



Peasant coffee in the Los Tuxtlas Biosphere Reserve, Mexico: A critical evaluation of sustainable intensification and market integration potential

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Abstract

Production of low-input, shaded coffee in the Los Tuxtlas UNESCO Biosphere Reserve (LTBR), Veracruz, Mexico, an economically marginalized but ecologically rich region, was strongly affected by the collapse in international prices and the reconfiguration of the Mexican coffee sector in the 1990s. This place-based study used qualitative methods to investigate local strategies to reactivate coffee cultivation and improve market integration. Ninety-five producers, processors and cooperative representatives were interviewed to: 1) characterize the different actors in the local coffee commodity chain; 2) explore how producers, organized or not, shape and are constrained by the local coffee sector, and 3) evaluate whether producers' land use strategies may be compatible with conservation in the LTBR. We combine the Land Sparing and Sharing framework with the UNESCO Biosphere Reserve zonation system to conceptualize how coffee plantations can be spatially integrated in protected areas and facilitate synergies between local livelihoods and conservation.

Our empirical study illustrates the complexity and dynamism of the LTBR coffee sector. It highlights the resourcefulness of producers in adapting their cultivation systems, but also the narrow maneuvering room farmers have to exploit textbook synergies between conservation and fair trade and / or "certified organic" markets. In principle, coffee cultivation can be expanded and intensified without affecting remaining primary forest (Land Sparing) and contribute to maintain a diverse landscape matrix in productive agroforestry systems (Land Sharing). However, few producers have the means required to successfully achieve profitable and long-term market integration. Future research on sustainable land use management in, and around, protected areas needs to explicitly address local, sectoral and market dynamics as drivers of land use at the local level. Although these dynamics may create windows of opportunity for the biggest and best-connected producers, they exacerbate asymmetries inside peasant farming communities and weaken producers' cooperatives.

Introduction

Times are difficult for Latin American peasant coffee producers. The worst outbreak of coffee rust (*Hemileia vastatrix*) disease seen in four decades has severely affected crops and livelihoods in the region since 2008 (Avelino et al., 2015). At the same time, the impacts of El Niño Southern Oscillation and climate change on coffee harvests worldwide are becoming increasingly evident (Gross, 2014; Eakin, 2005). Since the collapse of the International Coffee Agreement (ICA) in the late 1980s, the global coffee sector has undergone drastic transformations that have produced recurrent boom and bust phases (Daviron and Ponte, 2005). The sector has been characterized by rapid expansion and intensification of cultivation based on green revolution technologies, especially in new coffee-producing countries, which have led to persistent imbalances between supply and demand and high price volatility (Eakin et al., 2009). Through high downstream

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concentration of the commodity chain, and marked asymmetries in bargaining power, a few actors control the final coffee added value, while peasant producers receive declining returns and often live in pervasively precarious conditions (Gresser and Tickell, 2002; Gonzalez de Molina, 2013).

The vast majority of coffee producers are smallholders^[1], who harvest coffee under various degrees and types of shade, but produce a substantial proportion of world coffee volumes (Jha, et al. 2011). Coffee cultivation regions are also highly-diverse ecologically, but often marginalized economically (Greenberg et al., 1997; Calo and Wise, 2005; Myers et al., 2000; Méndez et al., 2010a). This has prompted attempts to reassert the agroecological value(s) of shaded coffee by re-framing it as a strategy for reconciling biodiversity conservation with local rural development needs (Moguel and Toledo, 1999; Perfecto and Armbrecht, 2002; Perfecto and Vandermeer, 2010; Perfecto et al., 2009). Success stories include that of the *Café la Selva* cooperative (Equator Initiative, 2012) in Chiapas, southern Mexico, which has received international awards recognizing the synergistic effects it created for: 1) coffee producers, organized in a strong cooperative that fosters organic conversion and community development; 2) international and national buyers, who can access a high-quality coffee and offer producers a more profitable price; and 3) national and international consumers, who enjoy *la Selva's* fine coffee and the satisfaction of supporting both environmental and social improvement. In this paper, we focus on the Los Tuxtlas Biosphere Reserve (LTBR) in Veracruz, southeast Mexico, to analyze to what extent the land use and market integration strategies adopted by local coffee producers enhance local livelihoods and conservation goals. We deliberately chose a region, which is characterized by serious structural obstacles (in this respect it is similar to the *la Selva* coffee region), but where coffee is of secondary importance in terms of state and national production. Our aim was to investigate the strategies that producers deploy to adapt shaded coffee systems and improve added value, the constraints they encounter and broad implications for conservation. Two main research questions guided our case study, as follows:

- How do peasant farmers, organized or not, shape the local coffee sector, and how are they constrained by it?
- What are the implications of producers' livelihood and market integration strategies for land use and conservation in the LTBR?

First, we introduce key insights from the literature on potential synergies between coffee cultivation as a livelihood strategy and its conservation potential. We specifically link existing coffee cultivation systems to the Land Sparing – Land Sharing framework and the zonation system of United Nations Educational Scientific and Cultural Organization (UNESCO) Biosphere Reserves in order to conceptualize avenues for the spatial integration of coffee cultivation systems in protected areas. Second, we present the LTBR and our case study approach. Third, we synthesize our findings on local initiatives to adapt to changes in the coffee market and exploit windows of opportunity. Finally, we critically assess the opportunities and obstacles that peasant producers encounter in their efforts to integrate their production into this global commodity chain.

Compatibility of coffee cultivation systems and conservation areas

The different types of coffee cultivation range from intensive high-yields with low-biodiversity sun coffee monoculture to low-yields with high-biodiversity shaded coffee systems (Moguel and Toledo, 1999). The issue of how to balance coffee productivity and economic profitability with the imperatives of conservation (Isakson, 2009) is related to the wider debate on how to conceptualize land use to achieve these goals (Grau et al., 2013). Two opposing approaches have been proposed:

- Land Sparing, which promotes the spatial separation of intensive agricultural areas (to satisfy global food and energy needs) from strict conservation areas (to preserve threatened natural biodiversity) (Green et al., 2005; Balmford et al., 2005; Ewers et al., 2009; Phalan et al., 2011) and,
- Land Sharing, which fosters agroecological systems (to achieve regional food security) within a diverse ecological and landscape matrix (Pretty, 2003; Harvey et al., 2008; Perfecto and Vandermeer, 2010; Tschamtkke et al., 2012; Chappell et al., 2013).

Applying the Land Sparing - Land Sharing framework to coffee cultivation, though still hotly debated, is useful, because it allows explorations of possible spatial synergies and conflicts between coffee plantations and conservation areas. Peasant shaded coffee cultivation is a common agricultural practice in and near many protected areas in Latin America (Tejada-Cruz et al., 2010; Jha et al., 2011; Marchant and Borsdorf, 2013; Valencia et al., 2014). Here, we focus on UNESCO Biosphere Reserves, which foster the spatial juxtaposition of strict biodiversity conservation in core zones with sustainable land use in buffer and transition zones (UNESCO, 1984, 2008; Ishwaran et al., 2008). In principle, different coffee cultivation systems can be assigned to these different protected areas' zones, thereby creating a spatial continuum between Land Sparing and Land Sharing (de la Vega-Leinert, 2014) (Table 1).

Table 1. Coffee cultivation systems in the Land Sparing - Land Sharing framework and UNESCO zonation

| Land Sparing Land Sharing framework | UNESCO Biosphere Reserve Zonation ^a | Land use and coffee cultivation systems ^b |
|---|---|---|
| Land Sparing | Core Zone | Strict conservation |
| Land Sharing | Buffer Zone | Rustic Substitution of forest undergrowth with coffee Traditional polyculture ("coffee gardens") Coffee is combined with a number of native and domesticated, subsistence and commercial crops under shade from original forest (from which timber and other forest products are extracted) |
| Land Sharing | Transition Zone | Commercial polyculture Removal of native forest and replacement through commercial trees that can provide shade (e.g. Inga sp.) and cash crops (e.g. Pepper, Pimenta dioica sp.) Coffee and other cash crops (e.g. bananas, citrus fruits) Shaded monoculture Coffee monoculture under simplified shade from Leguminous trees (e.g. Inga) |
| Land Sparing | Outside of the protected area | Unshaded coffee monoculture Specialized coffee plantations with no tree cover |

^aZonation of UNESCO Biosphere Reserves and corresponding land use based on UNESCO (1984). See also de la Vega-Leinert (2014).

^bCategorization of coffee management types based on Moguel and Toledo (1999)

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In peasant systems, coffee cultivation is often combined with staple and commercial crops in a complex agroforestry system (Moguel and Toledo, 1999; Hernández-Martínez et al., 2009). Some authors have stressed that shaded coffee permits complex, multi-layered vegetational structures that act as repositories for biodiversity and corridors through fragmented landscapes (Perfecto et al., 1996; Bhagwat et al., 2008; Perfecto et al., 2009). Numerous studies provide evidence of the conservation potential of such plantations (Méndez et al. 2010a and b; Valencia et al., 2014) and of their role in the maintenance of key ecosystem services, such as pollination (Vergara and Badano, 2009) and carbon sequestration (Balderas Torres et al., 2010). Shade can be restored and preserved using native and / or commercial species, which even under intensive management, can make an important contribution to regional forest diversity (López-Gómez et al., 2008). However, where growing conditions are less favorable, an overly dense forest canopy can substantially decrease coffee yields (DaMatta, 2004; Soto-Pinto et al., 2000; Läderach et al., 2011). Preserving a near-natural, diverse and dense canopy, therefore, may not be to the benefit of producers if it affects profitability.

Avenues proposed to achieve synergies between the protection of biodiversity and the improvement of livelihoods crystallize around the issues of how to improve peasant coffee systems sustainably and create better market access for producers. Sustainable intensification has been the topic of much discussion (Cook et al., 2015). In this paper, we use sustainable intensification to indicate approaches that improve the productivity of low-input systems through traditional agroecological practices combined with locally-adapted agricultural extension methods that do not cause environmental deterioration (Pretty, 1997; Twomlow et al., 2002; The Royal Society, 2009; Altieri, 2012; Gonzalez de Molina, 2013). For some authors, sustainable intensification must, however, transcend exclusively agrotechnical or marketing-oriented approaches to also pursue equity in terms of the distribution of the benefits of coffee sales, the self-determination and empowerment of local farmers, and transparency in decisions affecting local communities (Altieri, 2012; Loos et al., 2014). Approaches that are compatible with the Land Sharing concept emphasize the socio-ecological value of agroforestry systems and aim at increasing productivity (e.g. by diversifying crops and adopting agroecological extension measures), while restricting the expansion of plantations into forested areas (e.g. through land use zoning) (Bertrand et al., 2011; Lin, 2011; Weber JG, 2012; Phalan et al., 2016). Provided a balance is struck between shade quality (tree composition and richness) and quantity (canopy density), agroecological cultivation can help increase productivity, while also preserving the richness of an area's biodiversity and ecological connectivity (Perfecto et al., 2005; Gordon et al., 2007). Possible strategies to improve producers' livelihoods include the incorporation of certification schemes (organic / fair trade) that provide a monetary revaluation of a farming system that combines high intrinsic, environmental and social values and compensates lower yields with higher prices and / or public subsidies (Philpott et al., 2007).

Authors have argued that shaded coffee plantations, in and of themselves, cannot guarantee the conservation of biodiversity (Rappole et al., 2003). Indeed, shaded coffee systems in Latin America have been established in forested areas and intensified based on typical green revolution agricultural extension measures (Bertrand et al., 2011). This has resulted in the removal and impoverishment of primary forests, their replacement by commercial shade tree monoculture, loss of landscape connectivity and biodiversity, and increasing environmental contamination due to chemical inputs and declining ecosystem service provision (Peeters et al., 2003; Philpott et al., 2008; Tejada-Cruz et al., 2010; De Beenhouwer et al., 2013; Ceddia et al., 2013; Valencia et al., 2014). To combat these impacts, sustainable intensification, from a Land Sparing perspective, should

emphasize a spatial separation between strict conservation areas (to maximize biodiversity) and sun plantations on areas already under exploitation (to maximize yields). For some, micro-scale sun coffee monoculture (or integrated open canopy cultivation) is a promising avenue for intensifying peasant plantations, while allowing forest regeneration on degraded land (Chandler et al., 2013; Phalan et al., 2016). However, sun coffee monoculture under conventional cultivation – even at small scale – requires substantially more investment than diversified, low-technology, low-cost shaded plantations (Gordon et al., 2007).

The Los Tuxtlas Biosphere Reserve

The LTBR is an emblematic case for exploring the complexity of local coffee sectors in economically marginal regions, in and around protected areas, and for analyzing the windows of opportunity open to producers to recover from recurring international coffee crises and achieve integration into conventional or “green” / “ethical” niche markets.

Coffee cultivation in the LTBR and the local economy

The state of Veracruz is currently the second largest coffee-producing state in Mexico after Chiapas (Servicio de Información Agroalimentaria y Pesquera – SIAP, 2016 - Table 2^[2]). Though peasant coffee in both states is cultivated in similar shaded systems at higher elevations, since the 1990s, Chiapas has solidified its position in the organic shaded coffee niche and attracted important international players to its production zones (Equator Initiative, 2012; Renard, 2012). In contrast, coffee from Veracruz is sold mostly in conventional markets, and the existing geographic denomination has not yet achieved international visibility (Muñoz and Arredondo, 2003). The LTBR is the main coffee-growing area in southern Veracruz, but it currently plays a minor role in terms of production with only 2.6% of state production. In the early 1990s, coffee was cultivated on ca. 6,400 ha and supported some 1,700 families (Comisión Nacional de Áreas Naturales Protegidas - CONANP, 2006). Since coffee producers were heavily-dependent on the technical and financial support of the Instituto Mexicano del Café (INMECAFE) (Potvin et al., 2005), they were devastated by the dismantling of that state agency, an event that coincided with the collapse of the ICA in 1989 and the ensuing deterioration of

Table 2. Coffee production in the Los Tuxtlas Biosphere Reserve in 2014 in context^a

| | Cultivated area (Ha) | Harvested area (Ha) | Production (Tons) | Yield (Tons/Ha) | Production value (1000 US \$) ^b |
|--|----------------------|---------------------|-------------------|-----------------|--|
| National | | | | | |
| Total conventional | 715,069.1 | 677,086.18 | 1,126,989.1 | 1.7 | 294,662.3 |
| Total organic | 22,051.1 | 21964.9 | 38,780.5 | 1.8 | 10,993.0 |
| Chiapas | | | | | |
| Total conventional (% national production) | 248,811.6 (34.8) | 242,778.2 (35.9) | 376,576.6 (33.4) | 1.6 | 104,833.9 (35.6) |
| Total organic (% national production) | 11,061.5 (50.2) | 10,986.3 (50.0) | 25,266.9 (65.2) | 2.3 | 6,631.3 (60.3) |
| Veracruz | | | | | |
| Total conventional (% national production) | 146,619.4 (20.5) | 138,512.8 (20.5) | 353,697.2 (31.4) | 2.6 | 87,135.1 (29.6) |
| LTBR ^c | | | | | |
| Catemaco | 677.0 | 677.0 | 2437.2 | 3.6 | 466.2 |
| Hueyapan de Ocampo | 550.0 | 550.0 | 1430.0 | 2.6 | 312.6 |
| Mecayapan | 147.0 | 147.0 | 279.3 | 1.9 | 66.4 |
| Soteapan | 2,402.0 | 2,402.0 | 8,166.8 | 3.4 | 1,896.8 |
| Total conventional (% state production) | 3,776.0 (2.6) | 3,776.0 (2.7) | 12,313.3 (3.5) | | 2,742.0 (3.1) |

^aTable 2 presents information from the four principal municipalities that produce coffee in the LTBR. These are located inside the buffer and transition zones of the Biosphere Reserve according to the full UNESCO zonation (Guevara Sada et al., 2000).

^b1 Mex. Peso = 0.05465 US\$ - indicative exchange from <http://www.oanda.com/lang/de/currency/converter>. Accessed on 20.02.2016.

^cDespite some overlap, the Sierra de Santa Marta catchment corresponds broadly to Soteapan / Mecayapan, while the Zapoapan de Cabañas catchment includes Catemaco and Hueyapan de Ocampo (Source: SIAP, 2016).

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coffee prices (Pérez Akaki and Echánove Huacuja, 2006). What's more, this occurred against the backdrop of massive restructuring of Mexican agriculture, as the country prepared its entry into the General Agreement on Tariffs and Trade (GATT) and the North-American Free Trade Agreement (NAFTA) (Yúnez-Naude, 2002). As a result, coffee cultivation area in the LTBR reached only ca. 3,800 ha in 2014 (Table 2), though it still constituted an important source of employment and income. The LTBR illustrates the situation of such marginalized coffee production areas, the potential to regain the former importance of coffee in the local economy, and their implications for land use, livelihoods and conservation.

The local economy in the LTBR relies primarily on agriculture, supplemented by domestic tourism. Maize cultivation and cattle herding are predominant activities, associated with a range of subsistence and commercial crops (Paré and Fuentes, 2007; Nadal and García Raño, 2009). Slash-and-burn cultivation is still common, with plots being converted to extensive pasture as soil fertility decreases (Durand and Lazos, 2008; Siemens, 2009). On higher ground, agroforestry systems have long incorporated coffee production (Paré et al., 1997). Two distinct, but partly-overlapping coffee catchments can be observed. The first one is located on the southern slopes of the Sierra de Santa Marta Volcano (primarily in the municipalities of Soteapan and Mecayapan). Here, coffee is produced conventionally, generally in rustic systems that incorporate coffee into primary forested areas, and traditional polyculture, mixing it with a variety of subsistence and commercial crops (Figure 1). The second is located further west, centered on Zapoapan de Cabañas, where coffee is grown on substantially lower altitudes (primarily in the municipalities of Catemaco and Hueyapan de Ocampo). Management styles include traditional and commercial polycultures as well as coffee monoculture under the simplified shade of *Inga* trees (CONANP, 2006), though plantations here have often successfully undergone organic conversion. This diversity in cultivation systems in such a relatively small region makes it possible to explore a broad range of paths towards market integration.

Living conditions in the LTBR are characterized by medium to very high indexes of socio-economic marginalization due to the prevailing precariousness of incomes, and generally deficient conditions of housing, sanitation, health, education and road infrastructure (Consejo Nacional de Población – CONAPO, 2010). In 2004, the average household in the Sierra de Santa Marta lived well under the poverty line of 2 US\$ per person per day, with most income provided by state subsidies (for coffee and maize production and poverty alleviation programs), sales of agricultural products (especially coffee) and / or seasonal employment (e.g. during coffee harvests) (Ayuntamiento de Soteapan, 2010)^[3]. These peasant households live at the margin of a monetary economy in a context of high structural development deficiencies and have little maneuvering room to raise alternative income, let alone make investments (de la Vega-Leinert et al., 2015). Since the 1990s, peasant farmers have deployed a number of strategies to cope with the liberalization of agriculture, with important environmental implications for the LTBR (Nadal and García Raño, 2009). Emigration in the region has also become a common strategy to cope with land scarcity, low profitability of agricultural activities and lack of employment and perspectives (Paré and Fuentes, 2007).

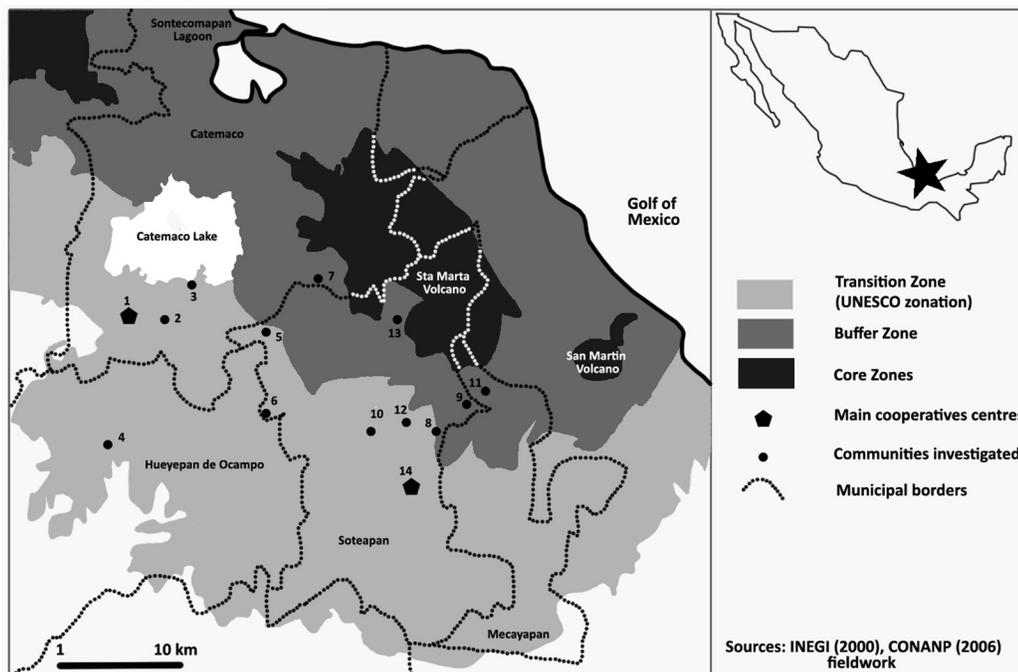


Figure 1
Location of the coffee producing communities studied in the Los Tuxtlas Biosphere Reserve.

This map illustrates the eastern part of the Los Tuxtlas Biosphere Reserve. The full zonation according to the UNESCO is displayed in different shadings. The numbers of the communities studied are as follows: 1– Zapoapan de Cabañas (Cerro Cintepec Cooperative); 2 – El Aguila; 3 – El Porvenir; 4 – Los Mangos; 5 – La Magdalena; 6 – Hilario C. Salas; 7 – Miguel Hidalgo; 8 – Ocotál Chico; 9 – Ocotál Grande; 10 – Ocozotepec; 11 – Plan Agrario; 12 – San Fernando; 13 – Santa Marta; 14 – Soteapan (Unión Regional)

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Trends in land tenure, use and conservation

Los Tuxtlas region is one of the five richest biodiversity hotspots in Mexico, thanks to its combination of diverse geological substrates, steep altitudinal gradients (from 0 to 1,720 m above sea level) and maritime influences from the Gulf of Mexico. The LTBR is a comparatively small (155.122 ha), densely-populated protected area (ca. 32.000 inhabitants in 2001; CONANP, 2006). Characterized by a complex mix of public, private and communal land tenure, it reflects the area's colonial and post-revolutionary heritage (Paré and Fuentes, 2007). From the 1930s to the 1970s, agrarian reform (re-)allocated land to local indigenous communities and landless peasants from different areas of the country (under either the common property *ejido* system, or as private property in agricultural colonies), though later plots were often remote and unfit for cultivation (CONANP, 2006; Negrete-Yankelevich et al., 2013). Land allocation was conditioned on use, a fact that spurred a process of deforestation (Durand and Lazos, 2008), which was exacerbated from the 1950s onwards by national programs designed to expand the agricultural frontier into peripheral forested lands through cattle-ranching and intensified coffee cultivation (Paré and Fuentes, 2007; Potvin et al., 2005). Not surprisingly, vast deforestation ensued, with up to 85% of forest loss around the San Martín Volcano to the west (Dirzo and García, 1992).

Conservation efforts resulted in the designation of a protected area in 1998 that became the UNESCO LTBR in 2006. It consists of three core zones for the strict protection of ecosystems, habitats and ecological processes, with a surrounding buffer zone, where the LTBR management fosters ecological restoration and conversion to sustainable agricultural practices (CONANP, 2006). Although a spatially-explicit transition zone exists in the UNESCO's documentation, it is not recognized in the LTBR's official conservation mandate (Guevara Sada et al., 2000). In this paper, we consider the entire UNESCO zonation, with coffee plantations in the Sierra de Santa Marta catchment lying generally within the buffer zone (with remote ones near the core zone of the Santa Marta volcano), and those in the Zapoapan de Cabañas catchment mostly within the transition zone (Figure 1 – Table S1).

The revocation of the protection of communal land tenure under the *ejido* system in 1992 enabled two important processes: the issuing of individual private land titles (which formalized the fragmentation of *ejido* plots between descendants) and the provision of a mechanism for the acquisition or leasing of individual plots (which formalized processes of land concentration) (Paré and Fuentes, 2007). Furthermore, the LTBR was designated with little participation from the local population, but imposed significant land use restrictions in the buffer zone and expropriated ca. 16,000 ha, formerly under communal and private tenure, to establish one of the core zones (Durand Smith and Ruiz Cedillo, 2009). This exacerbated land scarcity, which particularly affects the most marginalized farmers. Resistance to strict conservation regulations has resulted in noncompliance and spreading land use into the margins of the core zones (Negrete-Yankelevich et al., 2013; CONANP, 2011). The LTBR thus provides a good example of the tensions that exist in protected areas in Mexico (Brenner and Job, 2012).

Methodology

We developed this case study following empirical qualitative methods (Punch 2013; Yin, 2009). Based on the above literature review of possible synergies and conflicts between conservation and land use in peasant coffee systems, we used sensitizing concepts^[4], such as “agroecological systems”, “livelihoods”, “market integration” and “producers’ cooperative” to frame our fieldwork goals, namely:

- to characterize the different actors in the local component of the coffee commodity chain, with a focus on coffee producers’ cooperatives, and
- to identify the main land use and commercial strategies that different actors deploy to improve their livelihoods and access to markets.

We collected data through semi-structured interviews, non-participant observation (e.g. visits of coffee plantations and processing plants), unpublished documents (e.g. internal reports, external technical evaluations, organic certificates) and on-line information (e.g. webpages of coffee processors and retailers, official statistical information from governmental sources). We identified the main coffee producing communities, coffee cooperatives and different actors of the local coffee sector together with our key informants, in particular the LTBR management team, community leaders, cooperative representatives and agricultural experts. We did not strive to obtain a representative sample of coffee producers, rather to capture the diversity of contexts producers face, and the alternatives they chose. Therefore, rather than randomly selecting our interview partners, we purposely targeted them to obtain information from the major coffee communities and the different types of actors we had identified through preliminary conversations (i.e. independent and organized producers, cooperatives and private processors). We conducted 45 semi-structured interviews, in Spanish, between August and October 2011. One problem encountered in the field was that many coffee plantations were remote and difficult to access. To resolve this, producers were sought at home or at community centers and

processing plants. We either interviewed people individually or in groups, ranging from 2 to 25 participants. Group size varied as a function of who was present at the time of our visits and who attended group meetings. Key informants – those responsible for setting the meetings up, influenced group composition. Thus, local community leaders convened producers irrespective of their cooperative membership, while cooperative leaders convened their members irrespective of their community. In total we interviewed 95 people, including community leaders, producers (cooperative members or not) from the 14 most important coffee producing communities of the LTBR (Figure 1) and the major local private coffee processing and roasting firms (Table S1). We updated the information in conversations with our key informants during a subsequent visit in 2013 and per email communication up to 2015. Interviews ranged from 15 minutes to 2.5 hours, and were recorded digitally after obtaining consent from interviewees.

We did not aim to collect statistically relevant data to measure the productivity of coffee systems and the compatibility of producers' land use strategies with specific LTBR conservation goals. A vast body of literature on productivity, ecological implications and conservation potential of shaded coffee systems exists (see literature review above). Instead, our intention was to more explicitly relate producers' land use and market integration strategies to explore to what extent shaded coffee systems allow synergies between conservation and local livelihood needs. We focused on obtaining as much information as possible on producers' strategies and the opportunities and barriers they encounter in their efforts to adapt their activities to changing conditions in the international commodity chain. A list of questions (Table S2) was used to collect information on farm data that included size, mix of crops, management practices, cooperative membership, and land use and commercialization strategies. Additional questions to representatives of processing plants addressed strategies to improve coffee production, enhance quality and develop commercial paths and alliances within the commodity chain. For cooperative members and representatives, further questions considered cooperative management and the benefits and constraints of membership. Conservation actors were interviewed specifically about topics related to coffee cultivation and land use restrictions in the LTBR. We iteratively adapted our initial list of topics and the interview template to include new elements that emerged in conversations, and we approached additional actors who interviewees identified as important. In this way, we progressively developed the interview script and gained a gradually more complex understanding of the local actor constellation and its dynamics (See Text S1 for a template interview script).

To assess whether we had reached a sufficient degree of saturation we followed (Padgett, 1998) and triangulated the information obtained through interviews with other sources, in particular expert opinions from our key informants, non-participant observations and the on-line documents we had collected. We continued to carry out interviews until all major communities and actor groups had been approached and the information collected did not bring new aspects of relevance, given available time and resources. Most of the formal interviews were then transcribed verbatim for detailed content analysis.

Transcripts^[5] were coded using the software Atlas.Ti. We followed a combined inductive and deductive approach to systematically identify commonalities and differences in the interview material (Glaser and Strauss, 2010). Thematic categories and codes were formulated based on our list of topics (Table S2) and related together through axial coding in constant comparison of the interview material (Corbin and Strauss, 2008). We derived the results described in the following section based on the coding analysis. More specifically, we created Table 3 by synthesizing the range of measures applied to adapt productive systems, identifying generic land use strategies and associating potential impacts for conservation based on our literature review. Table 4 summarizes the information collected on the main strategies deployed by specific processing cooperatives and private firms to access and develop markets. Table S3 illustrates the range of potential benefits and constraints of cooperative memberships, as perceived by the interviewees. Finally, Table S4 provides descriptive information on selected cooperatives, with a focus on their membership, cultivation context, processing infrastructure, coffee quality, financing and buyers.

Results

Peasant shaded coffee plantations in the LTBR

All 14 communities studied obtained land through the agrarian reform, primarily in the 1960s and 1970s. Twelve of these are run under the common *ejido* regime; the other two are agricultural colonies under private tenure (Table S1). Individual land allocations originally ranged from 20 to 26 ha under both systems, divided into various plots. Access to coffee plantations often entails a one-to-two-hour uphill walk, but pasturelands and arable plots are closer to the settlements. Individual plots vary significantly in size, which is mainly due to two processes. First, farmers have generally divided their plots among their descendants. Through fragmentation, farmers may currently have only one or two hectares at their disposition, as an independent producer from Ocotol Chico makes clear:

"I have to make do with the little land that [my father] leaves me, (...) as you know, people keep growing but the land does not grow, so the little land that my father will leave me (...) he leaves me a plot of 1 to 2 ha, from now into the future, if I have a child, two children, I will also have to accommodate [my children] on the same land because there is no way, no, there is no [other] way."^[6]

Wealthier farmers nevertheless have the possibility to either acquire or lease additional land, which, on the contrary, results in the effective concentration of land by a few actors. Thus, in the Zapoapan de Cabañas community, one producer controlled as much as 60 ha in 2011, 20 ha of which under coffee cultivation. The latter is an exception, as coffee plantations generally range in size between 1 and 7 ha. Obviously, harvest volumes differ widely according to the area cultivated, elevation, the cultivation system and the maturity of the coffee plants. In the aftermath of the collapse of coffee prices in the 1990s, many plantations were abandoned or received little attention due to chronic shortages of capital and labor. Despite dwindling production, farmers still harvest coffee on plantations that they do not actively maintain. Without pruning, clearing of weeds and (organic / chemical) fertilizing, coffee harvests dwindle. Production on neglected plantations, therefore, can be as low as 0.4 tons of cherry coffee per year /ha and only bring a minor income. More successful producers may harvest 2 to 3.5 t of cherry coffee per year /ha. Yields are significantly affected by extreme weather conditions, especially during the flowering season (April to May) and, in recent years, by coffee rust disease. Depending on the coffee variety, plant maturity, altitude and management style, harvests can run from November to March. Sales of coffee that matures before or after the main harvest depend on a small pool of local buyers because external buyers are only present in the area from December to February. This typically affects plantations run under rustic cultivation on higher ground, especially that which borders the Santa Marta Volcano core zone.

The local coffee sector

In the LTBR, producers, local buyers who supply local or regional processors, private processors and roasters act side-by-side, in joint action or direct competition to secure a critical mass in coffee volumes, expand processing infrastructure and access markets. Depending on their resource base and degree of (collective) organization, coffee producers have greater or fewer opportunities to negotiate beneficial alliances and improve their control over the local component of the commodity chain. Marginalized independent producers, for whom coffee cultivation is one among several income-raising activities, often lack the resources to systematically renew coffee plants, apply chemical inputs, undergo organic conversion or pay laborers to tend their plantations. Moreover, they are rarely in a position to negotiate advantageous prices. Only when coffee demand and prices are high (e.g. when regional harvests are low) do windows of opportunity open, allowing independent producers to offer their coffee to a range of competing intermediaries. In contrast, producers, who are organized in cooperatives may enjoy a range of benefits (Table S3; see also (Méndez et al., 2010b)). In the best cases, these include: an agreed-upon price for the entire harvest^[7], pre-financing and emergency loans, collective ownership of the processing infrastructure, technical support in agricultural extension and to apply individually or collectively for public federal subsidies^[8], and the possibility to participate in cooperative strategic decision-making and management. The producers who have the largest plantations and obtain high harvests benefit the most from cooperative membership because they are best positioned to take advantage of capacity-building and economies of scale, while sharing risks and costs with others. Cooperative membership, however, also implies specific constraints (e.g. delayed payment, financial co-liability) and additional costs (e.g. membership fees, agricultural extension to satisfy certified coffee quality standards), which disproportionately impact those cooperative members who produce small harvests.

The two most important cooperatives in the study area are *Cerro Cintepec* and *Unión Regional*^[9] (Table S4). Both date back to the 1980s when they were established as local contact and relay organizations for INMECAFE. With the dismantlement of the state firm, the local coffee sector gradually reorganized around these cooperatives, as they were able, to a certain extent, to salvage some of INMECAFE's processing infrastructure and benefit from preferential public loans. Centered on the Catemaco District, *Cerro Cintepec* (located in Zapoapan de Cabañas) has the most complete processing infrastructure and, since 2000, has successfully fostered a conversion to organic cultivation. In 2013, it had over 360 members and 692 ha of certified organic coffee, combined with a diversified commercial agro-silvo-pastoral system (including litchi, bananas, green pepper^[10], decorative palms, reforestation measures, cattle, sheep and maize production - (Cooperativa Cerro Cintepec, 2011, 2013)). In recent years, it earned both fair trade and organic certifications for the North American and European markets^[11]. By pooling its harvests with those of other cooperatives in the Redcafé and Café y Desarrollo fair trade / organic networks, it also gained access to foreign importing cooperatives. It further created a registered brand of roasted coffee (Café Sierra de los Tuxtlas) and produced both conventional (for local consumption) and organic coffee (offered to tourists and the national market). Brand visibility is restricted, however, and integration into the embryonic national fair trade/ organic market entails high promotional costs. *Cerro Cintepec* has no serious competitors locally, but, in times of coffee scarcity, it must compete with other intermediaries, some local, others foreign. Because it pays for its members' harvests in two installments (often with significant delays due to chronic under-capitalization), the cooperative faces difficulties in ensuring the loyalty of its members over the long term, as in times of scarcity, private buyers

may offer higher prices and immediate full payment for the harvests. *Cerro Cintepec* has no member exclusion clause, but if its producers do not meet the organic quality standards, their coffee is paid at the lower, conventional prices.

The *Unión Regional*, based primarily in the Soteapan District, was (at the time of this fieldwork) in a restructuring phase^[12] led by the local municipal authorities. It shares a number of characteristics with *Cerro Cintepec* because it commands a large membership (317 members in 2013) and sufficient coffee volumes and processing capacity to produce export-grade green coffee (Table S4). It receives coffee from 12 communities, many of which lack reliable road systems, and so has developed a decentralized processing infrastructure. This cooperative seeks primarily to improve the quality and quantity of coffee production by expanding cultivated areas, renewing plantations, and through capacity-building and agricultural extension. It has not yet initiated a process of organic conversion, so it sells its coffee on the conventional market through a private regional exporting firm based in northern Veracruz. The *Unión Regional* has many direct competitors, all of which seek to capture the coffee produced in the higher grounds of the Sierra de Santa Marta. These include primarily external intermediaries, the large private processing firm *CASISA (Café de la Sierra, S.A.)* and, to a lesser extent, *Cerro Cintepec* and other small cooperatives, when they draw coffee from the same communities. Of these, *CASISA* is the most important local competitor. This private firm mobilizes significant capital, infrastructure and competence, and captures and processes the biggest volumes of local conventional coffee for export-quality green coffee and its own registered brand of roasted coffee, *Café Junco*.

The local coffee sector in LTBR is complex, fragmented and dynamic and actors change categories fluidly as opportunities arise. In conversations with producers, it took time to establish whether producers were independent or organized, and if the latter, to which cooperative they belonged and which position they held in the local coffee sector. The bond to a cooperative may be easily severed, and producers may leave one cooperative to establish their own, with more or less positive outcomes. Thus, the *Sociedad de Solidaridad Social (SSS) Campo Alemán* in the Los Mangos community seceded from *Cerro Cintepec* in the midst of complaints about lack of transparency in management and price setting decisions. Nevertheless, it did not emerge as a functioning cooperative, so that its members soon became independent producers.

“Cerro Cintepec is a cooperative we belonged to at the beginning, when it integrated INMECAFE, but [after] 8 or 7 years, we organize the SSS Campo Alemán, because [Cerro Cintepec] was the only buyer and therefore paid [the price] it wanted. That’s why we organized [SSS Campo Alemán], to make competition and, in this way, raise the prices. But (...) the original committee [finished their term] and another committee was elected. This committee started to malfunction until the organization had to be dismantled. [That’s when] we became independent producers. We cannot integrate [Cerro Cintepec] again, because we would need to meet the requirements to do so. We were from there, established another organization and lately we are independent.”

A more successful story is that of a group of small organizations, *Cerro del Gallo*, *Uxuctero*, and *SSS Ocotales*, which were created by former members of the *Unión Regional*. They cooperate to complete the volumes required by regional roasters and occasionally roast their own coffee to sell locally (Table S4). Those independent producers, ex-cooperative members or advisers who command sufficient financial resources, may expand their activities and set up their own businesses. For example, a producer and *Unión Regional* member recognized the difficulty for independent producers (to get good prices) and cooperative members from remote communities (to deliver their coffee to the *Unión Regional*). He turned this into an opportunity to become a local intermediary for external buyers after acquiring processing equipment.

“I am a member of the Soteapan cooperative [la Unión Regional], I harvest my own coffee and I buy coffee [to] (...) the producers, who are not in a group [independent producers] and come to [me] to sell it. They bring me all their coffee and I buy it. (...) This year I will continue to buy. Now I have a dryer. I don’t have any problems anymore. I don’t have enough [place] to let [the coffee] air dry, so with the dryer it is much easier. (...) I am from here, from la Magdalena and I know [everybody] here and I get along with everybody. (...) I sell to independent [buyers], to coyotes. This is how we work here. Here, there is nobody else that buys the coffee. (...) It is very difficult to get the coffee to Soteapan (...). The [Unión Regional] has not put a collection point here.”

These emerging entrepreneurs compete with established cooperative and private firms to capture harvested coffee for external actors, but also forge new alliances with local business partners, who can facilitate market entry in importing countries. For example, *Café Oro de Los Tuxtlas* emerged in 2014 as a partnership between a former leader of the *Unión Regional* and a tourist operator based in Catemaco who has good connections to German importers^[13].

Land use strategies and their implications for conservation in the LTBR

Based on our interviews with coffee producers and processors and our field visits, we created an inventory of possible measures producers deploy to adapt to changing constraints (principally to buffer falling coffee prices) and to take advantage of emerging opportunities in local commodity chains. Seen collectively, these measures point at three generic land use strategies, namely: the improvement of coffee cultivation (in quantity and / quality), the diversification of agricultural activities, or the abandonment of (coffee) cultivation. These strategies are synthesized in Table 3 and can be associated with different degrees of agricultural intensification, environmental impact and conservation potential. We derive indications of compatibility and incompatibility of producers' land use strategies with conservation based on our literature review on the Land Sparing and Land Sharing framework and its application to coffee cultivation systems.

Table 3. Land use strategies and associated measures to adapt agricultural systems in the LTBR and their compatibility with conservation under Land Sparing and Land Sharing

| Land use strategies and adaptation measures | Compatibility with conservation under Land Sharing concept | Compatibility with conservation under Land Sparing concept |
|--|--|---|
| A. Increase coffee production volumes | | |
| A.1. Expand cultivated surface | | |
| A.1.1 On purchased / leased land | Depending on previous land use / forest cover and composition | Depending on previous land use / forest cover and composition |
| A.1.2 On native forest plots | Not compatible, because it leads to changes in forest composition / cover | Not compatible, because it leads to changes in forest composition / cover |
| A.1.3 On plots used for other activities | Compatible. Ecological restoration through the establishment of a productive agroforestry system. | Depending on potential for intensification. If marginal yield increases are expected, land use should be abandoned to allow ecological restoration |
| A.1.4 On degraded / marginal land | Compatible. Ecological restoration through the establishment of a productive agroforestry system. | Not compatible. Degraded / marginal land should be abandoned to allow ecological restoration |
| A.1.5 On commercial forest plots | Compatible. This can allow the establishment of a productive agroforestry system | Compatible This can increase the productivity of the plot |
| A.2 Changing shade composition / cover | | |
| Thinning shade | Compatible if this does not lead to a simplification of the agroforestry system | Depending on shade type and potential for intensification. If shade is from native trees and marginal yield increases are expected, the coffee plantation should be abandoned to allow forest regeneration |
| Replacing native shade trees by commercial species | Not compatible, because this leads to a simplification of the agroforestry system | Not compatible. Extensive coffee plantations should be abandoned to allow forest regeneration |
| Removing shade | Not compatible, because this leads to a simplification of the agroforestry system | Depending on shade type and potential for intensification. If shade is from native trees and marginal yield increases are expected, the coffee plantation should be abandoned to allow forest regeneration |
| A.3. Application of agricultural extension measures | | |
| A.3.1 Reactivation / Intensification measures: | | |
| Renew plantation (culling coffee plants) | Compatible | Compatible |
| Renew plantation (improved varieties) | Compatible, if new varieties do not need higher chemical inputs | Compatible |
| Increase density of saplings | Compatible, if this does not lead to a simplification of the agroforestry system | Compatible |
| Increase applications of chemical inputs | Not compatible, because this leads to a simplification of the agroforestry system | Compatible |
| A.3.2 Organic conversion | Compatible | Compatible, if conversion ensures increasing yields it over the long term |
| B. Diversification: | Compatible, if on same plot. Shade coffee polyculture in LTBR may comprise: pasture (cattle, sheep) for meat & milk for local consumption, subsistence crops, commercial crops (fruits, green pepper, decorative palms), apiculture, forestry (for timber and non wood products), ecotourism, and payment for ecosystem services programs (for the restoration of springs and soil). As a whole the Cerro Cintepec cooperative shows the highest level of diversification. | Compatible, if on separate plots. Coffee plantations may be combined with a number of activities performed on other plots: pasture, staple crops in monoculture (maize, beans), commercial crops (peanuts, decorative palms, fruit, sugar cane), forestry (for timber and non wood products), fish farming, (eco)tourism, and payment for ecosystem services programs (for strict forest protection and restoration of springs and soil) Currently, there is limited surface of coffee cultivated without shade (e.g. on garden plots that surrounds houses). |
| C. Abandonment of (coffee) cultivation | | |
| C.1. Conversion to other crops under shade / commercial forestry | Compatible, if this does not lead to a simplification of the agroforestry system | Compatible, if this leads to agricultural intensification |
| C.2. Temporary abandonment of land use, with possible reactivation at a later stage (e.g. through sale / leasing plots to other farmers) | Not compatible. Land Sharing thrives to maintain valuable agroecological system for biological and cultural diversity | Not compatible. Extensive coffee plantations should be abandoned over the long term to allow forest regeneration |
| C.3. Permanent abandonment of land use | Not compatible. Land Sharing thrives to maintain valuable agroecological system for biological and cultural diversity | Compatible, because it can allow forest regeneration over the long term |

Raise coffee production volumes

Since the 1990s, the area under coffee cultivation in the LTBR has shrunk considerably. In 2011, however, rising coffee prices and dwindling volumes of high quality Arabica milds worldwide spurred a reactivation of coffee cultivation in the region. Producers can improve coffee harvests through two main approaches, which may be combined. First, producers may expand cultivated area (A.1 in Table 3). Purchasing or leasing additional land for this purpose (A.1.1) requires financial resources, only available to few producers (e.g. the biggest producer of the *Cerro Cintepec* cooperative who alone controls 60 ha of land). Alternatives (A.1.2 to A.1.5) include clearing patches of forest (especially on higher grounds bordering the core zone), converting areas dedicated to other, less profitable agricultural activities, and introducing coffee on degraded or marginal land (e.g. deforested riparian stretches) or on commercial forest plots (A.1.5). At the time of this fieldwork, measures A.1.2 to A.1.4 were implemented in the Sierra de Santa Marta catchment, particularly through the efforts of the *Unión Regional* (for cooperative members) and *CASISA* (for independent producers). A *CASISA* representative explained their strategy in the Sierra de Santa Marta as follows:

“In the higher part of the Sierra de Santa Marta, the productivity is low. It is not possible to diversity [by planting other crops] there, and anyway this is very good land for coffee cultivation because it is on high ground and it is protected by the [volcano]. Strong northern winds do not affect them. (...) It is our intention that there should be more coffee in the region (...). [Now] the price of coffee is very good, the people are motivated [to plant coffee], we are trying to exploit this (...). This is why we produce 150 thousand plants. The idea is to establish more coffee [plantations] here in the region (...) There are areas that are not used, where there is pasture. And people say: ‘I will plant coffee on stream banks.’ (...) And this is very good, because it is going to maintain and protect the aquifers. (...) If we plant coffee in the region (...) people plant trees for shade, so we are reforesting indirectly the Sierra de Santa Marta.”

Unless it involves clearing primary forest, the expansion of coffee cultivation can be considered compatible with conservation, because it can foster the protection of springs and soils, the ecological regeneration of degraded land (particularly important in a Land Sparing perspective) and the reactivation of diversified agroforestry systems (particularly important in a Land Sharing perspective).

A second group of measures mentioned during the interviews is the changing shade composition or tree cover (A.2). This ranges from thinning shade trees (to allow more light in the undergrowth), replacing native shade with commercial tree species, to completely removing shade trees. Generally, these methods can be seen as more problematic from a conservation point of view. From a Land Sharing perspective, changing shade composition and cover may lead to the impoverishment of the agroforestry system, while from a Land Sparing perspective, in principle, extensive agricultural systems, especially under native shade, should be abandoned to enable forest transition.

In plantations close to the LTBR core zone of the Sierra de Santa Marta Volcano, the alteration of shade is grounds for conflict between producers and conservation actors. An independent producer from the Santa Marta community insisted:

“No, this is precisely what I was telling the people from CONAFOR [the National Forest Commission] and the [Biosphere] Reserve, I tell them ‘good that you came, because we are going to cut [some trees] there.’ He said ‘but there will be no shade.’ [‘The problem’, I answered], ‘is that ... in which month can we harvest?’ (...) [when the producers from San Fernando] clean everything, that means finishing the harvest, where can we sell our production if it grows under shade? (...) we have to cut [the trees] so that the coffee matures (...) quicker.”

In contrast, on lower ground, especially in the Zapoapan de Cabañas catchment, coffee plantations have been strongly shaped by the intensification measures promoted by INMECAFE, which encouraged the establishment of very simplified shade coffee systems. Currently, reforestation measures that include native, shade and commercial tree species and can incorporate coffee are implemented (A.1.5).

Expanding cultivated area may increase production volumes, but alone, this does not necessarily result in productivity gains. To this aim, by LTBR coffee producers employ a range of agricultural extension measures to intensify production under conventional or organic cultivation systems (A.3. in Table 3). These measures are generally compatible with conservation, both from Land Sparing (if they increase productivity) and Land Sharing (unless they involve a higher use of chemical inputs) perspectives. Organic cultivation can help to raise yields substantially through organic composting and mitigation of pests / diseases, while also improving coffee quality and market value, without requiring the expansion of the cultivated area. As such, in our case study area it represents the most promising avenue for sustainable intensification. In the Zapoapan de Cabañas catchment, this has been the core strategy of *Cerro Cintepec*, which has played a fundamental role by coordinating organic conversion, certification and control processes and providing incentives and capacity building. In contrast, many producers in the Sierra de Santa Marta catchment, organized or not, lack the resources to invest regularly in chemical inputs and their production may be considered to be de facto organic. In principle, the main actors of the coffee sector in this catchment could initiate a formal organic

conversion and certification program and push the creation of a high-altitude label. This could benefit producers by establishing quality standards that help them negotiate higher prices. Nevertheless, fierce internal competition between the main cooperative and private actors impedes the concerted effort required to achieve these costly endeavors.

Diversify production systems

Peasant coffee farmers in the LTBR traditionally deploy a range of subsistence and commercial activities depending on their resource base. A cooperative member from the El Aguila community stated:

“The majority [of us] on the land, we cannot only rely on one thing, right? On the land we need to have [a little bit of] everything, some chicken, a pig, a horse, a little cow, and different crops, right? Different varieties for subsistence, for food, this is how we feed ourselves (...) Here, we have litchi, there are oranges, [green] pepper, cattle, here there is everything (...) the litchis are to sell and also for our own use, (...) the pepper is commercial, because we don't eat it, oranges are also for own use, and there are also bananas.”

Shaded coffee plantations in LTBR are polycultures of different degrees of vegetational complexity that can be associated with Land Sharing (B in Table 3). Occasionally, coffee is also cultivated without shade, but this is marginal. Coffee polycultures may border patches of primary forest, but are generally spatially separated from pasture and arable plots (e.g. maize, beans, peanuts, litchi). These plots may be quite distant from one another, often due to the land allocation process during the agrarian reform. This diverse spatial constellation enables, in principle, the land use segregation concept embodied within Land Sparing.

In the LTBR, we identified many efforts to diversify productive systems. In remote localities where plantations have not been carefully maintained, producers, whether independent or organized, may harvest dwindling coffee harvests, while seeking integration into other commodity chains and sectors. For example, the Sierra de Santa Marta Project has provided substantial governmental subsidies to develop communal eco-tourism infrastructure (Paré and Fuentes, 2007). A second important crop in coffee polyculture is decorative palm for export. Palms of the *Chamaedorea* family were originally obtained from primary forest plots, but as these partly became integrated into the LTBR core zones, NGO and public subsidies promoted their cultivation as an alternative source of income (Velázquez Hernández, 2010). Moreover, green pepper is also a frequent shade tree incorporated into coffee polyculture systems. As with coffee, producers of decorative palms and green pepper, who are not organized in a cooperative, generally sell their harvest to private buyers in difficult conditions. Farmers are also experimenting with handicrafts based on water hyacinth (*Eichhornia crassipes*), the collection of wild Sapote mamey (*Pouteria sapota*) and wild orchids, and honey production with European and native bees. In addition, producers may apply to payment for ecosystem services programs (e.g. the program PSA-CABSA Program that provides payments for carbon, biodiversity and agroforestry services (Corbera et al., 2009). Palm and eco-tourism cooperatives do exist, but they are not necessarily integrated with the coffee cooperatives. Once again, *Cerro Cintepec* has taken the lead by encouraging the integration of different agro-silvo-pastoral activities that exist in, and around, its coffee plantations. Private firms are also developing complementary activities, for example tourist activities related to coffee (*Café Oro de los Tuxtlas*), but also fish-farming (*CASISA*) to supply local restaurants.

Convert to other land uses

During past periods of low coffee prices, farmers with fewer resources and opportunities may have converted their plantations to other agricultural activities, principally pastureland, to subsist. Interviewees mentioned this strategy, although infrequently at the time of this fieldwork, as an adaptation to price collapses. This applies particularly to independent producers, who cannot benefit from the social safety nets provided by cooperatives, and producers, who harvest low coffee volumes on neglected plantations. For example, an independent producer from the Miguel Hidalgo community mentioned:

“If the coffee still had a good value we would have continued planting more plants. But as the price fell, the coffee did not have any more value. What we did was to plant pasture for the cows.”

Another from the community of Santa Marta emphasized:

“This is precisely what people say now, ‘it is better to plant maize’, even if the Biosphere [Reserve people] says that we are not allowed to cut [the trees], ‘we are going to plant maize, because otherwise what are we going to [eat]?’... Bread is the biggest necessity, isn't it?”

Coping strategies can lead to the clearing of coffee plantations, but also to the deforestation of primary forest. For (McSweeney (2004), native timber can act as a “natural insurance” and buffer economic losses in times of crises, even if these may put the resource base at risk over the long term.

Household members often engage in different off-farm activities (e.g. as hired agricultural laborers or in the tourism sector) to complement income from coffee. In the Los Mangos community, an independent producer stated:

“I am the municipal police agent. I serve the people in the community, but I like other jobs, whatever, for example, I have learned to be a painter, to paint houses, a little masonry, a little carpentry, a little garden work, a lot, a lot of things, but working on the land is what I prefer, the land, cattle herding and all this.”

But local employment is limited and, since the coffee crisis of the 1990s, many farmers have emigrated to seek employment outside the region and abroad, as our interviewee from Miguel Hidalgo added.

“No, I tell you, here there is not enough to eat, we cannot make ends meet, even if we cannot say that we are suffering hunger, but one wants to improve one’s life. And when one does not find a door, there is no other way than to migrate. And this is a bad thing, because sometimes one cannot cross the border. (...) However you look at it, it is sad, I say it is sad, because in the past this did not happen. When there was sufficient coffee, one did not have to migrate, there was no reason, because there was work and there was money.”

Land left unattended after emigration may be passed on to landless farmers under the *ejido* system, though it may also be leased or sold. Our interviewee from Santa Marta explained:

“There are some who go away, let’s say, some ejidatarios go and they leave their plots to their sons. But sometimes their son also wants to go, then this plot will go to someone else, [someone] who lives here, because this person needs land, doesn’t he? So the land is given to him, because in principle there is nobody working that land.”

Plots that are very remote and difficult to farm may be completely abandoned. Should plots still contain primary forest, they could become eligible for inclusion in the national program for payment for ecosystem services (ProÁrbol), but strict prohibition of use (among other caveats), often acts as deterrent for producers who are reluctant to relinquish their land use rights (Weber M, 2012). One producer from the Ocotac Chico community explained his decision not to participate in ProÁrbol:

“ProÁrbol, yes, there are some who have entered the program, who have more land, or more plots, (...) I did not enter the program because I say that I am going to sow plants, I had to sow some plants (...), so that [the land] is useful, that’s why the plots [have been given to us as] personal plots, right?”

Strategies to improve processing and commercialization

Additionally, coffee producers may strive to enhance their access to markets at the processing, roasting and commercialization stages. Table 4 synthesizes the information we collected (via interviews, visits to premises and on-line searches) on the measures that the main actors in the LTBR coffee sector have performed and / or initiated to improve commercialization. These primarily include infrastructure developments, marketing and networking strategies. Some actors (*Cerro Cintepec*, *CASISA*, *Café Oro de los Tuxtlas*) have adopted many of these measures, indicating that they are more innovative and explore more commercialization avenues than others (*Unión Regional*, smaller cooperatives). In our case study, the possibility to capture locally a higher proportion of the final coffee added value, for example by retailing roasted coffee (cups, as in the case of *Café Oro de los Tuxtlas*) or by developing and marketing products of higher added value (such as decaffeinated and instant coffee as *CASISA*¹⁴) has apparently more to do with entrepreneurial flair, knowledge of local and tourist preferences, investment capacity and good networking than official quality labels and certification (as in the case of *Cerro Cintepec*). Indeed, recognizing the marketing potential of the Los Tuxtlas region (i.e. higher elevation, Biosphere Reserve), the private firm *Café Oro de los Tuxtlas* advertises a 100% organic coffee on its webpage, even though it has no official organic certification. *Cerro Cintepec*, in contrast, uses organic and fair trade certifications and networks to raise its national and international visibility to some degree, but these standards of quality have not yet resulted in their securing long-term contractual agreements (Table S4).

Table 4. Strategies to improve commercialization and market access^a

| | CASISA (Café Junco) | Café Oro de los Tuxtlas | Cerro Cintepec (Café Sierra de los Tuxtlas) | Unión Regional | Small cooperatives ^b |
|---|------------------------|----------------------------|---|-------------------|------------------------------------|
| Expand infrastructure | | | | | |
| Processing and storage infrastructure (for export) | + | + | + | + | – |
| Roasting machinery / equipment | + | + | + | – | + ^c |
| Exploit market niche | | | | | |
| Obtain official certification (organic, fair trade) | – | – | + | – | – |
| Focus marketing on quality markers (with no official certification) | + | + | – | – | – |
| Create a registered brand | + | – | + | – | – |
| Relate to tourist activities / products | – | + | + | – | – |
| Create a coffee shop | – | + | – | – | – |
| Develop alliances and enter networks | | | | | |
| With other local coffee cooperatives | – | – | – | – | + |
| With national and international organic / fair trade coffee networks | – | – | + | – | – |
| With other local private business partners | – | + | – | – | – |
| Commercialization paths | | | | | |
| Diversify products (export green coffee, different sorts of roasted coffee) | + | + | + | – | – |
| Direct sale to local consumers / | + | + | + | – | + |
| Direct sale to tourist establishments / tourists | + | + | + | – | – |
| Access to local tourist shops | + | + | + | – | – |
| Own (coffee) shop | + | + | – | – | – |
| Online presence (webpage, social media) | + | + | + | – | – |
| Online (direct) sales | + | + | + ^d | – | – |
| Regional fairs | – | – | + | – | – |
| Sales to local processor / intermediary | – | – | – | – | + |
| Direct sales to international import firm | + | + | – | + | – |
| Direct sales to regional export firm | – | – | – | – | – |
| Export through cooperative network | – | – | + | – | – |

^a+ indicates that the strategy is applied; – indicates that the strategy is not applied. Data used to derive + and – include: statements by interviewees, direct observation (of the processing and roasting plants / products on sale) and consultation of websites (when available)

^bWe consider three small cooperatives: Cerro del Gallo (Unión de Productores Forestales Indígenas Kallukotsik), Uxuctero, SSS Ocotales

^cManual roasting uses simple household equipment

^dvia commercialization partner

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Discussion

Peasant farmers' production capacity and market access are strongly influenced by external factors, such as biophysical and climatic conditions, federal government policies, international trade frameworks and market dynamics (Eakin, 2005; Eakin et al., 2009; Ponte, 2002; Tucker et al., 2010; Jha et al., 2011; Gonzalez de Molina, 2013). Typically, farmers rely on combinations of on- and off-farm strategies (including migration) to cope with marginalization, adapt to exogenous changes and take advantage of new windows of opportunity (Conway and Cohen, 1998; Gordon et al., 2007; García-Barríos et al., 2009; Eakin et al., 2009; Méndez et al., 2010a and b; Bathfield et al., 2013). The case of the LTBR illustrates the serious obstacles coffee producers have to recover from the repetitive deterioration of international coffee prices and the reconfiguration of the Mexican coffee sector. Our data showed that coffee producers in the LTBR choose from several main land use strategies (Table 3). At the time of fieldwork, producers were reactivating, improving and expanding shaded coffee plantations to exploit a period of high coffee prices¹⁵. In terms of conservation, the extension of coffee plantations can stimulate reforestation, ecological restoration (especially over degraded, marginal land) and the maintenance of a diverse landscape matrix (Land Sharing). Producers can also, in principle, intensify coffee cultivation without expanding into remaining native forest patches through appropriate agricultural extension methods (Land Sparing).

Many of the practical measures producers deploy in the LTBR are compatible with both Land Sparing and Land Sharing. Table 3 highlights the substantial common ground between these two approaches, helping to overcome the conceptual dichotomy embedded in this framework (Phalan et al., 2016; Schroth et al., 2015; Fischer et al., 2008; Fischer, 2015). Nevertheless, some measures mentioned, including expanding over native forest, shade removal and more frequent applications of chemical inputs are, strictly-speaking, incompatible with sustainable intensification and the land use restrictions stipulated in the LTBR's charter

(CONANP, 2006). This can cause friction between producers and conservation actors, especially in the higher grounds that border the core zone of the Sierra de Santa Marta. There, if producers considered clearing coffee plantations, either for pasture or arable cultivation, to generate income over the short term, in practice they tended to neglect the coffee plants and harvest ever decreasing coffee volumes. For Haggard et al. (2013), converting coffee plantations to pasture entails sacrificing the time, work and resources invested over prior years. This strategy thus aims more at securing subsistence rather than increasing profitability, although it endangers producers' long-term resource base (Bacon, 2005; Aguilar-Støen et al., 2011).

A major hurdle for coffee producers in the LTBR is securing access to markets, although several factors can facilitate this. First, producers' resource endowment (primarily in terms of land, but also of physical access to agricultural extension methods) is key. The LTBR producers who control more land can achieve important harvest volumes. As cooperative members, they can also take full advantage of the economies of scale, collective investments and risk-sharing that those organizations provide (Table S4). This can spur a virtuous circle, as more productive plantations provide higher returns, increasing investment capacity for additional fields and labor, access to agricultural extension methods, and diversification activities (Ruben and Masset, 2003).

Second, producers may face more or less land use restrictions according to the location of their plantations in the zonation scheme of the LTBR, and the presence of native forest patches in their plots. Plantations located in the transition zone are not officially under the mandate of LTBR management and are, therefore, not affected by land use restrictions. There, native shade has long since been removed and replaced by commercial timber species. In contrast, plantations adjoining the LTBR core zones, are more or less severely affected by land use restrictions to protect shade and patches of primary forest. However, because coffee plantations there are primarily extensive agroforestry activities, conservation authorities encourage their maintenance, while they combat the on-going process of deforestation to open pasture lands in areas adjoining, or actually inside, the LTBR core zones (CONANP, 2011).

Third, the integration in cooperative networks or other business alliances often determines producers' access to processing infrastructure and their capacity to position their coffee strategically in different markets. Typically, producers have three alternatives: selling coffee cherries to a (local) buyer (as an independent producer), becoming a member of a cooperative to take some control in the processing and commercialization process (Tables S3 and S4), or becoming a private buyer and / or processor themselves. The local coffee sector in the LTBR presents a complex constellation of cooperatives, private firms and local and external intermediaries who pursue different avenues to improve coffee production and commercialization potential, though few have the means required to successfully implement the full range of measures we identified (Table 4).

Finally, organic and fair trade certification, as in the case of *Cerro Cintepec*, benefits mostly those producers who can concentrate on coffee as a primary activity and produce sufficient harvest volumes. Despite organic and social premiums, a higher coffee price only translates to a higher income if a critical quantity of coffee can be sold over the long-term. Organic conversion, cultivation and certification processes are time, resources and labor-intensive and do not necessarily, or significantly, improve farmers direct incomes (Bacon et al., 2008; Méndez et al., 2010b; Wilson, 2010; Beuchelt and Zeller, 2011; Weber JG, 2011; Ruben and Fort, 2012). At a community level, organic and fair trade premiums may, however, substantially help improve productivity and have a range of indirect positive benefits, not addressed in our study, in terms of health, housing, education, social learning and producers' empowerment (Bray et al., 2002; Méndez et al., 2010b; Ruben and Fort 2012 for a review). For Barham et al. (2011), certified coffee should therefore be seen as one income source in a diversified and complementary set of livelihood strategies, including agricultural intensification, access to education, fair pay for work, and remittances.

The gourmet, fair trade and sustainable coffee sectors have opened new commercial niches for peasant farmers, but have led to the multiplication of coffee certification schemes (Calo and Wise, 2005; Ruben and Fort, 2012). As ever-greater amounts of certified coffee entered a rapidly-saturating market, chronic oversupply and intense competition has resulted in declining prices for certified coffee (Weber JG, 2007; Jaffee, 2007; Reynolds, 2009; de Janvry et al., 2010). In this context, new aspirants seeking access to certified markets face more complex barriers and need to accumulate costly certifications in order to compete with already established actors (Gómez Tovar et al., 2005). This is well illustrated in the case of the *Cerro Cintepec* cooperative. Though unique in LTRB in that it combines a long existence, an interesting leadership in diversification and organic conversion, an active strategy towards integration in national and international cooperative networks and multiple certifications, the cooperative had neither established a secure market niche nor long-term export contractual arrangements by 2013 (Table S4).

The case of the LTBR also provides insights on how local coffee sectors evolved in Mexico under different agricultural policy and trade contexts. Until the collapse of the ICA, Mexican peasant coffee producers could capture a substantially larger share of the final added value in the production and commercialization framework provided by INMECAFE (Pérez Akaki and Echénové Huacuja, 2006). Since the dismantlement of this state-led firm, local cooperatives, such as *Cerro Cintepec* and *Unión Regional*, stepped into this vacuum to salvage coffee cultivation in the region. While in the 1980s and early 1990s they achieved a critical mass of organized producers and developed substantial processing infrastructure (Table S3), they are increasingly weakened by a range of internal and external problems. For the agronomist who advised the *Unión Regional*

in 2011, the list of main obstacles that the cooperative would need to overcome was long. It included: the low productivity of coffee plantations, the high economic marginality and low awareness among cooperative members (that hindered the implementation of long-term collective strategies), the chronic lack of infrastructure and technical support (for production, processing and commercialization), insufficient networking (to public administrations and international buyers), lack of capital and financial support, and internal management rife with problems, including corruption. These serious deficits often contributed to increasing producers' mistrust in cooperative structures, encouraging disloyalty, and often driving producers to sell their harvest to the highest bidder and / or establish their own small cooperative or business.

The LTBR offers a good nursing ground for emergent entrepreneurs who are forging new alliances to capture local coffee harvests and improve their ability to compete downstream. For example, the *Café Oro de los Tuxtlas* partnership was created in 2014 and, by 2015, it had already developed several brands of coffee for local sale, while it exported green coffee to Germany. Nevertheless, it is too soon to evaluate whether this new business will consolidate a market niche and achieve profitability over the long term. This mirrors the situation with the international coffee sector, where recent partnerships between global actors in the roasting and retail markets (e.g. Starbucks) and conservation NGOs (e.g. Conservation International) may capture high-quality coffee, ensure traceability, while bypassing intermediaries (Bitzer et al., 2008; Reynolds, 2009; Renard, 2010; Jaffee, 2012). Though creating new market opportunities for peasant coffee producers, this is effectively watering down the strict regulations of certified coffees, and sidestepping cooperatives via direct contractual negotiations with producers (Macdonald, 2007; Weber JG, 2007; Renard, 2012).

Our research indicates that changes in local sectoral and market dynamics may open windows of opportunity for some producers, but also exacerbate asymmetries inside peasant farming communities, while weakening producers' cooperatives. This is in keeping with other field studies on efforts to reconcile conservation and livelihoods in peasant coffee cultivation in Mexican Biosphere Reserves, which show, at best, mixed results (on forest protection, see Tejada-Cruz et al., 2010; on improving producers' control of their livelihoods, see Renard, 2012). Further, in recent years, new obstacles such as shrinking price margins in certified markets or the devastating effects of coffee rust is pushing many Latin American peasant farmers to revert back to conventional cultivation methods (Gianessi, 2013; Avelino et al., 2015), even though this may jeopardize decades of efforts and compromise future access to quality markets. We note, with interest, that great effort is being devoted to opening new avenues that will help restore degraded and deforested land by fostering sustainable intensification in commercial agroforestry activities (e.g. Schroth et al., 2015; Phalan et al., 2016). Nevertheless, in keeping with Kremen (2015) and Robbins et al. (2015), we argue that a greater emphasis should be given to understanding interactions between biodiversity, farming practice, land tenure systems, market dynamics and the institutional and policy frameworks that constrain peasant agroforestry systems and producers' cooperatives. Future research on sustainable land use management in and around protected areas needs to more explicitly consider the interactions between peasant farmers' resources, changing actor constellations and dynamics in local commodity chains.

Conclusions

Coffee is emblematic of North-South cash crops that intricately link economically-marginalized producers in developing countries with consumers in developed nations. Low input peasant shaded coffee, grown in economically marginalized, but ecologically rich regions, represents a substantial proportion of world coffee volumes. Our study of the LTBR showed the ongoing importance of the agroecological coffee systems there and highlights the resourcefulness of producers, who despite critical structural obstacles, continue to seek new ways to improve production against a backdrop of increasing international competition and stricter quality standards. Our study indicates that land use strategies in peasant shaded coffee plantation are often compatible with the conservation goals of the LTBR. In principle, coffee agroforestry systems can be intensified without affecting remaining primary forest patches (Land Sparing), while maintaining a diverse landscape matrix (Land Sharing). Our qualitative social science approach, nevertheless, did not allow a detailed agroecological analysis of the extent to which coffee producers' practices are compatible with the LTBR conservation goals.

Our study further emphasizes the close interactions between the land use and market integration strategies of coffee producers in their attempts to adapt their activities to changing conditions in the international commodity chain. In the LTBR, the capacity to improve agricultural systems and livelihoods over the long term depends largely on producers' access to financial resources, capacity building and networks that facilitate market access. Our results also illustrate the narrow maneuvering room that peasant farmers have to exploit textbook synergies between conservation and the fair trade and organically-certified coffee market niches in a region with serious deficiencies in structural development. Nevertheless, our study, by focusing on coffee, did not encompass the range of (agricultural) activities LTBR producers are deploying. It would be desirable to enlarge this initial scope to investigate in detail the factors that influence producers' decisions on which mix of crops they use and which commodity chains they seek to integrate, as well as the land use implications of these decisions. Further, the key findings of this study, though to a certain extent emblematic of peasant communities in South Mexico, would need to be complemented by additional, similar studies in order to better portray the range of contexts affecting coffee producers and of the options available to them.

Notes

1. The terms “smallholders” and “peasant farmers” are used interchangeably throughout the text.
2. Table 2 presents information from the four principal municipalities that produce coffee in the LTBR. These are located inside the buffer and transition zones of the Biosphere Reserve according to the full UNESCO zonation (Guevara Sada et al., 2000).
3. In 2004 detailed household surveys calculated that, an average 5 person household in different municipalities of the Sierra de Santa Marta had a cumulative annual income ranging between 10,000 to 12,000 Mexican Pesos (Indicative conversion rate for 2004: 1 Mexican Peso = 0.089 US\$ = 890 to 1068 US\$).
4. Rather than hypotheses, qualitative research within the Grounded Theory approach uses sensitizing concepts to guide and frame the development of research questions, data collection and analysis (Bowen, 2006).
5. The interview material and Atlas.Ti hermeneutic unit of interview material is archived by the corresponding author.
6. All citations were translated from Spanish by the authors.
7. The usual practice of private buyers is to buy harvests based on daily international coffee prices.
8. The current subsidy program towards coffee production is Procafé from the federal Ministry of Agriculture Sagarpa. [www.sagarpa.gob.mx/Delegaciones/querequero/Documentos/2016/conv_procafe2016\[1\].pdf](http://www.sagarpa.gob.mx/Delegaciones/querequero/Documentos/2016/conv_procafe2016[1].pdf) – Accessed on 03.09.2016
9. The *Unión Regional*, also called Consejo Regional, emerged from the Sociedad de Solidaridad Social Sierra de Santa Marta, which re-organised the coffee production in this catchment after the dismantlement of INMECAFE at the end of the 1990s.
10. Green peeper is the dried unripe fruit of *Piper nigrum*.
11. Organic coffee receives an added premium (between 10 and 20% of conventional coffee price), which depends on quality and world prices trends. This differs from the fair trade coffee price, which sets a lower limit for coffee prices regardless global market prices, while the upper limit is set by adding a premium on top of world prices (International Trade Centre – ITC, 2011). For the LTBR, the reference price for export green coffee is Mexican prime washed, which falls under the category “other Milds”.
12. In 2011, interviews with coffee producers in the Sierra de Santa Marta catchment recurrently referred to the restructuring of the *Unión Regional*. The local authority was leading this process after reported fraud caused difficulties in fulfilling contractual arrangements with the exporting firm and increased debt. Part of the restructuring involved raising membership fees, which though modest (300 Mex. pesos = ca. 6 times a mean daily salary) excluded the most marginal producers. This led to a substantial loss of trust and the defection of many members. Accusations of fraud, bad governance, lack of transparency, and mismanagement are frequent in both coffee catchments. Though important, their analysis is beyond the scope of this article.
13. The tourist operator was one of our key informants during a number of years. From 2013 onwards, this actor initially attempted an alliance with *Cerro Cintepec* and together with the local technological university performed a study of possible avenues to develop coffee production in the region (Instituto Tecnológico Superior de San Andrés Tuxtla – ITS, 2013). Due to incompatibilities, the collaboration was interrupted. Subsequently, through email communication, we were informed of the creation of *Café Oro de los Tuxtlas*. Through consultation of the business website (<http://orodelostuxtlas.com>), we identified the private processor of this new partnership as the former ex-cooperative leader of the *Unión Regional*, who, at the time of our first visit to the Santa Marta catchment in 2010, had been accused of mismanagement of cooperative funds in interviews.
14. Based on information from firms’ website: <http://orodelostuxtlas.com> and <http://casisa.com.mx>. Accessed on 12.09.2016
15. Since data collection Mexico has been substantially affected by coffee rust. Producers are increasingly converting to Robusta coffee cultivation to combat this plague, which particularly affects Arabica coffee species. This is supported by public subsidies from the Ministry of Agriculture (SAGARPA) and encouraged by the transnational firm Nestlé. In Veracruz, 2000 ha had already been converted to Robusta by 2016. (Global Agricultural Information Network - GAIN, 2016). One of our key informants has confirmed that this is also taking place in the LTBR, though we have no information the locations and the surfaces involved.

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Contributions

- Contributed to conception and design: ACDLVL, LB
- Contributed to acquisition of data: ACDLVL
- Contributed to analysis and interpretation of data: ACDLV, LB
- Drafted and/or revised the article: ACDLVL, LB, SSK
- Approved the submitted version for publication: ACDLVL

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Competing interests

The corresponding author is not aware of any competing interest relating to this paper.

Supplemental material

- **Table S1. Characteristics of communities studied and of numbers of interviewees from different groups. DOC Format**
This table provides information on the communities studied (land tenure, location in relation to the UNESCO zonation) and interviewees doi: 10.12952/journal.elementa.000139.s001
- **Table S2. Main topics and sub-topics discussed in interviews and used to code interviews for content analysis. DOC Format**
This table presents the topics covered in the interviews and the main codes used in the content analysis. doi: 10.12952/journal.elementa.000139.s002
- **Table S3. An overview of advantages and disadvantages of cooperative membership. DOC Format**
This table presents a synthesis of the information collected on the advantages and disadvantages of cooperative membership. doi: 10.12952/journal.elementa.000139.s003
- **Table S4. Characteristics of three main cooperatives in the Los Tuxtlas Biosphere Reserve. DOC Format**
This table provides an overview of the main coffee cooperatives analyzed and their characteristics. doi: 10.12952/journal.elementa.000139.s004
- **Text S1. Template interview script. DOC Format**
This document presents a template of the script we used during semi-structured interviews. doi: 10.12952/journal.elementa.000139.s005

Data accessibility statement

The Atlas.Ti hermeneutic unit of interview material is archived by the corresponding author.

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