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Agroforestry for conserving and enhancing biodiversity

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Abstract The intricate relationship between biodiversity loss and human well-being is increasingly being understood in ecological and economic terms. Despite the knowledge of the multiple dimensions of this relationship and its importance, species and ecosystems are still disappearing at an alarming rate. Anthropogenic pressures are the prime reason for this trend, yet attempts to reduce such pressures and conserve species in protected areas have only achieved limited success. This has led to the realization that sustainable consumptive use approaches that can combine production and conservation functions are also important in conserving biodiversity in human-dominated landscapes. Agroforestry, as part of a multifunctional working landscape, can play a major role in conserving and even enhancing biodiversity from farms to the landscape level in both tropical and temperate regions of the world. This special issue is an attempt to bring together a collection of articles that not only explore and demonstrate the biodiversity benefits of agroforestry, but also the mechanisms by which agroforestry systems sustain such high floristic and faunal diversity. While it is important to conserve biodiversity in protected areas, the articles in the special issue reiterate the importance of agroforestry as a critical tool in conserving biodiversity in human-dominated landscapes.

Keywords CBD strategic plan · Sustainable consumptive land use · Habitat loss · Faunal diversity · Floristic diversity · Microbial diversity

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Introduction

Biological diversity or biodiversity, the result of 3.5 billion years of evolution, plays a vital role in sustaining human life and the health of our planet. Biodiversity is defined as the totality of genetic, species and ecosystem diversity that constitutes life on Earth. The year 2010 was the International Year of Biodiversity. It served mainly to remind us that biodiversity contributes immensely to the sustainable production of many of the commodities and services we depend on, yet it continues to decline at an alarming rate. The key factors contributing to this trend are overexploitation of species, invasion by alien species, environmental pollution and contamination, global climate change, alteration of ecosystems, and degradation and loss of habitats (Rands et al. 2010).

The efforts to conserve biodiversity from the local to global scale have been exceptional during the past two decades. Beginning with the United Nations Convention on Biological Diversity (CBD) agreed at the 1992 UN Conference on Environment and

Development, to the 10th Conference of the Parties (COP) of the CBD in Japan, serious efforts have been underway to negotiate both plans and targets to conserve biodiversity. The CBD is one of the most widely ratified treaties in the world with 87 % of its 193 parties having National Biodiversity Strategies and Action Plans. Despite increased conservation efforts by millions of people, organizations and world political powers, the pressures on biodiversity continue to increase with one endangered species lost every 20 min (Conservation International 2012). The vast majority of nations have fallen far short of the CBD's 2010 target to reduce biodiversity loss (CBD 2010a; Perrings et al. 2010). This prompted the CBD to develop a new plan of action, supported by 20 headline targets organized under five strategic goals for 2020 (Table 1, CBD 2010b). The mission of the new strategic plan is to take effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and eradicating poverty. This can be ensured by reducing pressures on biodiversity, restoring ecosystems, utilizing biological resources sustainably and sharing benefits arising out of utilization of genetic resources in a fair and equitable manner; providing adequate financial resources, enhancing capacities, mainstreaming biodiversity issues and values, effectively implementing appropriate policies, and making decisions based on sound science and the precautionary approach.

Based on the CBD Strategic Plan (Table 1), it is obvious that land use practices such as agroforestry, as part of a multifunctional landscape, will continue to play a major role in conserving and even enhancing biodiversity from farms to the landscape level in both tropical and temperate regions of the world. Protected areas alone cannot conserve biodiversity, particularly in human-dominated landscape where the pressure on natural habitat is intense for meeting food, wood and fiber needs. Habitat destruction continues to be a major problem around the globe. Albeit at a reduced rate, around 13 million hectares of forest were destroyed each year between 2000 and 2010 compared to 16 million hectares per year in the 1990s (FAO 2010). The global network of protected areas has continued to grow steadily since 1990s. The area of forest where conservation of biodiversity is designated as the primary function is around 460 million hectares or 12 % the world's forest area (FAO 2010). More than 95 million hectares were added since 1990, of which 46 % was designated between 2000 and 2005. Most but not all of them are located inside protected areas. While protected areas are important, other sustainable consumptive use approaches (Hutton and Leader-Williams 2003) that can combine both the production and conservation functions are extremely critical to conserving biodiversity in human-dominated landscapes.

How does agroforestry conserve biodiversity?

The mechanisms by which agroforestry systems contribute to biodiversity have been examined by various authors (e.g., Schroth et al. 2004; McNeely 2004; McNeely and Schroth 2006; Harvey et al. 2006; Jose 2009). In general, agroforestry plays five major roles in conserving biodiversity: (1) agroforestry provides habitat for species that can tolerate a certain level of disturbance; (2) agroforestry helps preserve germplasm of sensitive species; (3) agroforestry helps reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; (4) agroforestry provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (5) agroforestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat.

Designing and managing an agroforestry system with conservation goals would require working within the overall landscape context and adopting less intensive cultural practices to achieve the maximum benefits. Key design features that are known to enhance the conservation value of agroforestry include (1) high structural and floristic diversity (e.g. multiple species and vegetative strata); (2) minimal management intensity; (3) natural disturbance regime when possible (e.g., using thinning to reduce tree density or use of prescribed fire); (4) long rotation periods; and (5) strategic locations on the landscape (e.g., close to large natural habitats or between

Table 1 The Convention on Biological Diversity, Conference of the Parties 10 (COP 10) strategic goals and targets for biodiversity 2011–2020 (adapted from CBD 2010b)

Strategic goal	Targets by 2020
A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society	1. People are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably
	2. Biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems
	3. Incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions
	4. Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits
B. Reduce the direct pressures on biodiversity and promote sustainable use	5. The rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced
	6. All fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits
	7. Areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity
	8. Pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity
	9. Invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment
	10. The multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning
C. Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity	11. At least 17 % of terrestrial and inland water areas, and 10 % of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes
	12. The extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained
	13. The genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity
D. Enhance the benefits to all from biodiversity and ecosystem services	14. Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable
	15. Ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 % of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification
	16. The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is in force and operational, consistent with national legislation

Table 1 continued

Strategic goal	Targets by 2020
E. Enhance implementation through participatory planning, knowledge management and capacity-building	17. Each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan
	18. The traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the convention with the full and effective participation of indigenous and local communities, at all relevant levels
	19. Knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied
	20. At the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011–2020 from all sources, and in accordance with the consolidated and agreed process in the strategy for resource mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties

remnant forest patches). While agroforestry systems established on degraded agricultural and pasture land with little biodiversity value would certainly enhance biodiversity, clearing forest habitats or other native habitats of high biodiversity for agroforestry will have a negative impact.

Evidence is accumulating

We have seen a tremendous growth in the number of publications in the past decade dealing with the biodiversity values of agroforestry. However, comprehensive reviews and synthesis have been rare. The only available synthesis on this topic is from Schroth et al. (2004) who put together a comprehensive synthesis of the role of agroforestry systems in conserving biodiversity in tropical landscapes with examples from many different countries. The objective of this special issue is to bring together a collection of original research articles that deal with the biodiversity conservation values of agroforestry practices from both the temperate and tropical regions of the world.

Floristic diversity

The first set of five papers (Negash et al., Bardhan and Jose, Suarez et al., Appiah, and Cicuzza et al.) examines how agroforestry can help enhance native floristic diversity. While deliberate species selection for human consumptive use is evident in agroforestry practices (Jose 2011), they can still harbor a much higher species richness and diversity compared to monoculture cropping systems. The first paper by Negash et al. investigates the potential of indigenous, multistrata agroforests for maintaining native woody species diversity in the south-eastern Rift Valley escarpment of Ethiopia. They recorded a total of 58 woody species, belonging to 49 genera and 30 families from three different agroforestry systems. Among these tree species, 22 were of special interest for conservation, according to IUCN Red lists and local criteria. Bardhan and Jose show how homegarden agroforests can function as “intermediary” for conserving tree species diversity in Bangladesh. The tree species composition of homegardens and natural forests showed up to 30 % similarity and the species richness increased as the size of homegardens increased. These authors concluded that agroforestry could serve as an important ecological tool in conserving tree species diversity, particularly on a landscape like in Bangladesh where natural forests have declined and the remaining fragments are degraded.

Invasions by non-native species continue to be drivers of widespread changes in habitat composition and structure around the world. It is the second most significant threat to biodiversity, after habitat loss (Wilcove et al. 1998). However, non-native species are still being used widely in agroforestry systems to help meet the wood, food, fuel and fodder demand in many parts of the world. Lack of information on suitable native species and the non-availability of planting material often become a hindrance to native species selection in large scale farm forestry or restoration forestry projects. Suarez et al. in their paper conclude that indigenous knowledge is invaluable in making native species selections for such projects. They found that the local population in Veracruz, Mexico was highly aware of the varying functions of trees in their landscape. Appiah discusses the benefits of an indigenous mixed species plantation in harboring a diverse mix of understory plant species in Ghana. After eight years of establishment, species richness increased by 24 % and the number of families represented increased by 48 %. Half of the tested indigenous species had similar growth capacity to the comparable exotic species. The author concluded that planted indigenous species enhanced habitats for other forest tree species on degraded sites and thereby helped to recover biodiversity within an agricultural landscape. While agroforestry systems can sustain high herbaceous species richness and diversity in the understory, management intensity can be a major determinant of the conservation values of such systems. Using cacao agroforests in Central Sulawesi, Indonesia, Cicuzza et al. studied the change in herb species richness, cover, and biomass over three years under high and low weeding frequency as well as fertilized and non-fertilized treatments. Overall, they recorded 111 species; however, species richness, cover, and biomass were all significantly higher in the infrequently weeded plots compared to the frequently weeded ones.

Faunal diversity

The next six papers provide examples of how agroforestry can sustain higher faunal diversity. Since faunal diversity is closely related to the floral diversity, agroforestry systems with higher floristic and structural diversity have been shown to support greater faunal diversity compared to monocultural systems. Among the well-known examples are the shade coffee and multistrata Cacao (*Theobroma cacao*) agroforestry systems that include timber, fruit and native forest species. They contribute to biodiversity conservation by providing habitat for avian, mammalian, and other species, and by enhancing landscape connectivity, and reducing edge effects between forest and agricultural land (Perfecto et al. 1996; Moguel and Toledo 1999; Harvey and González Villalobos 2007). However, relatively little is known about the structural and floristic attributes of these agroforestry practices used by individual faunal species. Bakermans et al. studied the relationship between habitat characteristics and Neotropical migratory birds in shade coffee plantations in the Venezuelan Andes. They observed that the density of migrants was significantly related to both structural and floristic attributes of coffee farms. Specifically, upper canopy foragers were positively associated with number of large trees, tree canopy height, and understory vegetation density. Low canopy and ground foragers were positively associated with numbers of small and medium-sized trees and increased shade cover. They also showed that certain tree species, especially *Inga* spp., *Erythrina* spp. and *Acnistus arborescens*, were important components of habitat for the canopy foragers. They further concluded that that suitability of coffee agroforests for migratory birds might be improved by managing for particular structural and floristic characteristics.

Conservative estimates indicate that pollination represents about $200 billion dollars in annual benefits for both domesticated and wild plants (Costanza et al. 1997). Thus, the decrease in availability of pollinators can limit food production. While the emphasis of Peters and Carroll was the plant–pollinator interaction and their influence on bean production in *Coffea arabica* agroforests in Costa Rica, it gives us a rare glimpse of how phenology, particularly flower density, influences pollinators. Bee species richness was similar for four out of five flowering periods they observed, but nearly tripled during one high-density flowering period. Coffee flowering phenology, in turn, was proximately controlled by precipitation, and the differences in coffee flowering phenology interacted with bee species richness to influence initial fruit set rates. These authors also illustrate how coffee agroforests may better mitigate the negative effects of droughts. Some climate change models have predicted that many coffee-growing regions will experience drought which can lead to crop failure. Therefore, growing coffee under diverse shade trees may become increasingly important, not only for maintaining native bee species diversity, but also to improve soil moisture, thus mitigating the effects of drought. The competitive interactions between ants and bees for inflorescences of *Syzygium jambolanum* in an agroforestry system in Brazilian Meridional Amazonian were investigated by Dattilo et al. They concluded that ants prevented the access to bees and vice versa as the result of different ability of resource utilization and foraging strategies. Thus, preventing the access of ants to the floral nectar could increase the level of nectar available to pollinators of *S. jambolanum*, thereby increasing productivity and reducing economic losses.

Auad et al. estimated the abundance, diversity and constancy of families from the order Hymenoptera in a silvopastoral system in Brazil. They sampled 5,841 specimens in total, which included 549 species and were distributed among 11 families. They observed that the pastures managed in a silvopastoral environment harbored high numbers of natural enemies and beneficial insects. They attributed this to the structurally complex environments created by the silvopastoral system that provided microhabitats, greater protection from predators, and increased availability and diversity of food resources and nesting substrates. Neita and Escobar provides another interesting case study from the Pacific lowlands of Colombia in which they examined the changes in species richness, abundance, biomass, composition and functional group structure of the dung beetle (Scarabaeinae) communities that occur in three agroforestry systems in which the intensity of *Boroja patinoi* (an understory tree) canopy cover and density varied. Dung beetles are critical to a wide variety of ecological processes, such as the incorporation of organic matter into the soil, mixing of the different soil layers, control of parasites that affect domestic animals and human health, and the secondary dispersal of seeds, making them essential for both natural and agro-ecosystems. These authors showed that the structure of the dung beetle assemblage of *B. patinoi* growing below a diversified and permanent tree cover was similar to that of the primary and secondary forest. Beetle diversity in management systems with less tree cover or a high sowing density of *B. patinoi* was lower and very similar to that of abandoned agricultural fields. They concluded that *B. patinoi* agroforestry systems served as a valuable tool for biodiversity conservation and management in the wet tropical forests of the Pacific lowlands.

Rahman et al. assessed the effect of land use intensification on the distribution and abundance of soil invertebrate communities in a human-dominated biosphere reserve of international importance in India. Soil invertebrates were sampled in 15 land use practices ranging from simple and intensively managed annual crop fields through less intensively managed agroforestry and pristine forest ecosystems. They found the lowest taxonomic richness in annual crops and coconut monoculture plantations, while the highest was in the forests. Agroforestry systems had the highest diversity of ants with 21 species followed by forest ecosystems with 12 species. Earthworms and millipedes were significantly more abundant in agroforestry systems, plantations and forest ecosystems than in annual crop fields. They concluded that agroforestry could play a major role in biodiversity conservation in an era of ever-increasing land use intensification and habitat loss. While not focused entirely on biodiversity, the review article by Tsonkova et al. on ecosystem services of temperate alley cropping provides several examples of how alley cropping could enhance biodiversity on the landscape.

The role of agroforestry in enhancing biodiversity is much more important on degraded lands or in a landscape dominated by monoculture agriculture compared to a forested landscape. Contrary to their expectation, Smits et al. observed no differences on the dynamics of aphids and their predators between tree (*Populus* sp.; *Juglans* hybrid)—wheat (*Triticum turgidum*) alley cropping and wheat monocropping systems in France. They concluded that the high levels of landscape diversity in the study area due to nearby forest patches and fallows blurred the differences between the monoculture and alley cropping systems. These results also point to the experimental limitations encountered in several of the studies reporting the biodiversity values of agroforestry. The age, structure, and species composition of the agroforestry system, the duration of data collection (single season vs. multiple seasons), scale (small plot vs. large scale agroforestry installations), and the surrounding landscapes are all important factors that can influence the results when flora and fauna are monitored. Therefore, it is critical to investigate and report these variables in such studies along with the diversity of flora and fauna.

Soil microbial diversity

Heterotrophic microbial communities in soil mediate key processes that control ecosystem carbon and nitrogen cycling, and thereby represent a mechanistic link between plant diversity and ecosystem function (Zak et al. 2003). However, few studies have investigated the influence of plant diversity on soil microorganisms in agroforestry, yet there are reasons to expect that higher floristic diversity of agroforestry could exert positive influences on microbial communities.

Among the soil microorganisms, the fungi are exceptional for their heterotrophic activity for organic matter decomposition and potential as biological control agents of nematodes and arthropods. They are also associated with most plant species in symbiotic (mycorrhiza) or parasitic (diseases) relationships. The last two papers (Costa et al. and Arias et al.) report on fungal diversity in agroforestry systems. Costa et al. carried out their studies in three land use practices representing the Atlantic Forest, homegarden agroforestry and cassava (*Manihot esculenta*) monoculture system in Brazil. They calculated ecological indices of diversity, species richness, equitability, dominance, similarity and density. In general, Atlantic Forest soil presented the highest ecological indices followed by agroforestry. These authors also showed that the structure of the soil mycobiota of the Atlantic Forest and agroforestry were more than 50 % similar. They concluded that the similarity of the structure and composition of soil mycobiota between agroforestry and Atlantic Forest was mainly due to the rich plant diversity observed in the homegarden agroforest where 75 plant species per ha, including fruit and wood trees, co-existed. Arias et al. evaluated the arbuscular mycorrhizal fungal community as measured by spores in different coffee production systems in Mexico and compared them with the natural cloud forests. They reported that with the exception of one species exclusive to the forest, the coffee production systems all shared the same arbuscular mycorrhizal fungi species as the forest. The coffee production systems with the greatest similarity to cloud forest were the shaded traditional rustic system (with native forest canopy and some leguminous trees; no agrochemical use) and the shaded simple system (canopy dominated by leguminous trees; sparse use of agrochemicals). They concluded that some of the management practices such as weed control, and chemical fertilization might be influencing the abundance and composition of the arbuscular mycorrhizal fungal spores in coffee plantations.

Conclusions

Over the past two decades, we have become increasingly aware of the linkages between biodiversity loss and human well-being. While many of the key factors contributing to biodiversity loss are anthropogenic in origin, limited progress has been made to reduce such pressures even in countries where significant public funding has been invested. These realizations have led to the concept of multi-functional ecosystems that can conserve and enhance biodiversity while meeting other consumptive uses. Agroforestry is one such multifunctional working ecosystem that has been proven to be effective in conserving and enhancing biodiversity from the farm to landscape levels. This special issue is an attempt to bring together a collection of articles that not only explore and demonstrate the biodiversity benefits of agroforestry, but also the mechanisms by which agroforestry systems sustain such high floristic and faunal diversity. These articles add significantly to the growing body of knowledge on this complex topic that would help promote agroforestry. They also highlight the need for more rigorous long-term studies from agroforestry practices around the world. Long-term data sets are an essential resource in biodiversity research and monitoring. While it is important to conserve biodiversity through protected areas, the articles in the special issue reiterate the importance of agroforestry as a critical tool in conserving biodiversity in human-dominated landscapes.

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References

CBD (2010a) Convention on biological diversity secretariat, Global Biodiversity Outlook 3. CBD, Montreal

CBD (2010b) http://www.cbd.int/decision/cop/?id=12268. Accessed 10 April 2012

Conservation International (2012) http://www.conservation.org/learn/biodiversity/species/pages/projects.aspx. Accessed 9 April 2012

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260

FAO (2010) Global forest resource assessment. FAO Forestry Paper 163. Rome, Italy

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

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

Hutton JM, Leader-Williams N (2003) Sustainable use and incentive-driven conservation: realigning human and conservation interests. Oryx 37:215–226

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76:1–10

Jose S (2011) Managing native and non-native plant species in agroforestry. Agrofor Syst 83:101–105

McNeely JA (2004) Nature versus nurture: managing relationships between forests, agroforestry and wild biodiversity. Agrofor Syst 61:155–165

McNeely JA, Schroth G (2006) Agroforestry and biodiversity conservation—traditional practices, present dynamics, and lessons for the future. Biodivers Conserv 15:549–554

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

Perrings C, Naeem S, Ahrestani F, Bunker DE, Burkill P, Canziani G, Elmqvist T, Ferrati R, Fuhrman J, Jaksic F, Kawabata Z, Kinzig A, Mace GM, Milano F, Mooney H, Prieur-Richard A-H, Tschirhart J, Weisser W (2010) Ecosystem services for 2020. Science 330:323–324

Rands MRW, Adam WM, Bennun L, Butchart SHM, Clements A, Coomes D, Entwistle A, Hodge I, Kapos V, Scharlemann JPW, Sutherland WJ, Vira B (2010) Biodiversity conservation: challenges beyond 2010. Science 329:1298–1303

Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos H, Izac AN (2004) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, DC

Wilcove DS, Rothstein D, Dubow J, Phillips A, Losos E (1998) Quantifying threats to imperiled species in the United States. Bioscience 48:607–615

Zak DR, Holmes WE, While DC, Peackck AD, Tilman D (2003) Plant diversity, soil microbial communities, and ecosystem function: are there any links? Ecology 84:2042–2050