

## Chapter 11

## The potential for agroforestry to contribute to the conservation and enhancement of landscape biodiversity

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### Abstract

Agroforestry is increasingly being acknowledged as an integrated land use that can directly enhance agrobiodiversity and contribute to the conservation of landscape biodiversity, while at the same time increase, diversify and sustain rural incomes. There are valid concerns, however, that the biodiversity benefits of agroforestry may be misunderstood and the risks to biodiversity understated. This chapter therefore reviews some of the growing literature on agroforestry and biodiversity in order to clarify key relationships, including factors and processes that amplify or limit the contributions of agroforestry to biodiversity conservation. Four propositions are presented, with reference to evidence for the propositions and caveats to them. We conclude that agroforestry generally produces higher biodiversity benefits than both annual and perennial monoculture crop production, and that agroforestry is of the greatest benefit to biodiversity when it is a component of an integrated approach to land use. Important knowledge gaps remain, however, regarding the ways in which tree domestication and agroforestry promotion can be designed to stimulate new agroforestry systems that have greater positive impacts on wild biodiversity.

### Introduction

Agroforestry is increasingly being identified as an integrated land use that can directly enhance plant diversity while reducing habitat loss and fragmentation (Noble and Dirzo 1997). There are major concerns, however, that the deforestation benefits of agroforestry have been overstated (Angelsen and Kaimowitz 2004) and that the risks associated with agroforestry have not been adequately acknowledged. It is therefore more important than ever that both the scientific and development communities develop a more accurate and subtle understanding of the multiple links between biodiversity and agroforestry. This chapter reviews evidence that links agroforestry with biodiversity in an attempt to clarify

key relationships. It also examines the factors and processes that may amplify and limit the contributions of agroforestry to biodiversity conservation. It is organized as follows: the first substantive section presents important organizing concepts; the second section reviews the available evidence for and against four propositions about the relationship between biodiversity and agroforestry; and the final section discusses a number of issues for follow-up research.

### Organizing concepts

The United Nations Convention on Biological Diversity (UNCBD) defines 'biodiversity' as "...the variability

among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems." Spatial and ecological scales are therefore fundamental concepts in biodiversity studies. The UNCBD further defines agrobiodiversity as biodiversity that is important for agricultural production, including crop and livestock genetic diversity, wild biodiversity closely associated with domesticated species, and other wild biodiversity sharing the resources. 'Wild biodiversity' is biodiversity that has not been domesticated, while 'domestication' is the dynamic process of how humans select, improve, manage, propagate and integrate trees or other plants into land use systems. While ICRAF and its partners have conducted a great deal of work on below-ground biodiversity (e.g. van Noordwijk et al. 2004), we concentrate here on above-ground biodiversity at the landscape scale, explicitly focusing on the links between the planting and management of trees by farmers and biodiversity in the landscape.

Several definitions of the term 'agroforestry' are used in science and practice. Leakey's (1996) definition is used most frequently: "a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the landscape, diversifies and sustains production for increased social, economic and ecological benefits." Three aspects of this definition are important for the biodiversity value of agroforestry. Firstly, agroforestry involves the deliberate integration of trees with farms and landscapes, which may have direct and indirect effects on farm and landscape biodiversity. Secondly, there are trade-offs and complementarities between the social, economic, ecological and bio-

diversity benefits of agroforestry compared to other land use systems; indeed, the quantification of trade-offs has been at the heart of the research agenda of the Alternatives to Slash and Burn (ASB) Programme coordinated by ICRAF (Tomich et al. 2001). Thirdly, while some agroforestry practices in certain circumstances contribute greatly to diversification and sustainability, there are other circumstances where it contributes very little.

### Propositions about relationships between agroforestry and biodiversity

A number of recently completed review papers suggest ways in which agroforestry contributes to the conservation and protection of biodiversity, including that of both wild species and species more directly related to agricultural production (Boffa 1999; Buck et al. 2004; Cunningham et al. 2002; McNeely 2004; McNeely and Scherr 2003; Schroth et al. 2004a; van Noordwijk et al. 1997). These and other studies suggest four key relationships between agroforestry and landscape biodiversity.

#### 1. Agroforestry farmers and systems as promoters of plant diversity

**Proposition:** *While modifying natural vegetation for their productive use, farmers develop and maintain agroforestry systems that make substantial contributions to biodiversity in multi-functional landscapes.*

The proposition that agroforestry will result in 'substantial contributions' to biodiversity is supported by a good deal of evidence regarding the diversity of tree and vascular

plant species across a variety of landscapes, including those containing agroforestry systems. There are important caveats to the proposition, however: i) there are large differences in the biodiversity value of different agroforestry systems; ii) some of the more diverse agroforestry systems may become less diverse under high levels of population pressure; and iii) the commodities that underpin many of the most diverse agroforestry systems are subject to fluctuations and declines in profitability when adopted on a large scale.

The ASB programme has evaluated the biodiversity associated with a range of typical land use types, including agroforestry, that are found at the frontiers of tropical forests in Southeast Asia, the Congo Basin, and the Amazon Basin. Methods used and results generated by this comprehensive set of studies are available on the ASB web page ([www.asb.cgiar.org](http://www.asb.cgiar.org)). Summary results are also presented in Tomich et al. (1998) and Tomich et al. (2001). In general the results show that multistrata agroforestry systems contain an intermediate level of plant biodiversity that lies between primary forests and monocrop perennials or field crops. For example, Murdiyarso et al. (2002) compared the number of plant species found in different types of land use in the Jambi area of central Sumatra. They found that continuously cultivated cassava had 15 species per 1.5-hectare plot, oil palm plantations had 25 species per plot, rubber agroforests had 90 species per plot, while primary forests had 120 species per plot.

Gillison et al. (2004) found that complex agroforestry systems and shade-grown coffee both had much higher levels of biodiversity than simple sun-grown coffee, although all coffee systems had lower biodiversity than primary or secondary forests.

Similarly high levels of tree diversity are also reported for complex cocoa systems found in West Africa and Central America (Schroth et al. 2004b) and the intense homegarden systems found in many parts of Africa and Asia (Khan and Arunachalam 2003; Michon and de Foresta 1995). However, recent data from the Chagga homegardens in Tanzania indicate that tree populations in established gardens may become less dense and more fragmented over time if population pressures rise to very high levels (Misana et al. 2003; Soini 2005).

An alternative approach to agroforestry/forest management that has proved particularly effective in parts of East Africa and the West African Sahel, is described by one analyst as farmer-managed natural regeneration (Chris Reij, seminar at ICRAF, Nairobi, September 2004). The agroforestry parklands of the Sahel are one example – for several generations, farmers across the Sahel have deliberately selected and protected valuable indigenous trees located in their agricultural fields (Boffa 1999). The ‘Ngitili’ system practised in western Tanzania is another example. The Sukuma people – as individuals and groups – have traditionally set aside parcels of land and managed them as biodiversity reserves and fall-back resources. After years of neglect, this system has been revived in large areas of western Tanzania. Additional value has been added to many ‘Ngitili’ exclosures through the planting and management of valuable timber and fruit trees (Barrow and Mlengi 2003).

Assessing the value of farmer tree management to biodiversity is challenging. On-farm surveys in Cameroon, Kenya and Uganda show that the diversity of tree species hosted on African farms is greater than originally thought (Kindt 2002). However,

in these agroforestry systems, although there may be high species richness it is often accompanied by the infrequent occurrence of many species. For example, while 47 percent of species recorded in Uganda’s Mabira Forest were found on surrounding farms, more than half of the identified species numbered 10 individuals or less (Boffa, unpublished data), which may not be sufficient to sustain genetic diversity in the long term. Equally important is the extent to which agroforestry systems specifically contribute to the conservation of rare or threatened forest species. Data from these three countries indicate that few vulnerable or threatened species have actually been observed in agroforestry systems. More research is needed on the important functions and roles that tree diversity plays in landscapes in terms of conserving lesser known aspects of biodiversity, providing other environmental services and benefiting livelihoods.

A crucial question is how agroforestry systems with increased biodiversity value can be stimulated or enhanced in new environments. Agroforestry systems have the potential to evolve through succession toward mature, productive systems to form a mosaic of patches on a landscape while producing marketable tree products for improved livelihoods. Leakey (2004) proposes that domestication of valuable indigenous trees is a key starting point. The proposition is that farmers who recognize and are able to capitalize on the value of indigenous trees will be impelled to plant and protect trees of various types. ICRAF’s agenda of research on domestication, seed production and marketing of indigenous fruit and medicinal trees is largely based on this proposition. One of the challenges is to integrate domestication work with a broader conservation framework.

## 2. Agroforestry and pressures on forests and protected conservation areas

**Proposition:** *The increased uptake of agroforestry in multi-functional landscapes can reduce pressure on forests and protected conservation areas.*

This proposition is not supported by a large base of empirical evidence, but nonetheless has become the basis for including agroforestry in many integrated conservation and development projects. For example, one of the global champions for primate research and conservation, Jane Goodall, now supports agroforestry development as a way of protecting the remaining chimpanzee populations in the Gombe national park in Tanzania ([http://www.jane-goodall.ca/inst/inst\\_tacare\\_hist.html](http://www.jane-goodall.ca/inst/inst_tacare_hist.html)). There are four main caveats to this proposition: i) agroforestry will only result in reduced pressures on a protected area if the main pressure on that area is farmers’ collection of tree products; ii) agroforestry has the potential to increase pressure on forests and conservation areas if it results in increased clearance of primary forest for agroforestry; iii) the potential impact of agroforestry on protected areas depends upon the policy and institutional context affecting tree management and protected area use; and iv) it is difficult to separate the effects of agroforestry from other elements of buffer zone management that successfully reduce pressures on protected areas.

The proposition that agroforestry can reduce pressure on conservation areas is mainly based on evidence of the productivity of agroforestry systems compared to more extensive systems of land

management. For example, Ramadhani et al. (2002) found that 5-year-old woodlots of *Acacia crassicaarpa* in the Tabora district of Tanzania produced five times as much wood as mature 'miombo' woodlands. Simple calculations show that if all the wood needed for tobacco drying came from woodlots instead of the 'miombo', then 8 675 hectares of woodland would be conserved each year in the Tabora district. Govere (2002) attempted to test this substitution hypothesis for the example of improved fallows in eastern Zambia. His results are mixed: in one village the adopters of improved fallows gathered less wood than non-adopters; in another village adopters and non-adopters gathered roughly the same amount of wood.

A study by Garrity et al. (2002) around the Mount Kitanglad Range National Park in Mindanao, the Philippines, provides support for a link between agroforestry and reduced pressure on protected areas. Farmers around this area of high biodiversity were educated about the use of natural vegetative strips to stabilize hillside farming areas, and improved germplasm and nursery techniques to enhance on-farm production of fruit and timber. The key institutional innovation was Landcare – farmer-led knowledge-sharing organizations inspired by the Landcare movement in Australia. After a number of years, this combination of technical and institutional interventions produced positive impacts in terms of increased maize yields, greater density of fruit and timber trees, reduced runoff and erosion, enhanced environmental awareness, reduced encroachments into the park, and restored stream corridor vegetation. By 2002 there were more than 800 households in Mindanao that belonged to village Landcare chapters around the park boundary.

Another study of the buffer zone of the Kerinci Seblat National Park, Indonesia highlights the relationship between farm diversification and reliance on adjacent national park resources (Murniati et al. 2001). Comparing a sample of rice-only farms, mixed garden farms and a combination of both, the authors found that farms practising both rice growing and mixed gardening had 80 percent lower dependency on park resources. Factors associated with a higher propensity to extract from protected forest resources were low farm income and low supply of on-farm tree-based products, suggesting that agroforestry systems were particularly relevant in the buffer zones. ICRAF research around the Mabira Forest Reserve in Uganda suggests that larger scale economic forces and forest policy can have greater impact on protected areas than agroforestry and other development interventions undertaken around them. While resource extraction by adjacent communities increased with proximity to the forest, agroforestry in the buffer zone could not have any significant impact on the quantitatively far more significant pressures originating from outside the buffer zone, particularly from fuelwood markets for sugar and tea processing, and for brick and charcoal making (Mrema et al. 2001a; 2001b; 2001c; 2001d).

Angelsen and Kaimowitz (2004) argue that the conservation benefits of agroforestry have often been overstated, particularly in places where the forest frontier is still open to settlement and harvesting. Angelsen and Kaimowitz (2004) and Tomich et al. (2001) point out there are likely to be trade-offs associated with profitable agroforestry: on one hand, there will be pressure to convert primary forest to profitable alternative land uses; on the other hand, degradation of agroforestry systems may lead to conver-

sion to less desirable land uses. A classic case of these trade-offs is cocoa. Conversion of primary forest to cocoa production has been a major source of biodiversity loss in many parts of the humid tropics. However, compared to sun-grown cocoa or competing annual crops, shade-grown cocoa agroforests retain much higher levels of biodiversity (Donald 2004).

### 3. Agroforestry and habitat for wild species

**Proposition:** *Agroforestry can create habitat for wild species in landscape matrices surrounding forest conservation areas.*

The integration of trees into multiple-use landscape matrices can contribute to wild biodiversity through the maintenance of landscape connectivity, heterogeneity and complexity of vegetation structure, integrity of aquatic systems, and cleaner water. Trees can contribute nesting sites, protective cover against predators, access to breeding territory, access to food sources in all seasons, and encourage beneficial species such as pollinators. Evidence of the nature of these relationships has been generated through a fairly large number of field studies, most of which have focused on birds. One caveat is that there have been limited studies to date on how the spatial configuration of trees on farms and in landscapes affects the conservation of different types of biodiversity.

Buck et al. (2004) reviewed 12 studies that found agroforestry systems to provide habitat for diverse populations of birds, with the greatest amount of evidence pointing towards the habitat value of shade-grown

coffee and cocoa systems in Southeast Asia and Central America. However, there are also contrasting results: Soini (2004) found low levels of bird diversity in the multistrata Chagga homegardens of Kilimanjaro, Tanzania. Soini postulates that the very high levels of human population in those areas have created an inhospitable habitat for most bird species.

Naidoo (2004) presents a novel analysis of the relationship between forest types and bird types in and around the Mabira forest in Uganda. He analysed the diversity of songbirds along transects across different types of landscapes, from intact primary forest, to regenerating secondary forests and agricultural fields. Songbirds were classified as forest specialists, forest generalists, forest visitors and open habitat species. He found roughly similar numbers of total songbird species in each of the three land-use types, but marked differences in the percentages of different species groups. Forest specialists were not found in the agricultural area; open habitat species were not found in the intact forest. Statistical models of the habitat–species relationship showed that tree density and distance to intact forest had the greatest impacts on number of forest species. Model results indicate that greater tree density in agricultural fields could result in a sizeable expansion in the habitat of forest specialists within the forest and forest generalists in the forest margin.

Agroforestry can enhance connectivity and landscape heterogeneity in multi-functional conservation landscapes. Zomer et al. (2001) found that an agroforestry system involving *Alnus nepalensis* and cardamom contributed to the integrity of riparian corridors for wildlife conservation around the Makalu Barun National Park and Conservation Area of eastern Nepal.

Griffith (2000) suggests a different ecological mechanism by which agroforestry can contribute to biodiversity – by providing a low risk refuge in the case of fire. He assessed bird biodiversity in two agroforestry farms in the buffer zone of the Maya Biosphere Reserve in Guatemala in order to determine whether those farms had served as biodiversity refuges during the fires of 1998 that burned eight percent of the reserve. He found high numbers of bird species, including forest specialists and forest generalists – birds that are not usually found in agroforestry areas.

#### 4. Agroforestry and the threats of invasive alien species

**Proposition:** *Agroforestry development can be implemented in a way that reduces the risk of alien invasive species to acceptable levels, if adequate precautions are taken.*

In the introduction to this chapter we noted that there are major concerns in the conservation community about the potential threat that farmer planting of trees may pose to biodiversity. For example, the UNCBD Thematic Programme of Work states: “Tree plantations and agroforestry are important sources of biological invasions... Of species used for agroforestry around seven percent are said to be weeds under some conditions, but around one percent are weedy in more than 50 percent of their recorded occurrences.”

Evidence from across the world indicates that agroforestry projects have contributed to the ecological problems associated with alien invasive species. News of impending ‘fuelwood crises’ a generation ago led

to the creation of a large number of new agroforestry projects across the developing world in the late 1970s and early 1980s. While many of these projects undoubtedly contributed to increased energy supplies, they have also had negative consequences for welfare, biodiversity and water availability. Better design of the current generation of agroforestry projects should help to minimize negative impacts in the future. For example, ICRAF has adopted a policy that focuses on reducing the risk of introducing invasive alien species as part of new agroforestry research and development programmes. We are also conducting research on effective management of selected invasive alien species. For example, ongoing research on *Prosopis juliflora* in the Baringo area of Kenya indicates the potential benefits and limitations of effective management through sustained use.

#### Challenges for the future

The overall conclusion that emerges from this review is that agroforestry generally produces biodiversity benefits that are intermediate between monocrop agriculture and primary forests. The overall contribution of agroforestry to biodiversity conservation depends, therefore, on the type of land use that it replaces and on the attributes of the specific agroforestry system. The effectiveness of agroforestry in biodiversity conservation depends on the design of the system and the nature of the biodiversity to be conserved. Agroforestry is not a stand-alone approach to conservation. Rather, it needs to be seen as an element of conservation strategies, which also include policy and institutional changes, and spatial configurations that emphasize maintenance of natural habitats.

Additional research, including appropriate measurement, modelling and

experimentation, is needed, contained within the following recommendations:

- Broaden the agroecological focus of agroforestry and biodiversity studies to include more drylands and annual crop-based systems.
- Identify the key features of agroforestry systems – species composition, configuration, management, landscape position – that are most critical to supporting biodiversity in the landscape and in multiuse areas around protected areas.
- Evaluate the conditions under which market-led domestication and on-farm husbandry of valuable indigenous trees can stimulate a sequence of increased tree planting, more intensive land use, and less pressure on forest and land resources.
- Assess the landscape-level effects of new agroforestry systems, such as the improved fallows and rotational woodlots promoted in southern Africa.
- Give higher priority to the challenges of alien invasive species, with special emphasis on the development of management plans for species that have been associated with agroforestry.
- Expand the use of agroforestry systems in degraded lands to help restore the productivity and biodiversity of marginal lands.
- Fully explore the refuge value of agroforestry systems, such as those studied by Griffith (2000).
- Conduct more research into the important functions and roles that tree diversity plays in landscapes for conserving lesser-known aspects of biodiversity, providing other environmental services, and benefiting livelihoods.

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