CHAPTER 5

Community-based agroforestry initiatives in nicaragua and costa rica

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Introduction

Curbing the loss of biodiversity is a primary challenge to conservationists. Estimates of current rates of species loss range from 14,000 – 40,000 species per year (Hughes *et al.*, 2007), and although a variety of factors are implicated, habitat loss is repeatedly cited as an important cause (Sala *et al.*, 2000). Most ecosystems are under some degree of threat, however the loss of biodiversity associated with the destruction of tropical forests is a central concern (Bradshaw *et al.*, 2009). Tropical forests are occupied by 60% of the planet's species (Dirzo and Raven, 2003), yet they are also valued as timber and for agricultural land. As the result of logging and conversion, the world's tropical forests are being lost at a rate of 1.2% per year (Laurance, 1999), and the rate of deforestation appears to be accelerating (Hansen and DeFries, 2004).

The establishment of protected areas continues to be a central component of efforts to protect biodiversity; however it will be challenging to fully represent the world's biodiversity in protected areas in the face of the competing demands of a growing human population with its increased need for land and natural resources (Lele *et al.*, 2010). Human populations are projected to increase by 2-4 billion by 2050 (Cohen, 2003) with most of the increase occurring in developing countries, and although a growing proportion of the population is projected to occupy cities (Aide and Grau, 2004), human populations as well as the demand of city dwellers for natural resources from surrounding rural areas will still increase substantially (Laurance, 2007). These problems are compounded by the political instability that characterizes many tropical regions, which makes the enforcement of land protection difficult and ineffective, as well as widespread rural poverty, which brings the ethics of enforcement of land protection into question (Lele *et al.*, 2010).

In recognition of the logistic, political and humanitarian limitations of strict protection, agroforestry has become widely recognized as a supplementary component of biodiversity conservation. Agroforestry has been defined as "practices that involve the integration of trees and other woody perennials into farming systems" (Schroth *et al.*, 2004: 2). The original motivation for the development of agroforestry systems was to produce crops that were dependent on shade, or crops that were derived from trees (Sommariba *et al.*, 2004). More recently, access to specialty markets, as in the case of shade grown coffee (Rainforest Alliance, 2000), or direct payments for ecological services (Pearce and Moratue, 2004; Lele *et al.*, 2010) have provided additional motivation for the adoption of agroforestry by farmers in tropical regions. In this chapter, we discuss the value of agroforestry systems for conserving biodiversity, illustrating its potential and limitations in relation to two projects we have undertaken, one in Nicaragua in mixed productive systems featuring allspice (*Pimienta dioica*), and the other in Costa Rica in coffee (*Coffea arabica*) agroecosystems.

Agroforestry and biodiversity

Agroforestry systems can contribute to the conservation of biodiversity either by providing habitat directly, or by moderating the negative influences of the matrix surrounding remnant forests (Schroth *et al.*, 2004). Through its retention of tree cover, agroforestry systems can increase the structural similarity of agricultural areas to forest. Since in areas subject to high rates of deforestation, species associated with forest are typically the most threatened (Rappole *et al.*, 2003a), the conservation value of agroforestry systems is determined by the extent to which they resemble forest. Bhagwat *et al.* (2010) reported that on average, species richness in agroforestry systems was 60% of the species richness in forest. Agroforestry could increase tree cover in fragmented landscapes, providing habitat for species able to use non-forest, tree-dominated habitats. Additionally, agroforestry could potentially increasing connectivity among forest fragments (Laurance, 2004). Isolation has been shown to decrease the viability of forest species in remnant forest patches (Stouffer *et al.*, 2006). It is possible that some species that are unable to occupy agroforestry habitats could still benefit by tree cover in these habitats, providing protection and facilitating movement between remnant forest patches and potentially increasing population viability (Haslem and Bennett, 2008). Finally, forest fauna in remnant patches surrounded by open areas such as fields or pastures can be threatened by dessication from solar insulation or wind, factors that change microclimate conditions and perhaps food abundance (Laurance and Curran, 2008). It is hypothesized that forest remnants embedded in agroforestry would be buffered to a greater extent from these edge effects (Mesquita *et al.*, 1999).

An alternative way in which agroforestry could contribute to the conservation of biodiversity is by altering the behavior of farmers in relation to land use. Agroforestry systems typically include crops grown for extra cash or subsistence (Moguel and Toledo, 1999). Products such as fruit and fuelwood grown within agroforestry systems can replace resources traditionally extracted from forests that would otherwise be extracted from protected areas (Murniati *et al.*, 2001) reducing the dependence of rural people on forest reserves (Caviglia-Harris and Sills, 2005; Illukpitiya and Yanagida, 2008). Additional income from agroforestry crops, particularly higher value crops certified as "environmentally friendly", can also help alleviate rural poverty, which is strongly associated with the degree of dependence on forest resources (Murniati *et al.*, 2001). Forest resource extraction is considered a difficult and low-return activity that imposes an opportunity cost in terms of the allocation of labor to more profitable activities if available (Illukpitiya and Yanagida, 2008). Intact forests have values as windbreaks, erosion control or water supply that are recognized by farmers who might be expected to leave forests standing if other options are available (King *et al.*, 2006). The assumption that increasing income and intensifying production in buffer areas by means such as agroforestry will reduce pressure on core areas of reserves is an implicit assumption of many integrated conservation development plans (Murniati *et al.*, 2001).

Although agroforestry has the potential to promote biodiversity conservation by providing habitat for native tropical fauna and influencing farmer behavior, by itself it will be insufficient to maintain the entirety of tropical biodiversity (Bhagwat *et al.*, 2010; DeClerck *et al.*, 2010) because many forest-dependent species are absent from agroforestry habitats, as well as the possibility that increased income from agroforestry could result in increased demand that could increase deforestation (Rappole *et al.*, 2003a, b; Tejeda Cruz *et al.*, 2010). Nevertheless, the potential of agroforestry to provide an important component of a program for biodiversity enhancement could be realized, contingent on the recognition of its limitations as habitat, as well as critical evaluation of the effect of incentives on land use.

Assessing the value of allspice cultivation for conserving tropical biodiversity

In 1999, a collaborative project was undertaken by the Mesoamerican Development Institute (MDI) in cooperation with the Programa Campesino a Campesino (PCAC), the Nicaraguan Government, and the World Bank/Global Environment Facility (GEF) directed at alleviating rural poverty and stemming biodiversity loss in north central Nicaragua through the cultivation and processing of allspice. This region is a suitable area for this project because at the time Nicaragua was one of the poorest countries on Earth, with an average annual income of $1080 (Word Bank, 2010). The area is also unique from the standpoint of biodiversity conservation, in that it encompasses part of the Bosawás Biosphere reserve, the largest contiguous remaining tropical rainforest in Mesoamerica Smith, 2003; Figure 1).

Figure 1. Map indicating the approximate locations of the allspice project near Siuna Nicaragua and the coffee project at the Montes de Oro Cooperative, Costa Rica.

The Bosawás reserve was created in 1991 using the core-buffer model, in which local residents and government officials established management use zones, in which different activities would be allocated. These uses range from strict protection in the Saslaya National Park, which forms the core of the reserve, to varying levels of human use in the buffer zones (Smith, 2003). This core-buffer model is a classic example of the integrated conservation development plan (ICDP) in that it represents an attempt to increase support for conservation through a compromise between conservation goals, economic development and local self-determination (Smith, 2003).

The landscape in this area is a diverse mosaic of patches of remnant primary forest, degraded or regenerating secondary forest, mixed plantings of coffee, cacao, citrus and native overstory trees, pastures gardens and cereal crops (Smith, 2003). At the time of the study, allspice was being cultivated by a cooperative of nearly 100 subsistence farmers (CoopSiuna) in the buffer zone of the Bosawás Biosphere Reserve. This area has been settled only relatively recently by ex-combatants from Nicaragua´s civil war and, as a result, forest clearing for subsistence farming has increased along with extensive livestock operations, commercial logging, and mining (Smith, 2003). Despite efforts at control, deforestation was still progressing rapidly in the project area at a rate of about 2.1%/yr (GEF, 1997) and, within the reserve, the extent of agriculture and scrub habitat increased dramatically between 1986 and 1995 (Smith, 2003). Much of the forest clearing was by large land holders or commercial ventures. However at the inception of this project, the agricultural frontier had been pushed well into the reserve as the result of forest clearing by campesinos for small-scale commercial and subsistence farming.

The motivation for the project was the observation that the *status quo* situation in the Siuna region was not serving the interests of either rural communities, who were unable to adequately support their families through agriculture as practiced, or the interests of conservation, as indicated by continued deforestation in the Bosawás reserve. This project was based on the premise that intensive cultivation of value-added agricultural products would provide a break from the reliance on conventional agriculture, which on the region's poor and easily-eroded soils, contributes to the advancement of the agricultural frontier. Farmers value forest for a variety of ecosystem services, including watershed protection and non-timber products, and we assumed they would be motivated to conserve forest if alternative forms of making a livelihood that do not require deforestation were available.

Pilot research indicated that allspice showed high potential for providing the type of value-added agricultural projects that would provide these agroeconomic and biodiversity benefits. Allspice is a native understory tree belonging to the family Myrtaceae that occurs naturally in the Siuna region as well as the West Indies, Southern Mexico, much of Central America and the Caribbean. Allspice produces an aromatic fleshy fruit, as well as aromatic leaves, that are employed in cooking as well as medicines and aromatherapy. In most areas, including Siuna, the fruits of allspice are harvested and sold in their unprocessed form to middle men who sell the fruits to processors who then gain the value added from the sale of these processed products. The price paid to subsistence gatherers is very low, \$0.06-0.18/kg, which in addition to failing to support farmers economically, results in allspice trees having such low value that in many cases allspice fruits are harvested by felling the mature trees.

The production of value-added products from allspice consisted of two parts. The first was the production of raw allspice in sufficient quantities for processing. The second was the design and establishment of an inexpensive and durable processing plant for the extraction of essential oils. Both of these activities were undertaken by 54 community members who organized as shareholders of a new company as part of a community-level enterprise, the "Cooperativa Agropecuaria de Servicios de Extracción de Aceites Escenciales R.L.", which was formed during the preparation for this project. This effort included a business plan and feasibility study. Officers were elected and bylaws adopted during a series of workshops after which the new enterprise was incorporated with a small working capital fund with funds pooled from each member.

The combined area of parcels was 1,708 ha Inventories done by the Programa Frontera Agricola and the Programa Campesino a Campesino showed that at the outset 130 trees were in production. An additional 1,691 young trees (< 6 yrs) were expected to be in production within 2-4 yrs, and 16,500 young trees were being produced in a shareholders nursery. Allspice seedlings were established from seed and, after a single growing season, were interplanted with other crops such as coffee, bananas or citrus in a mixture determined by the individual farmer (Figure 2). The establishment of these "agroforestry systems" was intended to provide farmers with additional income and to buffer them from potential fluctuations in allspice price or supply. Allspice plantations matured rapidly, with 3-5 year old plants averaging >3 meters tall.

Figure 2. Allspice cultivation at the CoopSiuna cooperative in north central Nicaragua, 2002. Allspice plants are started from seeds in a nursery (a.) and are later planted in an agroforestry system (b.) with coffee, bananas, citrus and shade trees. Allspice is indicated by the white arrow in the image to the right.

The cultivation of allspice in a mixed productive system was significant from a biodiversity perspective. Pastureland in many areas of the tropics loses its fertility rapidly after clearing, and it is partially this rapid degradation that provides the motivation for continued deforestation. Degraded pastureland also has extremely low biodiversity value because the plant species diversity and structural complexity that determines species diversity are very low in these habitats. Degraded pastures are suitable for the establishment of agroforestry systems, however, and agroforestry systems have high plant diversity and structural complexity compared to pastures. Numerous studies have shown that agroforestry systems for coffee and cocoa support high numbers of native species of birds, mammals and reptiles and amphibians (Wunderle and Latta, 1996; Estrada *et al.*, 1997; Greenberg *et al.*, 1997a, b, 2000; Reitsma *et al.*, 2001; Hughes *et al.*, 2002; Daily *et al.*, 2003; Perfecto *et al.*, 2003; Tejeda-Cruz and Sutherland, 2004; see also Lin and Perfecto and, Bos and Sporn, this volume).

Based on these earlier findings, we sought to investigate the biodiversity value of allspice in Nicaragua. To accomplish this, we made systematic measurements of bird, mammal and reptile/amphibian abundance at allspice farms in the region in areas consisting of tropical moist and wet forest between 170 and 600 m in elevation (Box 1).

Box 1. Sampling design

The details of the study are described here briefly, but more detail can be found in King *et al.* (2007). We sampled biodiversity in four distinct habitats. First, we sampled primary forest because it represents the original habitat in the region that is currently threatened, and thus from a conservation standpoint, the biodiversity characteristic of primary forest would represent a standard by which other habitats could meaningfully compared in terms of their conservation value for biodiversity. Primary forest areas existed as large (>30 ha) patches of forest that had experienced no timber harvest, and were characterized by large, tall trees and open understory. We also sampled secondary forest because it is a widespread habitat with a more generalized fauna. Secondary forest had most of the original canopy removed, and had shorter, smaller trees and denser understory than primary forest. Allspice agroforestry systems consisted of allspice (~ 45%) that had been planted in pasture with other commercially valuable species such as coffee, cacao, and citrus (~ 5%) between 3 to 5 years before the commencement of the study. Allspice had shorter, smaller trees than secondary forest, but similar understory structure. Finally, we sampled pasture, because allspice plantations are to be planted on pasture, and the difference in biodiversity between allspice and pasture represents the increase in biodiversity attributable to allspice cultivation. Pasture areas consisted of grazed or recently grazed areas with grass or forb cover with scattered shrubs.

We sampled birds at 23 sites (six sites in each habitat, except five in secondary forest) from January–April 2003 and 2004 using mist nets (Karr, 1981). Ten mist nets, 12 m x 3 m, with 32 mm mesh were deployed in each site, 50 m apart, on a grid approximately 200 m · 250 m. Each site was sampled for 250 net hours. All birds captured were identified and then marked to distinguish them from new captures by cutting the tip of a single rectrix (in the case of residents), or by banding with US Fish and Wildlife numbered bands (in the case of Neotropical-Nearctic migrants). Birds were then released near the point of capture. The identity of all species was established using field-guides, scientific keys and consultation with experts at the University of Nicaragua, Managua and elsewhere.

We sampled mammals at 27 sites (seven sites in each habitat, except six in secondary forest) from July–November 2002 and 2003 using a 40-m diameter circular trapping array with

15 sample points, five equally spaced on an inner 20-m diameter circle, and 10 on the outer 40 m diameter circle. Twenty Sherman folding traps (8 cm x 9 cm x 23 cm) were placed in pairs at each of the inner five points and at five alternate points of the outer circle, one on the ground and one approximately 1.5 m up in a tree or shrub. Small (15 cm · 15 cm · 48 cm) Tomahawk folding traps were placed at the remaining five outer sampling points. Care was used to minimize human scent, and all traps were placed as firmly as possible on the substrate and concealed with brush and leaves. Large (25 cm · 30 cm · 80 cm) Tomahawk folding traps were placed at the center of the five sections bounded by the inner and outer sampling rings. Traps were baited with bananas and peanut butter and checked every 24 h. Finally, five 1-m radius circular unbaited tracking stations were established per site by digging up and removing the ground litter and vegetation, and then smoothing the soil so that tracks could be observed and recorded. Track stations were checked daily during the week-long trapping session and the presence and identity of tracks recorded.

We sampled reptiles and amphibians at 19 sites (three sites in primary forest, five in secondary forest, seven in allspice and four in pasture) from July 2002 to April 2004 using a combination of pitfall traps and timed searchers. Pitfall traps approximately 30 cm deep were placed between each of the inner sampling points. Each pitfall had 31-m long, 15 cm high vertical fences sunk into the ground radiating out from the pitfall traps at equal angles. Pitfall buckets were filled with water 5 cm deep and had 3-mm diameter holes drilled into the sides 5 cm from the bottom to keep them from overflowing in case of rain. Searches for amphibians and reptiles were conducted during the seven days of each trapping session. On some of the sites, vegetation-sampling points were established on a random bearing 10 m from each of the 10 nets or the 10 outermost Sherman traps in a random direction. The number of times vegetation contacted a 3-m pole held vertically at this random point was recorded in three 1-m height classes. In addition, the distance from that random point to the nearest tree that is part of the canopy was measured, as well as the species of tree.

Mixed productive systems accommodated a substantial portion of native biodiversity in the Siuna region. For example, numbers of bird species captured in allspice (77) was similar to the number captured in primary forest (70), a result that was born out when these data were corrected for sample size using rarefaction (King *et al,*. 2007). It is likely that mistnets in primary forest captured a lower proportion of the avifauna than in allspice because the 3 m tall mistnets were only 0.125% the height of the canopy in primary forest, but 43% of the height of the vegetation in allspice plantations. While we acknowledge that primary forest diversity could be underestimated in our study, Chandler (2010) corrected captures for primary forest habitats, and concluded the bias for comparisons with agroforestry habitats in Costa Rica was slight, so we believe the general pattern of similar diversity between primary forest and allspice in our study is real. Allspice also supported a similar number of mammal (19 vs 16) and reptile/amphibian (12 vs 17) species as primary forest, results that also were borne out by the results of rarefaction analyses (King *et al.*, 2007).

These results are similar to patterns reported in studies of vertebrates in other types of mixed agroforestry in the tropics. For example, coffee, cacao and other countryside habitats harbor a large number of native species (Wunderle and Latta, 1996; Estrada *et al.*, 1997; Greenberg *et al.*, 1997a, b, 2000; Reitsma *et al.*, 2001; Hughes *et al.*, 2002; Daily *et al.*, 2003; Perfecto *et al.*, 2003; Tejeda-Cruz and Sutherland, 2004; see also other chapters in this volume). These studies have been viewed in a positive light by many, and taken at face value, suggest that crops cultivated in a mixed productive system can ameliorate the effects of the destruction of primary forests on native forest biodiversity. The high species richness, as well as the high number of species reported only in allspice, is particularly striking considering that the oldest of these allspice plantations was only five years old. As time progresses, the structure of the habitat will become more similar to primary forest, and will likely support even more species. In contrast, Estrada *et al.* (1997) studied birds and mammals in forest and allspice in Veracruz, Mexico, and found fewer bird species per census point in allspice (3.0) than forest (4.9), a difference that was more apparent in mammals (2.0 vs 10.8 species; allspice and forest, respectively). The allspice plantations studied by Estrada *et al.* (1997) were unshaded monocultures, so the greater similarity between the plantations in our study and forest could be an indication of the value of a polyculture versus a monoculture.

Despite the fact that species richness is comparable between allspice and primary forest for some taxa, there were substantial differences in species composition between primary forest and the other habitats. For example, the similarity in bird fauna between primary forests and secondary forests, allspice and pasture as indicated by Jaccard similarity-coefficients was 0.48, 0.30 and 0.30, respectively (King *et al.*, 2007), indicating there were species present in mature forest that were scarce or absent from the other habitats, and vice versa. This is consistent with the findings of studies of other types of agroforestry systems such as coffee and cacao that have been cited as illustrations of the limitations of these systems in conserving native biodiversity (Heinen, 1992; Greenberg *et al.*, 2000; Reitsma *et al.*, 2001; Naidoo, 2004; Tejeda-Cruz and Sutherland, 2004). Bird species that were exclusively or more frequently caught in primary forest compared to secondary forest in this study were similar to those caught most often in forest in a similar study in Mexico (Tejeda-Cruz and Sutherland, 2004), and include mostly mid- and understory insectivores such as ovenbirds (Furnariidae) whose foraging opportunities diminish in relatively simplified agroforestry habitats.

Our observation that many forest specialists are scarce or absent from mixed productive systems containing allspice reflects an established consensus that agroforestry habitats are not sufficient to conserve forest specialists (Rappole *et al.*, 2003a; Tejeda-Cruz and Sutherland, 2004; Bhagwat *et al.*, 2008; DeClerck *et al.*, 2010), and that the tasks that remain to be accomplished vis-à-vis agroforestry and biodiversity conservation is to refine their application to increase their value for species that use them, as well as to explore socioeconomic aspects of their application that contribute to forest conservation. As an example of the former, allspice at our sites contributes to conservation of biodiversity because the mixed productive systems were sites converted from intensive agriculture to allspice through plantings. Thus, at the most elementary level, the cultivation of allspice provides a more complex habitat that will support more native species than the pasture it is replacing (Moguel and Toledo, 1999; Tejeda-Cruz and Sutherland, 2004).

In addition to the value of allspice as habitat for tropical species, the cultivation of allspice will create economic incentives that will further contribute to the conservation of biodiversity. The cultivation of allspice will reduce the economic incentive for the felling of mature allspice trees in areas of virgin forest, as was the previous practice. Previously allspice was exported in its whole form, and thus, the fruits had little value added. This type of disincentive to conserve low value forest resources was reported in Indonesia by Tyynela *et al.* (2003), who found that the value of non-timber forest products in their wild state was not a sufficient incentive to ensure their conservation. With the introduction of the technology for the production of essential oils, wild allspice trees will increase in value, which will discourage harvesting allspice by cutting down fruiting trees.

A final potential benefit that allspice cultivation could have relative to biodiversity conservation is related to the increased income that the marketing and sale of essential oils would provide. The alleviation of poverty is widely seen as an essential component of integrated conservation-development projects and similar programs (Bassett, 2010), and in Indonesia, income was a key predictor of dependency on resource extraction from reserves (Murniati *et al.*, 2001). Increased income can potentially cause an incentive to clear additional forest, especially in situations where there is a lack of idle, low value agricultural land, which is often the case in frontier areas (Tyynela *et al.*, 2003) or where the products derived have high value relative to other crops (*e.g.*, shade coffee) such that an incentive is provided for farmers to convert native habitats (Tejeda-Cruz *et al.*, 2010). Presumably a condition of certification for products from agroforesty systems could be that they were planted in reclaimed fields or pastures, although the use of pastures could force farmers to clear forest to grow subsistence crops in areas where cleared land is scarce (Tyynela *et al.*, 2003). We suggest the incentive for clearing to plant allspice at our sites is likely to be less pronounced because the concentration of value for allspice through distillation of essential oils will make the production of allspice less extensive relative to an agroforestry system that yields a raw material. Finally, in this particular project farmers are exclusively reclaiming formerly intensively-cultivated agricultural land for the cultivation of allspice.

Conserving forest-dependent species in coffee agroecosystems

Coffee is the second most valuable internationally traded commodity after petroleum, valued at $10 billion annually in Latin America alone. Coffee cultivation occupies a large percentage of the arable land in the moist tropics, accounting for 38% of cultivated land in Mesoamerica (FAO, 2008). This illustrates the tremendous economic force of coffee cultivation in shaping land use and habitat availability in the tropics, and combined with the observation by many researchers that species richness is typically high in shade coffee, has caused many to view shade coffee as an important component of biodiversity in the tropics. This is especially true in cases where shade coffee is being replaced by monocultures of sun coffee, which has very little value as habitat for native tropical species. The relatively high species diversity in shade coffee has been communicated to coffee consumers through public relations campaigns (Conservation International, 2000; National Audubon Society, 2000; Rainforest Alliance, 2000), which have increased demand for shade coffee, and thus, price (Philpott *et al.*, 2007). Farmers are able to charge more for shade coffee, and this increased price provides an incentive for farmers to maintain habitat for species in shade coffee farms. Thus, shade coffee has potential as a market-based mechanism for maintaining tree cover in coffee growing regions.

The potential of shade coffee for conservation has been undergoing some refinement in recent years. Criteria that specify habitat characteristics that must be maintained in coffee farms for farmers to qualify for official certification have been updated to include features in addition to shade trees, such as bromeliads (Philpott *et al.*, 2007). Nevertheless, examinations of biodiversity in shade coffee systems have shown that there are forest-dependent species that do not occupy shade coffee farms (Greenberg *et al.*, 2000; Reitsma *et al.*, 2001; Naidoo, 2004; Tejada-Cruz and Sutherland, 2004) resulting in a recognition that shade coffee is insufficient to represent important elements of tropical biodiversity (Rappole *et al.*, 2003a; Tejeda-Cruz and Sutherland, 2004; DeClerck *et al.*, 2010). This potential rests on the assumptions that the incentives of increased prices for shade coffee won't result in the conversion of native habitats to coffee or the conversion of complex shade coffee systems to simplified ones to increase yield, and those certification systems are rigorously implemented, assumptions that need to be critically examined (Rappole *et al.*, 2003b). In view of these shortcomings, current efforts to link coffee production to biodiversity now include efforts to understand the effects of economic incentives on farmer behavior (Tejeda-Cruz *et al.*, 2010), define the role of shade coffee as a component of a comprehensive conservation program (Bhagwat *et al.*, 2008), and to develop additional market-based strategies for biodiversity conservation that would accommodate forest specialists that do not occur in shade coffee (Arce *et al.*, 2009; Chandler, 2011).

Another front on which progress is needed to enforce the connection between market forces and conservation is the need to address the challenges to farmers of accommodating biodiversity in farmed areas. These include the administrative and economic costs of certifying shade coffee, as well as decreases in yield, both of which can inhibit the participation of farmers in shade coffee programs (Arce *et al.*, 2009). Certification of shade coffee requires that individual farms are visited by professional certifiers that verify that the habitat elements specified in the criteria are adequately represented (Philpott *et al.*, 2007). This process requires farms to pay certifiers, which can cost farmers as much as \$140/ha (Gobbi, 2000), and could cancel out the increased income of certified coffee (Lyngbaek *et al.*, 2001). Additionally, certification requires the maintenance of detailed logs on management activities, which can be difficult for farmers who are illiterate, which includes a substantial proportion of farmers in many coffee growing regions (*e.g.*, Montes de Oro in Costa Rica; Figure 1). Finally, shade coffee certification schemes require a minimum amount of canopy cover to provide the type of tree-dominated habitat that make coffee farms valuable for biodiversity (Perfecto *et al.*, 2005). In regions characterized by low cloud cover and sparse precipitation, shade trees are beneficial to coffee cultivation and can increase yields. In moist areas with high cloud cover however, maintaining the required levels of shade can substantially reduce coffee yields by reducing plant vigor and increasing the incidence of coffee leaf spot disease (*Mycena citricola;* Avelino *et al.*, 2006) and other pathogens.

Efforts to link shade coffee to biodiversity conservation have demonstrated the potential for harnessing the vast market forces associated with coffee to shape land use and conservation in coffee producing regions (Philpott *et al.*, 2007), however it is also clear that additional refinements are needed to better represent biodiversity, and to address agroeconomic and administrative impediments to accommodating native biodiversity in coffee farms. In 2004, we initiated a research project directed at assessing the potential role of coffee cultivation for biodiversity conservation with the Montes de Oro coffee cooperative, located in northwestern Costa Rica near the town of Miramar in the buffer zone of the Arenal-Tilarán Conservation Area (Figure 1). The Montes de Oro cooperative is made up of 300 families who maintain over 10,000 ha, much of which is devoted to coffee production. At the Montes de Oro Cooperative, a system of coffee cultivation is employed that maintains native forest without sacrificing yields. In this system, termed "Integrated Open Canopy" or "IOC" Coffee (Arce *et al.*, 2009), coffee is planted in 1-3 ha patches with little or no shade depending on local conditions, but typically too little to qualify for shade coffee certification (Figure 3). An equivalent area of adjacent forest is conserved. A typical parcel within the Cooperative is 4-6 ha in size, which results in units of production consisting of 2-3 ha coffee and 2-3 ha of forest. There are three features of this system that bear directly on its potential as a market-based mechanism for conserving forest habitats. The first of these is that the system optimizes coffee yields due to lower incidence of disease and better fruit set resulting from abundant sunlight, combined with fertilization from leaf fall and wind protection provided by adjacent forest. The second important feature of this system is that it maintains actual forest habitat for species that do not use shade coffee plantations. Finally, the criteria for certifying IOC are very simple; the only requirements being that an amount of forest equal to the amount of coffee is maintained and no forest is cleared to establish IOC farms.

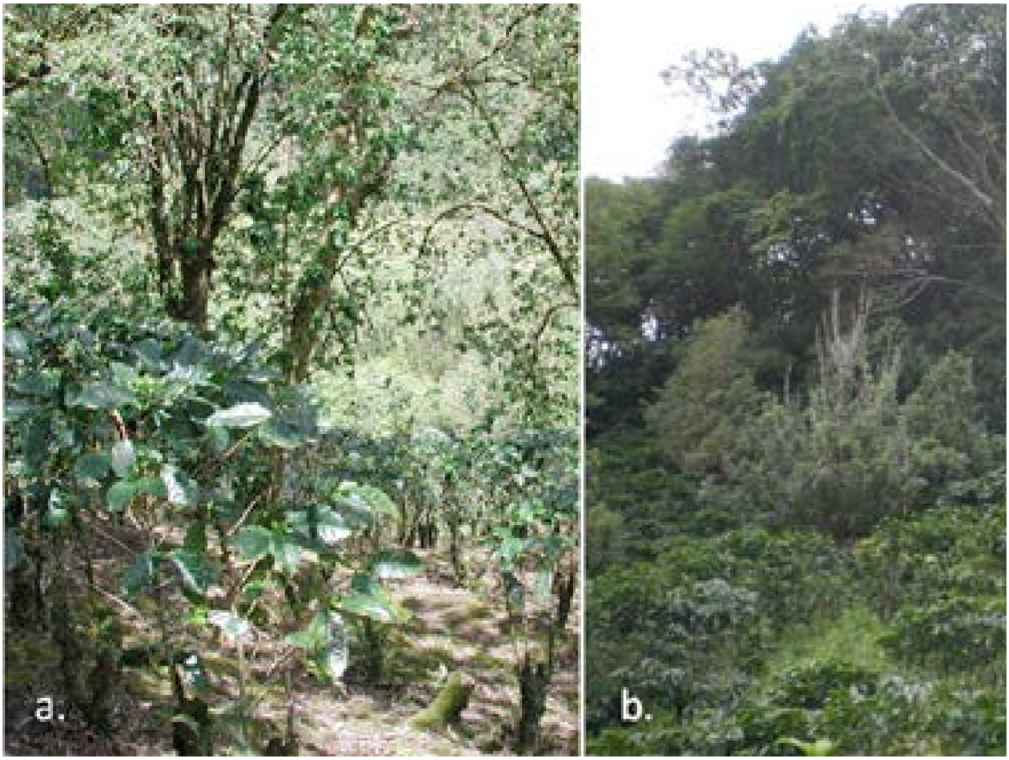

Figure 3. Coffee cultivation at the Montes de Oro coffee cooperative in Costa Rica, 2006 showings hade coffee (a) and Integrated Open Canopy (IOC) coffee (b).

Box 2: Sampling design in coffee plantations

To test the potential for IOC to support forest-associated species not found in shade coffee plantations, we sampled birds in seven sites each in IOC plantations, shade coffee plantations and primary forest during December-February 2005/06 and 2006/07 using standardized mist netting (Karr, 1981). Shade coffee plantations were best characterized as "commercial polyculture" as described by Moguel and Toledo (1999), which describes nearly all shade coffee in Costa Rica (Somarriba *et al.*, 2004). Each site was sampled once for three consecutive days with 10 12-m long nets placed in a grid 25 m apart. We captured 2,131 individuals representing 154 species during 6,618 net-hours. We calculated species richness separately for all species and for species that were captured most often in forest using sample-based rarefaction (Gottelli and Colwell, 2001). We did not analyze species richness of generalist species separately because they are not of conservation concern (Rappole *et al.*, 2003a).

Species richness of all species combined was similar in shade coffee and IOC coffee plantations; however, IOC coffee farms supported higher numbers of forest-associated species than shade farms. Furthermore, the similarity in species composition between forest and IOC was 40% greater than the similarity between forest and shade coffee (Chao-Jaccard similarity index = 0.81 and 0.58, respectively). Nonetheless, the number of forest-associated species in IOC farms was significantly lower than in primary forest sites, which underscores the importance of conserving large forest tracts.

IOC coffee production also offers important economic benefits to farmers. First, the more open conditions result in greater yields. Shade coffee in the Montes de Oro region typically yields 300-500 lbs/ha, whereas IOC coffee yields 1,500-2,000 lbs/ha of coffee (Montes de Oro Production Statistics), but since half of the land is forest, this comes to 750-1000 lbs/ha, still considerably higher than shade. Higher yields in IOC are attributable to a number of factors. IOC coffee is generally subject to lower levels of disease because producers have the option to create conditions of high illumination, which is known to discourage coffee leaf spot disease (Avelino *et al.*, 2006). Protecting adjacent forest can also increase yields because many coffee-pollinating insects depend upon forest for nesting habitat (Ricketts *et al.*, 2004). Forest buffers in IOC coffee also serve to protect coffee plants from wind damage (Harvey *et al.*, 2004), and help control erosion by disrupting and absorbing the flow of surface water (Pimentel *et al.*, 1987). Finally, in cases where forest areas are being allowed to regenerate, they can qualify for carbon credits under the Kyoto Protocol. An added bonus of the income this could generate is the certification needed for carbon credits would also suffice for certification for IOC. This certification would likely be far easier to complete than the detailed measurements needed for shade coffee certification, and in contrast, could lead to increased forest cover in tropical agricultural landscapes.

Conclusions

Although it is clear agroforestry cannot substitute for forest protection, it is also clear that there are ways in which agroforestry can contribute to conservation of tropical biodiversity by accommodating those elements of biodiversity that do occupy these habitats. For example, agroforestry can provide a matrix for remnant forest patches thereby providing connectivity and buffering edge effects. We describe two agroforestry projects that illustrate other ways in which agroforestry can contribute to biodiversity conservation. From Nicaragua, the project we described has the potential for allspice cultivated in a mixed productive system to play a role in restoring abandoned pasture and the distillation of essential oils to contribute to alleviating rural poverty, which is a precondition for implementing any comprehensive integrated conservation program. From Costa Rica we describe a system that increases coffee yields without requiring inputs of fertilizers or biocides, and in which conservation of actual forest is explicitly linked to production.

Both the allspice and IOC coffee projects can be viewed in the context of the debate between "land sparing" agriculture, in which intensive farming and higher yield make land available for preservation, versus "wildlife farming" in which the actual farms provide habitat (Green, 2005). Although allspice farming as proposed in our project creates habitat for native tropical biodiversity, and thus would be considered an example of "wildlife-friendly" farming, however the economic impacts of added value through distillation could have the same effect as a land-sparing system. Although allspice cultivation in Siuna does not involve increasing crop yield, as would be the case in a conventional land sparing system, it does increase the value of the crop, so that a given plot of land yields more income, which is effectively the same result. Whether or not increased income from essential oils will result in reduced pressure on protected areas in the same manner observed in more conventional agroforesty (Muraniati and Gintings, 2001; Illukpitiya and Yanagida, 2008) remains to be seen. One principal objection to the land sparing approach is the intensification is assumed to involve increased inputs of chemical biocides that can have severe consequences for biodiversity (Fisher *et al.*, 2008; Perfecto and Vandermeer, 2008), however the critical aspect of land-sparing is the yields, not the inputs, so this is not an inherent fault of land-sparing. Both the allspice project and the IOC coffee cultivation are examples of land sparing agroforestry systems that increase yields, although in the case of allspice, it is not strictly yields but value. In the case of IOC, reduce the needs for chemical inputs, because direct sun deters leaf rust and other pathogens.

The principal shortcoming of agroforestry is its failure to create actual forest conditions. IOC coffee represents an improvement in this respect, in that unlike other land sparing systems, it explicitly links production to forest conservation. IOC also addresses several impediments to the adoption of agroforesty, low yields and the costs associated with certification. IOC coffee is not a panacea, of course, because associated forest patches are relatively small and may be either secondary or primary forest. Nevertheless, diversity of forest species is higher in IOC, and remnant forests are an important feature for maintaining biodiversity in agricultural landscapes (Anand *et al.*, 2008).

The limitations of strict preservation in agrarian regions was recognized early on by conservationists, and led to the genesis of a new conservation approach exemplified by the ICDP approach, in which the needs of rural communities was explicitly recognized. ICDPs were an improvement over strict preservation, however despite some success, the top-down, externally imposed elements of this program has compromised its effectiveness because of the failure to encompass the needs of rural communities as well as critical ecological processes were reflected in the plans (Lele *et al.*, 2010). Perfecto and

Vandermeer (2008) make a compelling argument for the value of community based conservation initiatives developed in collaboration with local people (see also Lin and Perfecto, this volume). Only that way can the objectives of a project accurately reflect the socioeconomic and ecological context to ensure that the scale and scope of the project is appropriate to meet the needs and aspirations of rural people who depend on intact ecosystems for their quality of life. It is our hope that the work we have described herein make a contribution to that effort.

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