Biodivers Conserv (2007) 16:2237–2244
DOI 10.1007/s10531-007-9195-1

ORIGINAL PAPER

Biodiversity conservation in cocoa production landscapes: an overview

Götz Schroth · Celia A. Harvey

Received: 6 April 2007 / Accepted: 2 May 2007 / Published online: 8 June 2007

Abstract Cocoa agroforests that retain a floristically diverse and structurally complex shade canopy have the potential to harbour significant levels of biodiversity, yet few studies have documented the plant and animal species occurring within these systems or within landscapes dominated by cocoa production. In this special issue, we bring together nine studies from Latin America, Africa and Asia that document the contribution of cocoa agroforestry systems to biodiversity conservation, and explore how the design, management and location of these systems within the broader landscape influence their value as habitats, resources and biological corridors. Tree diversity within the cocoa production systems is variable, depending on management, cultural differences, location and farm history, among other factors. Animal diversity is typically highest in those cocoa agroforests that have high plant diversity, structurally complex canopies, and abundant surrounding forest cover. In general, both plant and animal diversity within cocoa agroforests is greater than those of other agricultural land uses, but lower than in the original forest habitat. There are several emerging threats to biodiversity conservation within cocoa production landscapes, including the loss of remaining forest cover, the simplification of cocoa shade canopies and the conversion of cocoa agroforestry systems to other agricultural land uses with lower biodiversity value. To counter these threats and conserve biodiversity over the long-term, land management should focus on conserving native forest habitat within cocoa production landscapes, maintaining or restoring floristically diverse and structurally complex shade canopies within cocoa agroforests, and retaining other types of on-farm tree cover to enhance landscape connectivity and habitat availability.

Present Address:
G. Schroth (✉) · C. A. Harvey
Conservation International, 2011 Crystal Drive Suite 500, Arlington, VA 22202, USA
e-mail: g.schroth@conservation.org

C. A. Harvey
Department of Agriculture and Agroforestry, Centro Agronómico Tropical de Investigación y Ensenañza (CATIE), Turrialba, Costa Rica
e-mail: c.harvey@conservation.org

Keywords Animal diversity · Cocoa agroforestry · Community composition · Landscape conservation · Natural forest habitat · Plant diversity

Introduction

Cocoa agriculture has played an important role in the transformation of lowland tropical forest landscapes in Latin America, Africa and Asia over the past centuries and continues to do so today. Cocoa is now grown in some 50 tropical countries, with smallholder farmers growing most of the world's 3 million tons of annual cocoa production (Lass 2004). In many regions, cocoa has been a driver of deforestation, with cocoa grown in plantations or agroforestry systems replacing the original forest ecosystems (Ruf and Schroth 2004). However, in comparison to other land uses that replace intact forest, traditional cocoa agroforests with diverse and structurally complex shade canopies are among the agricultural land uses that are most likely to conserve a significant portion of the original forest biodiversity (Rice and Greenberg 2000, Schroth et al. 2004).

Whereas shade coffee systems have received considerable scientific and public attention for their ability to maintain biodiversity (especially of migratory birds; e.g., Perfecto et al. 1996, Moguel and Toledo 1999), the same has not been the case for cocoa agroforestry systems and the landscapes of which they are part. Only a handful of papers have reported patterns of biodiversity within cocoa agroforestry systems (e.g., Faria et al. 2006, Harvey et al. 2006a) and most of these have been published in the last five years. The ongoing trend of simplifying the shade canopies of cocoa agroforestry systems and converting them to other agricultural land uses (such as pastures or annual crops, that are generally less compatible with biodiversity conservation) in various parts of the tropics has similarly received little attention from conservation biologists, despite the potential negative impacts on the biodiversity of the lowland tropical forest landscapes where cocoa is grown (but see Rice and Greenberg 2000). With a sustained increase of world chocolate consumption of 2–3% per year (Lass 2004) and growing human populations in many of the cocoa production regions, pressures to intensify cocoa production are likely to increase.

This special issue highlights the contribution of cocoa agroforestry systems to biodiversity conservation and explores the factors which make cocoa agroforests more or less effective contributors to conservation at the landscape scale. By bringing together biodiversity studies from cocoa growing regions of Central and South America, Africa and Asia, the special issue provides a global overview of the opportunities and threats to biodiversity conservation within cocoa production landscapes. In this introduction to the special edition, we highlight the key contributions of the individual papers to our understanding of the role of cocoa agroforestry systems in conserving biodiversity, propose management actions that can help enhance the contribution of these systems to conservation efforts, and identify research gaps which require further attention.

Highlights of contributions

In the first contribution, Van Bael and coworkers compare the bird diversity of shaded cocoa farms and fragments of natural forest in Bocas del Toro, Panama, to determine the role of cocoa agroforests as habitat for local forest and migratory birds. Although a large number of resident and migratory bird species occurred in shaded cocoa plantations, a substantial number of forest species (notably understory insectivores) were absent from the agroforests. Bird diversity in cocoa farms increased with increasing shade tree species richness and decreasing management intensity. These findings highlight the importance of both forest fragments and cocoa agroforests with diversified shade tree canopies for maintaining intact and diverse bird communities in agricultural landscapes.

In the second contribution, Harvey and Gonzalez address similar questions in neighboring Costa Rica. Comparing the bird and bat communities in cocoa agroforests with those of banana agroforestry systems, plantain monocultures and natural forest in Talamanca, they find that the cocoa (and banana) agroforests have a far greater habitat value for these groups than do the intensively managed plantain monocultures (which lack a shade canopy). However, while the composition of bat assemblages in forest and agroforests were very similar, the bird assemblages in agroforests were highly modified and lacked certain forest dependent species. These findings reinforce the point that while complex agroforests provide habitat for more species than monoculture plantations, the conservation of natural forest remnants is critical for conserving the full suite of local species in cocoa production landscapes. In addition, the results illustrate that different taxonomic groups respond in distinct ways to different land use types and management practices.

Next, Vaughan and coworkers examine the effects of tree species composition and the landscape context of a cocoa agroforest in Costa Rica on habitat use by three-toed and two-toed sloths (*Bradypus variegatus* and *Choloepus hoffmanni*, respectively). Using radio tracking, they demonstrate the role of cocoa agroforests, riparian forests and live fences in providing habitat, food resources and landscape connectivity for sloths. They also identify tree species that are used by sloths for feeding, resting or movement, and provide valuable recommendations for how to improve sloth habitat both at the field and landscape scales. Their study is one of the first to radio-track animal movement within cocoa production landscapes and it is clear that this method could be used with a greater number of species to better understand how animals use and move within such landscapes.

In the last paper from Central America, Dahlquist and colleagues examine why cocoa production systems are being replaced by land use systems of lower biodiversity value in indigenous territories of Talamanca, Costa Rica, despite efforts to promote cocoa agroforestry as a conservation tool in the region. Several reasons account for this decline, including increased problems with cocoa diseases, human population growth (and accompanying demand for land and food crops), integration of the indigenous communities into the cash economy, low prices and limited market access for cocoa (relative to alternative crops), as well as government policies that favor plantain over cocoa production. The study highlights the complexity of efforts to maintain biodiversity-friendly land use practices in the region. The authors recommend a number of policy changes which may help to stem the conversion of cocoa agroforests to other land uses, including more technical support to cocoa farmers and greater flexibility in the marketing of timber from farms as an additional source of income to cocoa farmers.

The next two contributions are from southern Bahia, Brazil, a cocoa region that is known for its diverse traditional cocoa agroforests (''cabrucas''; Johns 1999). Building on an earlier publication (Faria et al. 2006), Faria and coworkers compare the assemblages of five biological groups (ferns, frogs, lizards, birds and bats) in cabrucas and primary forest in two contrasting landscapes, one dominated by cabrucas and one dominated by forest. While the authors find many forest species occurring within the cabrucas, some species are only found in the forests, reconfirming the fact that cabrucas are not substitutes for natural forests. Furthermore, cabrucas in the landscape with less forest cover were biologically impoverished compared to cabrucas in the landscape with greater forest cover. Their results highlight the importance of forest cover within the agricultural landscape not only as habitat for species that do not tolerate conditions within the cocoa agroforestry systems, but also as sources of colonists for adjacent agroforestry areas.

In the second paper from Brazil, Delabie and colleagues review the available information on ant biodiversity in cocoa agroforests in southern Bahia, emphasizing the high diversity of the ant fauna of these systems and its similarity to the ant fauna of native forests. The authors suggest that the relatively intact ant communities within traditional cabrucas provide natural pest control and, in doing so, provide economically important ecosystem services to cocoa farmers and consumers by reducing the need for pesticides. However, this rich native ant diversity is currently threatened by the intensification of cabruca management and the increased fragmentation of both forest and cabruca habitats.

The final three contributions take the reader to Africa and Asia, where much less research has so far been carried out on the biodiversity of cocoa production landscapes than in Latin America. Sonwa and coworkers explore the tree diversity of cocoa farms in three sub-regions of southern Cameroon which present a gradient of population density, market access and land use intensity. They find an impressive overall richness of 206 tree species which is higher than values reported from other cocoa production regions in Africa and Latin America (e.g., Johns 1999; Suatunce et al. 2003). However, tree diversity within the agroforests declines with increasing land use intensity: in the region where population density is highest and markets are most accessible, the native forest species within cocoa agroforests are increasingly being replaced by exotic fruit trees. While the inclusion of fruit trees into the cocoa agroforestry systems helps farmers obtain additional income, some traditional forest products become scarcer and the tree biodiversity of the traditional agroforests is significantly reduced. The authors suggest that developing markets for a wider range of products found in the traditional cocoa systems could to some extent stem the loss of on-farm biodiversity in this part of Cameroon.

A second paper from Cameroon by Laird and colleagues contrasts the importance of tree diversity within cocoa farms for indigenous versus migrant households. Although both indigenous and migrant farmers retain and plant useful species within their cocoa farms, the indigenous households retain and plant a higher density and diversity of non-cocoa trees and use a wider range of non-tree species from their farms. In addition, the indigenous farmers tend to have a greater number of native and wild species in their farms. Overall, these results suggest that indigenous households depend to a greater degree on biodiversity and, by extension, that biological diversity is related to cultural diversity.

In the final paper, Bos and coworkers expand our knowledge of the relative importance of agroforests and natural forest as well as the effects of management intensity with their research on beetle and ant communities in the understory of cocoa plantations and natural forest in Sulawesi, Indonesia. The authors find similar richness, but different composition of ant and beetle communities in cocoa agroforests and natural forests. They stress the need to conserve natural forest in the landscape even in the presence of high-quality agroforestry habitat, although agroforests are a valuable complement to natural forest especially for ants. The authors also highlight the need to consider various biological groups in management decisions owing to taxon-specific responses to disturbance and agroforest management, a point also made by other authors in this volume.

Discussion

The collected papers show that cocoa agroforestry systems can make a significant contribution to biodiversity conservation at both the plot and landscape scales by providing habitat and resources to a wide range of plant and animal species. However, not all forest species are able to use cocoa agroforests as habitat, and cocoa agroforests appear to host more forest species if they are situated in landscapes with high forest cover, suggesting that forests serve as important source areas for species in agroforestry landscapes. Furthermore, agroforests are often subject to processes that reduce their habitat value, ranging from the replacement of native forest trees with planted fruit trees (often including exotic species) to the outright conversion to other land uses. It is thus clear that relying on cocoa agroforests alone for the conservation of forest biodiversity would be ineffective for some species and risky for many others. The conservation of biodiversity in cocoa production landscapes requires the conservation of sufficient areas of natural habitat, but can benefit greatly from the additional habitat that complex cocoa agroforests can provide. Other forms of on-farm tree cover (such as riparian forests, live fences and dispersed trees) can similarly help increase the conservation value of the agroforestry matrix.

While these principles are robust enough to hold across a wide range of biological groups, it is important to keep in mind that different groups respond differently to different habitat types, management practices and landscape contexts, and might therefore require different conservation strategies. For example, bats seem to adapt very well to somewhat disturbed agroforestry conditions (in Latin America), as do ants (in Latin America and Indonesia), while understory birds are known to be very sensitive to the changes in habitat conditions that accompany the conversion of forest into cocoa agroforests, and the same seems to hold for forest beetles (in Indonesia). It is important to collect more information on the factors that determine habitat quality for different species groups both at the scale of the agroforestry plot and agroforestry landscapes, so that appropriate management guidelines can be developed. Several of the contributions in this special issue make important contributions to this goal.

While the papers in this special issue collectively highlight the important contribution that cocoa agroforests can make to biodiversity conservation within cocoa production landscapes, they also identify important threats to which these agroforests and their associated biodiversity are exposed in different parts of the world. These range from a market-driven simplification of shade canopies, through biological impoverishment of agroforestry habitat as a consequence of the progressive loss of natural forest in the surrounding landscape, to outright conversion of agroforestry systems to land uses of low habitat value. Because the factors that drive such processes are diverse and site dependent, the solutions will similarly need to be comprehensive and sensitive to site-specific factors.

Based on the presented information, successful conservation strategies in cocoa landscapes will most likely include the following elements:

(1) The conservation of existing forest remnants in production landscapes should be of highest priority. In agricultural landscapes where forests are degraded or highly fragmented, reforestation and restoration activities may be necessary to reestablish habitat and landscape connectivity (Fischer et al. 2005).
(2) Where traditional, high diversity agroforests still exist, special efforts should be made to protect them from intensification and simplification of the shade canopy, and from conversion into other land uses. Once such traditional systems have been lost, they

are slow and difficult to restore, owing to the peculiar conditions under which they have often developed (Ruf and Schroth 2004).

(3) Where cocoa agroforests have already been simplified, programs to diversify these systems both through tree planting and facilitation of natural regeneration will have positive impacts on biodiversity. Planting programs should include species that are useful to farmers (including timber and native fruit trees; see Sonwa et al., this issue; Laird et al., this issue) and that are easily incorporated into existing management practices, but also species that are beneficial for fauna (preferably based on local scientific research; see Vaughan et al. this issue) as well as rare and threatened tree species.

(4) Efforts to maintain or increase the biodiversity of cocoa production landscapes need to consider also non-cocoa agricultural areas within the landscape. Riparian forests, living fencerows in pastures or around crop fields, isolated trees and other arboreal elements can make an important difference for many species, including wide-ranging and not strictly forest dependent ones (see Vaughan et al., this issue; Harvey et al. 2004, 2006b) and should be strategically incorporated into agricultural landscapes.

Possible tools for conserving forest, avoiding the replacement of diverse agroforests by less diverse land use systems, and promoting biodiversity friendly practices throughout agricultural landscapes include eco-friendly certification, research and extension to increase agricultural production while maintaining the diversified tree canopies, market development for non-cocoa products from such systems, and possibly payments for environmental services including carbon sequestration, watershed services and scenic beauty (see Dahlquist et al., this issue; Sonwa et al., this issue). Moreover, the conservation of local cultures, traditions and knowledge can be intimately interwoven with the valuation and conservation of native biodiversity (see Laird et al., this issue).

Research needs

Although this special edition significantly enhances our overall knowledge of the role of cocoa production landscapes in biodiversity conservation, there are still important gaps which should be addressed by future research. More information is needed on the impact of landscape structure and composition on biodiversity, a topic which to date has not received sufficient attention within cocoa production landscapes (but see Faria et al., this issue). Special attention should be paid to determining how different amounts of native forest cover in the landscape influence the biodiversity within cocoa production landscapes, whether there are thresholds of necessary forest cover to sustain this biodiversity, and how animal and plant diversity is influenced by different mosaic patterns of forest and agroforest areas (see Faria et al., this issue). More studies on animal movements and demographics within agricultural landscapes are needed in order to determine the underlying factors driving these patterns and to develop practical recommendations for farm and landscape management to benefit mobile and wide-ranging species (see Vaughan et al., this issue). We also need a better understanding of the dynamics of cocoa agroforestry systems and landscapes over time and how these changes impact plant and animal communities. For example, how do the aging and corresponding structural changes in cocoa canopies affect the diversity of birds and other species? What are the dynamics of natural regeneration within cocoa agroforests and how can management facilitate the maintenance of a diverse tree canopy? And, how are different elements of biodiversity on the farm and in the wider landscape affected by the simplification and conversion of cocoa agroforests?

Last, but not least, it is important to understand trade-offs between productivity and conservation and the economic costs of conservation friendly practices to land users so that more effective policies and incentives can be designed to conserve biodiversity in cocoa landscapes. Quantifying the benefits (both short and long-term) of biodiversity within agroforestry landscapes to farm productivity, for example via pest and disease control, also requires attention (see Delabie et al., this issue). All of this information can help enhance the role of diverse cocoa production systems in biodiversity conservation and ensure that cocoa production landscapes continue to harbor diverse animal and plant assemblages in the years to come.

Acknowledgements We would like to thank Professor David Hawksworth for his support for this special issue and our referees (Inge Armbrecht, Rebecca Ashley Asare, Jim Barborak, Julio Baumgarten, Merijn Bos, Thomas Brooks, Jacques Delabie, Tom Dietsch, Robert Ewers, Sam Fujisaka, Jefferson Hall, Robert Keys, Jeremy Lichstein, Robert Nasi, Stacy Philpott, Sara Scherr and Teja Tscharntke) for their thorough revisions of the papers in this collection. C.A. Harvey gratefully acknowledges financial support from the CORRIDOR project (INCO-Dev 517644) and the Bank of the Netherlands Partnership Program with the World Bank.

References

Faria DR, Laps R, 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

Fischer J, Lindenmayer DB, Manning AD (2005) Biodiversity, ecosystem function and resilience: ten guiding principles for commodity production landscapes. Frontier Ecol Environ 4:80–86

Harvey CA, Tucker N, Estrada A (2004) Live fences, isolated trees and windbreaks: tools for conserving biodiversity in fragmented tropical landscapes? In: Schroth G, Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL, Izac AMN (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, D.C., pp 261–289

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

Harvey CA, Medina A, Merlo Sánchez D, Vílchez S, Hernández B, Sáenz JC, Maes JM, Casanoves F, Sinclair FL (2006b) Patterns of animal diversity associated with different forms of tree cover retained in agricultural landscapes. Ecol Appl 16:1986–1999

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

Lass T (2004) Balancing cocoa production and consumption. In: Flood J, Murphy R (eds) Cocoa futures—a source book on some important issues facing the cocoa industry. CABI-FEDERACAFÉ, USDA, Chinchiná, Colombia, pp 8–15

Moguel P, Toledo VM (1999) Biodiversity conservation in traditional coffee systems of Mexico. Conserv Biol 13:11–21

Perfecto I, Rice R, Greenberg R, van der Voorst ME (1996) Shade coffee: a disappearing refuge for biodiversity. BioScience 46:598–608

Rice R, Greenberg R (2000) Cacao cultivation and the conservation of biological diversity. Ambio 29:167–173

Ruf F, Schroth G (2004) Chocolate forests and monocultures: a historical review of cocoa growing and its conflicting role in tropical deforestation and forest conservation. In: Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL, Izac AMN (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, D.C., pp 107–134

Schroth G, Harvey C, Vincent G (2004) Complex agroforests: their structure, diversity, and potential role in landscape conservation. In: Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL, Izac

AMN (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, D.C., pp 227–260

Suatunce P, Somarriba E, Harvey C, Finegan B (2003) Composición florística y estructura de bosques y cacaotales en los territorios indígenas de Talamanca, Costa Rica. Agroforestería en las Américas 10:31–35