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Perceptions of Trees Outside Forests in Cattle Pastures: Land Sharing Within the Central Volcanic Talamanca Biological Corridor, Costa Rica

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Abstract Trees outside forests can play an important role in production and conservation and increase connectivity within agricultural landscapes. However, farmers' perceptions of the trees and the values they place on them will determine the extent to which they will do so in the future. In a case study in Costa Rica, northwest of the Central Volcanic Talamanca Biological Corridor, we conducted 42 semi-structured interviews with farmers and other key informants. Results show that farmers maintain trees on their land and attribute to them diverse values (technical, economic, ecological, social, cultural, aesthetic, and heritage). Farmers reported limitations to the maintenance of trees (lack of financial capital, labour, land area, technical assistance, and adapted species). In addition to potentially unsustainable Payments for Environmental Services, there is scope for more collaborative approaches to conserving the trees built on existing farmer practices.

Keywords Trees outside forests · Dairy farming · Farmers' perceptions · Agricultural landscape connectivity · Payments for Environmental Services · Central Volcanic Talamanca Biological Corridor · Costa Rica

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Introduction

Tropical deforestation has been cited as one of the primary causes of global environmental change (Martin 2015), and agricultural expansion is its most significant proximate cause (Geist and Lambin 2002). The relationship between tropical forests and agriculture is therefore of crucial importance for global conservation priorities. A useful wider context for this issue is the 'land sharing' versus 'land sparing' debate in conservation, which highlights two opposing approaches to reconciling productive use of lands with conservation goals. On the one hand, we can attempt to integrate conservation and production on the same areas of land by the introduction of land use practices that enhance biodiversity ('land sharing'). Alternatively we can separate them, adopting more intensive forms of production in certain areas and thus easing the demand for land and allowing other areas to be set aside in perpetuity for conservation ('land sparing') (Phalan *et al.* 2011a; Phalan *et al.* 2011b). This debate is currently being played out in the Brazilian Atlantic forest community of Bombas (Thorkildsen 2014). Whilst this dichotomy is inevitably simplistic (Tscharntke *et al.* 2012), not least because it does not incorporate the issue of connectivity, it provides a useful framework within which to consider tradeoffs between different forms of productive land use with different values for conservation. Agroforestry has been extensively promoted as a 'land sharing' option that is highly productive and of high biodiversity value (Bhagwat *et al.* 2008; de Foresta et al. 2013; McNeely and Schroth 2006). For example, this benefit has been shown on birds, bats, dung-beetles, and terrestrial mammals in Costa Rica (Harvey *et al.* 2006a; Harvey and Villalobos 2007) and ants in Southern Mexico (Perfecto and Vandermeer 2002). However, little attention has been given to more intensive forms of use. Specifically, cattle pastures have often been discounted out of hand as incompatible with

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conservation, especially in Latin America (Geist and Lambin 2002). Absentee and hobby farm owners with extensive cattle pastures in the northern lowlands of Costa Rica exemplify this incompatibility. These landowners' attitudes towards trees have not shifted to recognize their intrinsic, economic, or ecological values (Schelhas and Sánchez-Azofeifa 2006). Given that "approximately two-thirds of deforested lands become pasture in the Neotropics," any measures that enhance the biodiversity value of cattle pastures could have a major impact on overall biodiversity retention (Lerner *et al.* 2015).

One measure is to increase trees outside forests (TOFs) on pastureland. TOFs are recognized as making an important contribution to conservation, especially trees on farms that can enhance biodiversity. They include trees in live fences, scattered trees, and trees in riparian corridors (Chazdon *et al.* 2009; Harvey *et al.* 2006b; Shaver *et al.* 2015). They provide "habitats outside formally protected land, connecting nature reserves and alleviating resource-use pressure on conservation areas" (Bhagwat *et al.* 2008). They also contribute to livelihoods, providing numerous ecosystem services. Faced by a lack of documentation on TOFs, the United Nations Food and Agriculture Organization (FAO) has undertaken studies largely to better inform national forestry policies (Bellefontaine *et al.* 2002).

Much of the research on TOFs has been natural science based and/or quantitative. Even though some studies consider quantifiable social and economic aspects such as functions, uses, and services, they do not take into account the more qualitative aspects of farmers' own perceptions, especially in relation to the different values farmers give to the same tree. The promotion of trees on farms as a way of conserving biodiversity or biological connectivity requires a qualitative approach to understanding what is important to farmers for conserving existing trees or planting new ones and moreover to understand complexity of tree cover dynamics in agricultural lands (Louman *et al.* 2016).

We here present a case study from a dairy farming area in Costa Rica, which is often portrayed as particularly inimical to the conservation of biodiversity. Increased biodiversity in cattle pastures comes from the presence of trees, which in turn depends on farmers valuing them enough to keep them on their land. Therefore we are interested in understanding farmers' perceptions and values of trees.

Today, conservation in Costa Rica is influenced by a regional emphasis on connectivity and an ecological focus on human-modified landscapes, especially agricultural systems, due to Mesoamerica's unique context: a bridge between two continents and a barrier due to its volcanic central mountain range (De Clerck *et al.* 2010). Part of the Mesoamerican Biological Corridor, the Central Volcanic Talamanca Biological Corridor (CVTBC) was created in 2003. Its main goals are to restore and maintain biological connectivity, which involves connecting protected areas (Turrialba Volcano National Park, Tapanti National Park, Barbilla National Park) to enable the movement of flora and fauna between them and to mitigate habitat fragmentation and population isolation. Biological corridors, which include human-modified and natural landscapes, are embedded with biocultural values such as pluralism, a concept implying that "each group accepts and values the others' right to exist within the same ecological space" (Loring 2016).

The CVTBC's management committee has identified several objectives including improving nature conservation, especially soil, watershed and biodiversity protection, and enhancing economic and social conditions in the area for the well-being of the population. Within the CVTBC, fragmented forests and pastures are the two main land uses (52% and 24% respectively) (Murrieta Arévalo 2006; Ramírez Chávez 2006). Although forest connectivity has been studied in the CVTBC, the positive impact of TOFs within the agricultural landscape still needs further investigation.

"Trees outside forests" have been described by Bellefontaine *et al.* (2002) as "trees on land not defined as forest and other wooded land." Within the agricultural landscape of the corridor, trees outside forests can be found in coffee agroforestry systems, live fences, along roads and in human settlements, dispersed in pastures, and in riparian areas. Live fences are "narrow linear strips of planted trees, generally consisting of a single row of a few densely planted species established and managed by farmers" (Chacón León and Harvey 2006). Their primary purpose is to provide fencing to restrict animal movement and they are an integral component of farm production systems (Harvey *et al.* 2005; Sibelet 1995). Dispersed trees include isolated trees, pasture trees, scattered trees, or remnant trees (Manning *et al.* 2006). They can have multiple functions (Torquebiau *et al.* 2002) and different origins: they may be left after forest clearance, appear through natural regeneration, or be planted by farmers (Harvey and Haber 1999). Riparian areas are linear elements defined by their proximity to rivers, streams, and watercourses (Bennett 1999) that can vary from a few rows of trees a couple of meters wide to a whole forest patch.

Various studies in Costa Rica have reported a range of productive and ecological roles of live fences, dispersed trees in pastures, and riparian trees: diversification of production and income, increase in total productivity, and provision of fencing and shade (Love *et al.* 2009). At a local scale, they provide habitat, shelter, and resources for some plant and animal species, and they increase plant species richness and structural complexity (Chacón León and Harvey 2006). At a landscape scale, live fences and riparian trees increase connectivity for animals (Bennett 1999). Live fences, dispersed trees in pastures, and riparian trees improve genetic connectivity for tree populations (Manning *et al.* 2006). Finally, they play a key role in defining the composition and connectivity of the agricultural landscape (Harvey *et al.* 2005). Because they play "productive and environmentally protective roles," they have been highlighted as keystone elements to contribute to both sustainable development and conservation within agricultural landscapes (Harvey *et al.* 2011). Thus, TOFs merit consideration as they can contribute to the improvement of both conservation and landscape connectivity.

However, major conflicts have been reported concerning tree retention within pastures, including in the northwest part of the case study site, which is mainly dedicated to dairy-cattle pastures (Murrieta Arévalo 2006) managed by smallholder farmers. In order to achieve its conservation goals, the CVTBC must work in alliance with farmers and other local stakeholders and therefore must understand how farmers manage trees in order to effectively support and foster sustainable management of tree cover. We describe the extent to which farmers in the northwest part of the CVTBC maintain TOFs on their land, their perceptions of trees on their land, possible limitations of having trees on their land and their willingness to maintain or plant new trees. We then explore ways of building on local farming knowledge and practices in order to support productive systems and at the same time increase the presence of TOFs.

Methods

Study Area

The study was conducted principally in the Santa Cruz district, canton of Turrialba, province of Cartago, Costa Rica (Fig. 1). The district is 127 km^2 and has an estimated 3421 inhabitants (INEC 2015). The exact study site encompasses a larger area than Santa Cruz district covering areas of traditional dairy activity, including the localities of San Antonio, El Carmen, Santa Cruz, Torito, Guayabo, Calle Vargas, Calle Leiva, Las Abras, Las Virtudes, La Pastora, El Volcán (La Picada, Finca Central, La Fuente, El Triunfo, El Tapojo) in Santa Cruz district, and Los Bajos and Bonilla in Santa Teresita district. This rural area is relatively homogeneous in terms of its natural resources, farming activities (mainly livestock (52%) and forest (38%) (Fig. 2)), and infrastructure, trade, and local development. Its main urban center is Santa Cruz de Turrialba.

The study site, located on the slopes of Turrialba Volcano, ranges in altitude from 900 to 3000 masl; the average temperature ranges from 10 to 19 °C; annual precipitation ranges from 3000 to 3500 mm with an average humidity of 85% (Blanco 2007). The Santa Cruz area is part of the North Sub-Corridor, one of the six sub-corridors of the Central Volcanic Talamanca Biological Corridor. It is a mountainous area with fertile volcanic soil that falls into the Wet Tropical Forest life zone (Holdridge 1967). The Turrialba Volcano is protected by a national park of approximately 1600 ha that encompasses its closest slopes. Our study site, although at its border, is outside the park. Since the late 1990s, acid rain and sulfur dioxide and other corrosive gases have damaged much of the vegetation on farms in the volcano's immediate vicinity. In 2010 a new eruptive period began. Since then, gas emission has increased and there have been several ash emissions. Aside from a brief period in 2011, the national park has remained closed to the public since 2010. The area is dedicated to raising cattle especially for dairy production and processing traditional handmade cheese in family-owned farms. "Turrialba" cheese has been produced for more than a century in this area and is known throughout Costa Rica.

Data Collection and Analysis

We utilized an open-ended, qualitative approach to explore local people's perceptions without imposing a predetermined framework. We conducted 42 semi-structured interviews with key informants and farmers (Newing 2011; Sibelet *et al.* 2013). In order to understand current local issues related to production, land-use, tree cover, local stakeholders, and local initiatives, we conducted key informant interviews with organizations working in the area in the agricultural and environmental sectors. We interviewed 12 people from institutions, associations, and the local offices of the Ministry of Agriculture and Livestock (*Ministerio de Agricultura y Ganadería*- MAG) and the Ministry of Environment and Energy (*Ministerio de Ambiente y Energía*- MINAE). Each interview consisted of questions on topics such as the organization's goals and activities and the informant's perceptions of farmers' management of tree cover on farmland in the area (see Appendix 1).

We conducted 30 on-farm interviews with farmers (24 males and 6 females, average age 45; this reflects a gender imbalance amongst farmers) (Appendix 2). The first part of the interview consisted of questions about trees on farmers' land, their origins, the farmers' reasons for maintaining them or not, the values they attribute to them, factors limiting trees' presence and use, as well as farmers' willingness to plant new trees. The second part consisted of questions about farm production, management, and change, and farmers' participation in projects and involvement in social networks. No predefined list was introduced to farmers concerning their reasons for maintaining trees or the values they attributed to them, in order not to influence their answers. The interviews concluded with a visit to the farmer's land during which we received more in-depth explanations about tree presence and use. The interviews lasted from an hour and a half to three hours.

We constructed a sample of farmers based on names obtained from a variety of sources, including the members of the local cattle farmers' association, farmers we met by chance,

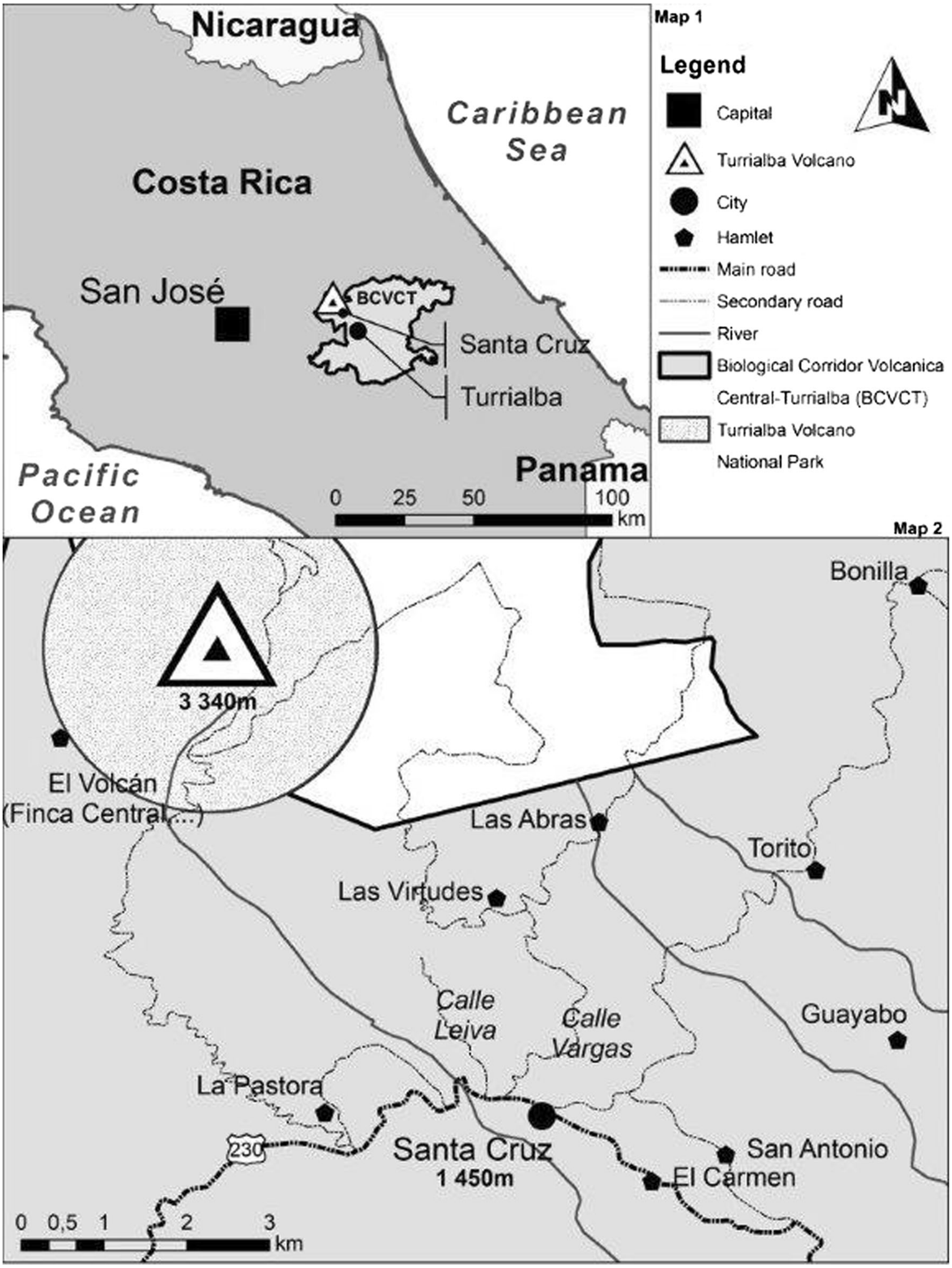
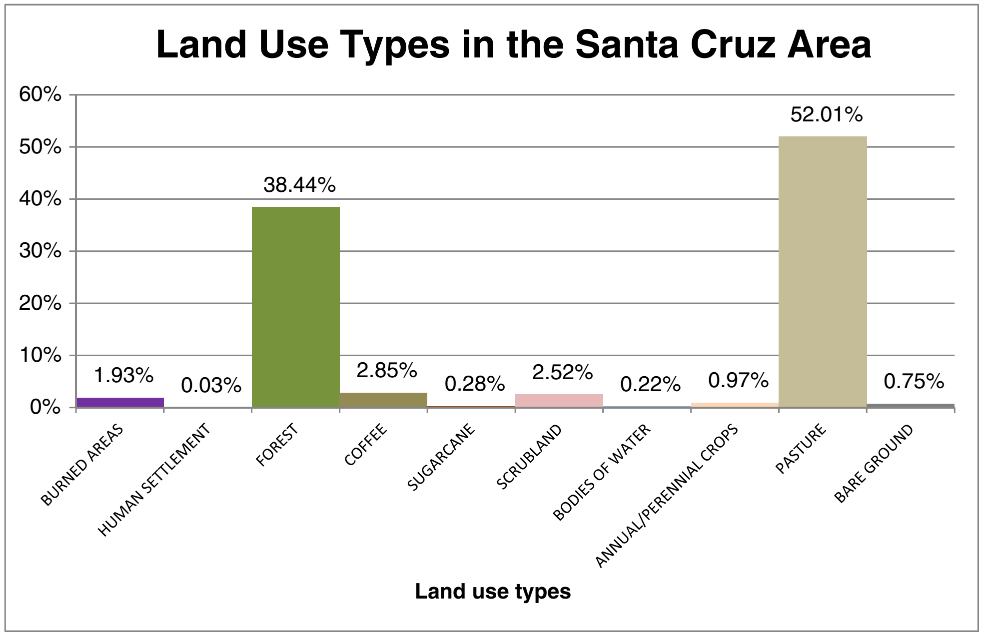


Fig. 1 Study area in the north-west of the Central Volcanic Talamanca Biological Corridor in Costa Rica

and additional farmers identified through snowball sampling. When several people were recommended, we always tried to meet people different from those seen before according to the descriptions informants could give. We looked for a diversity of situations. Although we took notes during the interviews, we also recorded each interview in order to to complete the notes. We analysed interview responses and notes and coded for themes that were developed from the text.

Fig. 2 Land uses types in the Santa Cruz area (made with ArcGIS)



Results and Discussion

Diversity of Farmers Interviewed

Findings indicate both farm and farmer diversity (Table 1). We considered farm and farmer diversity in terms of type of production, production diversification, product commercialization, involvement in local organizations and technological level of the farm. Based on these we developed five farmer categories. Category A includes dairy farmers who process traditional cheese and sell it to a local retailer. Category B includes farmers with product diversification. Category C includes farmers who have greater involvement in professional and community organizations. Category D includes owner-managers who use a high level of technology on their farm. Finally, category E includes farmers who are entrepreneurs managing a farm business and commercializing diverse products on the national market. Among the farmers we interviewed, farm size ranged from 1.5 ha to 370 ha with an average of 32 ha, and herd size ranged from 7 to 400 with an average of 47. Although most farmers lived and worked on their farm with their family and had learned to farm from their parents, farm size and herd size point to a high level of diversity among farms in the Santa Cruz area.

Farmers' Trees on Their Land

All farmers interviewed maintained trees on their land. The TOFs in the agricultural landscape of Santa Cruz were found in live fences, within pastures, in riparian areas, in home-gardens, around homes and farm buildings, and along trails and dirt roads. Eighteen farmers (62%) expressed a willingness to plant more trees on their land, generally in areas that were not productive including very steep slopes dangerous to cattle, and along farm boundaries, buildings or riparian areas. They were interested in planting tree species which were sources of timber and fruit and native trees that provide habitat and resources to wildlife (such as *Psidium guajava* and *Ocotea floribunda*).

Trees within pastures were generally in low densities and dispersed because they competed with grass for light, water, and nutrients and were viewed as reducing pasture productivity. Dispersed trees within pastures were occasionally pruned to limit shade. Shade management has been described as a key factor influencing farmers' decisions whether or not to maintain trees within pastures (Harvey and Haber 1999). Similarly, on farms in Santa Cruz, farmers selected trees that provided limited shade in pastures in order to prevent excessive soil humidity and mud during the rainy season. Most trees within pastures were remnant trees. Farmers explained that they did not plant trees in pastures because the livestock would browse or trample the seedlings. Farmers practise pasture rotation, but the rotations are not sufficiently long to allow saplings to grow large enough to resist livestock damage.

Farmers cited few tree species that can be used in live fences and all of them were native species. *Erythrina* sp. (Coral tree) was the most common and traditionally used native species; *Trichanthera gigantea* (Trichanthera) and *Drimys* sp. (Moor Pepper) were also mentioned. In the areas of El Volcan, Las Abras, and Los Bajos, *Erythrina* sp. did not grow because of the altitude. In Las Abras and Los Bajos, *Drimys* sp. was used for live fences. No species was reported to be adapted for live fences in the area of El Volcan. The main

Table 1 Typology of the five different categories of farmers and farms ($n = 29$*)

Category and number of farmers of each category within the sample	Characteristics of farms and farmers' Strategy
A Traditional dairy farmer (5)	Dairy cattle and traditional cheese production sold to a local retailer Basic technological level of the farm No other activities
B Farmer adopting product diversification (10)	Dairy cattle and traditional cheese production Diversifies his production with pig, poultry or vegetables Will to develop the farming activity by improvement or extension of current production
C Farmer involved in professional and community organisations (4)	Dairy cattle production and traditional cheese production Diversifies his production with pig, poultry or vegetable but also different type of cheese, new types of products, tourism activities Involved in local organisations, local initiatives, in relation with other stakeholders and institutions
D Owner-manager (6)	Dairy cattle production with higher technological level Development of non-traditional activities: milk marketing, small cheese factory processing new types of cheese
E Entrepreneur managing a farm business. Owner with a high education level (4)	Diverse products including dairy and meat products sold to a national market High technological level with international standards Professional technical team.

*Some data from one of the 30 interviews was missing, so we considered only 29 interviews for this table

advantage of a live fence is its suitability for vegetative propagation using cuttings, which is easy and inexpensive[1]:

> "You look for the larger branch of the tree, you cut it, you plant it and that's all. It doesn't cost a thing and it's easy." "If I produce my own posts [for live fences] I don't have to buy them, the farm saves on it." [Farmer respondent 4]

To limit shade, *Erythrina* sp. trees are pollarded regularly. Young branches and leaves known to be very palatable for cattle are used as fodder. They are also sometimes used as green fertilizer. Trees are pollarded once or twice per year depending on branch length. The cut branches that are straight and long enough (so that the leaves were out of reach of the cattle) are used as cuttings, which are planted directly in the ground in order to create new fences, thicken existing fences, or replace dead trees. After three years, the young trees are ready to be pruned. The wood provided by the other cut branches is chopped and used as fertilizer or fuel wood. To improve the barrier-quality of the live fence, four strands of barbed wire are usually fixed onto the living posts; this was sometimes considered a drawback as barbed wire can injure livestock. However, a few farmers began using insulators to attach electric fencing, rather than barbed wire onto the living posts.

Values Given to Trees

We established a link between farmers' reasons for having, maintaining, using, or planting trees and farmers' values concerning trees (Table 2). Farmers expressed technical, economic, ecological, social, and cultural values of trees (Louman *et al.* 2016). Those most cited were: provision of posts for live fences (83%), timber production (79%), wildlife

Table 2 Values given to trees by farmers/ *farmers' reasons* and the number of farmers that have expressed them in the Santa Cruz area in Costa Rica ($n = 29$*)

Values given to trees by farmers/ Farmers' reasons	Number of farmers that have expressed the value	Percentage of farmers that have expressed the value
Technical value		
- *Posts for live fence*	24	83
- *Cattle shelter*	19	66
- *Pasture fertilisation*	10	35
Economic value		
- *Source of timber*	23	79
- *Source of fuelwood*	16	55
- *Provision of fruit*	14	48
- *Provision of fodder*	5	17
Ecological value		
- *Wildlife protection*	21	72
- *Watershed protection*	18	62
- *Air quality*	7	24
- *Soil protection*	4	14
- *Microclimate*	2	7
Heritage	10	35
Aesthetic	13	45
Cultural	3	10
Social value		
- *Recreational*	3	10
- *Sharing*	2	7
- *Medicinal*	1	4

*Some data from one of the 30 interviews was missing, so we considered only 29 interviews for this table

[1] Successful propagation by cuttings has also been identified as a reason why smallholder famers preferred certain tree species in live fences in Costa Rica and other Central American countries (Budowski and Russo 1993). This practice exists also in Ethiopia (Ango *et al.* 2014) and in the Comoros Islands (Sibelet 1995).

protection (72%), shelter for cattle (66%), watershed protection (62%), and source of fuel wood (55%). Fodder production, reported as a common use of trees outside forests elsewhere in Costa Rica (Morales-Hidalgo and Kleinn 2001) was infrequent in Santa Cruz and windbreaks were absent.

Farmers in categories A and B expressed mostly technical and economic values for trees. They value the additional production of goods and services trees provide. Farmers in all categories expressed ecological values of wildlife and water protection. These values may be transmitted through environmental awareness campaigns carried out by local institutions and associations as well as through the media. Farmers in categories C and D expressed technical and economic values but they also expressed heritage, recreational, social, cultural and medicinal values. Farmers in category E expressed fewer technical and economic values but more diverse ecological ones including that trees provided ecosystem services that benefited the farm and the environment. Overall, there is not a significant distinction of values among the different categories of farmers, just trends.

Technical Values

Technical values of trees are related to uses that supported or improved farming activities such as posts for live fences, shelter for livestock, or fertilizer for pasture. Farmers considered trees in live fences differently depending on the fence's function: whether it divides pastures within the farm or is located along the farm's border. To border the farm and mark the property line, as in many other countries (Altieri and Farrell 1984; Saïd and Sibelet 2004), live fences were recognized as having the advantage of being rooted, and thus more durable than a fence post:

> "In the farm boundaries there are live fences because it is more strict: it is unforgivable that cows get out of the farm, nobody wants the neighbour's cow to come and graze your pastures." [Farmer respondent 19]

To divide pastures within the farm, some farmers preferred electric fences because they needed only one or two wires, not barbed wire, so they would not harm cattle. Farmers' uses and considerations of live fences did not differ from research findings in other areas of Central America (Chacón León and Harvey 2006; Harvey *et al.* 2005; Love *et al.* 2009).

Live fences are an important feature of the agricultural landscape of Santa Cruz. Key informants reported that converting fences to live fences would increase positive impacts on conservation. Indeed, a previous study in a predominantly pasture landscape in northern Costa Rica showed that converting all fences to live fences would increase the ecological impact of live fences and would have a positive impact on landscape connectivity by increasing the physical connectivity (Chacón León and Harvey 2006). Finally, trees were also valued as shelter, mainly to give cattle shade from the sun but also from the rain: as one farmer noted, "trees are my best cowshed." Although few farmers valued trees as fertilizers through nitrogen fixation or organic input of dead leaves and wood, some did consider *Erythrina* sp. useful for these attributes.

Economic Values

Economic values are related to production of goods including timber, fuel wood, fruit, and fodder. Timber from exotic (*Cupressus* spp., *Eucalyptus* spp. or *Pinus* spp.) as well as native species is used mostly on the farm to build the house and various farm structures (cowshed, dairy, cow-paths in the pastures, fence posts). In the isolated areas of Los Bajos and El Volcan, timber is still the only available construction material as the impassable road prevents delivery of goods from outside. A few farmers reported commercialisation of timber, which is sold in the neighbourhood and through social networks. Although the goal of commercial timber operations is to increase income, it is not very profitable due to the small scale, and space and time it takes away from other farm activities:

> "It was a way to get me a Christmas bonus. But I'm not doing it again."[Farmer respondent 19 who planted 60 cypresses and sold them at 2 years old.]

Few data are available in Costa Rica about the economic importance of timber use of TOFs. However, the amount of timber they provide compared to the total amount of timber officially produced nationally has increased since 1990 (Morales-Hidalgo and Kleinn 2001). Timber is the most traded product of TOFs. Timber trading has to be authorized by the Ministry of Environment and Energy through the issue of logging permits. Unfortunately, there are no clear policies concerning the management of timber as a natural resource (Morales-Hidalgo and Kleinn 2001). However, several studies have reported the considerable potential for trees on farmland to be commercialized on the national timber market and thus provide a new source of income for small farmers (Harvey and Haber 1999; Scheelje Bravo 2009). Nonetheless, the potential ecological impact of such a development has not yet been assessed.

Fuel wood is another form of economic value for trees. Some households still use only fuel wood for cooking even though electric and gas stoves are common. In the highest areas, farmers also have fireplaces. Sources of fuelwood are fallen trees, unwanted trees, and wood left from pruning. If the quantity from these on-farm sources is not sufficient, the rest is obtained through social networks or is collected on neighbours' or relatives' land with permission.

The most common fruit tree is *Psidium guajava* (guava), which grows naturally. Other fruit trees reported (orange, lemon, banana, plantain, peach, medlar, elderberry, fig, avocado, palm) were given to farmers by neighbours and relatives. Fruit trees are planted near buildings and along roads and trails, and the fruit is used in the household to make juices, jams, and traditional recipes and to be eaten fresh. Guavas and bananas are used to feed cattle and pigs. A study of coffee farmers' perceptions of trees in the Nicoya Peninsula of Costa Rica reported that farmers generate additional income from the sale of fruit provided from several species of shade trees found within and along the edges of their coffee agroforestry systems (Albertin and Nair 2004). Farmers also assign economic value to live fences for the use of *Erythrina* sp. and *Trichanthera gigantea* leaves as animal fodder. Such use is marginal and was reported as a secondary food supply in times of shortage of grass.

Ecological Values

Ecological values were related to ecosystem services trees provide including wildlife, watershed, and soil protection, air quality and distinct microclimate effects. With regard to wildlife protection, one farmer stated: "I left this tree because quetzals and toucans come to eat the fruit, it is really nice." Farmers expressed values related to watershed protection especially when they pointed to the presence of trees along permanent watercourses and springs on their land, which they asserted help to prevent the watercourses from drying out:

> "I have the feeling [that] felling a tree here [along the river] would be like deciding to dry out the river. Just pastures without trees! I can't imagine the rivers are going to dry out!" [Farmer respondent 6]

Costa Rica's Forestry Law 7575 states that areas within 15 m of a watercourse and on slopes greater than 45 degrees are considered protected areas where logging is forbidden (MINAE 1996). During farm visits we observed that this is respected along watercourses situated between steep slopes, where logging the patches of native forest is undesirable due to their difficult access. However, the law has not been respected along watercourses in flatter areas, where often only a two-meter or narrower strip of trees remains. Although farmers are aware of the law, and no farmer we interviewed openly disapproved of it, they appeared not to know the specific areas that are considered protected. Key informants reported that farmers often consider that 15 m from a watercourse was "exaggerated" and thus rarely respected. Given the many watercourses in the mountainous landscape of Santa Cruz, riparian forests would provide high landscape connectivity if Forestry Law 7575 were fully respected. However, the law is vague about the type and size of watercourses concerned, though clarification prior to enforcement could decrease the feeling among farmers that the law is too strict and thus improve landscape connectivity and watershed protection.

In areas closest to the volcano, trees are considered protection for pasture from volcanic gases and ash and for their beneficial impacts on the microclimate beneath them:

> "Trees are like a big umbrella, when the volcano woke up, the pasture under them didn't get burned. Pastures don't get burned by the frost under the trees, they are necessary to protect the pastures." [Farmer respondent 1]

Indeed, trees are less vulnerable to ash than pasture (De Schutter *et al.* 2015) and their canopy foliage can intercept the particles of tephra from falling on the ground (Ayris and Delmelle 2012).

Social and Cultural Values

Little research has been done specifically on the socio-cultural aspects of TOFs in Costa Rica. However, one study of farmers' reasons for leaving trees in pastures around Monteverde found they included provision of fruit for human consumption, improved aesthetic quality of the farm, and medicinal uses (Harvey and Haber 1999). Another study investigated farmers' values of forest patch conservation in Coto Brus (Jantzi *et al.* 1999) and found that 24% of respondents referred to the beauty or value of nature that forest patches contribute to the farm. Morales-Hidalgo and Kleinn (2001) investigated the planting of fruit trees for household consumption near homes, and more recently, Louman *et al.* (2016) highlighted that when territorial process emphasizes the strengthening of social (organizational capacity, sharing of information) and human (health, education, technical assistance) capital, there is more probability that development efforts will be accompanied by a process of recovery of the trees in agricultural landscapes.

Our results also found that trees are maintained on farmland for their beauty and to enhance the scenery:

> "Trees were left here and now they are like an ornament. It is something nice to help feel good." [Farmer respondent 5]

Home grown fruit from trees is sometimes given to relatives, neighbours, and friends or is exchanged within social networks. The exchange corresponds to a social value while home-grown fruit has a cultural value. Using fuelwood to cook and to prepare traditional recipes represents sentimental and cultural values of trees:

> "It is a matter of tradition, to sit close to the warm woodstove and to save on electricity as well, but most of all for tradition. It is actually an expensive whim, to go with

> the car and the saw takes time, sometimes in quite rugged area, to get fuelwood. But, it is part of the tradition." [Farmer respondent 7]

Other cultural values are expressed as heritage values in farmers' strategies. Heritage value consists of maintaining timber trees to pass on as an inheritance and trees for transmitting knowledge. In relation to the former, the trees are traditionally used for construction and are given to children or grandchildren for them to build their houses. In relation to the latter, farmers want to leave trees so that their children will recognize them and know their uses:

> "It is important that my children know it: it is a blessing from God, each tree has its use. The cypress for example is good for timber but has no use for a lot of other things." [Farmer respondent 6]

Conservation of trees for the transmission of knowledge is also associated with native species that are perceived to be rare.

Forested areas that farmers preserve are also valued as places to spend time with family and as a tourist attraction, which represented a recreational value. Two farmers we interviewed have developed agro-tourism activities on their farms to appeal to tourists who can enjoy the area and see farming activities, native trees and their uses, and the animals they attract. Although rare, some farmers also pointed out the medicinal value of certain species of native trees.

Similar social and cultural values have been witnessed in other contexts. For example, villagers gave social values to trees as sacred places, landmarks, and sources of medicine, as well as for their aesthetic qualities (Rival and Gilroy 1998), in Zimbabwe (Goebel *et al.* 2000; Mandondo 1997), in the Comoros Islands (Saïd and Sibelet 2004), in Madagascar (Marie *et al.* 2009), and in Greece (Stara *et al.* 2015). Although these values are marginal compared to the technical, economic, and ecological values expressed, they still contribute to the ways in which farmers value and maintain trees, as Oestreicher *et al.* (2014) suggest in their study of livelihoods in the Brazilian Amazon.

Limitations to Tree Retention And Tree Planting

As shown above, farmers already place considerable value on trees on their land. However, they consistently mentioned several factors that limited the presence of trees on their land, which relate to: (i) financial capital, (ii) human capital, and (iii) land tenure. First, farmers stated they lacked sources or financial means to obtain seedlings or saplings. Second, labor availability is the key issue related to human capital, and farmers especially mentioned lack of time to maintain or plant trees. Third, smallholder farmers considered they lacked sufficient land to maintain or plant trees. According to key informants, farms are becoming smaller, which increases competition between trees and pastures.

Additionnally, technical factors were mentioned including: tree species adapted to the many altitudinal ranges in Santa Cruz varied and farmers in the highest areas indicated a lack of species suitable for live fences. Farmers cited difficulties in protecting saplings in pastures from livestock damage and mentioned it is more feasible to protect them in live fences. They also cited a lack of natural regeneration within pastures. Fencing around young trees in pastures would prevent livestock damage them and increase their chances of growing to maturity. However, protecting saplings within pastures is not considered feasible as it is time-consuming, would require more fencing material, and would reduce pasture area. Live fences can be an option for low-cost establishment of trees in pasture landscapes as they protect seedlings and young trees from cattle damage (Love *et al.* 2009). Lack of natural regeneration within pastures might cause a decrease in overall tree cover in the future. One way to prevent this decrease may be to incorporate animal-dispersed tree species into those used in live fences (Benayas and Bullock 2012), and thus should be considered by local authorities and organizations.

Six farmers (20%) reported attempts to propagate trees on their land. They collected seeds from native timber trees or from rare native trees they appreciated and planted them in an on-farm nursery. The seedlings were then planted and protected from livestock. Some farmers, aware of the damage cattle can cause to trees, transplanted saplings from pastures to protected areas inside fences or riparian areas. Nevertheless, not all of these attempts were successful, which highlights the need for technical assistance and research and development to better incorporate trees on farmland. This assistance would need to involve local people in determining appropriate techniques and practices to guarantee better tree planting (Galabuzi *et al.* 2014; Rives *et al.* 2013). Farmers also reported a lack of technical knowledge about tree species and management and mentioned a lack of technical assistance:

> "I don't know which tree I could plant and there is no one advising us about that." [Farmer respondent 27]

Opportunities for Retention and Planting of Trees

Farmers' perceptions of limitations suggest that two levels of action are needed in order to encourage an increase in the retention and planting of TOFs. First, there is a need for technical support to address the problems encountered by farmers who are already active in planting trees. Second, further research is needed in order to better understand the issues related to land, labour and finance, and how they play out for the different categories of farmers described earlier, and to identify points for potential intervention. We consider each of these points in turn, and conclude with some additional suggestions related to forest policy.

In relation to technical support, there is considerable scope for immediate collaboration with farmers through extension assistance. The National Training Institute (Instituto Nacional de Aprendizaje- INA) provides a variety of training opportunities related to agriculture, and offers a potential institutional framework for this kind of support (Instituto Nacional de Aprendizaje 2017). At a basic level, assistance with the sourcing of saplings, with the selection, adaptability, management, and use of different tree species, and with aftercare (particularly low-cost forms of protection of saplings from livestock) would answer some of the farmers' perceived needs. Support for the conversion of fences to live fences is a particularly promising area for extension work because of the high value that farmers place on them, but there is also scope to support farmers in simply planting trees for shade. In connection with the latter, further research is needed to determine tree density and spatial arrangements compatible with agricultural productivity (Harvey *et al.* 2008).

Extensionists could also promote additional measures to increase the conservation value of trees outside forests at no extra cost to farmers. For example, current pollarding and pruning regimes have an impact on habitat and resources available and limit colonisation by epiphytes, which provide additional resources for wildlife (Harvey *et al.* 2005). Seasonal changes in these regimes could have a positive impact on landscape connectivity (Harvey *et al.* 2005).

In relation to the limitations connected to finance, labour, and land, externally driven financial incentives for conservation may have a role to play. Payments for Ecosystem Services (PES) were introduced in the study area as an economic incentive created in recognition of the services that forests provide, such as water and wildlife protection and landscape beauty (Porras 2010). They could compensate for the additional resources and labour that tree maintenance requires (Estrada Carmona 2009). In 2003, agroforestry contracts were introduced within the PES schemes to encourage small farmers to participate, but to date their use remains limited and further modifications are required in order to appeal to small farmers (Estrada Carmona 2009; Porras 2010). To encourage tree retention on farms, any future PES should be high enough to compete with opportunity cost for farmers, in other words, they "should equal the costs incurred by retaining trees" (Key informant). Thus, through encouraging tree maintenance on farmers' lands, the PES scheme may continue to be a good supplementary tool to support the Biological Corridor.

Nonetheless, a high level of reliance on financial incentives would be risky in that they can create project dependency (McNeely 1988; see also Haltia and Keipi 1997) and weaken existing non-monetary values (Current and Scherr 1995; Fischer and Vasseur 2002; Koontz 2001). Our research suggests that much progress can be made without resorting to PES, through the use of participatory approaches to support existing values. This is in line with work by Louman *et al.* (2016), who found that a combination of efforts toward strengthening human, cultural, and social capitals had a greater effect on the presence of trees than the Forest Law of 1996 with its PES scheme.

Lastly, there is also a role for strategic planning and policy measures. New planning policies could be developed to promote tree cover in areas where it is lacking and between riparian areas, providing connectivity between native forest patches. Raising awareness about and enforcing the relevant stipulations in Forestry Law 7575 regarding riparian areas could increase this kind of forest cover. The adaptations of MINAE requirements and regulations regarding riparian areas and logging permits on farmland could be revised and enhanced to ensure conservation but also to allow sources of income and goods that benefit social and economic conditions of farmers.

Conclusion

Although major conflicts have been reported concerning tree retention within cattle pastures, we have shown that, at least for the case study site, there is a surprising amount of common ground between conservationists and cattle farmers and therefore high potential for tree retention. Farmers do maintain TOFs on their land for a diversity of reasons. All farmers attribute diverse values to trees, including technical values, through the provision of live fences or shelter for cattle; economic values, as sources of timber, fuel wood, or fruit (e.g., guava, bananas, peaches, among others); ecological values, for wildlife and watershed protection; and also social, cultural, aesthetic, and heritage values (inheritance of trees, transmission of knowledge, beauty of landscape). Two thirds of the farmers interviewed expressed a willingness to plant more trees on their land, generally in areas that were not productive such as very steep slopes dangerous to cattle, on the farm boundaries, alongside buildings, or along riparian areas. They were interested in planting tree species that are sources of timber and fruit, and native trees that provide habitat and resources to wildlife (such as *Psidium guajava* and *Ocotea floribunda*). One out of five of the farmers interviewed had tried to propagate trees on their land through experimental plantations or transplantations. However, these efforts were undermined by technical difficulties (transplantation, native species germination). Therefore, rather than simply rely on financial incentives, which are costly and difficult to sustain over the long term, there is considerable scope to work with farmers on areas of common ground, to manage TOFs in ways that address farmers' values as well as maintaining or increasing their lands' externally defined conservation value. This is in line with the concept of 'land sharing' in that the land continues in (intensive) production but with added conservation value.

In our view, conservation education and financial incentives such as PES are best used as supplementary measures to address and 'shrink' remaining areas of conflicting interest. These measures could be regarded as more in line with 'land sparing' in that they are based on the premise that current values and/or practices are not compatible with conservation and therefore that external values and incentives are needed. Obviously the extent to which this is the case varies from site to site. What we have attempted to show in this article is the extent to which a rather simple qualitative research process can reveal a surprising degree of common ground, even for dairy farming, which is widely regarded as incompatible with conservation.

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