'–10°55' S and 75°70'–75°10' W in the region of Pasco, province of Oxapampa and districts of Villa Rica, Oxapampa, Huancabamba and Pozuzo, and covers 122,000 ha of tropical cloud and lowland forest between elevations of 3643–460 m above mean sea level (AMSL). To the east and south of the Park lie the Yanesha Communal Reserve (covering 35,000 ha between 10°15'–10°50' S and 75°45'–75°08' W) and the San Matias–San Carlos Protection Forest (covering 145,000 ha between 9°90'–10°90' S and 75°25'–74°65' W), which comprise, together with YChNP, the Yanachaga Conservation Complex. The most exposed and developed axis of YChNP's surroundings is its western buffer zone (since the Yanesha Communal Reserve and San Matias–San Carlos Protection Forest offer protection to the east and south), where communities have formed around watersheds running down from the Park's western escarpment into the Chontabamba River (flowing south to north), and within which lies a main road (parallel to the river) and the provincial capital of Oxapampa. The population in this area is comprised of descendents of German colonists who established Oxapampa in 1890, and Andean migrant peasants (known as 'colonos') who settled in the area throughout the 20th century [21], as well as mixtures of the two. The region's proximity to Lima, coupled with this colonization pattern and its accompanying commercial knowledge, led to it becoming the site of the earliest timber extraction in the Peruvian Amazon [22]. Following the peak of this industry in the 1960s, inhabitants increasingly turned to nontimber land use practices to sustain their incomes and satisfy Lima's growing demand for agricultural produce [23]. Agriculture in the region developed through boom and bust cycles according to the demands of Lima markets, beginning with cattle and coffee and shifting through to potato (*Solanum tuberosum*), pumpkin (*Cucurbita* spp.), rocoto bell pepper (*Capsicum pubescens*) and, most recently, granadilla passion fruit (*Passiflora ligularis*) [24].

The second site is the buffer zone corridor formed between Manu National Park (MNP) and the Amarakaeri Communal Reserve (ACR) in south-east Peru. MNP lies between 11°30'–13°21' S and 72°42'–70°85' W, covers 1.6 million ha and ranges in elevation from over 4000 m AMSL in the Andean highlands to 365 m AMSL in the Amazonian lowlands. A total of 93% of the Park is contained within the region of Madre de Dios, province of Manu and districts of Madre de Dios, Manu and Fitzcarrald, with 7% stretching into the region of Cusco, province of

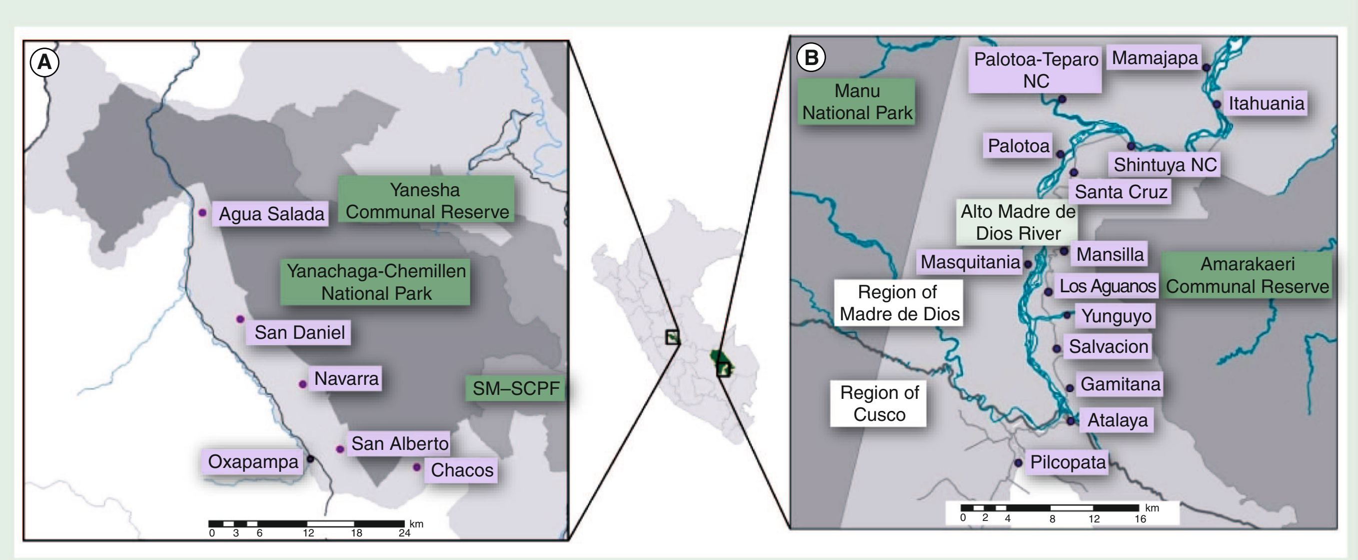

Figure 1. Case study sites. Buffer zones of **(A)** Yanachaga–Chemillen National Park and **(B)** Manu National Park. Darker shade indicates protected area; lighter shade indicates buffer zone.
NC: Native community; SM–SMCF: San Matias–San Carlos Protection Forest.
Shapefiles courtesy of Pasco Regional Government in Oxapampa, National Institute of Natural Resources in Puerto Maldonado and Asociación para la Conservación de la Cuenca Amazónica in Cusco.
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Paucartambo, district of Kosñipata. The 402,000 ha ACR lies to the southeast of MNP, between 12°30'–13°30' S and 71°33'–70°49' W, entirely contained in the region of Madre de Dios. The buffer zone corridor formed between the two protected areas runs southwest to northeast, divided by the Alto Madre de Dios River as it enters the region of Madre de Dios. The population of the corridor comprises seven indigenous communities (each of which has been granted territory surrounding their community as private property, ranging in size from 3000 to 38,000 ha) and colonos, primarily from the Cusco highlands, who have formed settlements along the length of the Alto Madre de Dios River. A road extends northwards parallel to the river, reaching as far as Itahuania (as of 2009) (Figure 1). The first commercial activity in the region was the extraction of natural rubber in the 1800s [25], although non-indigenous settlement in the region did not begin until commercial timber extraction commenced in the 1940s. The region's inaccessibility restricted the feasibility of exporting commercial agriculture to the city of Cusco until the 1990s [24], at which point the export of small amounts of banana (*Musa* spp. – both Cavendish and plantain) and pineapple (*Ananas comosus*) began.

An additional point of interest regarding the two sites is that they are both UNESCO Biosphere Reserves (MNP appointed in 1987 and YChNP in 2010). This is significant because, while this designation recognizes efforts seeking to reconcile conservation of biological and cultural diversity and economic and social development [101], it is not accompanied by financial support to maintain or further promote these ends. REDD+ in these areas therefore presents an innovative opportunity to realize the objectives of, and provide additional funding for, tropical forest biosphere reserves. Both areas are also being targeted as sites for REDD+-type initiatives by a range of state and nonstate actors [26], with these efforts being at their conceptual stages at the time of data collection in 2009.

Method

This research focuses on smallholders owning private plots within the buffer zones, many of which border the protected areas, as well as members of indigenous communities in the MNP–ACR corridor, whose territories increasingly form part of the forest–farm interface as they adopt practices introduced to them by colonos. A mixed methods approach was taken to the collection of data on household-level socioeconomics surrounding forestry and agriculture [27,28]. Smallholder surveys (n = 200) were used to collect quantitative data on private land use (forest area and their three primary productive land uses), land economy (income per activity), land use change motivations and income diversification. One hundred surveys were completed at each site in the settlements of Chacos, San Alberto, Navarra, San Daniel and Agua Salada in YChNP (Figure 1) between October and November 2008, and in each settlement and indigenous community between Pilcopata and Mamajapa in MNP (total of 14) (Figure 1) between June and August 2009.

Respondents were selected through a combination of judgment sampling, quota sampling and random walk sampling, carried out at each site in three stages. First, expert focus groups comprising local land use and forestry practitioners (two local government officials, two NGO representatives and a researcher: in the case of MNP this was a national researcher and in YChNP an international researcher with 5 years' experience in the region) were consulted to select representative communities in each study site. Second, a quota was set of 100 respondents per site, with the common characteristic of being a land owner (smallholders at both sites were owners of private property; however, in the case of indigenous communities, large areas of private property are collectively owned by community members). Third, a walk was started at a random point in each selected community and every second house screened along a path of travel, to ascertain the presence of a respondent meeting the above common characteristic. This approach was taken in order to capture and capitalize upon local knowledge, facilitate comparison of results between sites and avoid bias in household selection. One survey was collected per household of those meeting this characteristic. The surveys cover approximately 30% of households within the YChNP sample frame [Casimiro G, Pers. Comm.] and 20% of households within the MNP sample frame [Ochoa R, Pers. Comm.] (lower due to the frame containing the large settlement of Pilcopata). Individuals were informed that participation was entirely voluntary, conveyed the research objectives and explained that no direct benefits would accrue from participating in the research. Survey data were analyzed in SPSS and Microsoft® Excel.

Survey data were supplemented by qualitative semi-structured interviews with land users (n = 20) and key state (n = 18) and nonstate (n = 14) actors at each of the sites between July 2008 and August 2009. These were selected through stakeholder analysis and snowball sampling – where subjects recruit future subjects from their professional networks [29]. Interviews were recorded, transcribed and their content analyzed thematically. Themes covered in interviews were agriculture, production economy, land use change trajectories and alternative (nonagricultural) local income streams.

Results

Land use & land use economy

Land use

The first step taken in this study, to question how local populations can participate in REDD+, was to gain an understanding of how land is used and profited from. MNP smallholders possess considerably greater average property sizes and proportions of forest on their properties: 58 ha (SE = 7.20; SD = 71.63) and 73% (SE = 2.39; SD = 23.95) forest cover, compared with YChNP's 28 ha (SE = 3.22; SD = 32.08) and 41% (SE = 2.84; SD = 28.40) forest cover **(Table 1)** (significant to $p<0.05$ using Student's t-test, for both variables). This, together with YChNP's greater average proportion of fallow land (27% [SE = 2.35; SD = 23.51] vs MNP's 9% [SE = 1.59; SD = 15.94] – significantly different at $p<0.01$), may reflect the greater intensity of agricultural production in YChNP and greater rurality of MNP (lying further from a populated center and with poorer infrastructure and access routes than YChNP). YChNP smallholder's greater total area of land dedicated to cattle ranching (849 ha vs 194 ha in MNP – significant differences between the means found at $p<0.05$) could suggest greater ease of produce export and proximity to markets in comparison with MNP.

The primary agricultural activities (by total land area covered) are banana (216 ha) and pineapple (23 ha) in MNP, and granadilla (177 ha) and rocoto (35 ha) in YChNP **(Table 2)**. The principle explanation for the differences between the crop types at each site is elevation, with those at YChNP more suited to higher elevations, and those in MNP more typical of lowlands. In YChNP the granadilla passion fruit crop, growing as a vine, requires 600 wooden posts/ha on which to suspend wire at an elevation of 2 m, around which the vine wraps itself. It is relatively shade-intolerant, grown at high densities, and can produce fruit for 3–5 years (depending on how quickly soil fertility is degraded through use of chemical applicants). The crop is able to grow well on fallow land, although its popularity (due to the incomes it generates) and production method are driving forest degradation in addition to deforestation. One of its greatest impacts is its demand for wooden posts, which are required to be hardwood in order to withstand the high humidity. The second crop is the rocoto bell pepper, a high nutrient- and light-demanding ground-level shrub that is planted at high densities to maximize yields and prevent shading. It is widely believed among smallholders to grow optimally on land newly cleared of primary forest by burning (to return nutrients to the soil) and has a relatively short lifetime of 2–3 years.

By contrast in MNP, banana, a canopy-level herb that can reach 9 m (30 feet) in height, requires sufficient spacing between plants due to light requirements, although

Table 1. Averaged current land uses on survey respondents' properties.

Land use	National park	
	Yanachaga–Chemillen National Park (% total area)	Manu National Park (% total area)
Forest	41	73
Agriculture	9	10
Cattle	21	4
Reforestation	2	4
Fallow	27	9

they are able to grow on nutrient-poor soils and are shade tolerant (up to 50% for commercial production) [102]. The wider spacing required between banana plants and, thus, the lower planting densities help explain the greater average proportion of agricultural land in MNP compared with YChNP **(Table 1)**. Agroforestry with mixed native species (such as 'pashaco' [*Schizolobium amazonicum*], 'copal' [*Bursera cuneata*] and 'aguano' [*Cedrelinga catenaeformis*]) is common in MNP (57% of banana-producing respondents; note the greater average proportion of reforestation in MNP in **Table 1**), giving smallholders a longer term timber investment alongside the crop. The second most popular crop, pineapple, is grown at high densities (~15,000–20,000/ha) at ground level. It is moderately shade tolerant, although the crop's high nutrient demand means that forested areas are commonly burned prior to planting. It is rarely produced under agroforestry and individual plants can produce a maximum of two crops (one per year).

Land economy

Two broad characteristics emerging from net income and land use figures for the two sites **(Table 2)** are the greater average incomes per hectare (significant at $p<0.01$) of YChNP agricultural activities and the greater diversification of commercial production in MNP. This is suggestive of more intense, market-response production in YChNP and diversified, lower intensity production in MNP.

The majority of MNP respondents (83%) produce banana, yielding an average income of US$1131/ha/year (SE = 112.91; SD = 964.73), with the second most common productive land use being cattle ranching (at $178/ha/year [SE = 63.61; SD = 254.43]), followed by citruses (generic; at $344/ha/year [SE = 79.17; SD = 223.94]) in terms of respondent numbers – but pineapple (at $3335/ha/year [SE = 1459.35; SD = 4614.86]) in terms of land area covered. The high establishment cost of pineapple (~$1750/ha) is the primary barrier to entry to production of this crop, suppressing higher production levels despite it returning

Table 2. Net income from, and land cover of, commercial productive activities in Manu National Park and Yanachaga–Chemillen National Park[†].

Land use	Number of affirmative respondents[‡]	Mean hectares per respondent[§]	Total hectares covered by each land use[¶]	Mean net income/ha/year (US$[#])	Income range/ha/year (US$[#])	Income not reported	
						Too recent	Unknown
Yanachaga–Chemillen National Park							
Cattle	64	13.26	848.5	191	2832	4	
Coffee	3	1.83	5.5	534	279		
Granadilla	66	2.68	177.0	4646	8871	24	2
Reforestation	1	1.00	1.0			1	
Rocoto	35	1.01	35.2	2482	5702	4	10
Manu National Park							
Banana	83	2.61	216	1131	3626		2
Cattle	19	10.21	194	178	461		1
Citruses	15	1.27	19.0	344	675	8	1
Coca	4	0.93	3.7	3373	6148	2	
Cocoa	3	0.92	2.75	1440	2038	6	
Cocona	1	0.50	0.5	70			
Coffee	2	2.25	4.5	339	24	1	
Maize	5	0.80	4.0	1876	1967		
Papaya	1	2.50	2.5	56			
Pineapple	14	1.64	23.0	3335	10,129		
Aquaculture	2	0.75	1.5				
Rice	6	1.33	8.0	611	879	4	1
Yuca	14	0.88	12.25	1665	3375	2	1

[†]Income here refers to the value of goods sold; value of own produce consumed in the home not included; value of labor not included.
[‡]Respondents' primary, secondary or tertiary land use.
[§]For respondents who responded affirmatively to each land use.
[¶]By the 100 respondents at each site.
[#]US$1 = PENs/.2.87.

the highest per hectare income among MNP produce once harvested. These returns are, however, highly variable, as indicated by the income range figures. Meanwhile, the wide availability and comparatively lower establishment cost of banana (~$667/ha) are likely to have contributed to its widespread planting. Coca (*Erythroxylum coca*), a plant containing numerous alkaloids including cocaine, is found in the Cusco region of the MNP study area (principally in/around Pilcopata). The considerable income range depicts the disparity between sale for traditional (i.e., chewing and tea; ~$1.5–2/kg dry weight) and illegal (i.e., processing into cocaine paste: ~$3.5–4/kg dry weight) uses. Given the extralegal nature of the crop, it is likely that a greater number of respondents were producing coca than admitted to through the survey (despite assured anonymity). Although the financial returns from banana, pineapple and coca materialize within a year, MNP farmers are also found to diversify into products with longer productivity cycles (notably fruit trees), which provide limited but steady incomes, such as citruses, cocoa (*Theobroma cacao*), papaya (*Carica papaya*) and cocona (*Solanum sessiflorum*).

Granadilla is the modal commercial land use in YChNP, yielding the highest income across the two sites (averaging returns of $4646/ha/year [SE = 650.32; SD = 2843.42]). Cattle ranching is the second most common activity ($191/ha/year [SE = 76.52; SD = 462.45]), followed by rocoto ($2482/ha/year [SE = 1,065.92; SD = 2,542.34]). The extraordinary returns from granadilla are a product of comparatively high market demand and intense production methods, tempered by the high investment cost of crop establishment. The increasing popularity of granadilla production has driven up the cost of the requisite materials (wire as well as posts), with investment in 2008 standing at approximately $3000/ha. The considerable numbers of unreported income responses under 'Too recent' in Table 2 indicate that these have been recently established, in turn illustrating the recent growth in popularity of the crop. Similarly to MNP, cattle ranching in YChNP is generally of low intensity, although the income range in YChNP illustrates the high returns being received by some individuals. Rocoto has been a consistently popular commercial land use in the YChNP region since the 1980s [23], one reason being its importance in 'ceviche', a popular fish dish, ensuring ongoing demand from Lima. Rocoto also requires minimal investment so was adopted by many colonos upon their arrival in the area. However, it is subject to high price variations, as substantiated by the second highest income range among YChNP respondents and the highest frequency of 'Unknown' returns across the two sites. Smallholders cited price variations ranging between $0.30 and 15 per box (containing ~150 rocotos), and generating perpetual uncertainty as to whether their earnings would cover their investment.

To contextualize land economy through product life cycles (and, thus, account for non-income years), incomes of the three primary productive land uses (by land area) were averaged over 10 years (e.g., Borner *et al.*'s analysis of REDD feasibility in the Brazilian Amazon [30]) **(Table 3)**. The model incorporates expenditures for initial establishment and annual maintenance required for each crop, as these range considerably and, therefore, have a significant impact on averaged incomes, once they are deducted from the profit made. Time-averaged values are considerably lower than static ones, notably in the cases of pineapple and rocoto, although granadilla income remains far above all others. These values were then graphed on to a cost curve to illustrate the areal extent and income disparities between the activities **(Figure 2)**. This model is constrained by the assumptions of stability in price, production conditions and technology/tools available to smallholders.

To determine the extent to which PES could be cost effective at the two sites, the land economy data were used to calculate the carbon prices required to both replace (through compensated reforestation) and avoid (through compensated forest conservation) productive activities **(Table 4)** by accounting for the yearly rate of carbon uptake through reforestation and the carbon emissions avoided by not deforesting. Taking a conservative, time-averaged figure for the rate of carbon sequestration through reforestation in tropical regions of 5 tC/ha/year (18.34 tCO_2-e/ha/year) [31–33], reforestation carbon price values (C_x) ($/$tCO_2$-e) are calculated by dividing the time-averaged production incomes (i_x) **(Table 2)** by the CO_2-e sequestration rate(s):

$$\frac{i_x}{s} = C_x$$

Equation 1

Next, taking a conservative value for aboveground forest carbon (agC) of 100 tC/ha [34–36] (and therefore 367 tCO_2-e/ha) and a carbon payment period of 10 years [30], the production incomes (i_x) can be used to determine the carbon price (C_x) ($/$tCO_2$-e) required to fully compensate smallholders for avoiding each activity:

$$\frac{i_x}{\left[\frac{agC}{10}\right]} = C_x$$

Equation 2

This approach provides an indication as to whether current carbon prices could reduce the opportunity cost of leaving standing forest on smallholder properties [35] and, thus, the utility and realisitic economic prospects for PES at the two sites. Nevertheless, an important consideration here is that agricultural opportunity costs do not necessarily reflect the barriers to entry facing smallholders; for example, the start-up cost of planting a crop of pineapple.

▪ Drivers of forest cover change

This section addresses the research subquestion on the drivers of forestry decision-making. The greater proportion of fallow land and cattle pasture in YChNP **(Table 1)** has predictably resulted from considerably greater average past smallholder deforestation **(Figure 3)**. Taking projected deforestation and average forest cover figures, it was calculated that YChNP smallholders on average expect to deforest a further 20% of current forest cover

Table 3. Time-averaged economies of the three primary commercial activities at the two sites†.

Land use	Establishment (US$/ha)	Maintenance (US$/ha/year)	Productive period (years)	Requisite fallow period (years)	Time-averaged income over 10 years (US$/ha/year)
Yanachaga–Chemillen National Park					
Cattle	700	50	Ongoing	0	79
Granadilla	3000	1000	4	3	2480
Rocoto	500	500	3	5	850
Manu National Park					
Banana	666	400	5	2	546
Cattle	700	50	Ongoing	0	67
Pineapple	1750	300	2	2	930

†Calculated under the assumption that each hectare is used consecutively for the same activity over the 10-year period, including requisite fallow periods. A discount rate was not applied due to the wide variation and uncertainty in incomes received by smallholders from these activities. Cattle fetch higher sale prices in Yanachaga–Chemillen National Park.

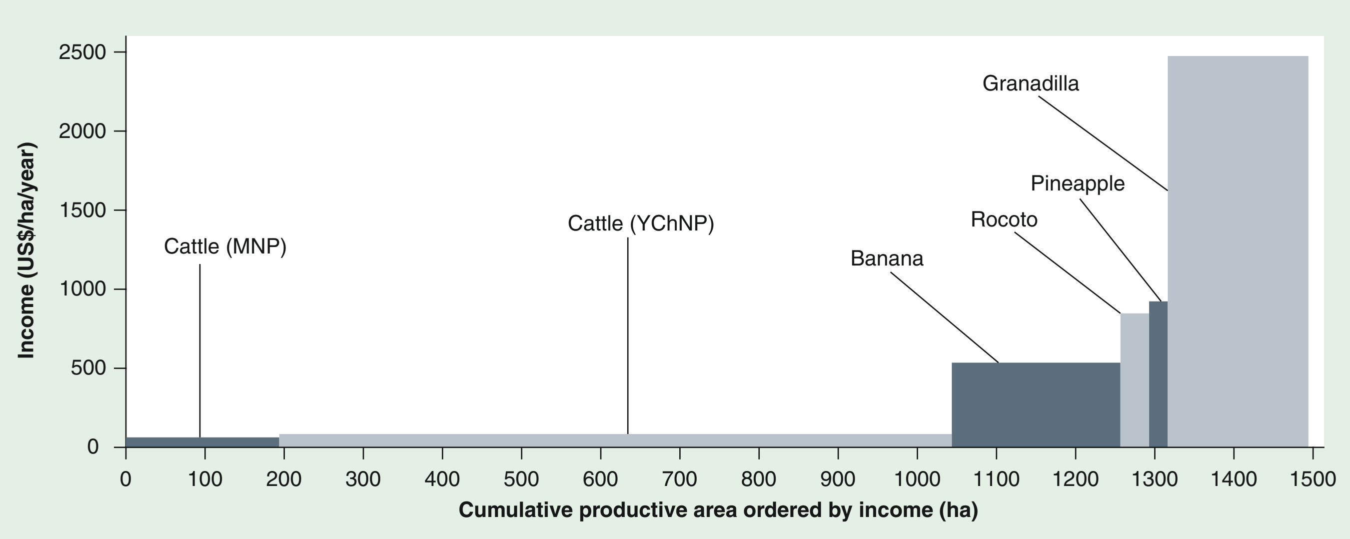

Figure 2. Productive area versus income cost curve of three primary activities at each site. Dark gray indicates MNP; light gray indicates YchNP.
MNP: Manu National Park; YChNP: Yanachaga–Chemillen National Park.

over the next 20 years, resulting in an ultimate average cover of 30%. This contrasts with MNP where, although future deforestation projections surpass those of YChNP, smallholders expect to conserve an average of 50% forest cover in the long term. Furthermore, YChNP smallholders project to reforest an average of 3.3 ha (17% of land area owned) over the same time period; those in MNP estimate 9.3 ha (25%).

Drivers of deforestation

The most common driver of projected smallholder deforestation at both sites is agricultural expansion for crops (Table 5), although this is more pronounced in MNP. Granadilla was explicitly mentioned by 57% of YChNP respondents as the crop driving their decision to deforest, reflecting the current production boom of this product. Cattle pose a greater deforestation threat in YChNP, likely due to the more developed export infrastructure and access to markets. The desire to reforest is a deforestation driver at both sites (smallholders want to plant commercially valuable species), although to a greater extent in MNP; while agroforestry is an additional minor driver in MNP.

Table 4. Carbon prices required to compensate smallholders for replacing and avoiding the most popular activities at each site.

Land use	Carbon price for replacing activity with reforestation† (US$/tCO$_2$-e)	Carbon price for avoiding activity‡ (US$/tCO$_2$-e)
Yanachaga–Chemillen National Park		
Cattle	4	2
Granadilla	135	68
Rocoto	46	23
Manu National Park		
Banana	30	15
Cattle	4	2
Pineapple	51	25

†Assuming a conservative carbon sequestration rate of 5 tC/ha/year from reforestation.
‡Assuming 100 tC aboveground forest carbon and payment spread over a 10-year period.

Drivers of degradation: use of forest products

Although no international agreement has been reached on the definition of forest degradation, it is taken here to represent processes through which land categorized as 'forest land' (according to the national definition) remains forest land, but brings about a loss of carbon stocks [37,38]. Forces of degradation are exerted on smallholder forests at both sites (Table 6). YChNP smallholders display a narrower use of forest products, focused entirely on timber, predominantly for granadilla posts. Other timber uses in YChNP include household carpentry and material for boundary fences. MNP smallholders are considerably more reliant on forests for fuelwood and as an income source through the sale of timber. They also make use of several nontimber forest products, such as medicinal plants and fruits, predominantly among respondents from the indigenous communities.

Drivers of forest maintenance & reforestation

Most respondents plan to conserve some forest cover (94% of MNP respondents; 88% in YChNP) and reforest (91% in MNP; 80% in YChNP) over 20 years, yet the most common driver of these actions at both sites is the extraction of timber (Table 7). Nevertheless, 'protection of the environment' (notably in YChNP) and 'preservation for future generations' (in MNP) also act as forest maintenance drivers. MNP respondents present a greater diversity of motivations for forest maintenance, including tourism and receipt of carbon finance, while maintaining a source of granadilla posts is a prominent objective in YChNP. A point of interest is the number of MNP smallholders expecting to reforest for agroforestry. Approaches to reforestation reveal further differences. MNP smallholders predominantly plan to plant mixed native species (such as pashaco: 86% of respondents expecting to reforest; Spanish cedar [*Cedrela odorata*]: 43%; and aguano: 38%) and harvest the timber after an average of 25 years, if at all. Those in YChNP aim to plant primarily non-native eucalyptus (*Eucalyptus* spp.: 79%) and pine (*Pinus* spp.: 44%), harvesting after an average of 13.5 years.

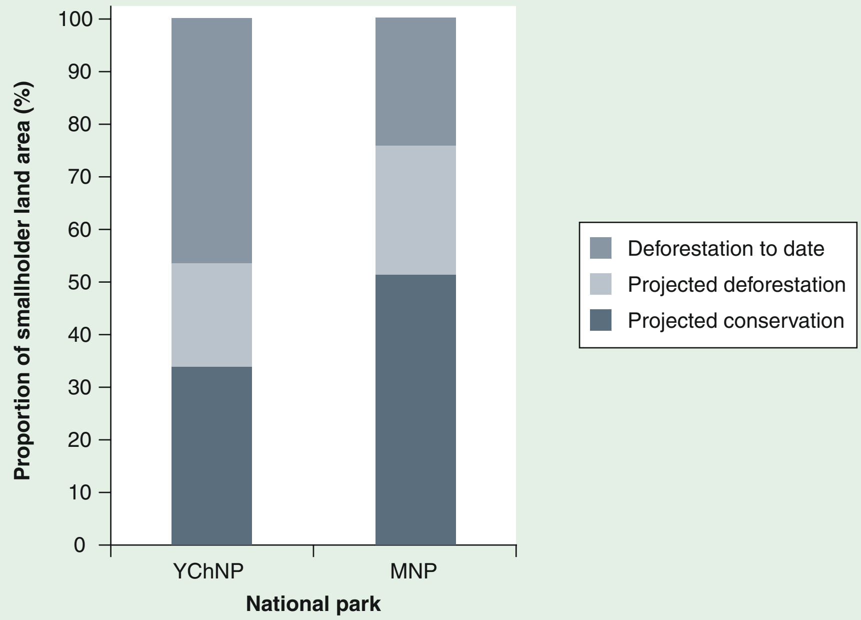

Figure 3. Averaged past and projected (as estimated by smallholders under a business-as-usual scenario over 20 years) use of original forested land cover when respondents arrived at their properties.
MNP: Manu National Park; YChNP: Yanachaga–Chemillen National Park.
Modified with kind permission from [76] © Springer Science + Business Media B.V. (2012).

▪ Income diversification

This section responds to the third research subquestion on potential alternative livelihood sources that could be promoted under REDD+. MNP smallholders diversify their income away from agriculture to a greater extent: 71% of respondents (with 23% of these earning two nonagricultural incomes) compared with YChNP's 34% (with 9% of these receiving two nonagricultural incomes). The greater income diversification evident among MNP respondents suggests a response to poorer access to markets (Table 8) [18]. Furthermore, alternative income sources in MNP reflect a more rural economy (chicken raising and radio operator) compared with those in YChNP (mechanic, electrician and taxi driver). No respondents in YChNP had an additional income from tourism, compared with 11% in MNP. At both sites, a number of alternative activities derive, directly and indirectly, from productive or extractive practices, notably the sale of timber, as well as laboring, transporting produce and trading.

Discussion

This section draws on the results to set out four REDD+ strategies that may be applicable at the two study sites, considering key emissions sources and land use decision-making at each.

▪ Payments for ecosystem services

For the purposes of this assessment, the PES approach is taken to encompass the compensation of smallholders for forest conservation and forest carbon stock enhancement through reforestation. In this way, smallholders would voluntarily and freely decide how many hectares they would like to conserve or reforest under the program, and be compensated accordingly (e.g., Ecuador's Socio Bosque program).

The near ubiquitous aspiration among smallholders at both sites to conserve and reforest affords good prospects for the PES approach. These pre-existing

Table 5. Motivations driving projected deforestation.

Deforestation motivation	Respondents (% at each site)	
	Yanachaga–Chemillen National Park	Manu National Park
Agricultural expansion: crops	33[†]	68
Cattle pasture expansion	23	11
Reforestation	2	15
Agroforestry		3

[†]57% of this 33% specifically stated granadilla production as their motivation for clearing forest.

Table 6. Forest product use by smallholders at the two sites.

Forest products used by smallholders	Respondents (% at each site)	
	Yanachaga–Chemillen National Park	Manu National Park
Timber: posts (granadilla)	75	
Fuelwood	15	63
Timber: commercialization	10	58
Timber: own use	20	7
Fruit		3
Medicinal plants		3
Bamboo		1
Leaves		1
Seeds		1
None	13	7

inclinations could, however, call into question the additionality of carbon savings. This could be overcome in one of two ways, depending on the primary focus of the PES intervention.

The first option, following Ecuador's Socio Bosque program, is to largely overlook additionality issues if the initiative aims go beyond financial efficiency to poverty alleviation [39]. This position is strengthened in light of the social, economic and environmental uncertainties faced by Amazonian smallholders regularly leading to unforeseen and/or unplanned land use outcomes (e.g., reducing immediate cash constraints through the extraction and sale of timber [17]). The carbon sold from such a program could then be discounted at a higher rate to account for the possible additionality issues [40] (i.e., whereas a reasonable discount rate for forest carbon credits could be 10% [34], under this scheme it could be set at, say, 25%).

A second option is to withhold a proportion of the carbon credits from sale to cover the risk that not all carbon benefits will arise. Under this 'buffer' approach in Costa Rica, the size of the buffer is proportional to the perceived level of risk [35]. While discounting generally reduces the value of credits, this approach can increase their value and the certainty that they represent real carbon reductions [36].

The differences in the average size and type of cover (i.e., forest versus nonforest) of smallholder properties at the two sites convey the first important distinction for the carbon effectiveness of PES interventions. The high forest cover and large size of MNP properties make the region a higher carbon landscape than YChNP, which, combined with the magnitude of anticipated deforestation, make conservation of carbon stocks a key REDD+ target. In YChNP, where the extent of fallow land is greater than that of forest, the prevention of the clearance of remaining forests would also be an important target, but would not produce the levels of (real or additional) carbon savings generated by this activity in MNP. To begin to generate a richer carbon landscape and REDD+ revenue for YChNP inhabitants, the restoration and reforestation of exhausted agricultural (fallow) land would likely be a more effective option.

The values shown in Table 4 can be compared with the price of carbon credits from the first REDD+ project in Madre de Dios [103] (the region containing most of MNP), at \$7/tCO_2-e, as well as the estimated average cost of 1 tCO_2-e in Peru of \$12.39/tCO_2-e [41]. Against these figures, the results suggest that a low carbon price (\$4/tCO_2-e) could make forest conservation cost efficient against cattle ranching at both

Table 7. Smallholder motivations for forest maintenance and reforestation.

Forest maintenance and reforestation motivation	Respondents (% at each site)			
	Yanachaga–Chemillen National Park		Manu National Park	
	Maintenance	Reforestation	Maintenance	Reforestation
Source of timber	28	66	21	85
Protect the environment	29	11	20	5
Source of timber for granadilla posts	49	22		
Unable to work the land	11	2	29	
Preserve for future generations	3		13	10
Attract tourism			23	
Prevent landslides	8		1	4
Seed bank			4	2
No valuable timber remaining	1		2	
Agroforestry				17
Sylvopasture		2		
To receive carbon finance			2	
Source of medicinal plants			1	

sites [42]. The like-for-like replacement or avoidance of cash crops is untenable at current carbon prices, particularly given the carbon price slump in mid- to late-2011 [104], although two factors provide some promise for a PES approach to REDD+ at these sites. First, in the face of income uncertainties and variations (Table 2) and establishment costs of crops, PES may be viewed as an attractive steady alternative or (more likely) supplement to current incomes for some smallholders. Second, with some economic models suggesting carbon prices could rise to \$30/tCO_2-e over the next 20 years [43] – and with evidence of this reflected in Australia's recent adoption of a carbon floor price of \$23/tCO_2-e [44] – it is possible that carbon could, in future, provide a more viable economic alternative to all crops in MNP, and medium-income ones (e.g., rocoto) in YChNP.

Reduced forest degradation

Reducing degradation can be a highly effective REDD+ strategy: Asner *et al.* attributed 20% of emissions from the Brazilian Amazon (~0.1 billion metric tons of carbon) to degradation [45]. Strategies to reduce forest degradation, while aiming to reduce forest carbon emissions, do not have to involve direct payments as with PES and can be more focused on capacity building on forest management interventions, as well as consideration of wider causations and solutions. The drivers of forest degradation highlight important differences between the sites regarding smallholder forestry decision-making. A major distinction is the greater direct use and sale of wood products by MNP smallholders in comparison to the main indirect use in YChNP as an agricultural tool (granadilla posts). These trends are supported by smallholders' motivations for reforesting and conserving, showing high demand for maintaining and creating sources of timber.

The most direct intervention to reduce degradation is improved forest management, a common one of which is reduced impact logging (RIL). While able to effectively reduce the rates of forest carbon stock losses compared with conventional logging [46–48], RIL is also likely to be attractive to smallholders because they can increase forest resilience to fire [49] and increase the value of future timber, as damaged trees have higher rates of mortality [48,50]. RIL operations could focus on smallholder training in practices such as preharvest forest inventories, road and skid trail planning, preharvest vine cutting, directional felling and replanting [51,52]. More formal approaches such as forest certification (e.g., Forest Stewardship Council) are generally less advisable at the smallholder level given the high costs [53], unless these schemes have strong state backing [54,55]. Particularly in MNP, this REDD+ strategy could focus on capacity building and awareness-raising of RIL methods and economic benefits [52]. A significant advantage of this strategy is the guaranteed additionality of emissions reductions from the implementation of RIL given that smallholders almost exclusively do not follow any specific procedures for reducing residual stand damage during timber harvest [48]. A wider consideration in MNP is many smallholders' reliance on fuelwood for energy. This driver is likely to attenuate in the long term as regional development leads to infrastructure improvements. More immediate action could be taken through a carbon-financed improved efficiency cookstove program [56], which would not only decrease fuelwood demand [57] and, thus, lower emissions (calculated at between 1.6 and 7.5 t CO_2-e/household/year [58]), but also improve health through reduced indoor air pollution [59,60].

Addressing the primary driver in YChNP, timber extraction for granadilla posts, is challenging given the popularity of, and returns on, the crop. At current granadilla prices this driver will remain a considerable challenge to tackling forest degradation. Dedicated reforestation plantations could attenuate extraction from natural forests, but these would take time to grow; in addition, these would be discarded following

Table 8. Sources of alternative smallholder incomes.

Source	Respondents (% at each site)	
	Yanachaga–Chemillen National Park	Manu National Park
Sale of timber	1	36
Shop	12	10
Production on other land	7	2
Laborer	2	5
State employee	2	5
Tourism		11
Trader/intermediary	2	2
Teacher	1	2
Driver	2	1
Pension	1	2
Aquaculture		3
Protected area employee		3
Business person	1	1
Apiculture	1	1
NGO employee		1
Radio operator		1
Chicken raising		1
Mechanic	1	
Doctor	1	
Electrician	1	
Taxi driver	1	

the end of the crop's life cycle. Therefore, a further option is to finance the treatment of timbers used to prolong their useful lifetime and allow their continued use. Agroforestry (reviewed in the next section) offers further promise. Nevertheless, with the popularity of crops in the YChNP region having fluctuated over time [61], it is likely that the current boom will eventually attenuate, and with it the demand for posts.

Enhanced carbon production

Moving beyond pure forestry strategies, this section considers the extent to which carbon stocks could be enhanced in, and emissions reduced from, smallholder properties. Key considerations here are that REDD+ interventions should not lower productivity (and therefore returns) beyond that which smallholders may receive from carbon; and that strategies must consider the IPCC land use categories relevant to REDD+.

In MNP, a clear strategy is the promotion and financing of agroforestry, which has been proven to be an effective and cost-efficient carbon-enhancing practice [62–64]. Agroforestry also reduces environmental risks by mitigating the impact of heavy rains and providing a wind buffer for crops. Further benefits include soil protection, biodiversity conservation and enhancement [65,66], and economic diversification [67]. That agroforestry is already practiced among some MNP smallholders is a significant advantage for REDD+ efficiency as fewer resources would need to be directed towards smallholder capacity building. In addition, given the aspiration among smallholders to adopt agroforestry, this strategy would simply require distribution of tree saplings and advice on planting (e.g., distribution, spacing and species combinations). An agroforestry program could be supported by the provision of organic fertilizers to allay concerns over soil fertility that often predicate the burning of plots prior to planting.

The intensity and physical nature of production in YChNP make agricultural carbon enhancements more challenging, but more effective than in MNP if they can be achieved. Although granadilla can be produced under agroforestry [68], this technique is currently unknown and unpracticed among YChNP smallholders. Capacity building here offers an important potential in-road. Demonstration sites would likely be required to validate the practice and its potential benefits (e.g., lower demand for posts, since wire could be strung between live trees) to smallholders. Fertilizer use could be promoted among rocoto producers to prevent forest clearance. A wider structural approach would be to target and incentivize the intensification and increased efficiency of agricultural production in the region [69], with the objective of reducing the need for forest clearance for crop establishment. This option would involve capacity building on production methods, including support to facilitate land zoning and strategic planning of land use of smallholder plots (e.g., for planting in highest fertility soils). Support with transport links, to reduce smallholder postharvest expenditures, could also support this strategy. This approach acknowledges the primacy of agriculture to local livelihoods and aims to work with the existing objectives of smallholders (production) and may, therefore, represent the 'path of least resistance' in terms of integrating REDD+ locally.

Regarding cattle ranching (applicable at both sites), interventions could be integrated with no economically detrimental (and indeed even positive) corollaries. Two prominent strategies for increasing carbon stocks in these areas are interspersed reforestation (silvopasture) and border planting reforestation to create 'living fences'. Under this approach for REDD+, the level of reforestation in pasture areas would have to be such that it would change the (IPCC) land use category from 'grassland' to 'forest land' – following Peru's national definition of forest land; that is, 30% crown cover, 5 m minimum height and 0.5 ha minimum area [28]. These strategies additionally generate co-benefits for smallholders in the form of timber revenues, shading, protection of soils and provision of diversified fodder (which could potentially reduce the incidence of a disease, bovine enzootic hematura, which is currently prevalent in YChNP [70]).

Income diversification

The final strategy is the consideration of income alternatives to carbon-intensive production, which could be promoted under REDD+. This is an important area of enquiry given that, if REDD+ interventions act to reduce agricultural and/or extractive intensity, alternative livelihood options must be made available to ensure long-term sustainability of carbon reductions and enhancements.

In MNP the first option is tourism. Although 11% of respondents currently receive an income related to tourism, this activity is currently greatly suppressed as a local revenue stream. Private companies hold a monopoly, with visitors transported between isolated private lodges (on the adjacent side of the river to the majority of settlements) that bring their supplies from Cusco. The aspiration of many respondents to participate in the tourism industry (Table 7) provides a potential foundation for REDD+ interventions to build local capacity for the provision of touristic services and goods, as well as negotiate enhanced local engagement with the Cusco-based agencies.

Two productive activities also offer potential, the first of which is aquaculture. MNP's clay soils and abundance of water lend it the ideal characteristics for this activity, from which commercialization can begin after just 5 months, produce up to 10,000 kg meat/ha/year and can generate returns of up to $30,000/ha/year. The current barriers to entry are the provision of fry, the high cost of fishmeal and technical expertise. Interventions could target the lowering of these barriers and promote this activity through capacity building, targeted micro-enterprise loans and increased market connectivity for inputs and produce. Moreover, aquaculture under agroforestry can provide shade and biomass for fish, increase carbon sequestration, consolidate soils and provide an additional harvest for smallholders (e.g., citruses) [71]. Nevertheless, the risks associated with this practice [72–74] warrant in-depth feasibility analyzes prior to its recommendation. A second productive activity, currently practiced at both sites, is apiculture. This activity produces a potentially premium-market exportable product in honey and supports an additional ecosystem service in the form of pollination. It is also boosted by reforestation/agroforestry [75], making it highly REDD+ compatible. These alternative MNP activities are also potentially reinforcing, with the fish farms and beehives forming part of community ecotours.

With YChNP livelihoods currently highly dependent on agriculture, smallholders may be more resistant to alternatives. Here, where tourism is largely limited to visitors attracted by the Tirolean culture and architecture of the region's towns [24], smallholders display little enthusiasm for participation in the industry (Table 7). Nevertheless, the decent infrastructure of the region, reliable services (e.g., electricity, water and restaurants), cloud forest landscape and accessibility of the national park all create favorable conditions for various forms of tourism. Interventions could therefore target the diversification of the character of tourism itself, to include adventure (e.g., mountain biking) and nature tours. In addition, the attractiveness of aquaculture and apiculture to smallholders could be investigated – practices that could also be promoted here, capitalizing on the region's strong trade links with Lima.

Conclusion

This article analyzes smallholder land use, decision-making and income diversification strategies at the forest–farm frontier in the Peruvian Amazon to draw out local REDD+ strategies. The comparative analysis found that the landscapes and livelihoods at the two study sites are highly heterogeneous, in turn illustrating the need for different strategies to contextualize REDD+ locally. The benefits of this approach go beyond local acceptance (and thus greater prospects for participative equity) to increased cost efficiency (through specific targeting rather than a blanket approach) and environmental effectiveness (by targeting the greatest sources of emissions and areas where forest carbon stocks can be enhanced). The contextual interventions center around four central REDD+ strategies: PES, reduced forest degradation, increased carbon production and income diversification.

In YChNP, where agricultural production is historically intense, PES schemes could be used to incentivize the reforestation of fallow land and the conservation of the remaining forest pockets. However, a key challenge is the demand for posts for the hugely popular granadilla crop. The resultant forest degradation could be attenuated through dedicated reforestation plantations and demonstration plots to illustrate the viability of the crop under agroforestry. Beyond this, REDD+ funds could be used to promote agricultural intensification to reduce encroachment into the forest–farm frontier. In MNP, PES would likely be more effective if targeted towards forest conservation. In addition, smallholder capacity could be built on sustainable forest management practices to reduce forest degradation, and common agroforestry practices financially rewarded or materials subsidized. Wider structural interventions could target energy supply, for instance through improved-efficiency cookstoves, and promotion of tourism and alternative productive activities such as aquaculture and honey production. Both sites could benefit from financially supported carbon enhancements in their pasture fields, which could have additional benefits for cattle.

The performance of the REDD+ mechanism in mitigating climate change ultimately depends on providing the right incentives at the local level for local action. It is therefore key that the design of interventions goes beyond the superficial consultation of local people to the full integration of their practices and decision-making. Only in this way will REDD+ strategies and policies be accepted and thus be more sustainable in the long term. This article argues for a locally informed evaluation of land use, land use economy and surrounding decision-making, and, thus, of smallholder engagement in REDD+ and for a wide conception of the potential strategies and tools under the mechanism to maximize flexibility. This article offers a unique insight into the ways local people living in high-priority conservation areas (protected area buffer zones) can participate in the REDD+ mechanism, by capitalizing on existing practices and landscape characteristics. With additional effort (and financing) by policymakers and international donors to this end in Phase 1 of REDD+, prior to demonstration (Phase 2) and full national implementation (Phase 3), the mechanism is likely to garner greater local support and, subsequently, adoption.

Future perspective

Perhaps the most underacknowledged decision adopted to date on the REDD+ mechanism under the UNFCCC is the one relating to phased implementation. Within this framework, Phase 2 is currently particularly neglected. Phase 2 is about piloting, testing, monitoring, learning and refining methods and approaches – and repeating this process as necessary in order to design effective, efficient and equitable REDD+ strategies. It is also about interpreting and extrapolating local lessons from research and demonstration activities into national REDD+ policies and measures. A challenge countries are likely to face here is deciphering the extent to which local lessons can be extrapolated into national policies and measures, while targeting the greatest sources of forestry emissions and the easy forest carbon stock gains. This phase is therefore likely to take time; for example, 5–10 years for many countries, but will be critical to the effective functioning of the mechanism in Phase 3. REDD+ implementation is, then, best viewed as a long-term undertaking requiring a flexible and learning-by-doing approach.

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Executive summary

Background

- The REDD+ mechanism could offer financial alternatives to agriculture for smallholders living and producing in the buffer zones of protected areas, as a means to slow or reverse the deforestation and forest degradation trend at the Amazonian forest–farm frontier.
- Local landscapes are highly socially and economically diverse; therefore, REDD+ interventions must account for these by targeting emissions reductions and carbon enhancements in a cost efficient and environmentally effective manner, while seeking to maximize participative equity.

Experimental

- Data on smallholder land use, forestry decision-making and alternative (nonagricultural) livelihoods were collected through household surveys and interviews in the buffer zones of two Amazonian protected areas; Yanachaga–Chemillen National Park (YChNP) and Manu National Park (MNP).

Results

- The intensity of agriculture in the western buffer zone of YChNP has lead to widespread deforestation of smallholder properties and relatively high returns on crops, particularly the granadilla passion fruit, which requires 600 wooden posts/ha to suspend wire around which the vine wraps itself.
- Smallholders around MNP receive lower incomes from their crops, greatly rely on forests for timber and fuelwood, and have more diversified incomes.

Discussion

- Potential smallholder REDD+ interventions fall into four strategies.
- Payments for ecosystem services would directly reward reforestation and conservation on a contractual basis. To maximize cost efficiency and environmental effectiveness, payments for ecosystem services should target reforestation in YChNP and conservation in MNP; although smallholders should be given both options to ensure equity of opportunity.
- Interventions to reduce forest degradation should address the demand for granadilla posts in YChNP through dedicated reforestation plantations, while focusing on capacity building on reduced-impact logging practices and the feasibility of a regional improved-efficiency cookstove program in MNP.
- Enhanced-carbon agriculture REDD+ interventions would be simpler to implement in MNP due to the existing practice of agroforestry; profit-driven producers in YChNP would likely be harder to pursuade, although this could be instigated through granadilla agroforestry demonstration plots. Cattle pastures could be partly reforestated at both sites, which would additionally generate benefits for the livestock.
- The promotion of alternative income streams is the final REDD+ strategy, among which in MNP is ecotourism; a monopoly over which is held by private companies. Potential productive alternatives at both sites are aquaculture and honey production.

Conclusion

- Local REDD+ strategies should be contextually informed and allow for the widest conception of potential strategies under the mechanism to maximize flexibility – and thus participative equity, cost efficiency and environmental effectiveness.

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