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Conservation in tropical landscape mosaics: the case of the cacao landscape of southern Bahia, Brazil

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Abstract A recent debate has contrasted two conservation strategies in agricultural landscapes; either "land sparing" farm development combining intensive production practices with forest set-asides, or "wildlife-friendly" farming with greater on-farm habitat value but lower yields. We argue that in established mosaic landscapes including old cacao production regions where natural forest has already been reduced to relatively small fragments, a combination of both strategies is needed to conserve biodiversity. After reviewing the evidence for the insufficiency of either strategy alone if applied to such landscapes, the paper focuses on the cacao production landscape of southern Bahia, Brazil,

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once the world's second largest cacao producer. Here, small remaining areas of Atlantic Forest are embedded in a matrix dominated by traditional cacao agroforests, resulting in a landscape mosaic that has proven favorable to the conservation of the region's high biodiversity. We show that current land use dynamics and public policies pose threats but also offer opportunities to conservation and describe a three-pronged landscape conservation strategy, consisting of (i) expansion of the protected areas system, (ii) promotion of productive yet biodiversity-friendly cacao farming practices, and (iii) assistance to land users to implement legally mandated on-farm reserves and voluntary private reserves. We discuss recent experiences concerning the implementation of this strategy, discuss likely future scenarios, and reflect on the applicability of the Bahian experience to biodiversity rich cacao production regions elsewhere in the tropics.

Keywords Agroforest · Atlantic Forest · *Cabruca* · Landscape scale conservation · On-farm reserves · *Theobroma cacao*

Introduction

Theobroma cacao L. is a tree species of the humid tropical lowlands. It grows in tropical forest areas that are of particular concern for biodiversity conservation, including "biodiversity hotspots"—areas of high natural biodiversity that have already suffered substantial habitat loss—and "high biodiversity tropical wilderness areas"—tropical forest areas that are still largely intact. The former category includes the Atlantic Forest of Brazil and the rainforests of West Africa and Indonesia (Myers et al. 2000; Mittermeier et al. 2004), and the latter category includes the Amazon basin, Central Africa and New Guinea (Robles Gil et al. 2002). As with other tropical crops, past expansion of cacao production has occurred at the expense of tropical forests, initially in Latin America where the cacao tree is native, and then during the course of the twentieth century in West Africa and Southeast Asia where most cacao is produced now (Rice and Greenberg 2000; Ruf and Schroth 2004; Clough et al. 2009; Clarence-Smith 1996). In view of steadily increasing market demand for cacao, a challenge in the future will be to increase per-area yields in established cacao farms to reduce the need for further area expansion (Gockowski and Sonwa 2011), and to direct the establishment of new farms to land that is already deforested, thereby preventing further forest conversion and encouraging the reforestation of degraded land with cacao agroforestry systems. The probability that such a strategy will be successful increases with the expansion of global carbon markets (Gockowski and Sonwa 2011) and the increasing demand for environmental certification on the global commodity markets (Millard 2011).

Even if efforts to stabilize the cacao-forest frontiers are successful, however, this still leaves the task of conserving the native biodiversity—defined as the diversity of genes, species and ecosystems—in the mosaic landscapes of already established cacao production regions. This category includes old cacao landscapes of Latin America, such as parts of Chiapas in southern Mexico, Talamanca in Costa Rica, Bocas del Toro in Panama, coastal Ecuador and southern Bahia, Brazil. In these landscapes, cacao has been grown for half a century or more, and cacao farms are part of a mosaic of land uses that include (secondary) forests, annual food crops, fallows, and usually some pasture. For example, in southern Bahia in the Atlantic Forest zone of coastal Brazil, the main cacao production region of the country that until the early 1990s was the world's second largest cacao producer, natural ecosystems are already profoundly altered through many decades of cacao farming and other agricultural land uses (Dean 1995; Tabarelli et al. 2010). Natural forests have been reduced to less than 10% of their previous area (Landau et al. 2008), yet recent botanical surveys in the region found some of the highest values of plant species richness per unit area of any place on earth as well as high plant endemism (Martini et al. 2007; Thomas et al. 1998; Amorim et al. 2005). The region also hosts high levels of faunal endemism and is considered one of the five centers of endemism for the Atlantic Forest based on the distribution of terrestrial vertebrates (Silva et al. 2004; Tabarelli et al. 2010). Other cacao mosaic landscapes also host substantial levels of biodiversity, such as the Montes Azules region in the Selva Lacandona of southern Mexico, parts of the coastal lowlands of Ecuador, and Talamanca in Costa Rica (Harvey et al. 2006; Harvey and Villalobos 2007). The challenge is to conserve this lowland tropical forest biodiversity without compromising development opportunities for local people and cacao production. Failure to achieve the latter would increase the demand for cacao elsewhere, fuel the periodic shift of cacao production regions that has historically been a characteristic of this crop, and increase the pressure on natural ecosystems in those regions where production is expanding (Ruf and Schroth 2004; Clarence-Smith 1996; Clough et al. 2009).

Traditionally, cacao has been grown under diversified tree shade, making its production compatible with conserving certain types of biodiversity (Rice and Greenberg 2000). These traditional cacao agroforests are still common in production regions in Latin America and, to a lesser extent, of Africa (e.g. southern Cameroon; Sonwa et al. 2007), while most cacao production in West Africa and Asia takes place in lightly shaded systems. Cacao agroforests, locally called *cabrucas*, are also the dominant form of cacao farming in southern Bahia (Araujo et al. 1998). Cacao systems shaded by native trees are superior in terms of biodiversity conservation to other tropical plantation crops, such as oil palm (*Elaeis guineensis*), monoculture rubber (*Hevea brasiliensis*) or (unshaded) robusta coffee (*Coffea canephora*), and to pasture (Rice and Greenberg 2000; Schroth et al. 2004). The relative shade tolerance of the cacao tree and this "agroforestry tradition" make cacao an ideal crop for biodiversity-friendly (or "wildlife-friendly") farming.

A question attracting a lot of recent attention is whether biodiversity conservation in managed landscapes can be better achieved through a "land sparing" agricultural development strategy emphasizing high yields that allow larger areas to be set aside for conservation, or a "wildlife-friendly" agricultural strategy where farm areas have higher habitat value themselves but also lower yields (Green et al. 2005; Wade et al. 2010; Gockowski and Sonwa 2011). These alternatives are highly relevant in agriculture-forest frontier areas, including areas of active cacao expansion. However, in mosaic landscapes with a long history of human settlement, where natural habitat has been reduced to a small fraction of its original extent, the conservation of biodiversity requires a combination of forest set-asides and biodiversity-friendly farming, rather than only one or the other. In the following, we will briefly outline the rationale of a landscape conservation approach that emphasizes the complementarity of conservation set-asides and biodiversity-friendly farm management. Then we review the ongoing efforts to implement such a strategy in the cacao production landscape of southern Bahia. The paper concludes with some lessons learned that could be of use for conservation in other tropical mosaic landscapes.

Complementarity of forest set-asides and agroforests in biodiversity conservation

Traditional cacao production systems conserve more biodiversity than most alternative agricultural systems due to their shade canopy which combines remnant forest trees and planted trees (Rice and Greenberg 2000; Schroth et al. 2004; Cassano et al. 2009). Cacao agroforests in Brazil and parts of Africa (e.g. Cameroon) were typically created by thinning natural forest and under-planting it with cacao trees (Fig. 1; Johns 1999; Ruf and Schroth 2004; de Rouw 1987; Sonwa et al. 2007). While some trees in the shade canopy of such agroforests are retained from previous forests, others are planted, and the shade canopy of old cacao agroforests may be variously dominated by timber trees, fruit trees or (introduced) legume trees, depending on region and management history. Depending on the method of establishment, the tree species richness of cacao agroforests can be high. Sonwa et al. (2007) inventoried a total of 206 tree species in cacao agroforests in southern Cameroon, with a dominance of fruit species including the native oil palm; Van Bael et al. (2007) found 102 tree species in cacao farms in Bocas del Toro, Panama, of which the timber species *Cordia alliodora* was the most common one with 42% of all stems; Rolim and Chiarello (2004) counted 105 tree species in traditional cacao agroforests (*cabrucas*) in Espírito Santo, Brazil, Lobão and Valeri (2009) found 101 tree species in three *cabrucas* in the neighboring state of Bahia, including the emblematic *pau-brasil* (*Caesalpinia echinata*) and the rare *jacarandá-da-Bahia* (*Dalbergia nigra*), while Sambuichi and Haridasan (2007) even counted 180 tree species in similar systems in Bahia. Although *cabrucas* are often rich in planted or self-regenerated exotic fruit trees such as jackfruit (*Artocarpus heterophyllus*), some high-value timber species such as *Cedrela* sp., *Nectandra* sp. and *Cariniana* spp. have also been found at higher densities in the shade canopies of *cabrucas* than in unprotected logged forests (Sambuichi 2002).

Cacao agroforests have been shown to provide habitat for many species of animals as well. In Bocas del Toro, Panama, they supported higher species richness and densities of

Fig. 1 Shaded cacao agroforest (*cabruca*), southern Bahia, Brazil (photo G. Schroth)

migratory birds than nearby forests (Van Bael et al. 2007). In Talamanca, Costa Rica, tracks of 13 mammal species of high or moderate conservation concern were found in cacao agroforests, as compared to tracks of 11 mammal species in natural forest, although the mammals in the agroforests tended to occur at low density as a result of hunting (Harvey et al. 2006). These agroforests provided suitable habitat for a large number of forest-dependent vertebrate (large mammals, bats and birds) and invertebrate (dung beetle) species (Harvey and Villalobos 2007). In a study comparing *cabrucas* and forest in Bahia, 173 species of birds and 41 species of bats were registered in *cabrucas*, as compared to 150 species of birds and 27 species of bats in nearby forest (Faria et al. 2006), and overall animal species richness was higher in *cabrucas* as a result of an increase in generalist species outweighing the decrease in forest specialists (Pardini et al. 2009). As recently as 1994, a new bird genus and species, *Acrobatornis fonsecai*, was discovered in a *cabruca* plot located in the Serra das Lontras, a mountainous area of forest interspersed with *cabrucas* in southern Bahia (Pacheco et al. 1996) (see Fig. 2). Sixty-one species of snakes have been found in southern Bahian cacao farms, including the endemic *Atractus guenteri* and *Bothrops pirajai* (Argôlo 2004). Bahian cacao agroforests are also known to harbour a high invertebrate diversity in soil and litter (Delabie et al. 2007), including the endemic Theraphosidae spider *Avicularia diversipes* (Bertani and Fukushima 2009) as well as parasitoids of cacao pests whose diversity increases with the diversity of the shade tree stratum (Sperber et al. 2004).

This high species diversity for agricultural systems raises the question: where cacao agroforests occur on a significant scale, would they alone be able to conserve local

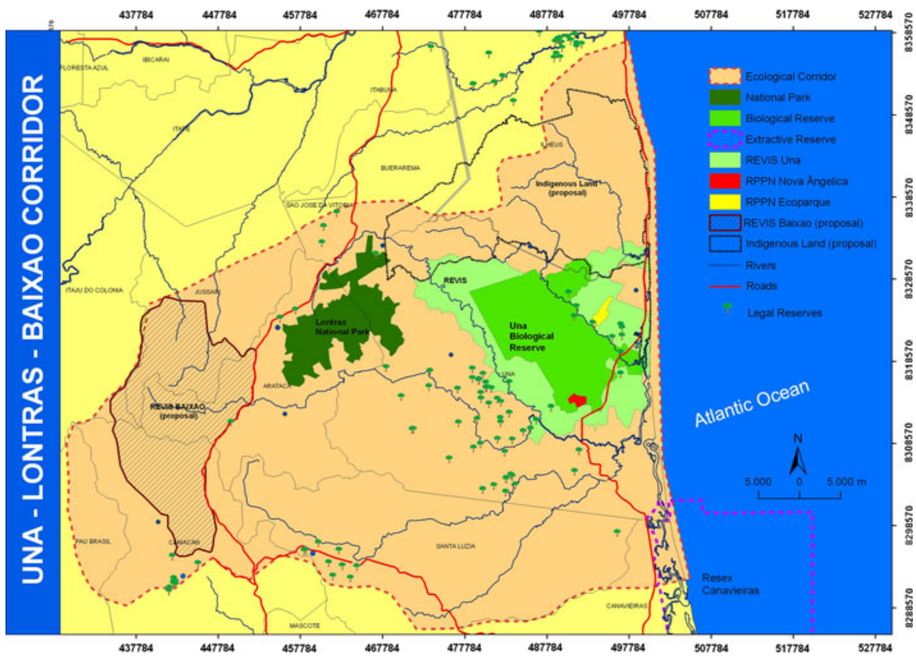

Fig. 2 The biologically important Una–Lontras–Baixão corridor in the cacao region of southern Bahia, Brazil. Much of the agricultural (non-forest) land between the existing and proposed protected areas in the corridor is occupied by shaded cacao plantations (*cabrucas*). *REVIS* wildlife reserve, *RPPN* private reserve, *Resex* extractive reserve. Not all RPPNs are shown

biodiversity so that set-asides of natural habitat would not be necessary? Research shows that this is not the case, for several reasons. First, even in extensively managed and structurally diverse agroforests, certain groups of species are generally underrepresented or absent. For example, understory birds are largely absent (Van Bael et al. 2007; Harvey and Villalobos 2007), tree regeneration is affected by slashing which threatens the persistence of native forest species (Rolim and Chiarello 2004), and some mammals are hunted either for food (Harvey et al. 2006), as pets or because they damage the cacao pods. Similar observations have been made for agroforests of coffee, rubber and other tree crops in several continents (Beukema and van Noordwijk 2004; Thiollay 1995; Tejeda-Cruz and Sutherland 2004). It can be safely generalized, then, that even extensively managed, structurally complex agroforests are no equal substitute for natural habitat in terms of biodiversity conservation (Schroth and Harvey 2007).

Second, a recent comparison of plant and animal assemblages of *cabrucas* in landscapes with little (<5%) and abundant (>50%) natural forest cover in southern Bahia revealed that *cabrucas* lost species as the surrounding forest cover decreased, suggesting that forest was necessary as source habitat for many species occurring in the cacao farms (Faria et al. 2006, 2007). Absence of nearby forest as source habitat could also explain why few resident forest bird species (as opposed to many migrant forest species) were found in cacao plantations in Tabasco, Mexico, despite their relatively diversified, planted shade (Greenberg et al. 2000). Other authors have shown that the number of forest bird species in shade coffee plantations decreased with increasing distance from natural forest (Tejeda-Cruz and Sutherland 2004). It is also known that the occurrence of some army ants (Ecitoninae) in southern Bahian agroecosystems depends on their connectivity to forest remnants (Delabie et al. 2007). Such interactions between forest and agroforestry habitat are still poorly understood but suggest that a minimum amount of natural forest cover in the landscape is necessary to ensure the persistence of certain species in agroforests. Future research should address whether there are thresholds of forest cover in a given landscape below which species numbers decline and how the natural forest areas should be arranged to be most effective. The answers may be species dependent but common patterns are likely to exist.

Third, many biodiversity-friendly traditional agroforestry practices are under threat as economic pressures oblige land users to intensify their management practices or even switch to other, more profitable crops. Relying on agroforests alone as a safeguard against species extinctions would thus be a very risky strategy even for those species that tolerate somewhat disturbed agroforestry conditions. Economic pressures may lead to outright land use change or to changes in management practices. As discussed in more detail below, increasing labour costs, low cacao prices and decreasing cacao yields after the appearance of the witches' broom fungus (*Moniliophthora perniciosa*) in Bahia led to logging and sometimes conversion of *cabrucas* (Alger and Caldas 1996; Araujo et al. 1998), followed now by rehabilitation measures that often go along with thinning of the shade canopies. Similar processes have affected traditional agroforests in other places. In West and Central Africa, cacao was initially grown under relatively dense forest tree shade, and in places such as southern Cameroon this still is the case (Sonwa et al. 2007). However, overall practices have evolved towards the use of less shade during the course of the twentieth century (Ruf and Schroth 2004). Research in southern Cameroon has shown that increased market access and land use intensity drive a simplification of cacao agroforests, with native forest tree shade being progressively replaced with—often exotic—fruit trees in the proximity of the capital Yaoundé (Sonwa et al. 2007). As for cacao, the diversified shade canopies of traditional coffee plantations in many parts of Central and South America were also replaced with simplified, mono-specific shade as part of the intensification of coffee production practices during the 1970s and 1980s (Perfecto et al. 1996). Once such changes have taken place they are slow and difficult to reverse because of the long time that large forest trees require to re-grow, and also because of the specific socio-economic and ecological conditions under which these extensive management practices have evolved.

It is thus clear that in the absence of natural forest habitat, even widespread, high-quality agroforests are insufficient to conserve the full set of local biodiversity in the lowland forest regions where cacao is grown. However, the fact that protected areas and conservation set-asides of natural forest are necessary for conservation does not negate the importance of the state of the agricultural matrix around and between fragments of native habitat. Within a hostile agricultural matrix, species populations in forest fragments are at risk of becoming genetically isolated and exposed to competitive invaders, and smaller populations may go extinct (Laurance and Vasconcelos 2004; Tabarelli et al. 2010). For example, computer models for the long-term survival probability of golden-headed lion tamarins (*Leontopithecus chrysomelas*)—an endemic primate species of southern Bahia—contrasted populations in forest areas of different size (Holst et al. 2006). They found that the tamarin population in the Una Biological Reserve (Fig. 2) with a forested area of >10,000 ha would present little risk of extinction or genetic impoverishment over a 100 year period. For a smaller population in the nearby Serra das Lontras with an area of only 1,668 ha at suitable elevation, however, the model predicted an extinction risk of up to 27% (depending on assumptions such as disease outbreaks) and significant genetic impoverishment over the same period (Holst et al. 2006). In reality, much of the agricultural area between these two forests consists of *cabrucas*, which if suitably managed can provide relatively high-quality habitat for lion tamarins (Oliveira et al. 2011). If these are conserved and managed to provide connectivity for the primates, the extinction risk of the smaller sub-populations would be reduced and they might then even serve as "stepping stones" to other large areas of suitable habitat, such as the Serra do Baixão further to the west (Fig. 2; Holst et al. 2006). Similar strategies apply to other endemic, endangered mammals of southern Bahia known to occur in *cabrucas*, such as the maned sloth (*Bradypus torquatus*), whose habitat requirements are however less well understood (Cassano et al. 2011). These recommendations are also consistent with those made for various regions of Mesoamerica, where several primate species have been seen moving between forest fragments using and sometimes residing in shaded coffee and cacao ecosystems (Estrada et al. 2005).

Cabrucas also act as important corridors for other biological groups inventoried in the Una region of southern Bahia. This area is characterized by small forest patches that are physically connected to the large forest block of the Una Biological Reserve by a matrix of *cabrucas* and secondary forest (Faria et al. 2006). In this landscape, small forest fragments (<100 ha) have been shown to harbour the same species richness, abundance, diversity and nearly the same species assemblages as the large forest tracts (>1,000 ha) for ferns, butterflies, leaf litter reptiles, amphibians, bats, birds and small mammals (Pardini et al. 2009). The apparent absence of local species extinctions even in the smaller forest fragments of the Una landscape is most likely attributable to the high "permeability" of the matrix of *cabrucas* and secondary forests for the forest fauna. Secondary forests and *cabrucas* complement each other in providing habitat specifically for the rich bird fauna of the region. The large shade trees in the *cabrucas* offer a variety of resources for canopy frugivorous and insectivorous birds, whereas the dense understory of the secondary forests supports many bird species that avoid *cabrucas* whose understory consists mostly of cacao trees and is periodically slashed (Laps et al. 2003). Only some forest interior specialists like the Screaming Piha (*Lipaugus vociferans*) and the White-tailed Trogon (*Trogon viridis*) that tolerate neither matrix habitat nor forest edges are absent from the small fragments; these species can only survive in relatively large blocks of natural forest. The amazingly rich bat assemblages of *cabrucas*—including most disturbance and fragmentation sensitive species—on the other hand, are partially explained by the presence of a canopy layer that still provides part of the food resources and a protective cover that most forest bats require during flight, while the herbaceous layer offers food resources for understory species (Faria et al. 2006; Faria and Baumgarten 2007). Unfortunately, such detailed landscape scale studies of species assemblages in cacao agroforests and forest have not been carried out in other cacao mosaic landscapes.

These examples demonstrate that if conservation outcomes are to be achieved in landscapes that are dominated by agricultural land use, as is often the case in tropical biodiversity hotspots including important cacao production areas, both conservation set-asides and conservation management of the agricultural matrix between such reserves are necessary and their management and conservation need to be integrated at the landscape scale. The following section reviews recent experiences in attempting to implement such a landscape conservation strategy in the relatively well-studied cacao landscape of southern Bahia. While some of the information presented is specific to this landscape, we believe that the strategy bears interesting lessons for other tropical mosaic landscapes, including in regions that have been less well researched.

Integrating forest conservation and agroforestry in southern Bahia

Within the biologically rich Atlantic Forest region of southern Bahia, the area between the Una Biological Reserve in the east and the Serra do Baixão in the west, with the Serra das Lontras in the middle, has been identified as a priority region for the conservation of the region's biodiversity and received much attention by biological scientists (Fig. 2). With 18,500 ha of Biological Reserve area since the expansion in 2007, surrounded by over 23,400 ha of the privately owned Una Wildlife Refuge which was created in the same year and most of which is forested, the Una Biological Reserve is one of the largest blocks of forest in southern Bahia. It harbours populations of several endangered endemic species of large mammals, such as the golden-headed lion tamarin, the yellow-breasted capuchin monkey (*Cebus xanthosternos*), the southern Bahian masked titi monkey (*Callicebus melanochir*), the maned three-toed sloth (*Bradypus torquatus*), and the thin-spined porcupine (*Chaetomys subspinosus*), as well as several rare and endemic species of birds, invertebrates including spiders and ants (Delabie et al. 2007; Cassano et al. 2009), and trees (Amorim et al. 2008). The Una Biological Reserve and its surroundings were the focus of several inventories, all of which reported high species richness of several biological groups including ferns (Paciencia and Prado 2005), bromeliads (Fontoura and Santos 2010), frogs (Silvano et al. 2003), birds (Laps et al. 2003), small terrestrial mammals (Pardini 2004) and bats (Faria et al. 2006). The recently created Serra das Lontras National Park is one of the last remnants of montane Atlantic Forest in north-eastern Brazil and hosts at least eleven threatened bird species, five of which were only recently or are currently being described (Silveira et al. 2005), as well as populations of the yellow-breasted capuchin monkey, the golden-headed lion tamarin and 709 species of plants (Amorim et al. 2009).

Much of the agricultural area between these three forest blocks is occupied by *cabrucas*, whose important role in providing additional habitat for plant and animal species and avoiding the genetic isolation of populations in the protected areas and the many small forest fragments throughout the landscape has been reviewed above. During the 1990s, when historically low cacao prices coincided with the arrival of the devastating witches' broom fungus in southern Bahia, many *cabrucas* were abandoned and conservationists feared the large-scale conversion of *cabrucas* into land uses of lower biodiversity value, including cattle pasture and unshaded robusta coffee (Araujo et al. 1998). While this did not occur on the expected scale, many *cabrucas* were logged of their valuable timber as farmers struggled to obtain an income from their cacao farms. To save the cacao industry of Bahia, efforts are underway throughout the region to replace the traditional cacao trees that are highly susceptible to the witches' broom fungus with more resistant and productive material through grafting and replanting. However, these efforts often are accompanied by the thinning of the shade tree canopies to increase the returns to investments in the cacao. Furthermore, some farmers turn to rubber trees or exotic timber species for shade instead of the traditional mixed forest and fruit tree shade to increase and diversify their income (Fig. 3).

Conservation organizations working in the region are taking a three pronged approach to conserve and restore a landscape that is conducive to biodiversity conservation, despite the threats of land use change towards more intensive and less conservation friendly

Fig. 3 Cacao plantation shaded by rubber trees. Note the simple structure of the canopy compared with that of the forest-like traditional *cabrucas* (photo G. Schroth)

management practices. This approach includes (i) supporting the government in the creation and consolidation of new protected areas in places of highest conservation priority; (ii) the promotion of conservation friendly management of the *cabrucas* (and other agricultural areas), backed up by capacity-building and organizational strengthening of farmers to increase the profitability of their farms; and (iii) incentives and support to farmers for creating and restoring the set-asides that are required on every farm according to Brazilian environmental legislation, complemented by the creation of private, voluntary reserves. We review each of these three components in turn.

Expansion of protected area system

Until 2004, southern Bahia including its cacao region had only 0.88% of its area covered by protected areas in the more restrictive categories of Park or Reserve (Categories I and II of the International Union for the Conservation of Nature and Natural Resources—IUCN). In view of this undesirable situation, non-profit organizations conducted studies and biological surveys which served as basis for a 2004 proposal to the Ministry of the Environment to increase the total area under protection to 6.09% of the southern Bahia region. In response, the Government of Brazil initiated in the year 2006 a legal process, including public consultations, that resulted in the expansion of the Una Biological Reserve by 7,100 ha (in addition to its previous 11,400 ha), the creation of the Una Wildlife Refuge (23,405 ha), the Serra das Lontras National Park (11,336 ha), and the Serra do Baixão Wildlife Refuge (37,169 ha, creation proposal in final development stage). The expansion and creation of these protected areas between extensive areas under *cabrucas* are important tools to assure, in the long term, a landscape favorable to biodiversity conservation as well as the production of cacao and other agricultural goods.

Conservation management of *cabrucas*

The Appendix provides a preliminary list of guidelines for biodiversity-friendly management of cacao farms in southern Bahia. The promotion of biodiversity-friendly management practices in the *cabrucas* necessarily has to be compatible with measures to increase cacao yields against the pressure of the witches' broom disease, since otherwise cacao growing may not survive in the region. However, since the investments in the cacao production systems in the form of replanting, grafting and pruning are often accompanied by the thinning of the shade canopies to create optimum growing conditions for the rehabilitated tree crops, guidance is needed on canopy management that retains as much as possible the favorable habitat conditions of traditional *cabrucas* without compromising the productivity of the system. Gramacho et al. (1992) recommended a shade level of 40–50%, to be attained by spacing planted shade trees such as *Erythrina* sp. or *Spondias mombin* at 24 m by 24 m, i.e., 17.4 trees per hectare (earlier recommended shade levels in Bahia had been much lower; see Johns 1999). Such spacing recommendations do not apply to the mixtures of planted and naturally grown trees of various species, sizes and crown shapes that are characteristic of *cabrucas*. For example, Johns (1999) measured shade levels of 50–60% provided by 68–76 trees per hectare belonging to a large number of species in *cabrucas*. Therefore, farmers need training to estimate (or measure) the level of shading in their *cabrucas* and to make appropriate management decisions (i.e., thinning or lopping trees where shade is too dense while retaining those that are most valuable for biodiversity; managing natural regeneration; and planting shade trees including rare tree species and species that are beneficial for fauna; Oliveira et al. 2010).

While controlling shade levels is important to create a suitable environment for the cacao trees, the habitat conditions for fauna species are often determined by more specific (and often insufficiently known) characteristics of the shade canopies. For example, recent research using radio-collars on several groups of golden-headed lion tamarins in forest, abandoned and active *cabrucas* in the Una reserve and surrounding landscape identified hollow trees, which the tamarins use as sleeping sites, and epiphytic bromeliads in the tree canopies, where they feed on small animal prey, as critical resources (Raboy et al. 2004; Oliveira et al. 2010). This suggests that conserving the old trees laden with epiphytes (and presumably occasional holes) in *cabrucas* as well as other farm areas is a key measure for maintaining and improving the habitat for these primates, as well as for endemic canopy ants (Feitosa et al. 2011), pollinators and parasitoids (Sperber et al. 2004). Unless farmers are specifically educated about the value of such old trees for conservation, these could become early victims of intensification measures. Oliveira et al. (2010) present a list of 155 species of plants from 49 families of which lion tamarins consumed mostly fruits, but also nectar, flowers and (occasionally) gum. This list, obtained under conditions where the tamarins had a choice of a large number of tree species both in natural forest and abandoned *cabrucas*, can be used as a guide for which tree species should be retained or promoted on farmland to improve the habitat conditions for these primates. Subsequent research showed that the exotic jackfruit trees offer a key resource to the lion tamarins through the large amount and favorable timing of their fruit production (Oliveira et al. 2011), suggesting that under certain conditions, select exotic species may play an important role in biodiversity-friendly management strategies.

A similar research approach was used by Vaughan et al. (2007) to study habitat conditions, resource use and home ranges of two sloth species (*Bradypus variegatus*, *Choloepus hoffmanni*) in a shaded cacao plantation and the surrounding landscape in Talamanca, Costa Rica. Their findings pointed to the importance of structurally complex and species rich riparian forests as well as living fence rows as movement corridors, a finding that is relatively safe to generalize to other landscapes. They also identified tree species that were used by the sloths in each habitat.

Studies that identify critical factors determining habitat quality need to be carried out more widely and for other species that occur in cacao production landscapes. For instance, data from an on-going study in southern Bahia show that the thin-spined porcupine rarely ventures into *cabrucas*, not even to cross small distances from one forest fragment to another (Giné et al. 2010). Establishing the explanatory variables for this habitat avoidance (low abundance of plant species used as food resources; discontinuity of the tree canopy in *cabrucas* preventing proper locomotion, etc.), may help to identify possible ways to adjust the management of *cabrucas* to make them more hospitable for this species. This could include planting certain tree species and maintaining a denser canopy cover at least in some sections of *cabrucas*, as well as ensuring connectivity between forest areas in the landscape wherever possible.

If measures that are beneficial for biodiversity also generate income they will be more widely adopted by land users. Cacao farmers in Bocas del Toro, Panama, for example, commonly plant timber trees (*Cordia alliodora* and a large number of other species) with their cacao as an additional source of income, thereby also creating additional bird habitat (Van Bael et al. 2007). Since timber trees need to reach a relatively large size to become valuable, the effect of associating timber trees with cacao on structural diversity—an important predictor for habitat quality for many species—would likely be positive in most cases. Some non-timber trees and useful palms are likely to have similar effects on simultaneously diversifying income sources and increasing the structural and tree species diversity of cacao agroforests. For example, the Amazonian açai palm (*Euterpe oleracea*) is now being planted more widely in *cabrucas* and other farm areas for the production of fruits and hearts-of-palm, which can both be produced much more easily and sustainably from this species than from the native jussara palm (*Euterpe edulis*). Incentives for biodiversity-friendly cacao production are discussed in more detail below.

On farm reserves

In view of the comparative richness of plant and animal life in traditional *cabrucas*, it is important to maintain and increase their value as additional habitat, complementing the relatively few nature reserves in the region. However, since disease pressures, socioeconomic forces and policy changes may lead to (temporary) abandonment, intensification and even conversion of *cabrucas*, it is essential that a landscape conservation strategy is flexible and resilient. A key element of this strategy is written in the Brazilian environmental legislation, including the Forest Code of 1965, which requires that 20% of each farm (the "legal reserve") plus all riparian areas, steep slopes and hilltops ("areas of permanent preservation") are kept under natural vegetation (Appendix). Economic uses are permitted in the former but not the latter category of set-asides. The fact that today only 11–16% of the Atlantic Forest are estimated to be under forest cover (Ribeiro et al. 2009), and even less in southern Bahia, shows that this legislation is widely not being implemented. The restoration of legal reserves and areas of permanent preservation would result in a several-fold increase in off-reserve forest cover and the creation of a network of forest areas, often interconnected through riparian forests as linear corridors, across the region. Benefits would ensue not only for biodiversity conservation, but also for the conservation of water and soil.

Few farmers comply with the Forest Code, however, with substantial variation between parts of Brazil and types of land use. In the cacao region of Bahia, a survey of three municipalities found that 93% of the land holdings did not have their legal reserves legalized, even if they had forest remnants in their properties (V.M.A. Fernandes, M. Araujo et al., unpublished data). There are various reasons for this situation, the principal one being that until recently there was little political will on the side of the concerned government agencies to implement this legislation. In addition, the process of the regularization of the legal reserve is slow and demanding in terms of paperwork, which makes it difficult to understand and comply with on the part of the farmers.

In recent years, however, both the environmental authorities and the Treasury have begun to require proof of this regularization, in the latter case in an attempt to increase rural tax revenues because land holders who do not have a legal reserve are obliged to pay higher land taxes. This situation opened a window of opportunity for non-profit organizations that offer technical and legal assistance to farmers who wish to regularize their properties. This support includes the compilation and organization of the necessary documentation and the topographic mapping of the properties with a Global Positioning System (GPS). A project implemented by the non-profit organization *Instituto de Estudos Socioambientais do Sul da Bahia* (IESB) with support from various entities has already helped create legal reserves in 59 properties, comprising a total of 1,840 ha of reserve land, in the Una-Lontras Corridor (Fig. 2). Unfortunately, a recent public debate about relaxing the requirements of the Forest Code with regard to the legal reserves and areas of permanent preservation has meant that land owners are now reluctant to comply with legislation that might change in the foreseeable future.

Economic incentives could further reduce the opportunity cost of setting aside land in compliance with existing legislation. For areas of permanent preservation, where no economic uses are permitted, this could involve carbon trading, while the cost of establishing legal reserves could partly be offset through the production of non-timber (and eventually timber) products, in addition to carbon credits in some cases (Manfrinato 2005). Federal legislation also permits the inclusion of *cabrucas* into legal reserves for family managed farms of less than 50 ha, and there is an ongoing discussion to change the Forest Code so as to permit it also for larger farms, although this is being opposed by environmental organizations. Furthermore, compliance with environmental legislation is a criterion of environmental certification systems for cacao (e.g. Rainforest Alliance) that are beginning to be used in the region. Globally increasing market demand for certified cacao may thus provide additional incentives for the setting aside of legal reserves and areas of permanent preservation.

Like legal reserves, Private Reserves of Natural Heritage (*Reservas Privadas do Patrimonio Natural—RPPN*) can also contribute to improving the quality of the landscape for native species (Costa 2006; Pinto et al. 2004), the main difference to legal reserves being that they are not required but only encouraged through modest tax benefits. A further motivation for land owners to create RPPNs is that they are not subject to expropriation of unproductive land for the establishment of agricultural settlements. The area protected in such private reserves experienced a 15-fold increase in the region over the past 10 years, largely through the technical and legal assistance of non-profit organizations, and had reached a total area of over 136,000 ha in 721 individual reserves in the Atlantic Forest by end April 2011 (http://www.reservasparticulares.org.br). The private reserve system is thus emerging as a promising tool to ensure the conservation of the many relatively small forest remnants that are scattered over the landscape of the Atlantic Forest, including the cacao region of southern Bahia.

Discussion

The manner in which cacao farming evolved to become the dominant land use in southern Bahia during the nineteenth and twentieth centuries ensured that the agricultural landscape remained relatively favorable for the conservation of the region's biodiversity. This makes the region an interesting model for other tropical land use mosaics that were shaped by tree crop agriculture. Despite the reduction of the natural forest cover of southern Bahia to less than 10% and its high degree of fragmentation, formerly high logging activity and continued hunting pressure, no species extinctions have yet been reported. In contrast, new species continue to be described including from the cacao ecosystems themselves, such as the bird *Acrobatornis fonsecai* (Pacheco et al. 1996), the frog *Physalaemus erikae* (Cruz and Pimenta 2004), and the ants *Typhlomyrmex meire* (Lacau et al. 2004) and *Anochetus hohenbergiae* (Feitosa et al. 2011). This favorable conservation outcome for an old and thoroughly transformed forest landscape (Dean 1995) was achieved almost accidentally: for farmers it was cheaper to establish new cacao farms by under planting thinned natural forest with cacao seedlings than to clear-fell the areas for planting, and so a diversified canopy of native forest trees was conserved in the *cabrucas*. When government extension promoted more intensive cacao farming methods and drastic shade reduction in the 1960s and made access to credit dependent on their adoption, farmers proved risk-averse and reluctant to trade their proven though not very productive farming methods for the recommended practices that would have made them more dependent on costly agrochemical inputs (Johns 1999). Coincidentally, even some introduced exotic shade tree species proved to have some positive biodiversity impacts. Due to their open crown architecture *Erythrina* species are preferred hosts for canopy epiphytes, which have recently been shown to support a rich invertebrate fauna (Feitosa et al. 2011), while jackfruit provides critical food resources for species such as the golden-headed lion tamarin (Oliveira et al. 2011) and other mammals. The cacao crisis of the 1990s and early 2000s, which is not yet overcome, initially increased pressure on the cacao ecosystems as the *cabrucas* were stripped of their valuable trees, but overall increased their conservation value as management was extensified, workers left the rural areas and moved to the cities, and many farms were abandoned, favoring their recolonization by native trees (Sambuichi et al. 2011). In fact, considering that scientific interest in the conservation value of the cacao landscape of southern Bahia largely coincides with the cacao crisis, some care is needed in studies of the temporal dynamics of *cabrucas* to not confound a state of temporary extensification or abandonment of cacao farms with a baseline of "traditional" *cabrucas*.

Considering the low productivity of southern Bahia's cacao farms averaging per-hectare yields of less than 250 kg, which contrasts sharply with Brazil's otherwise highly efficient agroindustrial sector, it is hard to imagine that the present state of affairs can continue for long. The traditional cacao farms will have to intensify or risk being replaced by other, more profitable crops and land use systems. What will these unavoidable changes mean for biodiversity? Already there are promising experiences with producing cacao with irrigation under planted shade in southern Bahia, and under full-sun conditions in drier parts of Brazil (G. Schroth, personal observation). These systems, while potentially "land-sparing", have little potential (or intention) to contribute to the biodiversity-friendly matrix that the traditional cacao farms are providing now. As mentioned before, there also are intensification efforts on the traditional cacao farms of southern Bahia, involving replanting and grafting of the cacao trees as well as thinning of the shade canopies. More drastic changes include the replacement of exotic shade trees, such as *Erythrina*, with rubber trees. Since current environmental legislation restricts the felling of native forest trees, including on cacao farms, these interventions in the shade canopies focus primarily on the exotic (and, in the case of jackfruit, invasive) species and may include the pruning of branches of native species, although this is an expensive measure. As long as legislation remains the same and continues to be enforced, the established forest trees in the *cabrucas* are relatively secure, but may not be allowed to regenerate (Rolim and Chiarello 2004). The legal protection of native forest trees also limits the potential for land use change in the *cabrucas*, since alternative crops such as robusta coffee, rubber, oil palm or eucalypts do not tolerate the same amount of shade as does cacao.

Government and non-governmental organizations in southern Bahia are discussing whether the extraction of timber from *cabrucas* under a management plan should be permitted, and these discussions could lead to several outcomes. The most optimistic of these would be a diversification and increase of income for the cacao farmers. Such increases could allow them to pay off farm debts that currently paralyze investments and to reinvest into more productive cacao systems. Additional income derived from the shade trees would also provide an incentive to conserve and actively regenerate this highly diverse tree stratum of the cacao farms, and—critically—provide an additional incentive to establish and legalize the legal reserves and areas of permanent preservation, a prerequisite for approval of management plans by environmental authorities. A pessimistic scenario, on the other hand, would be that, with notoriously inadequate oversight by the authorities, the felling of the overstory of *cabrucas* would open the way for a progressive conversion into less diverse land use systems. It would also lead to the resurgence of the logging sector in the region, which may in turn facilitate the illegal extraction of timber from forest areas.

Existing and new forms of environmental certification could help to shift the balance towards the first of these two scenarios. Such certification can provide additional mechanisms both of control and of technical assistance to farmers while helping to increase environmental awareness among land users and providing access to markets for sustainably produced, "biodiversity-friendly" cacao and farm timber. Already, the Rainforest Alliance (www.ra.org) is making inroads into the Bahian cacao sector with the first certified farms, attending to an increasing global demand for certified cacao. Further, the creation of a seal for "biodiversity-friendly" cacao based on more site and species specific criteria has been under discussion among local institutions for a number of years (see Appendix). While in the public perception, environmental certification is mostly seen under the perspective of price premiums in return for environmentally correct farming practices (a form of environmental service payment), the access to training and technical assistance that often comes with certification can be just as important, and can make a critical difference especially where farmers have to deal with complex environmental and labour legislation, as is the case in the Bahian cacao sector.

Conclusions

While the expansion of cacao production (especially during the second half of the twentieth century) has undoubtedly caused significant deforestation, many cacao landscapes still offer relatively favorable conditions for biodiversity conservation compared to other forms of agriculture. This is due to the low degree of mechanization of cacao farms, the traditional practice of growing cacao under the shade of forest trees that is still widespread in Latin America (less so in Africa and Asia), and the mosaic of cacao farms and forest remnants that is characteristic of many of these landscapes (Schroth and Harvey 2007). Where cacao farming becomes unprofitable and farms are converted into other land uses such as cattle pasture, impacts on biodiversity are usually negative.

In southern Bahia, where natural forest has been reduced to a small fraction of its original extent, no vertebrate extinctions have yet been reported (though local species extinctions, such as of the northern muriqui—*Brachyteles hypoxanthus*—have occurred), and this may partly be due to the relatively favorable matrix of *cabrucas* that form much of the agricultural landscape (Cassano et al. 2009). Cacao farms alone would have unlikely sustained the full set of local biodiversity, but nor would the many small fragments of remaining forest habitat have maintained their present species assemblages over the long term without the support of a benign matrix in which shaded cacao farms presently play a key role. The present land use situation is dynamic, however, and although the *cabruca* system has survived the combined disease and price shocks of the 1990s, complacency would be erroneous. The current trend towards intensification of cacao production in southern Bahia, motivated in part by relatively favorable cacao prices, poses new threats to the ability of the landscape to sustain its remaining biodiversity. At the same time, the resurgence of interest in cacao also offers new opportunities to make cacao production economically more sustainable and to thereby reduce the risk of land use change.

The baseline is thus characterized by high threat but also significant opportunities for conservation on a landscape scale. In response to these challenges, a strong group of environmental organizations and government agencies are in the process of designing and implementing a comprehensive strategy of recovering and consolidating the ability of the cacao landscape of southern Bahia to sustain its exceptional biodiversity without compromising opportunities for socio-economic development—including the production of cacao. Key elements of this strategy are the expansion and consolidation of the protected area system, the promotion of agricultural practices that are beneficial to biodiversity conservation based on the traditional *cabruca* system, and technical and legal assistance as well as economic incentives to land owners to implement both legally required and voluntary on-farm set-asides. In combination, these initiatives can make important contributions to the implementation of the Central Biodiversity Corridor of the Atlantic Forest and the Ecological Corridor concept as a new unit of landscape scale conservation planning (Fonseca et al. 2004; Ministério do Meio Ambiente 2006; Tabarelli et al. 2010).

This landscape strategy offers opportunities for synergies between governmental and non-governmental stakeholders, including the private sector. The critical task of reducing the opportunity costs for land users of biodiversity-friendly management, including that required by law, will greatly benefit from a stronger integration of new approaches to technical and legal assistance to land users from non-governmental organizations, innovative certification systems based on solid science, and emerging environmental service markets such as carbon trading and preferred buying schemes for farmers who meet environmental standards. The more successful such integrated efforts are in making biodiversity-friendly landscape management economically feasible for often indebted farmers, the easier it will be for government agencies to enforce existing environmental laws and to adopt more conservation friendly policies and legislation. A stronger exchange of experiences between cacao producing regions in different countries and continents on various levels may help develop further such applied concepts of landscape scale conservation and sustainability and to implement them more widely in cacao production landscapes around the globe.

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Appendix: Some recommendations for biodiversity-friendly management of cacao farms in southern Bahia, Brazil

Cabrucas

Manage at least half of the cacao area of the farm as *cabruca*, *tentatively* defined as a cacao production system with at least 30% cover in the canopy stratum, with at least 50% of the canopy area provided by native trees and at least 20 native tree species per hectare. Ensure that spontaneous or artificial regeneration are adequate to fill canopy gaps and replace aging shade trees as necessary. Do not convert *cabrucas* into simpler structured cacao production systems.

Respect the legal restrictions on felling native Atlantic Forest trees. Where the reduction of the shade level in *cabrucas* is inevitable, remove or (preferably) prune exotic and common tree species and conserve native, slow growing and rare species. Conserve trees that provide food, nesting or other resources to fauna, such as hollow trees, fruit trees and trees carrying epiphytes. Maintain epiphytes also in the understory as far as possible. When thinning the shade canopy, attempt to maintain some paths with connecting crowns for arboreal fauna.

Manage *cabrucas* and other farm areas to conserve soil and water. Use agrochemicals only as needed and with orientation from a qualified professional. Consider using organic practices.

Forest conservation

Demarcate, register and (if necessary) restore a legal reserve on the farm or an alternative area within the same watershed, as required by law. If possible, plan the legal reserve to form large continuous blocks with other forest areas, reserves of neighboring properties, riparian corridors and *cabrucas*, maximizing connectivity and minimizing edge effects. Use the legal reserve only in conformity with the legislation. Do not permit access of livestock to the legal reserve.

Maintain at least 50% of each property under forest cover, including "true" forest, *cabrucas*, and other agroforestry systems with similar vegetation structure. Do not convert mature or secondary forests of more than 10 years for agriculture. Use only areas of young regrowth for establishing annual crops and pastures, and locate such land uses in such a way that they do not isolate or increase the borders of forest fragments and *cabrucas*. Restore connectivity in farms where forest fragments and *cabrucas* have become isolated.

Do not illegally extract or permit the extraction of timber. The selective harvesting of trees in *cabrucas* and legal reserves is permitted as long as it is in conformity with legislation.

Maintain or restore forest cover in at least 90% of the "areas of permanent preservation", including riparian buffer strips and steep slopes. Do not use agrochemicals in these areas and manage them in such a way as to avoid any visible erosion.

Fauna conservation

Do not hunt or permit hunting. Encourage small livestock husbandry by farm employees as alternative sources of protein.

References

Alger K, Caldas M (1996) Cacau na Bahia: decadência e ameaça à Mata Atlântica. Ciência Hoje 20:28–35

Amorim AM, Fiaschi P, Jardim JG et al (2005) The vascular plants of a forest fragment in southern Bahia, Brazil. SIDA 21:1726–1752

Amorim AM, Thomas WW, Carvalho AMV, Jardim JG (2008) Floristics of the Una Biological Reserve, Bahia, Brazil. Mem New York Bot Gard 100:67–146

Amorim AM, Jardim JG, Lopes MMM et al (2009) Angiospermas em remanescentes de floresta montana no sul da Bahia, Brasil. Biota Neotrop 9:313–348

Araujo M, Alger K, Rocha M, Mequita CAB (1998) A Mata Atlântica do Sul da Bahia—situação atual, ações e perspectivas. Serie Cadernos Reserva Biosfera Mata Atl 8:1–35

Argôlo AJS (2004) As serpentes dos cacauais do sudeste da Bahia. Editus, Ilhéus

Bertani R, Fukushima CY (2009) Description of two new species of *Avicularia* Lamarck 1818 and redescription of *Avicularia diversipes* (C.L. Koch 1842) (Araneae, Theraphosidae, Aviculariinae)—three possibly threatened Brazilian species. Zootaxa 2223:25–47

Beukema H, van Noordwijk M (2004) Terrestrial pteridophytes as indicators of a forest-like environment in rubber production systems in the lowlands of Jambi, Sumatra. Agricult Ecosyst Environ 104:63–73

Cassano CR, Schroth G, Faria D, Delabie JHC, Bede L (2009) Landscape and farm scale management to enhance biodiversity conservation in the cocoa producing region of southern Bahia, Brazil. Biodivers Conserv 18:577–603

Cassano CR, Kierulff MCM, Chiarello AG (2011) The cacao agroforests of the Brazilian Atlantic forest as habitat for the endangered maned sloth *Bradypus torquatus*. Mamm Biol 76:243–250

Clarence-Smith WG (1996) Cocoa pioneer fronts since 1800—the role of smallholders, planters and merchants. Macmillan Press, Houndmills

Clough Y, Faust H, Tscharntke T (2009) Cacao boom and bust: sustainability of agroforests and opportunities for biodiversity conservation. Conserv Lett 2:197–205

Costa CMR (2006) RPPN Mata Atlântica—Potencial para Implantação de Políticas de Incentivos às RPPNs. Conservação Internacional, Fundação SOS Mata Atlântica and The Nature Conservancy, Belo Horizonte

Cruz CAG, Pimenta BVS (2004) New species of Physalaemus Fitzinger, 1826 from Southern Bahia, Brazil (Anura, Leptodactylidae). J Herpetol 38:480–486

de Rouw A (1987) Tree management as part of two farming systems in the wet forest zone (Ivory Coast). Acta Oecol Oecol Appl 8:39–51

Dean W (1995) With broadax and firebrand—the destruction of the Brazilian Atlantic forest. University of California Press, Berkeley

Delabie JHC, Jahyny B, Nascimento IC et al (2007) Contribution of cocoa plantations to the conservation of native ants (Insecta: Humenoptera: Formicidae) with special emphasis on the Atlantic Forest fauna of southern Bahia, Brazil. Biodivers Conserv 16:2359–2384

Estrada A, Saenz J, Harvey CA et al (2005) Primates in agroecosystems: conservation value of some agricultural practices in Mesoamerican landscapes. In: Estrada A, Garber PA, Pavelka MSM, Luecke L (eds) New perspectives in the study of Mesoamerican primates: distribution, ecology, behavior, and conservation. Springer, New York, pp 437–470

Faria D, Baumgarten J (2007) Shade cacao plantations (*Theobroma cacao*) and bat conservation in southern Bahia, Brazil. Biodivers Conserv 16:291–312

Faria D, Laps RR, Baumgarten J, Cetra M (2006) Bat and bird assemblages from forests and shade cacao plantations in two contrasting landscapes in the Atlantic Forest of southern Bahia, Brazil. Biodivers Conserv 15:587–612

Faria D, Paciencia MLB, Dixo M, Laps RR, Baumgarten J (2007) Ferns, frogs, lizards, birds and bats in forest fragments and shade cacao plantations in two contrasting landscape in the Atlantic forest, Brazil. Biodivers Conserv 16:2335–2357

Feitosa RM, Lacau S, Da Rocha WD, Oliveira AR, Delabie JHC (2011) A giant new arboreal species of the ant genus *Anochetus* from Brazil (Formicidae, Ponerinae). Ann Soc Entomol France (in press)

Fonseca GAB, Alger K, Pinto LP, Araujo M, Cavalcanti R (2004) Corredores de biodiversidade: o corredor central da Mata Atlântica. In: Arruda MB, Sá LFSN (eds) Corredores Ecológicos: uma Abordagem Integradora de Ecossistemas no Brasil. IBAMA, Brasília, pp 47–65

Fontoura T, Santos FAM (2010) Geographic distribution of epiphytic bromeliads in the Una region, Northeastern Brazil. Biota Neotrop 10:127–132

Giné GAF, Duarte JMB, Faria D (2010) Feeding ecology of a selective folivore, the thin-spined porcupine (*Chaetomys subspinosus*) in the Atlantic forest. J Mamm 91:931–941

Gockowski J, Sonwa DJ (2011) Cocoa intensification scenarios and their predicted impact on climate change, biodiversity conservation, and rural livelihoods in the Guinea rainforest of West Africa. Environ Manag. doi:10.1007/s00267-010-9602-3

Gramacho ICP, Magno AES, Mandarino EP, Matos A (1992) Cultivo e Beneficiamento do Cacau na Bahia. CEPLAC, Ilhéus-Itabuna

Green RE, Cornell SJ, Scharlemann JPW, Balmford A (2005) Farming and the fate of wild nature. Science 307:550–557

Greenberg R, Bichier P, Angón AC (2000) The conservation value for birds of cacao plantations with diverse planted shade in Tabasco, Mexico. Anim Conserv 3:105–112

Harvey CA, Villalobos JAG (2007) Agroforestry systems conserve species-rich but modified assemblages of tropical birds and bats. Biodivers Conserv 16:2257–2292

Harvey CA, Gonzalez J, Somarriba E (2006) Dung beetle and terrestrial mammal diversity in forests, indigenous agroforestry systems and plantain monocultures in Talamanca, Costa Rica. Biodivers Conserv 15:555–585

Holst B, Medici EP, Mariano-Filho OJ et al (2006) Lion Tamarin population and habitat viability assessment workshop 2005. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, pp 90–107

Johns ND (1999) Conservation in Brazil's chocolate forest: the unlikely persistence of the traditional cocoa agroecosystem. Environ Manag 23:31–47

Lacau S, Villemant C, Delabie JHC (2004) *Typhlomyrmex meire*, a remarkable new species endemic to Southern Bahia, Brazil (Formicidae: Ectatomminae). Zootaxa 678:1–23
Landau EC, Hirsch A, Musinsky J (2008) Vegetation cover and land use in the Atlantic forest of southern Bahia, Brazil, based on satellite imagery: a comparison among municipalities. In: Thomas WW, Britton EG (eds) The Atlantic Coastal Forest of northeastern Brazil. The New York Botanical Garden Press, New York, pp 221–244
Laps RR, Cordeiro PHC, Kajiwara D et al (2003) Aves. In: Rambaldi DM, Oliveira DAS (eds) Fragmentação de Ecossistemas. Causas, Efeitos sobre a Diversidade e Recomendações de Políticas Públicas. Ministério do Meio Ambiente/SBF, Brasilia, pp 153–181
Laurance WF, Vasconcelos HL (2004) Ecological effects of habitat fragmentation in the tropics. In: Schroth G, Fonseca GAB, Harvey CA et al (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, pp 33–49
Lobão DEVP, Valeri SV (2009) Sistema cacau-cabruca: conservação de espécies arbóreas da floresta Atlântica. Agrotropica 21:43–54
Manfrinato W (2005) Áreas de Preservação Permanente e Reserva Legal no Contexto da Mitigação de Mucanãs Climáticas. The Nature Conservancy do Brasil, Rio de Janeiro
Martini AMZ, Fiaschi P, Amorim AM, Paixão JL (2007) A hot-point within a hot-spot: a high diversity site in Brazil's Atlantic forest. Biodivers Conserv 16:3111–3128
Millard E (2011) Incorporating agroforestry approaches into commodity value chains. Environ Manag (in press)
Ministério do Meio Ambiente (2006) O Corredor Central da Mata Atlântica: uma Nova Escala de Conservação da Biodiversidade. Ministério do Meio Ambiente, Conservação Internacional & Fundação SOS Mata Atlântica, Belo Horizonte
Mittermeier RA, Robles Gil P, Hoffmann M et al (2004) Hotspots revisited. CEMEX, Mexico City
Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J (2000) Biodiversity hotspots of conservation priorities. Nature 403:853–858
Oliveira LC, Hankerson SJ, Dietz JM, Raboy BE (2010) Key tree species for the golden-headed lion tamarin and implications for shade-cocoa management in southern Bahia, Brazil. Anim Conserv 13:60–70
Oliveira LC, Neves LG, Raboy BE, Dietz JM (2011) Abundance of jackfruit (*Artocarpus heterophyllus*) affects group characteristics and use of space by golden-headed lion tamarins (*Leontopithecus chrysomelas*) in cabruca agroforest. Environ Manag. doi:10.1007/s00267-010-9582-3
Pacheco JF, Whitney BM, Gonzaga LP (1996) A new genus and species of furnariid (Aves: Furnariidae) from the cocoa-growing region of southeastern Bahia, Brazil. Wilson Bull 108:397–433
Paciencia MLB, Prado J (2005) Effects of forest fragmentation on pteridophyte diversity in a tropical rain forest in Brazil. Plant Ecol 180:87–104
Pardini R (2004) Effects of forest fragmentation on small mammals in an Atlantic forest landscape. Biodivers Conserv 13:2567–2586
Pardini R, Faria D, Accacio GM et al (2009) The challenge of maintaining Atlantic forest biodiversity: a multi-taxa conservation assessment of specialist and generalist species in an agro-forestry mosaic in southern Bahia. Biol Conserv 142:1178–1190
Perfecto I, Rice RA, Greenberg R, van der Voort ME (1996) Shade coffee: a disappearing refuge for biodiversity. Bioscience 46:598–608
Pinto LP, Paglia A, Paese A, Fonseca M (2004) O papel das reservas privadas na conservação da biodiversidade. In: Castro R, Borges ME (eds) RPPN: Conservação em Terras Privadas—Desafios para a Sustentabilidade. Edições CNRPPN, Planaltina do Paraná, pp 14–27
Raboy BE, Christman MC, Dietz JM (2004) The use of degraded and shade cocoa forests by endangered golden-headed lion tamarins *Leontopithecus chrysomelas*. Oryx 38:75–83
Ribeiro MC, Metzger JP, Martensen AC, Ponzoni F, Hirota MM (2009) Brazilian Atlantic forest: how much is left and how is the remaining forest distributed? Implications for conservation. Biol Conserv 142:1141–1153
Rice RA, Greenberg R (2000) Cacao cultivation and the conservation of biological diversity. Ambio 29:167–173
Robles Gil P, Mittermeier RA, Mittermeier CG et al (2002) Wilderness—Earth's last wild places. CEMEX, Mexico City
Rolim SG, Chiarello AG (2004) Slow death of Atlantic forest trees in cocoa agroforestry in southeastern Brazil. Biodivers Conserv 13:2679–2694
Ruf F, Schroth G (2004) Chocolate forests and monocultures—an historical review of cocoa growing and its conflicting role in tropical deforestation and forest conservation. In: Schroth G, Fonseca GAB, Harvey CA et al (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, pp 107–134

Sambuichi RHR (2002) Fitossociologia e diversidade de espécies arbóreas em cabruca (Mata Atlântica raleada sobre plantação de cacau) na região sul da Bahia, Brasil. Acta Bot Bras 16:89–101

Sambuichi RHR, Haridasan M (2007) Recovery of species richness and conservation of native Atlantic forest trees in the cacao plantations of southern Bahia in Brazil. Biodivers Conserv 16:3681–3701

Sambuichi RHR, Vidal DB, Piasentin FB et al (2011) *Cabruca* agroforests in southern Bahia, Brazil: tree component, management practices and tree species conservation. Agric Ecosyst Environ (under review)

Schroth G, Harvey CA (2007) Biodiversity conservation in cocoa production landscapes: an overview. Biodivers Conserv 16:2237–2244

Schroth G, Harvey CA, Vincent G (2004) Complex agroforests—their structure, diversity, and potential role in landscape conservation. In: Schroth G, Fonseca GAB, Harvey CA et al (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, DC, pp 227–260

Silva JMC, Sousa MC, Casteleti CHM (2004) Areas of endemism for passerine birds in the Atlantic Forest. Glob Ecol Biogeogr 13:85–92

Silvano DL, Colli GR, Dixo MBO, Pimenta BVS, Wiederhecker HC (2003) Anfíbios e répteis. In: Rambaldi DM, Oliveira DAS (eds) Fragmentação de Ecossistemas. Causas, Efeitos sobre a Diversidade e Recomendações de Políticas Públicas. Ministério do Meio Ambiente/SBF, Brasilia, pp 183–200

Silveira LF, Develey PF, Pacheco JF, Whitney BM (2005) Avifauna of the Serra das Lontras–Javi montane complex, Bahia, Brazil. Cotinga 24:45–54

Sonwa DJ, Nkongmeneck BA, Weise SF et al (2007) Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon. Biodivers Conserv 16:2385–2400

Sperber CF, Nakayama K, Valverde MJ, Neves DS (2004) Tree species richness and density affect parasitoid diversity in cacao agroforestry. Basic Appl Ecol 5:241–251

Tabarelli M, Aguiar AV, Ribeiro MC, Metzger JP, Peres CA (2010) Prospects for biodiversity conservation in the Atlantic Forest: lessons from aging human-modified landscapes. Biol Conserv 143:2328–2340

Tejeda-Cruz C, Sutherland WJ (2004) Bird responses to shade coffee production. Anim Conserv 7:169–179

Thiollay JM (1995) The role of traditional agroforests in the conservation of rain-forest bird diversity in Sumatra. Conserv Biol 9:335–353

Thomas WW, Carvalho AMV, Amorim AM, Garrison J, Arbelaez AL (1998) Plant endemism in two forests in southern Bahia, Brazil. Biodivers Conserv 7:311–322

Van Bael SA, Bichier P, Ochoa I, Greenberg R (2007) Bird diversity in cacao farms and forest fragments of western Panamá. Biodivers Conserv 16:2245–2256

Vaughan C, Ramirez O, Herrera G, Guries R (2007) Spatial ecology and conservation of two sloth species in a cacao landscape in Limón, Costa Rica. Biodivers Conserv 16:2293–2310

Wade ASI, Asase A, Hadley P et al (2010) Management strategies for maximizing carbon storage and tree species diversity in cocoa-growing landscapes. Agric Ecosyst Environ 138:324–334