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Is timber management a realistic conservation alternative for indigenous Amazonian communities?

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ABSTRACT

Indigenous people, who are often economically, socially, and culturally dependent on forests, represent important stakeholders in forest management. Due to high costs, indigenous communities partner with external institutions to harvest timber, often resulting in forest degradation within their territories, internal and external conflicts, and disinterest in starting new timber management projects. Using a standardized methodology to investigate the outcomes of previous community forestry projects presents an opportunity to better understand and potentially resolve these issues. Hence, we conducted research in the Sinchi Roca I native community in Peru. Our objectives were (1) to describe the process of timber harvest, (2) to analyze gender differences in local perceptions of timber management, and (3) to evaluate the outcomes of the timber activity, applying socioeconomic criteria and indicators. Data collection included in-depth interviews, focus group discussions, and intra-household surveys. We found that locals partnered with a company for timber harvesting, which led to a sanction from the Peruvian government. Timber harvesting was therefore negatively perceived in the community, with 83.75% of survey respondents dissatisfied with the activity and 88.75% reporting internal and external conflicts due to the presence of the company. Moreover, women did not have a major role in timber harvesting, nor did they actively participate in planning meetings. Results suggest that improving future timber management projects in indigenous communities requires that projects be adapted to local realities and encourage local participation, including training for locals in governance, administration of documents, and negotiations with external stakeholders.

Keywords: Community forest management; Gender participation; Kakataibo; Local perception; Multivariate analysis.

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SIGNIFICANCE STATEMENT

Indigenous communities have an invaluable role in forest management: They can be important allies in conservation efforts and reduction of deforestation. However, even though Amazonian indigenous communities have this invaluable role, they usually do not possess the infrastructure and equipment necessary to conduct commercially viable timber harvesting, leading to their partnering with external institutions (i.e., private companies, NGOs), often under disadvantageous terms. This study develops and tests a method to better evaluate community forest management according to global and locally appropriate standards to better inform investments and priorities for future conservation projects. We further contribute to the literature by highlighting gender roles in participation in timber harvesting, which is less commonly studied. Better evaluations and contextualization of indigenous community and private sector forestry partnerships are essential, especially in Peru, where NGOs are very active in working with native communities and often impose their own conservation priorities ahead of communities' local realities and priorities.

INTRODUCTION

Forests play an important economic, social, and cultural role in the livelihoods of indigenous communities (Coomes et al. 2016; Godoy et al. 2002; Khasa and Dancik 1996; Schaafsma et al. 2014). Indigenous people represent important stakeholders in forest management worldwide because of the amount of land they occupy. While indigenous communities only represent 6.2% of the world's population (ILO 2019), they participate in the management of at least 28% of the Earth's surface (FAO and UNEP 2020). Deforestation, especially in tropical forests, threatens biodiversity and particularly affects indigenous populations who have a high dependency on forest resources. Important drivers of deforestation in tropical forests include urban expansion, illegal mining, palm oil plantations, and slash-and-burn agriculture (Armenteras et al. 2017; Espejo et al. 2018; Lambin et al. 2003; Vijay et al. 2016). Within tropical forests, the Amazon has been listed as a major deforestation front despite being one of the most biodiverse ecosystems in the world (Charity et al. 2016; Prussmann et al. 2015). The Amazon retains 83.4% of its original forest cover, about 639 million hectares. However, between 1985 and 2018, 69 million hectares were lost, and lands designated for agriculture and ranching grew by 172% (Mapbiomas Amazonía 2020).

Collectively-owned and lands managed by local indigenous communities are increasingly globally important for biodiversity conservation and reducing deforestation. Beyond the fact that these lands are home to a high diversity of species, community management tends to be a less costly and potentially more effective conservation strategy than conventional public protected areas (Blackman et al. 2017; RRI 2020). Research suggests that community forest management (CFM) may be particularly effective at reducing deforestation (Ceddia et al. 2015; Nolte et al. 2013; Schleicher 2017). For example, in the Amazon, indigenous territories account for about 45% of the land area classified as wilderness, but less than 15% of forest loss in the region (Fernández-Llamazares et al. 2020).

In this research, we consider CFM to be the decisions, practices, and activities carried out by local and indigenous communities for the planning of current and future use of timber and non-timber forest resources. CFM includes governance structures and the internal regulations and technical criteria used to create forest management plans. The goal of CFM is to promote economic, social, and environmental benefits at local, regional, and national scales (Agrawal and Ostrom 2008; De Camino 2000; Dourojeanni 2009; Larson 2013; Tchikangwa et al. 2001). CFM requires adequate internal organization within the communities and efficient, clear state regulations (that are comprehensible and viable) in order to mitigate market pressures contributing to forest degradation (Nalvarte 2015; Rebugio et al. 2010).

To evaluate the sustainability of CFM, one common method is the use of principles, criteria, and indicators (CIFOR 1999; FAO 2016; OIMT 2005). One of the advantages of this method is that changes in social, economic, and ecological variables can be objectively assessed. Criteria are nested within principles and the indicators are nested within these criteria. Principles are defined as the essential elements or objectives of forest management (Sabogal et al. 2004). Criteria describe the conditions that must be satisfied for forest management to be considered sustainable. They evaluate important aspects of forest planning such as forest-use categories, productivity, protection and the social roles of forests (FAO 2016; OIMT 2005). Each criterion relates to a key element of sustainability (principles) and is characterized by a series of corresponding indicators. Indicators are defined as quantitative, qualitative, or descriptive parameters which are periodically measured and can identify the direction of change for a given criterion (FAO 2016; OIMT 2005; Sabogal et al. 2004). Indicators should be clear, realistic, and easy to control. However, while indicators can signal change and are part of environmental management systems, they cannot show on their own whether forest management is

sustainable (OIMT 2005).

Research evaluating the sustainability of CFM has been conducted on all continents, most notably in Asia and Africa. Mahanty and Guernier (2008) identified social, political, economic, and environmental benefits and costs of collectively managed forests throughout Asia; Nguyen et al. (2008) in Vietnam, and Rebugio et al. (2010) in the Philippines. Outside Asia, Kajembe et al. (2006) studied factors contributing to the conservation success of CFM in Tanzania. Here, CFM improved forest health and increased locals' quality of life.

In Latin America, CFM focuses on timber harvesting and is principally promoted by external organizations outside the community. This CFM is characterized by projects of a limited duration that prioritize international agendas over local priorities (FAO 2010). Nonetheless, a few cases have been successful. In countries like Mexico and Guatemala, where CFM has contributed to local community empowerment, CFM promotes local socioeconomic benefits, and maintains forest cover (Bray et al. 2008, Rodriguez and Fleischman 2018; Stoian et al. 2010).

In contrast to these occasional successes, important CFM projects conducted in the Amazon forests of Bolivia, Peru, and Brazil have largely failed to achieve the desired outcomes. These initiatives have not adapted to local realities as external institutions have instead expected local communities to manage their forests in accordance with the priorities established by these outside agencies (Medina et al. 2008).

Understanding why CFM has had limited effectiveness as well as the impacts of CFM on indigenous communities and its potential to stem land-use change is particularly relevant in Peru. Peru contains about 11.4% of the Amazon's forest cover. However, between 1985 and 2018, the country lost 11.2 million hectares (1.5%) of its Amazon forest cover and areas designated for agriculture and livestock grew by 35% (Mapbiomas Amazonia 2020). Forest loss tends to be particularly acute in uncategorized lands, indigenous communities, rural landholdings, and forest concessions, with a 37.04%, 18.96%, 15.15%, and 12.38% loss of forest cover in these lands, respectively, between 2001 and 2018 (Geobosques 2020; Rubin de Celis et al. 2019). The departments with the greatest cumulative loss of forest cover were San Martin, Loreto, and Ucayali.

In Peru, forest ownership and access vary from other countries. According to the Constitution of Peru (1993), forests are a national heritage, and the State is sovereign over all uses of the forest. The general population can access forest resources through administrative documents awarded by forest and wildlife authorities, such as the National Forest and Wildlife Service (SERFOR for the Spanish acronym), or regional governments, like the Regional Forest and Wildlife Authority (ARFFS for the Spanish acronym). In contrast, for indigenous communities, the access to forest resources operates under a different set of rules. The Forest and Wildlife Law N°29763 recognizes exclusive subsistence harvesting rights of indigenous communities, which do not require a contract (SERFOR 2015). However, indigenous communities are required to seek permissions or authorizations for commercial use depending on criteria such as harvest intensity, the size of the area, and the level of impact of harvesting operations. Communities must present a General Forest Management Plan to the forestry authorities. The Organization for the Supervision of Forest Resources and Wildlife (OSINFOR for the Spanish acronym) supervises the compliance with these regulations.

This use of CFM has had some successes in Peru. One successful case of CFM was documented in the indigenous community Belgica (in Madre de Dios), where the community, with support from an NGO and an alliance with a private timber company, obtained the Forestry Stewardship Council Certification (FSC) (Salirrosas personal interview 2016). Other successful cases of CFM have been reported by Bueno et al. (2006), Gaviria and Sabogal (2013), Nalvarte (2015), and Vera (2014). From these examples, success was evidenced by obtaining forest certification, improving local leadership in their respective communities, achieving unity and collective goals towards the development of their communities, improving capacities, and having approved management plans and annual operating plans, among other indicators.

However, outside these cases, few CFM initiatives have been successful according to sustainability indicators. Although forestry in Peru has a high economic potential, the activity only represents 1% of the country's Gross Domestic Product (GDP) (Held et al. 2015), suggesting economic potentials of CFM are currently underrealized. The majority of indigenous communities utilize forests for subsistence purposes or commercialize a few individual products with little value added. Others cede the commercial use of their forests to third parties, selling standing trees to companies generally under disadvantageous conditions for the communities (Sabogal 2008; USAID 2021).

Despite efforts to improve CFM, there are still gaps in understanding the sustainability of CFM because much of the literature does not adopt principles, criteria, and indicators that can be used for comparative and long-term studies that are appropriate to the realities experienced by indigenous communities in the Amazon. Local perceptions of forest management for timber and gender differences in these perceptions are similarly understudied. Gender perception studies are relevant since local knowledge and

perception about changes in the environment as well as the use of a resource can vary according to the exposure to the activity or the environment as well as the role each party takes in the activity or other social factors. For example, men or women may take a role in the activity that culturally is not associated with them due to becoming a widow or because they are accompanying their partner (Sobral et al. 2017; Quinn et al. 2003). These types of studies in native communities help address the question of how involved each party is in the activity, and for timber studies, specifically how involved women are in this activity since it is not a role they would normally take. There are studies in gender roles in participation within forest user groups but not specifically in timber management (Fitts et al. 2020; La Torre-Cuadros and Ross 2003; Sun et al. 2011; Sunderland et al. 2014). Specifically in Peru, many community forestry projects have been conducted in the country, but how well they performed is still unknown. In addition, much research done on this topic has not been published in scientific literature and is only available as internal reports for private consultancies or for the government agencies (Cossio et al. 2014).

To help address these issues, this study adds to research on community forestry in Peru in several ways. First, we put forth a set of standardized and reproducible criteria and indicators taking into account one community's local reality. We selected Sinchi Roca I as the local community for this study because it is a native community supported by an NGO with a contract with a timber harvesting company in one of the departments with the greatest deforestation rates in Peru. Sinchi Roca I practices CFM on its communally-owned land through the harvest of both timber and non-timber forest products for both subsistence and commercial purposes. In this paper, we focus on timber management. The methodology used in Sinchi Roca I can be used to evaluate the outcomes of CFM in communities with similar contexts. Second, we study local perceptions of timber management by gender to identify how involved each gender is in timber activity. Third, we make the information more accessible to different users and stakeholders by publishing in scientific literature.

The purpose of this article is to analyze the development of a CFM initiative in the Native Community of Sinchi Roca I in the Peruvian Amazon with three specific objectives: (1) to describe the process of timber harvest; (2) to analyze gender differences in the perception of timber management, as well as gender roles in the activity; and (3) to evaluate the outcomes of the timber activity by applying socioeconomic criteria and indicators.

MATERIAL AND METHODS

Study area

We conducted our study in the native community of Sinchi Roca I within the central Amazonian Forest of Peru. This region is classified as Tropical Wet Forest (T-wf) and Tropical Premontane Wet Forest (TP-wf; Holdridge 1987). There are three main vegetation types: lowland, upland, and terrace forest (next to the river) (MINAM 2019). The area has a predominantly tropical, warm, and humid climate. It has moderate drainage and does not flood (Quinteros 2001).

Sinchi Roca I is a community of 827 individuals in 110 families (MINSA 2015), located 25 km upstream of the San Alejandro River in the departments of Ucayali and Huanuco, Peru (Figure 1). Residents belong to the ethnic group Kakataibo (Pano linguistic family), and the principal economic activities for the community include slash and burn agriculture, fishing, hunting, forest product extraction (timber and rubber), and handicraft production. A typical salary for one day of labor is USD 10 (1 USD=3.25 PEN).

Sinchi Roca I was established in 1948. It has an adjacent sister community, Sinchi Roca II. Initially, the population that lived in the two communities were of the same families and had a joint management plan for timber harvest, but each have created separate management plans since 2008.

According to the Management Plan of 2011 (signed by a Forestry Engineer and required by the Forestry and Wildlife Law N°27308, now superseded by N°29763), Sinchi Roca I is entitled to 23 986 hectares (ha), including 18 752 ha for forest management. Sinchi Roca I manages additional areas for rubber harvesting outside of their legal boundaries that were part of the community's traditional territories (in current Sinchi Roca II's territory). The community held a contract with a timber harvesting company until 2016 when OSINFOR terminated the community's timber extraction permissions for a breach of the management plan.

Data collection

Initial data collection was done through a literature review of letters between the community and institutions (i.e., timber company, government agencies, local authorities), forestry management plans, Sinchi Roca I minute books (from their internal meetings), and project reports led by NGOs that worked with the community (See Table 1). This allowed us to better understand the community's context, the relationship between the community and the timber company, and to answer some of our criteria and indicators (See Table 5).

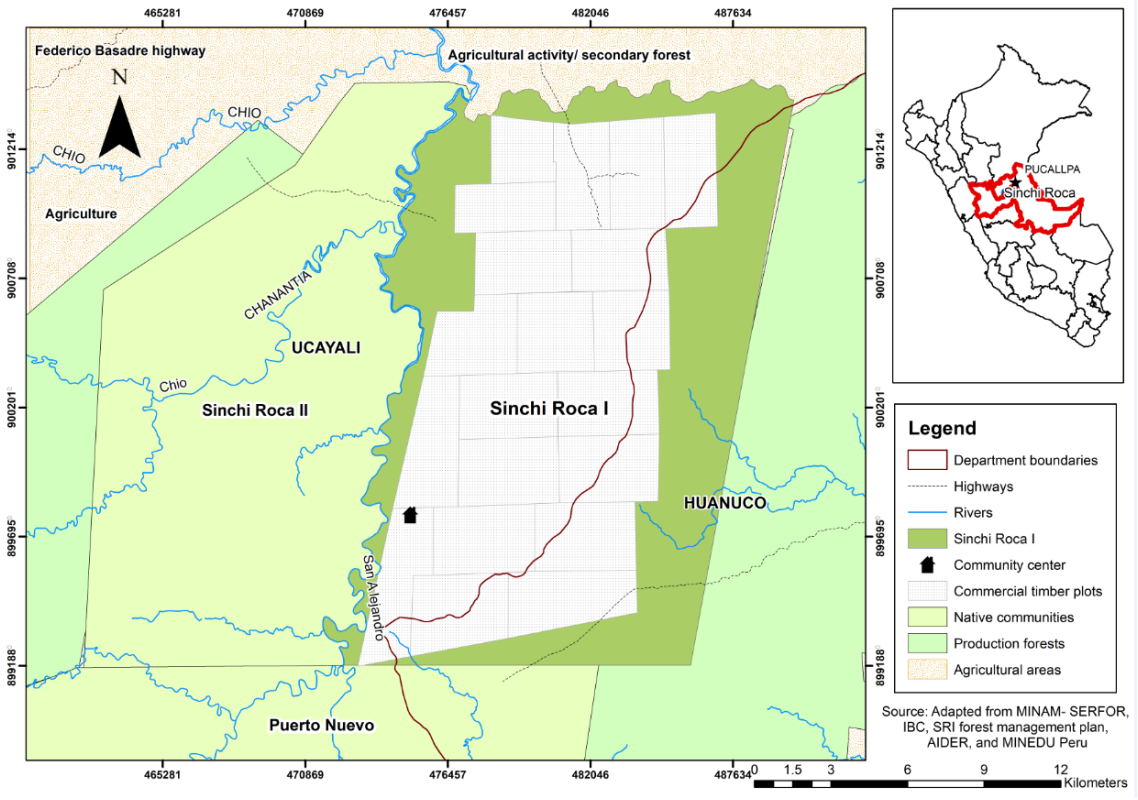

Figure 1. Location of Sinchi Roca I. Grey polygons represent the commercial timber harvest area where the management plan is implemented.

Description of timber extraction

We collected data in Sinchi Roca I in February 2016. To understand the history of timber extraction in the community and its socioeconomic impacts, we first conducted semi-structured in-depth interviews (as described in Bernard 2006) with five key informants in the community. Local authorities, including the community leader, lieutenant governor, president of the forestry oversight committee, former community leader and current president of The Native Federation of the Kakataibo Communities (FENACOCA), and a female leader who served as president of the Glass of Milk Association, participated in the interviews. Interview questions were designed by the research team to help answer our pre-established criteria and indicators (See Table 5) and were validated in an initial visit to the community in June 2015. This validation enabled us to better adapt the questionnaire to the community's reality. Interview questions focused on the current use of forests, how those uses have changed over time, the community's perceptions of forest activities, the involvement of institutions and projects in the area, and external sources of support for forestry activities.

In addition, we conducted two focus groups (Bernard 2006) in the community, one with individuals participating in the timber harvest (with 13 participants: 9 male and 4 female) and the other with women involved in forest activities (15 participants). As women mentioned not feeling completely free to express their opinions in the presence of men due to the community's social structure, we deliberately hosted this all-female focus group to better understand women's perception of forestry activities. The research team first spoke to the community leader about the best way to gather participants for each of the focus groups given the community's context. His approach was to do an open call for all community members who met our eligibility criteria (for focus group 1, that they work or had worked in timber extraction, and for focus group 2, women with some knowledge about the activity).

Participants described how they used forest resources (both timber and non-timber), as well as their perception of forestry activities and past institutions and projects involved in forestry in Sinchi Roca I. Participants were asked to complete a timeline highlighting important historic events related to forest management. In addition, they created participatory maps showing changes in resource management over time, zones of timber harvesting, other use zones, and areas of conflict. The participatory map exercise consisted

of community members filling-in a printed base map which initially contained rivers and community limits. The purpose of having pre-established limits was to get inhabitants oriented on the map so they could focus on naming the missing geographic elements and identifying different areas of importance (i.e., of land use or resource management), as well as other questions (Sheil et al. 2004; Boissière et al. 2006).

Perception of timber extraction in Sinchi Roca I

For this study, we consider perception as a person's direct experience and awareness about the environment together with indirect information that the individual receives from his social world that creates awareness to interpret situations and problems (Lazos and Paré 2000; Sirivongs and Tscuchiya 2012).

To compare men's and women's perceptions of timber harvesting, forest management, and changes in forest condition, we conducted intra household surveys (Bernard 2006) with male and female heads of household. Traditional gender roles defining women as primarily wives and mothers are prevalent within rural and indigenous Peruvian communities (Ames 2013). For this reason, we analyzed men's and women's perspectives as the local cultural context recognizes only these two gender identities and roles associated with them.

We surveyed 80 individuals (39 women and 41 men) in 41 households. According to the finite population formula (Aguilar-Barojas 2015), the minimum sample size for a community of 110 families (with values: p=0.5; Z score=1.96, d=0.125, N=110) was 39.66, hence our choice in sample size. We used a stratified random sampling design with 50% of surveyed households engaged in forest management and 50% not involved. The survey had a mix of open and closed ended questions as well as free-listing exercises and tables to complete. It covered (1) Demographics, (2) Forestry activities performed in the community, (3) Perception of benefits from and satisfaction with timber management, (4) Governance and participation in timber activities, and (5) Perception of forest status. As part of the survey questionnaire, participants were asked to list their economic activities in order of the time they dedicated to them. This was done to later compare similarities and differences by gender and economic activity among participants. In addition, some participants also responded to an in-depth interview with a different set of open-ended questions to obtain a more in-depth understanding of the community context (See Table 1). Results from the perceptions from the survey can be seen in Figure 3.

Outcomes of timber harvest using socioeconomic criteria and indicators

To evaluate the socioeconomic outcomes of timber management in Sinchi Roca I, we developed a set of 12 criteria and 32 indicators informed by CIFOR (1999), FAO (n.d.), ITTO (2005) and our previous pilot study. This simplified set of criteria and indicators (Table 5) was informed by the community's context and designed to be replicable for related research on the social and economic impacts of community forestry. Using the interviews, participatory maps, and survey data, we classified the outcomes of timber harvesting according to these criteria and indicators. In addition, to identify the patterns of deforestation in the area, we used geographic information systems' (GIS) tools to classify land cover and average annual deforestation. We worked with land cover (forest/non-forest in 2000, 2005, 2010, and 2013) shapefiles built by the AIDER NGO for previous projects they had with the community. These shapefiles contained the forest/non-forest area for the community which we used to calculate the deforestation rate. The mean annual deforestation rate for 5-year increments beginning in 2000 and ending in 2013 were calculated with the following formula:

$$D = \frac{(D1 - D2)}{N}$$

(OSINFOR 2014)

(D= mean annual deforestation rate, D1= deforested area at time 1 (ha), D2= deforested area at time 2 (ha), N= time period).

Table 1. Summary table of methodological tools used for data collection and their specific objectives.

Tool		Objective	Number
Literature review	Letters between SR I and institutions	Background and context analysis	13
	Private agreement contracts		3
	Documents		7
	SR I minute books		5
	2011 Forestry Management Plan		1
	Annual operating plan (plot 1), 2011		1
	Projects developed in the community		1
In-depth interviews		Gather general information and experiences with forest management, current uses of forests, projects and institutions present in the community	5
Focus groups		Group information on the use of forest resources	3
Participatory maps		Spatial information on the use of forest resources and conflicts	3
Intra household surveys		Gather information on household characteristics, forestry activities, benefits of forest management and perception, participation in forestry activities, and forest status	80
Direct observation		Socioeconomic situation and way of life of the population from a qualitative point of view. Visit to a rubber plot and mahogany plantation.	-

Ethics

We obtained the corresponding permission and consent from the Sinchi Roca I authorities and population for data collection.

Data analysis

Qualitative information gathered from the focus groups, intrahousehold surveys, and in-depth interviews was processed looking for systematic patterns of perceptions and impacts of timber harvesting. We used inductive data analysis (Creswell 2007) to derive categorical responses from the open-ended response items about perceptions of timber harvesting which we used in subsequent quantitative analyses comparing responses by demographic variables. We first used descriptive statistics to explore the data and later conducted bivariate and multivariate analysis.

To conduct statistical analysis, as some original categories did not have more than five observations in each, we regrouped age into three categories: $[15 - 30 >$, $[30 - 45 >$, and $[45+$ years. Demographic variables (gender and age) were compared with local perceptions of timber harvest. We chose age and gender as our grouping demographic factors since we were interested in highlighting gender perception for timber activities and given the hierarchical structure of the community, gender and age play a role in people's assigned chores. Other demographic variables like religion, marital status, and educational level (with the majority of respondents having only a primary education) showed little variation within our sample. Since these variables demonstrated insufficient variation during the exploratory analysis, they were excluded from the final Fisher and MCA statistical analyses. We measured these perceptions through five dichotomous variables and one categorical variable. The dichotomous variables were (1) timber activity: participated in any timber harvesting activity, either for subsistence purposes or with the company (yes/no), (2) perceived satisfaction timber: expressed satisfaction towards timber harvesting in general (yes/no), (3) perceived benefits timber: perceived that there were benefits from timber harvesting (yes/no), (4) forest management benefits perception: perceived that forest management was beneficial (yes/no), and (5) importance company: considered the timber harvesting company important for timber extraction (yes/no). The categorical variable was perceived forest condition: perceived forest status change in the last ten years (categories – no change, improved, or worsened).

To understand the relationship between each pair of variables, we used the Fisher exact test (Heumann et al. 2016). Due to the variable marginals being very uneven or some cells still having fewer than five observations after regrouping, we used this test instead of the Chi-square test. The Fisher exact test calculates an exact probability value for this relationship and tells us if there are nonrandom associations between the variables (independence). We used the XLSTAT-Student software with a 95% confidence level.

After performing a bivariate analysis, we conducted multivariate analysis to better visualize the relationship between all our demographic variables (age and gender) and our variables of interest (local perception of timber management), performing a multiple correspondence analysis (MCA) in SPSS for Windows, Version 25. The advantage of this method is that we can represent complex relationships in a reduced multidimensional space. Outputs of this analysis plot the original variables against the new dimensions according to their mutual correlations (Chi et al. 2013; Fitts et al. 2020).

To further analyze the differences between men and women and between members of the same gender group given the role that each economic activity plays in their livelihoods, we conducted a SIMPER (SIMilarity PERcentages) analysis. This analysis was done to detect which variables about perception of timber harvesting (satisfaction with timber harvest, benefits of timber harvest, and belief in presence of forest management) and economic activities characterized the similarities and differences between men's and women's responses. In this analysis, we examined participants' four most frequent economic activities based on the amount of time they reported dedicating to the activity (categorized as 1 through 4, with 1 being the activity in which they spent the most time). SIMPER is an exploratory analysis rather than a statistical testing framework (Clarke 1993) that we used to support the results obtained in the MCA. The basis of SIMPER employs the mathematical process of calculating similarity measures or similarity indices between two samples. We utilized the SIMPER method with the non-metric Bray Curtis index for two reasons. First, the econometric properties of the index emphasize situations of co-occurrence and dominance and allow comparisons with different units (Faith et al. 1987). Second, this index works well with attributes or categories. We used Primer v6 (PRIMER-E Ltd. 2006) for Windows for this routine.

Participatory maps were elaborated during the focus groups and later digitized and processed in ArcMap 10.1. We then overlaid all the participatory maps to combine results and obtain areas where locals use forest resources, conflict areas, and the area under a management plan.

RESULTS

Surveyed people range between 16 and 80 years old (mean of 37). An average of six people live in each household (ranging from two to 11). Locals have different levels of education. Almost half (45%) did not complete primary school, 28% completed primary school, 18% began but did not complete high school, 6% finished secondary school, and 3% had some higher education (technical training, college or university degrees). Ninety four percent of the surveyed people were married or cohabitants, 5% were divorced, and 1% were widows. For religion, 15% were catholic, 58% evangelical, and 27% did not follow a religion.

Sinchi Roca I members have a broad relationship with the forest that includes and extends beyond timber products. They are also highly dependent on non-timber products such as rubber (*Hevea brasiliensis*), medicinal plants (See Table 2 for species), fish, and wildlife. *Mazama americana*, *Cuniculus paca*, and *Pecari tajacu* are the most consumed wildlife species, with 63.75%, 55%, and 52.5% of survey respondents reporting consumption of these species respectively. Most common fish are *Prochilodus* spp., *Pseudoplatystoma* spp., and *Leporinus* spp., with 13.75%, 10%, and 6.25% of survey respondents reporting consumption of these species respectively. In addition, they extract fruits from the forest such as *Mauritia flexuosa*, *Bactris gasipaes*, *Oenocarpus bataua*, and *Inga* spp. Commonly used seeds for crafts include *Ormosia coccinea*, *Sapindus saponaria*, *Mucuna* sp., and *Thevetia peruviana*. Palm leaves for construction include *Attalea phalerata*, *Socratea exorrhiza*, and *Phytelephas macrocarpa*. For this manuscript, we focused on timber products.

Description of timber extraction

Through this study, we identified two purposes for timber extraction and the processes for each. The first purpose is to extract timber for subsistence purposes, which does not require any formal permission from authorities. This modality is usually used in secondary forests or areas close to locals agricultural plots and is at a low harvesting intensity. Communities also sell some of this timber to nearby localities at a small scale. The second purpose is commercial harvest through a management plan (approved by the forestry authorities). This is usually done in conjunction with a timber company that signs an agreement with the community. In Peru, this is a very common alliance as communities lack the infrastructure necessary to harvest timber at a commercial level.

Of the 41 households interviewed in our sample, 78% actively participated in subsistence timber harvesting, albeit for different purposes, such as home construction, for canoes, and firewood. Twenty-two percent of respondents were not actively harvesting and obtained wood for subsistence use through purchase in San Alejandro or through bartering. While some only used the wood for the construction of their homes, others also sold harvested timber in nearby big cities (e.g., San Alejandro). For commercial timber harvesting, an important result that we found was that the community does not have people trained to handle forest management documents such as the Forest Management Plan, the Annual Operations Plan, as well as extraction balances, log lists or transport guides. This prevents them from carrying out adequate monitoring and control of the timber company and the extraction itself.

Subsistence timber harvest

Timber harvesting for subsistence purposes starts with cleaning the area around the tree to harvest. The direction in which the tree is expected to fall is then identified. If there is not a very clear direction of fall, ropes are attached to the tree to lead its fall. Once the tree is down, it is limbed and cut in smaller commercial size logs (> 10 cm diameter). The local name for these logs is *tucos*. Logs are transported through the San Alejandro River by tying them together and making them float down the river (Figure 2). If the logs are unable to float, less dense species (e.g., *Ochroma pyramidalis*) are placed underneath. Depending on the tree species' commercial value, some are sold with no further transformation (just as logs), while some are transformed into smaller boards. No formal silvicultural activities are done for subsistence timber harvesting.

Generally, men are in charge of harvesting the trees and are present in all the stages of the harvesting. On the other hand, women help measure the logs and carry smaller ones, especially if the timber comes from areas near their agricultural parcels. When timber is extracted further away, men take a leading role and enter the forest in groups of 4 to 5 people. Table 2 shows the most common species harvested by the community for subsistence purposes. The most common species for timber products are *Guazuma crinita*, *Virola* spp., and *Manilkara bidentata* and the most common for non-timber products is *Hevea brasiliensis* (rubber).

(a)

(b)

Figure 2. Subsistence timber harvest in Sinchi Roca I. Panel A (left): Wood transportation down the San Alejandro River. Logs are tied with cables to form a flotation device. Panel B (right): Typical local house made of the wood harvested in their territory. The house structure, floors, and walls are made of wood, while the roof is either made of calamine or palm tree leaves.

Table 2. Most frequent woody species used by the Sinchi Roca I community and their application (n=80).

Scientific name	Common name	Family name	Percentage of surveyed people who use this species	Uses	Type of harvest
Guazuma crinita Mart.	Bolaina	Malvaceae	52.5	house construction, carpentry, small utensils, handicrafts, make rope from inner bark	subsistence
Virola spp.	Cumala	Myristicaceae	43.75	carpentry, construction, cabinetmaking	commercial, subsistence
Hevea brasiliensis (Willd ex a. Juss.) Mull. Arg.	Shiringa	Euphorbiaceae	31.25	rubber (sheets and liquid)	commercial, subsistence
Manilkara bidentata (A. DC.) A. Chev.	Quinilla	Sapotaceae	21.25	flooring, carpentry, cabinetmaking, infusions of medicinal leaves (for cancer), resin	commercial, subsistence
Myroxylon balsamum (L.) Harms	Estoraque	Fabaceae	17.5	flooring and structural (especially support/beams/rafters), resin (perfume and medicine)	commercial, subsistence
Pouteria reticulata (Engl.) Eyma	Caimitillo	Sapotaceae	12.5	timber, fruit	commercial, subsistence
Simarouba amara Aubl.	Marupa	Simaroubaceae	12.5	carpentry, cabinetmaking	commercial, subsistence
Matisia spp.	Sapote	Malvaceae	12.5	carpentry, furniture, shade, fruit, fuel, cabinetmaking	commercial, subsistence
Coumarouna odorata Aubl.	Shihuahuaco	Fabaceae	12.5	construction (especially support/beams/rafters), tool handles, decorative plates	commercial, subsistence
Vochysia venulosa Warm.	Maoba	Vochysiaceae	8.75	house construction, carpentry, cabinets, plywood	commercial, subsistence
Brosimum utile (Kunth) Oken	Panguana	Moraceae	8.75	construction, cabinetmaking, carpentry, resin	commercial, subsistence

Legend: Species common names were obtained through our intra household surveys. With these common names, we looked at the Sinchi Roca I Forest Management Plan to obtain the scientific names. The scientific names were then verified with the TROPICOS database (www.tropicos.org) and The Plant List (2013) for an updated taxonomic classification. The different uses were obtained from the intra household surveys and complemented with information from La Torre-Cuadros, 2011 and Reynel et al. 2003.

Commercial timber harvest

Commercial timber harvesting in Sinchi Roca I began in 2003 (as registered in the community's minute books). As the harvest was controlled by a timber company, very few locals were informed of the current situation and could not provide many details on how the process was conducted.

The main species extracted were *Manilkara bidentata*, *Coumarouna odorata*, *Myroxylon balsamum*, *Hura crepitans*, *Copaifera reticulata* (See Additional File 1 for a complete list of commercially harvested species). Roads for timber extraction were built in the area by the company who had a contract with the community at that time. In 2006, Sinchi Roca I obtained the Forestry Stewardship Council Certification (FSC) through the AIDER NGO. At that time, both Sinchi Roca I and II had a conjunct management plan and worked together harvesting forest resources. However, due to tensions between external agents and the communities, harvesting permissions by the original timber company were renegotiated, and eventually terminated. These tensions included illicit logging in the area, the loss of forestry certification, and conflicts between Sinchi Roca I and II and the original timber company.

In 2011, Sinchi Roca I revised its forestry management plan and developed a ten-year harvesting contract with a new company. After an inspection discovered a breach in the timber management plan, OSINFOR applied sanctions to the community and suspended timber harvesting permission in 2015. The breach included illegal logging outside the management area, reported volume harvested not coinciding with measured volume, burnt areas, unauthorized volume of certain species harvested, and harvested seeders. Locals reported irregularities with external invasions in their territories causing big areas to be deforested for agriculture. The sanction imposed by OSINFOR included a fine of USD 70 946.6 that Sinchi Roca I was responsible to pay. Up to that point, the forestry law (Law 27308) indicated that the community was entirely responsible for any sanctions with forestry activities, which changed in 2015 with the newer forestry law and regulations (Law 29763). The newer law indicates a shared responsibility between communities and companies working with them in natural resource management.

Perception of timber extraction and gender differences

The benefits perceived for timber extraction mostly correspond to low-level subsistence timber harvesting rather than commercial activities. Among the benefits, the most representative ones are that extracting timber provides income for basic needs, as well as firewood or construction materials for their houses (See Figure 3D). Firewood is an important resource for Sinchi Roca I since the majority of the families use it for cooking. Firewood is obtained from the secondary forests next to their agricultural plots. Only the school, some associations (i.e., banana or cacao committees, glass of milk association), or visiting technicians use gas for cooking. Access to electricity is also limited; they have a generator which provides electricity by hours.

During the surveys, one interesting detail mentioned by women was that the monetary income from small-scale selling of timber harvested for subsistence purposes allows them to cover their basic needs such as expenses for building their houses, buying boats or kitchen utensils, and especially, to buy calamine for their roofs (which is more expensive but more durable than using palm leaves for their roofs). Residents use the wood extracted from their territory to produce boards for house walls, beams, and flooring.

On the other hand, a greater portion of the population surveyed mentioned not perceiving much benefit from timber extraction (Figure 3C). Most of the reasons behind these statements were directly related to the timber company's work in the community. The main reasons for no benefits were that timber extraction did not create many jobs for locals (the company hired their own staff), lack of external support (from the Peruvian government, local authorities, and external institutions like NGOs), and that most of the benefits are exclusively for the community's authorities.

Just 15% of surveyed participants were satisfied with the way timber extraction was done in the community (for both subsistence and commercial purposes), while the remaining 85% were not satisfied with the activity. From the subset of people satisfied with the activity, the main reasons were the jobs generated (mostly for subsistence timber extraction), the income generated for basic needs, and the materials for house construction (Figure 3B).

On the other hand, the main reason for dissatisfaction was the impoverished status of the forest after timber harvesting (Figure 3A). Some respondents characterized the forest as being destroyed, while others commented that it is harder to find wildlife to hunt, having to walk further distances (which affects their connection with the forest for non-timber purposes). Another important reason for dissatisfaction was the lack of profits. Local families did not receive direct payments from the timber harvested by the company. In addition, locals commented that there was an existing debt with the company that did not allow them to receive the profits generated by the timber activity. Another reason why locals could

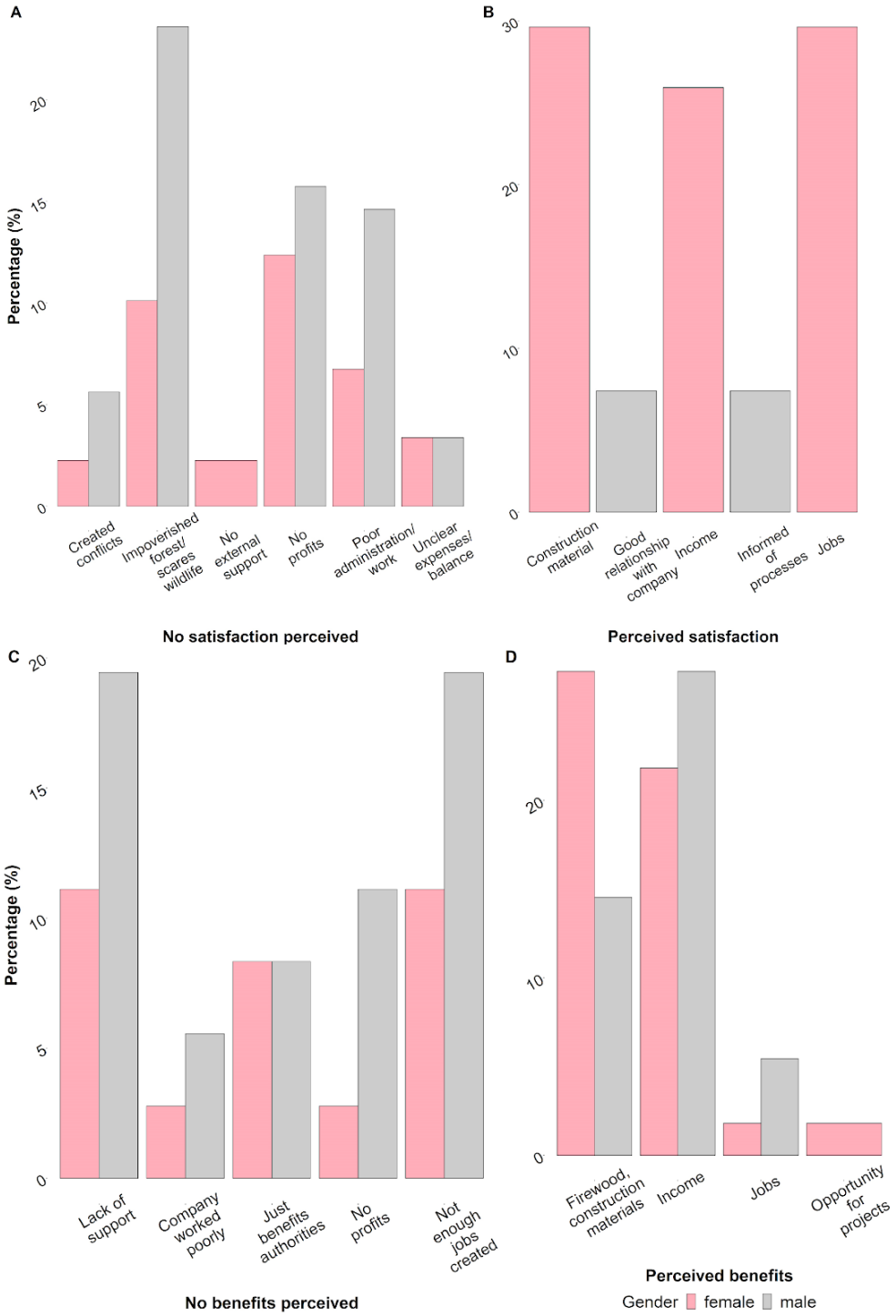

Figure 3. Reasons given for: A) No satisfaction perceived ($n_{males} = 56$, $n_{females} = 33$), B) Perceived satisfaction ($n_{males} = 23$, $n_{females} = 4$), C) No benefits perceived ($n_{males} = 23$, $n_{females} = 13$), D) Perceived benefits by locals for timber harvest activity ($n_{males} = 26$, $n_{females} = 29$). Respondents were allowed to mention more than one reason for their perception of benefits and satisfaction. Participants who did not give a reason for their perception of benefits or satisfaction were not included in the graph

not have received direct profits was the poor distribution of the money between the different stakeholders and authorities. Given the large dissatisfaction in the community towards timber harvest and the bad previous experiences, local authorities commented that the population in general was tired of harvesting timber,

did not want to work on it anymore, and were hesitant to start another contract with other timber companies. Authorities also mentioned that the community had never done timber management by themselves at a commercial level before nor had they anticipated doing so in the future.

At the end of our survey, we asked the respondents to give us recommendations for enhancing timber extraction. They mentioned a list of 16 recommendations. The three main ones were more training (20% of responses), working with more responsible and just companies (15%), and to stop working with timber (13.75%). Other recommendations included to reforest, to take care of the forest, and to better control and monitor their territory and the company's work (each of these were mentioned by 10% of respondents).

Fisher Exact Test

The Fisher Exact Test indicated no significant relationship between demographic variables (gender and age) with perception of benefits from timber harvesting, satisfaction with timber harvesting, perception of benefits from forest management, and beliefs in the importance of the timber company (all $p > 0.15$). However, there was a statistically significant relationship between perception of forest condition and gender (p=0.022, Additional file 2).

Multiple correspondence analysis

The MCA analysis allowed us to visualize in two dimensions (along the horizontal and vertical axis) which sociological and response variables characterized the differences between participants' answers. The vertical axis is an indicator of perception of forest condition and gender that explains 24% of the variation between respondents (dimension 1). A high score of this dimension is related to perception of forest and gender with similar scores (Table 3). The horizontal axis is related to age class and explains 20% of the variation (dimension 2).

We found that women tended to be less involved with timber harvesting activities and they perceived that the condition of the forest had not changed in the past 10 years, especially women in the 15–29-year-old age group. Men in the 30–44-year-old age group were more involved with the timber harvesting activity and perceived that the forest was in worse conditions compared to ten years ago. However, men in the 45+ age group, who mostly were not involved in the timber activity, perceived a better condition of the forest. For the perceived satisfaction variable, dissatisfaction towards timber harvesting (mostly for commercial timber harvest as seen in Figure 3) was associated with men between 30-44. In addition, for the perceived benefits variable this same group of men between 30-44 years were associated with not perceiving benefits from the timber activity (Figure 4 and Additional file 2). Moreover, the MCA analysis showed an association between men older than 30 and the perception of benefits from forest management itself.

SIMPER analysis

The main variables responsible for the similarity among men and the similarity among women are mentioned in Table 4. We identified six main economic activities (agriculture, fishing, hunting, handicrafts, rubber, and timber) performed by men and women in the community and ranked them in descending order according to the amount of time (hours per week) they dedicated to them (having the first economic activity the one they dedicated the most hours in a week).

Men had a higher level of overall similarity. The dissimilarity between men and women was 33.85%. The similarity found among men was due to sharing perceptions of forest condition and sharing their third and second economic activities. Meanwhile, the similarity among women was associated with them sharing the same second economic activity, being satisfied with timber harvesting, and perception of change in forest condition (Table 4). The differences between men and women were most associated with them not sharing their third and second economic activities (Table 4). Agriculture was the most time-intensive activity for both genders, while women described dedicating most time (in descending order) to fishing, hunting, timber, rubber harvesting, and handicrafts. Men spent most time (in descending order) in hunting, fishing, timber, rubber harvesting, and day-labor.

Outcomes of timber harvest using socioeconomic criteria and indicators

Land use

From the participatory maps and the in-depth interviews conducted, we found overlapping land uses and conflicts between the different categories of use (Figure 5). First, we noticed that subsistence timber harvest was done in areas surrounding their agricultural and wild rubber parcels. After training on forest management done by the National Forestry Chamber of Peru (CNF for its Spanish acronym), locals were more aware of not harvesting timber too close to rubber trees as falling trees may damage rubber trees and lower the profitability of rubber and natural regeneration. Since then, they harvest further away from their parcels to avoid land use overlap. They mainly extract timber from the secondary forest surrounding their parcels (local name: *purma*) or the community

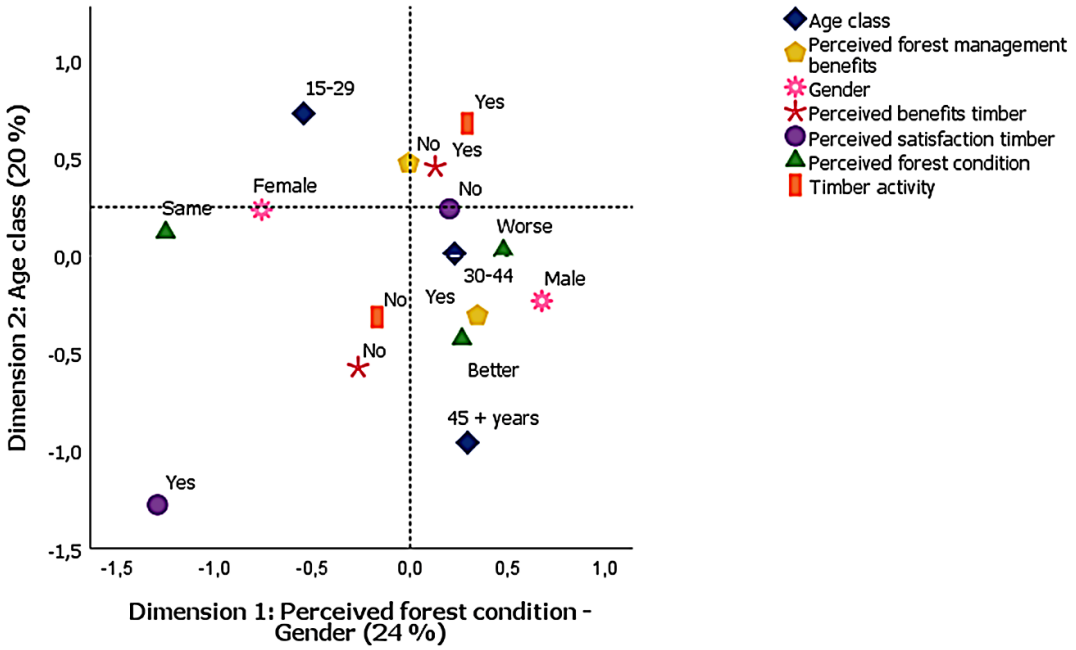

Figure 4. Representation of the two dimensional solution of the MCA. Data derived from female and male intra household surveys (n=80) about perception of timber (benefits and satisfaction), perception of forest management and perception of forest condition.

Table 3. Discrimination measures for each variable and dimensions in multiple correspondence analysis.

Variables	Dimension		Average
	1	2	
Age class	0.147	**0.439**	0.293
Gender	**0.515**	0.055	0.285
Perceived satisfaction timber	0.285	0.293	0.289
Perceived forest condition	**0.576**	0.027	0.302
Perceived benefits timber	0.039	0.256	0.148
Timber activity	0.047	0.212	0.129
Perceived forest management benefits	0.059	0.115	0.087
Total	1.669	1.396	1.532

Legend. The higher the value of the discrimination measure of a given variable in a given dimension, the higher the importance of that variable within that dimension. Highlighted in bold text are the most important variables for each dimension.

center (close to the San Alejandro River) to avoid increased costs for transportation. Locals mentioned that they walked an estimate of 30 minutes inside the forest to find the species to harvest.

Second, we observe from Figure 5 and Figure 6 that there are two mahogany reforestation areas (in yellow) planted in 2000. These have not undergone further silvicultural treatments and therefore only a portion of the trees have survived. Third, Figure 5 and Figure 6 show three REDD+ plots originally established by a project led by the AIDER NGO, which were later abandoned. Fourth, we observe areas of illegal harvest, including the area where the OSINFOR institution supervised the compliance of the management plan. Finally, we observe that on the eastern community border, there is a designated area for protection of unique habitats for macaws and other wildlife species. However, this area is affected by foreign invasions (Figure 6) that create deforestation in these critical areas and transform them to farmland or cattle raising.

Table 4. Results of the SIMPER (SIMilarity PERcentages) analysis.

Similarity among males (72.25 %)		
Variables	Individual contribution %	Cumulative %
Perception forest condition	18.70	18.70
Third economic activity	17.43	36.13
Second economic activity	16.58	52.71
Similarity among females (62.25%)		
Second economic activity	20.02	20.02
Perceived satisfaction timber	17.83	37.85
Perception forest condition	16.92	54.77
Dissimilarity between females and males (33.85%)		
Third economic activity	26.97	26.97
Second economic activity	22.70	49.67

Legend: Table includes only variables that had the greatest contribution to overall similarity or dissimilarity within and between genders, with a cumulative contribution greater or equal to 50%.

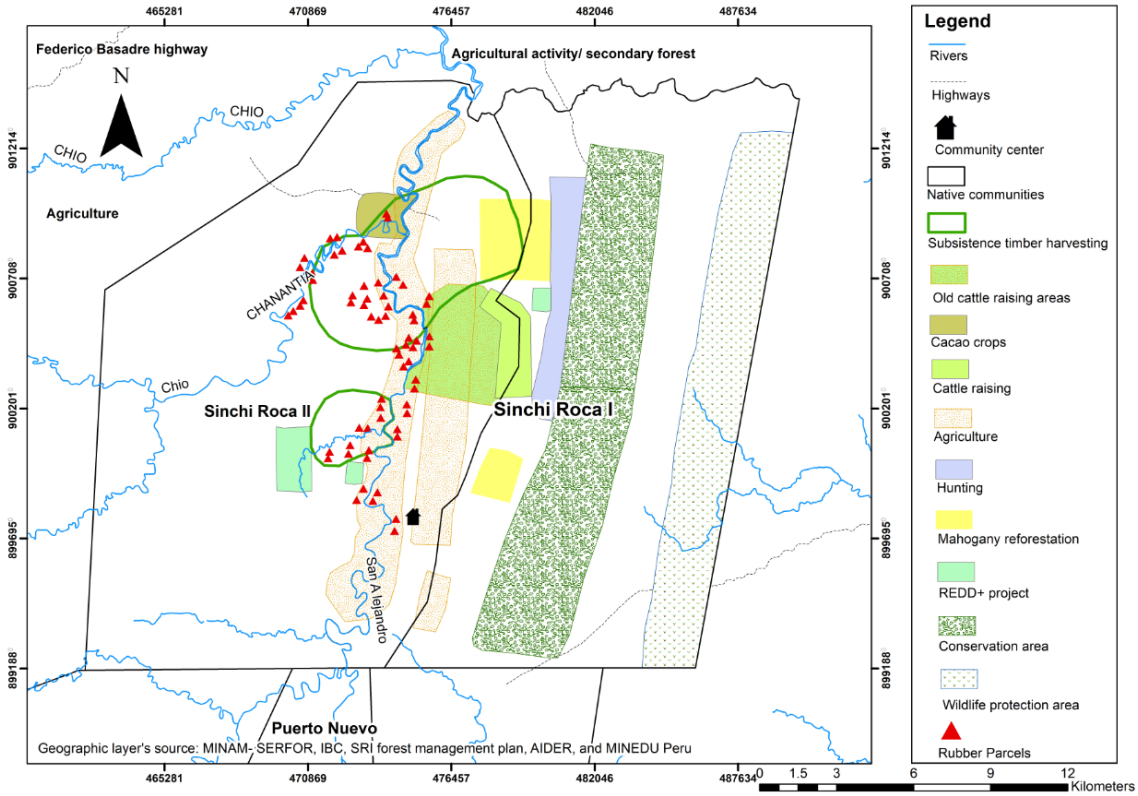

Figure 5. Land use in Sinchi Roca I elaborated through participatory maps.

Economic

Between 2011-2014, the timber company operating commercially in Sinchi Roca I harvested 30 089.118 m^3 of wood. *Copaifera reticulata*, *Chorisia integrifolia*, *Hura crepitans*, *Ceiba samauma*, and *Brosimum alicastrum* were the most extracted species, representing over half of the timber volume

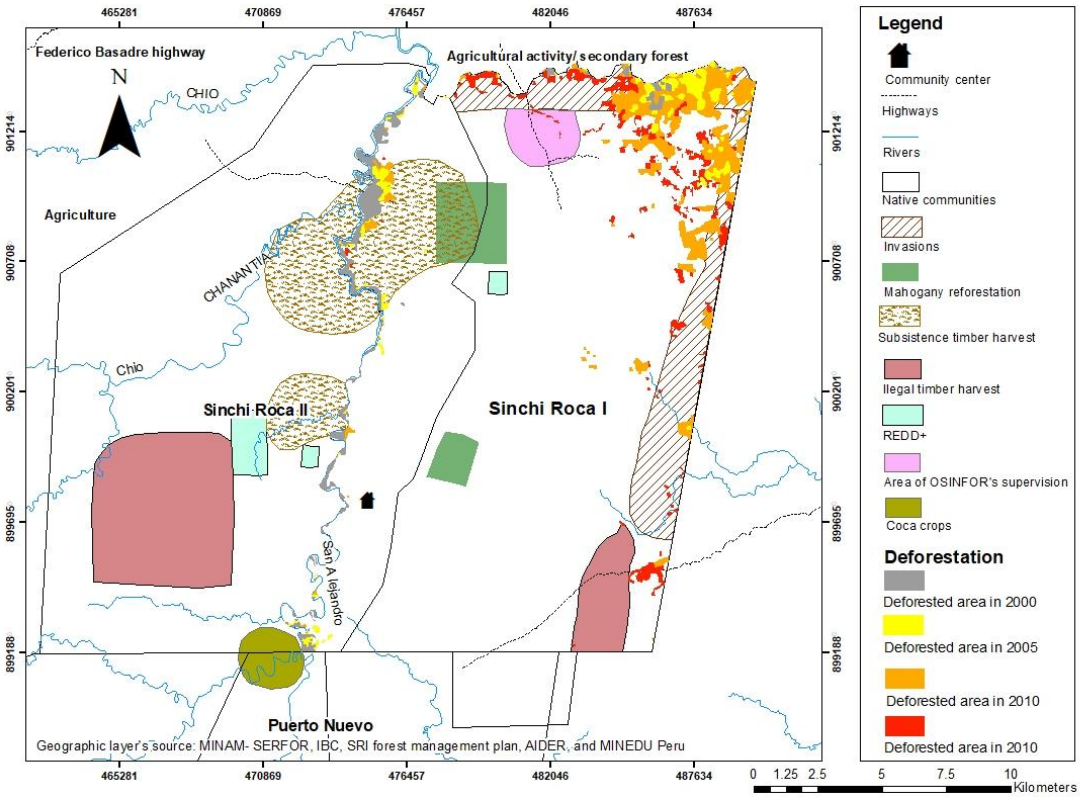

Figure 6. Land use conflicts and deforestation that occurred in Sinchi Roca I.

harvested (See Additional file 1 for a complete list of extracted species). While the amount of timber that the company was authorized to harvest varied by year and species (specified in the management plan), the company never exceeded these quotas. In the four years, the company harvested some 51 217.119 m^3 of round wood less than it was authorized to harvest by the approved management plan. Therefore, a potential exists for more revenue for the community which will still be sustainable.

The value of timber products commercialized between 2011 and 2014 generated USD 289 435.4 with USD 86 830.6 pertaining to the community. Had the company harvested the full volume of timber authorized by the management plan, the net revenue earned would have been USD 555 414.8, and the amount due to the community USD 166 624.4.

The amount of wood harvested annually by the participating families in the community for domestic purposes had an annual net value of about USD 73 304.7 (USD 1078.3 per family per year). Community members principally harvested *Manilkara bidentata*, *Copaifera reticulata*, *Virola* spp., *Vochysia venulosa*, and *Guazuma crinita* (representing 31.6%, 25.7%, 13.7%, 6.3%, and 6.0% of timber volume extracted for household use, respectively).

Timber harvesting in the community should have created job opportunities. Per the contract agreed upon by the community and the timber company, the timber company would hire traditional local taxonomists (local name: *materos*), timber cruisers and workers to operate the tractors and chainsaws. In addition, the company was to support two scholarships for students from the community to pursue technical degrees. However, the company only partially fulfilled the hiring agreements in the contract and did not fund the scholarships.

Generally, work for the timber company generated between 1 and 10 positions (as identified by locals in the surveys), with about 7 individuals serving as timber cruisers, identifying community boundaries, or working on the development of the management plan. Often, however, community members would leave before the completion of a project because the extended period of time in the field (usually a minimum of 4 weeks) competed with other obligations, particularly family obligations and work on the family farm.

The harvesting of timber by community members outside of work for the company often generated more jobs than positions with the timber company. Nearly 44% of participants surveyed described one to ten jobs associated with harvesting timber for subsistence purposes, while about 24% of participants could not think of any jobs associated with timber harvesting in the

community.

Income produced by timber management activities was distributed according to the contract between Sinchi Roca I and the timber company with 30% of profits for the community and 70% for the company. The company also played an important financial role for in-kind benefits in the community. They would lend the community cash money to cover their share in timber harvesting costs, as well as to cover community celebrations costs (i.e., anniversary celebrations, religious events), emergency medical costs, and construction of public infrastructure, or roads. This generated an ongoing debt from the community to the company that effectively precluded a termination of the timber harvesting contract, as the community made debt repayments through its share of harvested timber. The approximately USD 12 307.7 annual operating costs, contractually split evenly between Sinchi Roca I and the company, were paid annually by the company. Annual cash payments and payments in kind to the community by the company varied between USD 1538.5 and 4615.4, an amount deducted from the community's portion of the value of the timber harvest. For this reason, some residents described that the arrangement created a cycle of consistent debt to the company, rather than tangible benefits for community members. Therefore, the community's portion of timber harvesting income went towards repaying a debt to the company or got lost somewhere in the chain of command, rather than benefiting individual families. One redeemable point is the fact of not distributing the money to each family; if the money were divided the amount would be so small that it would not represent an amount that helps the family situation. One of the interviewees commented that if the full profit from timber harvesting activities was to be destined to carry out public work or community services, the changes in the community's lifestyle due to forest management activities would be more significant.

A large portion of interviewees (86.25%) described that income from commercial timber harvesting went principally to the head of the community, while 10% described that timber harvesting income went directly to the community. A slight majority (52.50%) indicated that they had received some sort of economic incentive from the company, while 46.25% of respondents said that they had not. Of the individuals who had received an incentive at some point in time, the largest portion (45.24%) indicated that they received a payment between USD 15.4 and 30.8, with 16.67% reporting receiving an incentive of less than USD 15.4, and 7.14% reporting receiving an incentive between USD 92.3 and 369.2. These incentives usually took the form of cash or other materials (such as food or school supplies). Some families, about 10% of interviewees, described receiving loans to care for sick relatives from the company. Most loans were between USD 61.5 and 92.3, although some residents described applying for loans between USD 307.7 and 769.2. Only 6.25% of interviewees described receiving a wage for employment with the company at some point. Wages varied between USD 92.3 and 369.2 per month, depending on the job.

Governance

Locals had different levels of participation in forestry related activities. Both men and women described participating in community assemblies related to resource management with 51.25% of respondents indicating that they always attended the meetings, 30% describing that they attended frequently, 15% reporting they sometimes attended, and 2.5% describing that they never did. While women described participating in meetings roughly as often as men, men more often described voicing opinions during the meetings and taking an active role in the decisions, whereas many women described only listening during the meetings. Women described that some men would be angry if women voiced their opinions and that they felt embarrassed or would be criticized for speaking out. Some women described that household and childcare obligations prevented them from attending the meetings, while both men and women mentioned spending time in the field tending to the family farm as a reason they could not attend meetings. Women also tended to have more limited Spanish proficiencies than men, limiting their opportunities to voice their opinions during meetings.

The seven books of meeting minutes that we reviewed documented 47 general assembly meetings related to forest management since 2003, with the largest portions of meetings (27.27%) related to paperwork processing and community administration, land invasion (16.36% of meetings) and the situation with the timber harvesting company (12.73% of meetings). A representative from the timber harvesting company was present for six of these meetings, while at least one of three community leaders (the community chief, municipal agent or the lieutenant governor) was present for each meeting.

Table 5. List of criteria and indicators used in the study showing summarized results and impacts.

Indicator	Result	Impact
Objective 1: Describe forest management activities done in the community		
Criterion: Forestry activities done in the community		
Forestry products extracted in a 10-year period Most common species harvested in the last 10 years	Timber and non-timber products extracted have not changed	0
Equipment used in commercial timber extraction	The company owns the basic necessary equipment; however, the community does not have access to them for external use	0
Equipment used in subsistence timber extraction	Locals have the basic necessary equipment (owned or rented) for cutting logs at a small scale, but not for further transformation (i.e. into boards)	+
Destiny of timber	Timber is sold to the cities of San Alejandro, Pucallpa, and Lima	+
Silvicultural techniques used in commercial timber extraction	They carry out basic silvicultural techniques; however, part of the breach in the management plan was for failure in maintenance of seeders (burnt and cut down)	-
Silvicultural techniques used in subsistence timber extraction	They do not perform any technical silvicultural activity	0
Objective 2: Evaluate and analyze the socioeconomic perception of community forest management in the inhabitants of Sinchi Roca I		
Criterion: Local perception of forest management		
Perception of change in forest condition (current vs 10 years ago)	The majority of the population considers that the forest is impoverished and affected by invasions	-
Local satisfaction with timber extraction	Most people do not feel satisfied with the activity: They did not see a direct income and they consider it destroys the forest	-
Recognition of the economic benefits of timber extraction	Most of the population recognizes that wood provides firewood and material for constructing their house	+
Priority of timber extraction within their economic activities	Timber extraction for subsistence purposes is carried out once or at most twice a year, which is why they consider it a complement rather than a priority activity	0
Role of the timber extraction company in the community	It generated conflicts in the community due to its mismanagement and breaches in the management plan. A debt was created between the company and the community	-
Objective 3: Evaluate and determine the economic and social outcomes of the current forest management system of timber products compared to the system before a more technical forest management		
Criterion: Existence and compliance with forest management and land use plans		
Percentage of activities indicated in the management plan completed	53.8% of the activities were completed. Those not fulfilled correspond to issues of community participation, training and forest recovery treatments	-

Existence of updated annual operating plans	Yes, there are updated documents	+
Percentage of activities indicated in the annual operating plans completed	88% of activities were completed. The remainder ones correspond to the irregularities found in the supervision with OSINFOR that were the cause of the fine	-
Criterion: Area of forest converted to permanent non-forest uses		
Deforested area during the last 10 years that has changed its use	The deforested area is located in places where there are invasions by farmers and ranchers who make changes in land use for agricultural parcels on large tracts	0
Criterion: Participation of different family groups in forest harvesting operations		
Number of families engaged in logging	78% of the families surveyed are involved in subsistence timber harvesting at different scales, either for domestic or commercial use.	+
Criterion: Volume of timber products extracted		
Volume of timber extracted and commercialized	There is illegal timber harvest made outside the authorized stands	-
Volume of timber lost	Loss of wood because of damage or decay is 20% of the volume. Due to the use of the axe and other extraction techniques, an additional 20% is lost	0
Criterion: Value of the forest products commercialized		
Agreements made with the timber company	Not all clauses of the contract were accomplished, especially the part of community participation	-
Income generated by commercial timber extraction	Even though there should have entered a considerable amount of money to the community, this was not reflected because of the bad management of both the company and the community	-
Income generated by subsistence timber extraction	The subsistence timber extraction, even at a low scale, generated income to the families	+
Criterion: Jobs generated due to timber extraction activities- Degree of participation of the people in economic activities related to timber		
Direct and indirect jobs created by timber extraction	The timber company hired less than five people during its time at the community. They brought their own external personnel	-
Criterion: Existence and implementation of regulations to ensure the health and safety of forestry workers		
Implementation of security measures	Most respondents only used rubber boots. A minority used other PPE (i.e. helmets, goggles, vests, masks), with most only using PPE for government inspections. Participants described heat and discomfort as reasons for not using PPE	-

Number of workers in the timber sector that wear personal protection equipment		
Criterion: Destiny and distribution of the income produced by forest management activities		
Number of people receiving any economic incentive from timber harvest Types of remuneration or incentives received by the community from the timber company Destiny of the income	An income of cash was not visible to the community. A huge debt to the company was created. Very few were beneficiaries of any economic incentive	-
Criterion: Community participation in forestry activities and management		
Number of coordination and management meetings that included forestry topics Number of people that participated in at least one coordination and management meeting on forestry related topics	There were 47 general assembly meetings in the community related to natural resources management, with an average of 60 participants. We observed a high participation rate of women in those meetings	+
Criterion: Authority's decision-making on topics related to forest management		
Number of meetings with the participation of the timber company in which community authorities have attended	In all meetings related to resource management at least one of the three communal authorities were present	+
Degree of participation in decision-making	Locals contribute to decision-making; however, they require more training in document administration, extraction balances, and cash flow to have better control of the activity and make more informed decisions	+

DISCUSSION

Improved understandings of the sustainability of CFM projects more broadly require standardized methodologies for evaluation that recognize local contexts (CIFOR 1999; FAO 2016; Wollenberg et al. 2007). In this study, we combine adapted FAO and ITTO criteria with criteria based on the community itself in a method that can be adapted to similarly evaluate CFM projects in other communities with similar contexts (with small scale forestry enterprises or contracts with timber harvesting companies, as well as with populations with similar socioeconomic characteristics). This methodology also contextualizes the broader contexts of land-use planning and land-use change as observed through satellite imagery and participatory mapping.

Through this study, we identified two purposes for timber extraction (subsistence and commercial) and the processes for each. Similar to most native communities in the Amazon and worldwide (Cossio et al. 2014; Coomes et al. 2016 Godoy et al. 2002 Khasa and Dancik 1996 Schaafsma et al. 2014), traditional timber use in Sinchi Roca I represents an important resource for their livelihoods. Commercially, the Sinchi Roca I community partnered with a private timber company. Many communities rely on these partnerships to be able to harvest at a commercial scale due to the lack of equipment, resources, and technical expertise to extract, transport, and sell the timber (Pokorny and Johnson, 2008; USAID 2021). Elsewhere in Peru, other communities that had a management plan and a contract with external companies have been fined by the Peruvian Government and forced to stop the harvesting activities until resolving issues (OSINFOR, 2020). Since we visited Sinchi Roca I, it has held two forestry permits. The first was issued in 2011 and expired in 2016 due to an inspection and audit by OSINFOR that resulted in a fine. To pay the approximately 304 526 USD fine, the community enrolled in payment programs for conservation and restoration. The second permit has been active since 2017 and the community continues to commercially harvest timber even though OSINFOR is processing a potential sanction for a breach in the management plan (OSINFOR 2020).

Despite their prevalence, community-private company timber-harvesting agreements often result in disadvantageous conditions for the communities, may result in indebtedness, and cause issues with local and national authorities (Hodgdon and Loewenthal 2015; Cossio et al. 2014). Communities often have less local control over more commercially valuable forest resources like timber, even while holding rights to manage less commercially valuable non-timber species (Anderson et al. 2015). In this study, Sinchi Roca I retained most of the burden of forest management without corresponding commercial benefits from forestry.

This study also contributes to a growing body of literature suggesting gender differentiation in use of forest products that parallel household divisions of productive and reproductive labor, and that men and women consider different factors in forest management decisions (Agarwal 2009; Sunderland et al. 2014; Villamor et al. 2014). Especially given that local conceptualizations and relationships to the forest transcend purely commercial terms (West 2005), adding a gender lens to perceptions of timber harvesting highlights these nuances. In Sinchi Roca I, women tended to play a more limited role and were more likely to perceive that the forest condition was the same as it was 10 years previously. Men, on the other hand, perceived a worsened forest condition, particularly with respect to timber species and wildlife.

As to benefits from the forest, both genders emphasized utilitarian values, albeit with a different focus on cash values. Women tended to describe non-monetary benefits such as the forest being a source of firewood, utensils, and construction materials, while men emphasized the monetary benefit obtained through selling forest products. This difference between men and women relates to their roles in generating income for the household, opportunities, and priorities (Agarwal 2009; Mai et al. 2011; Sunderland et al. 2014). Even if the community itself does not receive many direct benefits from the commercial harvest it may still affect them. Forest extraction has social effects on local knowledge and use of non-timber forest products as well as on ecological functions of the forest (Menton 2003; Rist et al. 2011). Logging alters conserved forests upon which the majority of communities depend for non-timber forest products and subsistence uses.

Many factors contributed to the failure of the timber extraction through a community forestry initiative in Sinchi Roca I. First, the community held a negative overall impression of commercial timber harvesting due to the disadvantageous contractual conditions, inequitable distribution of benefits and poor institutional arrangements (Cossio et al. 2014; Mayers and Vermeulen 2002). This situation was due in part to the absence of state legal counsel and that the timber company arrived in the community with a preestablished contract. Further, the company brought their own workers to conduct the extraction, so they rarely hired locals. Second, commercial transportation of timber also presents challenges as harvested timber is transported via riverways and can only be exported to market when the water level is sufficiently high. As such, only select species justify the transportation costs and these few commercial species are

selectively harvested. Third, Sinchi Roca I also experiences some challenges associated with forest management itself, such as the loss of marketable timber due to poor extraction techniques, low efficiency, and limited technical training.

Finally, locals usually lack the proper training to be able to monitor and manage administrative documents necessary for the extraction. The majority of CFM projects demonstrate a need for technical assistance and economic support to accomplish the desired outcomes (Pokorky et al. 2008; Santiago 2021; USAID 2021). Improved forest management requires extended technical accompaniment that trains community members in forestry techniques rather than short-term interventions with limited local involvement in timber extraction that may be more likely to be abandoned (Álvarez and Shany 2012; Herbohn et al. 2015). All the reasons above make it hard for the Sinchi Roca I community members to monitor the timber extraction process. Sinchi Roca I is a representative example of the current situation of timber management among local communities in Peru (Cossio et al. 2014).

While the above factors limited the local socioeconomic benefits of the community forestry initiative, external factors played a greater role in the deforestation experienced in the community. Within Sinchi Roca I, while the majority of the community is under an existing management plan, external factors simultaneously introduced land conflict through overlapping land-use designations. Most forest loss has occurred in the northeast sector of the community along an encroaching agricultural front. This situation in Sinchi Roca I is not unique and also occurs in other categories of landholdings in the country (private property, forestry concessions, protected areas, among others). Illegal harvesting and the occupation of areas for agriculture spur deforestation, with the encroaching agricultural front being the most important driver of land-use change (Armenteras et al. 2017; MAAP 2017; Porro et al. 2015; Rubin de Celis et al. 2019).

While our study focused on intra-community socioeconomic indicators of the success of CFM, future research with more attention to environmental indicators could be used to better evaluate the environmental sustainability of harvesting practices (Hajjar et al. 2016). Given the number and level of detail of the evaluation criteria that we used, these indicators and criteria would likely need to be grouped into larger, broader categories in order to scale up evaluation to a larger regional scale. The precision and usefulness of these indicators for evaluation depends on the availability of information and the length of stay in a given community. In Peru, existing information about community forest management is not always publicly available, which currently limits broad scale evaluations. This study exclusively gathered opinions of Sinchi Roca I residents due to the fact that we could not contact representatives of the timber company who had already left the community at the time of investigation.

CONCLUSION

Through this case study, we have analyzed the role timber harvesting has in a typical native community in Peru using criteria and indicators that can similarly be adapted to evaluate the sustainability of analogous small-scale CFM. The activity is usually done at a small scale for subsistence purposes, as well as in collaboration with a company for commercial purposes which has the necessary harvesting equipment that the community does not. In Sinchi Roca I, 30 species are harvested for subsistence purposes. For commercial purposes, the community had a contract with a timber company that agreed on a 0.3/0.7 proportion of income distribution for the community and the company respectively. These collaborations often do not represent an equitable or sustainable distribution of benefits as evidenced in this study by the community's indebtedness to the company, social conflicts, and the loss of their forest management permit due to breaches found during government inspections.

Only a few people observed direct benefits from commercial harvesting. Most acknowledged that the company served as a source of economic support for the community when they needed money (i.e., for anniversary celebrations, construction of communal infrastructure, etc.). These observations were influenced by gender and age, depending on what role community members played in these activities.

Despite the socioeconomic problems this community has experienced from timber harvesting, the activity did not cause deforestation noticeable through Landsat satellite images. Most of the deforestation occurred due to external invasions, as opposed to mismanaged harvesting. As we learned in this study, timber management is not always a realistic conservation alternative for small Amazonian communities. CFM has a large economic potential but needs more support from local governments and external institutions such as the National Forestry Chamber (CNF) or other NGOs to support a more equitable benefit distribution and to generate more favorable local perceptions. Locals need training in timber measurement, document administration, extraction balances, and cash flow to have better control of the activity and make more informed decisions. In addition, more support is needed to empower these communities for managing their own natural resources at a commercial scale and provide them with the equipment they need for a

commercial scale extraction as the way it is currently done is not viable for them or the ecosystem.

Overall, we observed that CFM for commercial timber harvesting did not yield the hoped-for success due to limited training, low levels of local empowerment, and little awareness of the responsibilities and rights of communities entering into CFM agreements with private companies. The lack of collaborative partnership formation between the company and the community generated disinterest among community members in the participation, fiscalization, and involvement in the commercial timber harvesting activities conducted in their forest. The high costs of timber extraction contribute to the need for private sector-community relationships for harvesting to be commercially viable. However, existing policies, laws, and company-community contracts are inflexible, disadvantageous for communities, and not contextualized for them.

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DATA AVAILABILITY

The data used in this research are available from the corresponding author upon request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: LAF, ZACB
Carried out the experiment: LAF
Carried out the data analysis: LAF, MALTC
Wrote the first draft of the manuscript: LAF, HL, MALTC, ZACB
Review and final write of the manuscript: LAF, HL, MALTC, ZACB
Supervision: MALTC, ZACB

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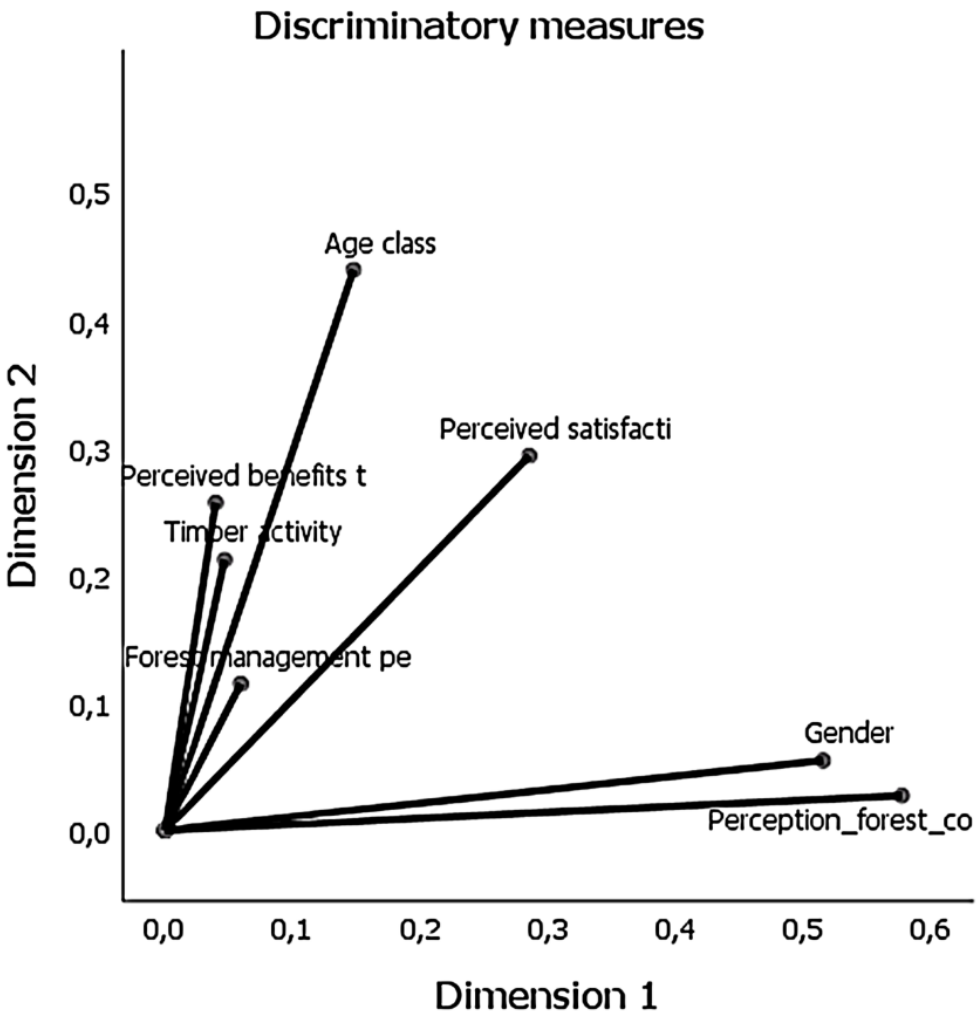
Additional Files

Add File 1. Fisher exact Test between perception of timber harvest and sociological variables.

Perception / sociological variables	Gender	Age calss	Education level
		p-value = 0.05	
Perceived satisfaction timber	0.22	0.73	0.19
Perceived benefits timber	0.50	0.92	0.91
Perceived of forest condition	0.02*	0.53	0.18
Perception of benefits from forest management	1.00	0.34	0.58
Belief in the importance of the company	0.85	0.83	1.00

Add File 2. Visual representation of the MCA discriminatory measures (complementing Table 3 in the main manuscript)



Legend: The length and angle formed by each vector represents the contribution of the variable in a two-dimensional solution.