Introduction

Mohammed Dore and Rubén Guevara

Within the last two decades of the 1900s, it has become clear that forests are not just timber, waiting to be cut down. Ecologists have succeeded in informing others that the forests have other vital ecological functions, such as helping regulate the hydrological cycle, the nutrient cycle and the carbon cycle. Forests also help preserve the soil from being eroded away; forests are repositories of biodiversity and, as part of the hydrological cycle, they also prevent flooding. It is now fashionable for economists to refer to these ecological functions as non-marketed 'environmental services', which they attempt to value as if they were ordinary consumable goods and services. The international community too has at last recognized the problem of global warming and the latter has become the subject of a global accord, following the signing of the United Nations Framework Convention on Climate Change and the Kyoto Protocol. The UN Framework Convention recognizes that the world's forests will have an important role to play in implementing a global strategy for reining in the global emissions of carbon, which is the main factor in global warming. It is also appreciated that conservation and growth of the forests will ease other so-called 'natural' disasters, such as floods, hurricanes, and ice storms. Indeed, one fear is that, with global warming and the possible intensification of the activity of El Niño, the severity and frequency of these disasters may be on the increase. While not all the scientific evidence is yet 100 per cent conclusive on the magnitudes of future climate change, there is a rising consensus that 'something's afoot'. As a result, the international community has now accepted the *precautionary principle*, which means that the global community should err on the side of caution. This is of course a clear step forward, but much more could have been done. For example, the global community is nowhere near to the adoption of a Global Forest Convention, although the idea for such a convention has been broached many times. Such a Forest Convention would have clear guidelines for the sustainable management of the forests of the world. In the absence of such a Convention, it is imperative to produce careful and painstaking analyses on the importance of the world's forests, and show how the forests may be harvested judiciously and

in a manner that might be considered at least partially ‘sustainable’. This requires that the analysis take into account the role that forests might play in mitigating global warming, in preventing soil erosion, and in helping to minimize the loss of biodiversity. We hope that this book is an example of such an analysis of a number of dimensions in the sustainable management of forests. In order to reach this objective, this book draws on the expertise in the western hemisphere on the analysis of forests.

The first part of the book concentrates on the relevant biophysical aspects of forest management, and the second on the valuation of forests for providing a carbon sink that absorbs, in part, the carbon that is released into the atmosphere through the burning of fossil fuels. The third part is a more detailed look at selected case studies on forest policy in North, Central and South America. In this Introduction, the first section provides the global setting within which the chapters of this book are set. Section two is an integrated and more detailed overview on the contents of each chapter.

SECTION 1

The total area of the world’s forests is about 3.4 billion hectares; that is, one-third of the world’s land surface is covered by woody vegetation (FAO, 1995). A considerable portion of the total forest area is so-called open woodland, including savannas. About half (52 per cent) of open and closed forests are in the tropics, with 30 per cent at high latitudes and 18 per cent at mid-latitudes. However, this forested area is decreasing annually by approximately 12 to 15 million hectares. Most of the annual decrease is taking place in the tropical world. In fact, in temperate and boreal regions, the forest area has slightly increased in recent decades. The main reasons for deforestation in the tropics are the conversion of forest to agricultural land and to pastures, and the cutting of fuelwood and timber.

In recent years, several international conventions or accords have addressed the problem of tropical deforestation from the various perspectives of biodiversity, climate change, ozone depletion and desertification, but, as stated before, a comprehensive accord on sustainable forestry still eludes the international community. In the circumstances, the one convention that could do something to aid forest conservation is the United Nations Framework Convention on Climate Change (UN FCCC). Its ultimate objective is the stabilization of greenhouse gas emissions in the atmosphere at a level preventing dangerous anthropogenic interference with climate, and minimizing risks to and adverse effects on ecosystems. This requires close attention to forestry. Consequently, the authors of this book review and discuss options for carbon management in the tropics in forestry and agroforestry systems,

and attempt to assess the feasibility of such actions. They also discuss some potential policy implications for tropical countries.

The Intergovernmental Panel on Climate Change (IPCC) has estimated that anthropogenic emissions of CO₂ in 1995 were 5.5 ± 0.5 GtC (GtC = gigatons, or billion tons of carbon) due to fossil fuel burning and cement production, plus 1.6 ± 1.0 GtC due to deforestation. During the last decade of the 20th century, about 45 per cent of anthropogenic emission stayed in the atmosphere, the remainder being taken up by the oceans and by land ecosystems (Table I.1). It might be useful to note that, before 1750, atmospheric CO₂ was 280 parts per million by volume (ppmv); in 1999, it is 365 ppmv. It is estimated that it is increasing by 1.5 ppmv per year. If we burn up all the world's fossil fuel of 5000 GtC, the atmospheric concentration of CO₂ could increase by a factor of 10, to 2800 ppmv, even after allowing for some absorption by terrestrial sinks. If that happens, it is estimated that the mean surface temperature of the earth could rise by anywhere between 4.5 and 15 degrees Celsius. Thus, in the larger scheme of things, the role of deforestation in total annual anthropogenic emission is small, but at between 22 and 50 per cent of emissions it is not negligible either.

Parties to the UN FCCC have agreed upon and committed themselves to certain actions in order to achieve the global objective of stabilizing atmospheric greenhouse gas concentrations. In principle, this target can be achieved by (a) reducing emissions of GHGs in the atmosphere (reduction of sources) and (b) removing GHGs from the atmosphere (enhancement of sinks). Research on climate change and land use in the tropics has mainly focused on the analysis of the impact of deforestation and other land use changes on greenhouse gas emissions and carbon budgets. However, some studies have attempted to quantify the potential of sustainable land use to sequester and accumulate carbon dioxide in tropical ecosystems, and others have attempted to put dollar values on boreal forests. Both types of study are represented in this book.

It should be noted that forests could also be a source of greenhouse gases, since forest ecosystems are estimated to contain more than 80 per cent of global above-ground carbon. Indeed, the scientific community has largely agreed that the tropical forest ecosystems have been net carbon sources, while the northern temperate and boreal forests are a major carbon sink (see, for example, Kauppi *et al.*, 1992; Sedjo, 1992). Recent results, however, show that mature tropical forests can accumulate carbon at a rate of 1–2Mg/ha/yr (Lugo and Brown, 1992; Grace *et al.*, 1995), which can offset emissions from deforestation and degradation (Brown *et al.*, 1996).

The carbon pool of any terrestrial ecosystem has two main components: the total area of the ecosystem and the carbon density per unit area. Thus, in order to enhance sinks and to maintain carbon pools, we can develop actions

Table I.1 Human perturbations to the carbon budget

CO ₂ sources	Flux (GtC/yr)
Fossil-fuel burning	5.5
Tropical deforestation	<u>1.6</u>
Total anthropogenic emissions	7.1
CO ₂ sinks	
Storage in the atmosphere	3.3
Uptake by the oceans	2.0
North. hemisphere forest regrowth	0.5
CO ₂ and N fertilization, climate	<u>1.3</u>
Total	7.1

Source: IPCC (1995).

to increase the area of these ecosystems, increase their carbon density, or both of these simultaneously. Several studies have attempted to estimate the potential land area available for afforestation, reforestation, agroforestry, conservation or other management options for carbon sequestration (for example, Houghton *et al.*, 1991; Nilsson and Schophauser, 1995). However, there are many constraints on how this can be achieved. The real availability of land for these programmes depends on economic, social, cultural and institutional factors which influence land use (Trexler and Haugen, 1995; Godoy *et al.*, 1998) (Table I.2).

The sustainable management of carbon pools in existing forests, agroforestry systems and agricultural lands offers an interesting option. The above-ground carbon content of tropical forest ecosystems varies between 25 and 250 t ha⁻¹. Thus reducing deforestation and increasing measures for forest protection offers a cost-effective way of reducing CO₂ emissions (Table I.3).

Table I.2 Land available for carbon sequestration in the tropics

Option	Area (10 ⁶ ha)
Plantation of degraded lands	0–579
Secondary forest suitable for protection	15–858
Areas with potential for agroforestry	356–500

Source: Houghton *et al.* (1991).

Other carbon management options related to existing production systems include the incorporation of trees into agricultural systems, whether as agroforestry or as a silvopastoral system. The above-ground carbon content of agroforestry and silvopastoral systems varies between 10 and 70t/ha, and the annual carbon flux to the system is between 1 and 10 ha/yr. When the carbon stored in the soils of these systems is considered, these figures can be multiplied by a factor of two (Tables I.4 and I.5).

Table I.3 Above-ground carbon storage in tropical forest carbon storage (tons per hectare)

Forest type	Primary	Secondary
Moist forests	230	190
Seasonal forests	140	120
Dry forests	60	25

Source: Brown and Lugo (1982); Brown *et al.* (1989).

It is of primary importance that the forest ecosystems of the world are in a state where their ability to act as sinks of greenhouse gases is maintained and enhanced. The measures required to achieve this may be summarized into four main types of general action:

1. Measures against desertification, deforestation and forest destruction. These should be aimed at the stabilization of forest area, where appropriate, and, where possible, increasing it further.
2. Promotion of overall health of ecosystems. This includes especially actions against harmful effects caused by pollutants.
3. Measures against the degradation of ecosystems (unsustainable management and so on) and measures that increase the potential of forests to act as sinks of GHGs (stocking densities, amount of biomass, and so on).
4. Promotion of scientific research, monitoring and information exchange on (a) forests as sources and sinks of GHGs, and (b) sustainable management of forests.

Of course, it is obvious that forestry, agroforestry and ecosystem management in the tropics cannot alone solve the problem of global warming, as the bulk of the emissions is due to fossil fuel burning. However, together with other measures, carbon management in tropical ecosystems can be one player in the global act, even though its contribution is difficult to quantify. It should also be noted that the management of tropical ecosystems might have functions and

Table I.4 Above-ground carbon storage in agroforestry and forestry in Central America

System Tree species	Life zone	Trees N/ha	Age (years)	C Storage tC/ha	C Flux tC/ha/yr
Cliricidia sepium	TPW	330	30	51.6	1.7
Cordia alliodora	TPW	278	10	24.9	2.5
Mimosa scarabella	TPW	650	2	14.2	7.1
Fuelwood Plantations					
L. leucocephala	TLD	3 800	5	28.9	5.8
Eucalyptus saligna	TPW	1 378	2.5	27.0	10.8
Trees in corrals					
Alnus acuminata	TLM	35	30	25.0	0.8

Note: TPW = tropical premontane wet forest; TLD = tropical lowland dry forest; TLM = tropical lowland moist forest.

Sources: Salazar (1984, 1986); Fassbender *et al.* (1991); Picado (1986); Martinez (1989); Canet (1986).

goals other than that of solving the problem of global warming. In addition, for very many people in developing countries, trees are the main source of energy. Forestland is also cleared for agriculture, for the production of food for a constantly increasing population. This makes forest conservation extremely difficult. These social imperatives create new challenges to the sustainable management of forests and to the maintenance of biodiversity. This is not to imply, however, that nothing can be done. Our minimum target must be the development of tools that allow a combination of these multiple objectives.

Table I.5 Carbon in Tropical Soils

Land use	Carbon storage (tC/ha)
Tropical forest	60–115
Agriculture (maize)	
Initial	35
After 50 years	9
Agroforestry	
Initial	8.9
After 9 years	24.1

Sources: Brown and Lugo (1982); Young (1989); Fassbender *et al.* (1991).

For carbon sequestration, the best carbon management option is reducing deforestation and promoting reforestation and afforestation. But there is also the question of carbon density and also the cost per ton of carbon. Reducing deforestation is also the lowest-cost means of increasing carbon sequestration. These carbon management options are summarized schematically in Table I.6.

The authors of the chapters of this book all argue that the world can do much to reduce the problem of carbon accumulation in the atmosphere by paying much greater attention to the conservation of the world's forests. As the western hemisphere still has vast tracks of forests, it is imperative that effort be devoted to a proper study of these forests. Section 2 below summarizes how each author in this book tackles the task.

Table I.6 Carbon management options and trade-offs

Option	Carbon density	Sequestration (short-term)	Cost per ton of carbon
Reducing deforestation and protecting forests	High	Low	Low
Reforestation and afforestation	Moderate	High	Moderate
Silviculture	High	Moderate	Low
Agroforestry	Low	Moderate	Moderate
Fuelwood plantations	Moderate	High	High
Forest products	Low	Low	Low

SECTION 2

The first chapter by Grace Saénz and her co-author offers an analysis of the ecological functions of forests and their respective implications for tropical forest management. They show that forest management does not merely mean ensuring the sustainable production of timber; it also means taking a series of measures to ensure the fulfilment of other ecological functions of the forests. Saénz and Robin aus der Beek concentrate on the following ecological functions: conservation of biodiversity, soil protection and the maintenance of the natural watershed. A properly conserved forest will also generate employment income, recreation and tourism benefits, and of course also provide timber. The authors draw important lessons in sustainable forest management from a case study of silviculture plots in the Villa Mills experimental area in Costa Rica. They demonstrate the importance of a specific analysis for each possible ecological function of forest management. De-

pending on the ecological, social, economic and cultural characteristics, forest functions will vary completely. This is another reason why a detailed analysis should be made for each specific case. The chapter points to some important lessons on the sustainable management of tropical forests.

In Chapter 2, Steven Shultz reports on two case studies that demonstrate the benefits of using GIS (geographic information systems) technology to integrate biophysical and socioeconomic data in order to plan various sustainable resource management activities. In the first case study, GIS is used to identify critical land use areas with information concerning the preferences and desires of local farmers in order to determine the benefits and costs of a reforestation programme. In the second case study, GIS is used to identify critical land uses, which were linked to socioeconomic data through the mapping of individual farm boundaries within the study area. This integration of data is then used for resource planning activities through the classification of different activities, such as soil conservation, reforestation or natural forest management, that were deemed most appropriate to the specific needs of farms, based on their size and characteristics. It also permitted the ranking of farms in order of priority for those most in need of soil conservation, based on their relative levels of land degradation.

These case studies show that natural resource professionals can use relatively simple and available methodologies to plan comprehensively the sustainable management of resources in other developing areas of the world. The major advantages of using GIS technology are the efficient identification and prioritization of critical land use areas within a watershed or study area, while taking into account both biophysical and socioeconomic data. Such integration is essential for planning and evaluating specific sustainable resource management plans over space and time. However, in order to use GIS and GPS (global positioning system) technology, national and local governments should spatially reference and maintain land use surveys, and make this information compatible with national GIS databases.

In the last chapter of Part I, Mark Johnston and Peter Uhlig present estimates of carbon storage in soils and vegetation in the forests of northern Ontario. North American boreal forests have been identified as a globally important carbon store, and are expected to play an important role in future climate change. However, landscape-scale estimates of boreal carbon storage were not available and so the authors fill in this gap by estimating carbon storage in soil and vegetation for a series of upland forested ecosystem types in northwestern Ontario, Canada, using data collected from the forest ecosystem classification system (FEC). Their estimates are for mineral soil to the depth of 100cm of forest floor, understorey and tree vegetative components. They find that the mean total carbon (C) density among all ecosystem types was $26.3 \pm 8.6 \text{ kg m}^{-2}$, and ranged from $14.1 \pm 4.5 \text{ kg m}^{-2}$

to $37.8 \pm 13.6 \text{ kg m}^{-2}$. Vegetative C density was highest in old-growth red and white pine types ($18.0 \pm 0.9 \text{ kg m}^{-2}$), while soil C density was highest on wet sites dominated by deep organic deposits ($26.3 \pm 13.6 \text{ kg m}^{-2}$). In general, vegetative C density was highest on productive sites, especially those with mixed species composition. Mineral soil C was also higher on productive sites, while forest floor C was greatest on sites with low rates of decomposition, due either to a lack or an excess of moisture. A comparison of C storage estimates derived from FEC data with those from forest resource inventory data for the study indicated that FEC data yielded higher estimates due to a bias in sampling that favoured mature, fully-stocked stands. These quantitative estimates will be helpful in obtaining a more complete picture of carbon sequestration in the forest ecosystems of the northern hemisphere.

Part II deals with aspects of the valuation of forests for carbon sequestration and the valuation of other ecological services provided by forests, such as prevention of soil erosion and facilitating the nutrient cycle. The first two chapters in this part estimate the value of forests for carbon sequestration in North America and in tropical America. However, their approaches are quite different. In Chapter 4, Mohammed Dore and Mark Johnston attempt to place a value on carbon sequestration of the boreal forests of Canada. The central objective of their work is to find and estimate econometrically a shadow price or the scarcity rent of forests for mitigating global warming. Furthermore, they show that the scarcity rent must be a cardinal measure which rises with increasing scarcity of the forests. They specify an optimal control model to derive a shadow price of forests, and the value of forests is computed via econometric techniques. They fit statistical models to carbon emissions in Canada and the amount of carbon sequestered by the boreal forests of Canada in order to obtain the scarcity rent of forests for carbon sequestration. The statistical models are used to compute the marginal social opportunity cost of forests per hectare. The authors argue that it is this opportunity cost that must enter any harvesting decision model or any other social cost–benefit calculation when making valuation decisions about the forests. They estimate that this social opportunity cost of forest is a premium of about 25 per cent and the value of the forest in 1986 Canadian dollars is between \$289 and \$412 per hectare. This is the valuation for only one ecological service provided by forests, which is carbon sequestration.

In Chapter 5, Octavio Ramirez treats the problem in greater detail. First he distinguishes between carbon *storage*, carbon *parking* and carbon *sequestration*. Storage is holding a stock of carbon in place, as in a mature forest; parking is a temporary store, whereas sequestration is the net growth in carbon stored. He looks at three kinds of forests in the tropics (primary forests, secondary forests and plantation forests) and he assesses each as

repositories of carbon. He argues that humid tropical secondary forests have a considerable potential for carbon sequestration and storage. Most of the carbon sequestration takes place during the first 20 years of growth. The per hectare economic value of the carbon sink service provided exceeds the market value of the land in most tropical humid regions of the world. Therefore, if the market value reflects the opportunity cost of the land, forest conservation is an economically sensible alternative. At a critical phase of global warming of the planet, carbon sequestration is valued and, sometimes, bilateral agreements are entered into in order to achieve the objectives of carbon sequestration. Such agreements are called *joint implementation agreements*. If a global carbon market eventually develops, promoting secondary forest regeneration and conservation can yield substantial economic benefits for developing countries, as they are rewarded for maintaining a carbon sink.

Ramirez relies on data from three experimental silviculture models: conventional harvesting (called 'control'), conventional harvesting with a posterior upper canopy treatment (called 'upper canopy'), and conventional harvesting followed by a liberation treatment, to promote the establishment of tree species with high commercial value (called 'liberation'). He finds that the upper canopy of the forest stores more carbon than the control during the first two production cycles, but posterior upper canopy treatment begins to surpass the control during the third cycle. This does not cause a significant difference in the economic value of this environmental service in the long term, because of the detrimental effect of the discount rate on the value of money in the distant future. In contrast, the much lower long-term levels of carbon storage in the liberation treatment, that remain after 60 years, have an economic cost (reduced payment) of around US\$250/ha in relation to the control or upper canopy treatment.

The liberation treatment, however, shows a financial advantage in both the short and the long term, mostly due to its greater production of high-value wood during the first harvest cycle. Therefore, if forest owners get no payment for the carbon storage service, they will prefer the liberation treatment. Such a decision results in a net economic loss to society of between US\$175 and US\$300/ha, depending on the discount rate assumed.

This translates into several hundred million dollars when considering the extension of natural forests areas even in a small country like Costa Rica. From the standpoint of the owners, conventional harvesting would be the preferred alternative for the management of natural forests. None of the silvicultural treatments investigated are justified from the social viewpoint: liberation is handicapped by its negative effect on biomass and upper canopy for its low impact on the commercial value of the harvests.

Costa Rica is currently paying forest owners US\$360/ha for the sustainable management of natural forests. This is little, even when compared just with

the economic value of the environmental service of carbon storage. According to this analysis, the Costa Rican payment is not sufficient to motivate long-term sustainable management of its primary forests. The advanced compensation mechanism adopted by Costa Rica, which provides 100 per cent of the payments for carbon storage during the first five years of a contract that has a 20-year duration, is also inadequate. Otherwise, the most attractive alternative is to engage in a forest management contract, make a technically appropriate initial harvest and sell or convert the land to another use five years later, once all contract payments have been received.

Ramirez concludes that, in both the short and the long term, the sustainable management of natural primary forests is more profitable than selling or using the land for cattle or agriculture, if owners are paid near the international rate of US\$10/ton for the carbon storage service provided by their forests. The compensation mechanism would then become even more critical. If credibility can be established among forest owners with respect to the fulfilment of the payment agreements, it would be preferable to distribute the payments evenly throughout the 20-year forest production cycles, making the necessary annual adjustments to compensate for inflation, so that real payments remain constant.

Overall, the analyses indicate that, if carbon sequestration is one of the main objectives of a system of forest incentives, promoting secondary forest regeneration should be a priority over primary forest conservation. This is not the case in Costa Rica's and most other developing country's incentive programmes. The fact that secondary forest ecosystems in their earlier stages of development are very vulnerable to land-use change provides an additional argument for higher incentives.

In Chapter 6, Dore, Kulshreshtha and Johnston consider the possibility of reforestation of tracts of land in the Boreal Plain Ecozone in Canada which were cleared for agricultural pursuits early in the 20th century in response to short-term high prices of grain on the international markets. They argue that the evidence on the volatility of grain prices and the soil characteristics of the land suggest that producing grain on these marginal lands is uneconomic and inefficient, and is viable only under massive subsidies from the governments. They demonstrate that the social gain from returning these lands to forests (either as agroforestry plantations or as commercial forest) exceeds the private gain of the use of these lands in producing low-yield grain and forage. This is based on comparing net social returns from each land use. The net social returns are estimated by using sophisticated econometric methods, and they avoid the use of discounting by using stochastic dominance. Having reached their conclusion that the marginal lands should be reforested, they then consider what sort of reforestation policy would enhance carbon sequestration on these lands.

In the final chapter of Part II, Tania Ammour and her co-authors consider the economic evaluation of two tropical ecosystems: the mangrove forests of the Pacific coast in Nicaragua and a subtropical forest in Guatemala. The economic value of goods as a stock corresponds to the potential gross income generated from the existing harvestable biomass in the forest, which means that natural capital is evaluated in terms of its productive capacity. The flow value of economic goods is measured according to the extraction rate of the resources, the associated costs, and the economic price of the products.

The authors begin with three hypotheses: (1) the sustainable management of these forests provides a higher value than traditional extractive practices; (2) the sustainable management of resources leads to greater value of the ecological services; and (3) the social value of the ecological functions is greater than the value of extracted commercial goods. All three hypotheses were verified in the two mangrove case studies.

The authors consider two alternative ways of managing the mangroves in Nicaragua. In the 8700ha considered, net benefit of traditional management of natural resources is US\$5.7 million over 10 years, using a discount rate of 10 per cent. In the second sustainable method, net benefits are almost twice that in the traditional management (US\$11 million). This demonstrates the higher value provided by ecosystems managed in a more sustainable way. The ecosystem value, on a per hectare basis, generated by goods and services is US\$700 in the traditional alternative and US\$1300 in the sustainable method.

In the traditional method, the large benefits obtained from fuelwood (US\$ 3 249 967, or about 90 per cent of value generated by all the goods) are mainly due to the low opportunity cost of labour, implying very low production costs. As a result, goods have a higher value (US\$3 596 785) when compared with services (US\$2 143 365). In the sustainable method, the goods have a value almost equal to the services value. This is due to the fact that all the goods were valued, including an additional good (bark for tannin). This result confirms the importance of ecological services generated by ecosystems in the Pacific wetlands.

The chapter then reports on the authors' second case study: the economic valuation of the forest in Petén, in Guatemala. In this case study, the authors find that the stock value of the forest is US\$5 072 850, equivalent to US\$787/ha, while annual flow is US\$195 543, equivalent to US\$30/ha. With both stock and flow values, environmental services contribute the greater part of total value (80 per cent and 62 per cent respectively). The erosion control contributes 73 per cent of total stock value of environmental services, while nutrient cycling is predominant (62 per cent) when evaluating the annual forest flow values.

When considering environmental services, the social value of erosion control amounts to 59 per cent of total stock value, while carbon sequestration

contributes 11 per cent. The importance of the social value of erosion control is probably due to poor soil characteristics and the valuation method used. Of the total annual flow values generated by environmental services, the social value of the nutrient cycle (as an ecological function) and, to a lesser extent, the bioversity attribute contribute 62 per cent and 39 per cent respectively. The importance of the nutrient cycle service reflects the low soil fertility and the role of fallen leaves as a main source of nutrients.

The final part of the book has three chapters. In the first, Kulshreshtha examines the Canadian Model Forest Program by focusing on the Prince Albert Model Forest (PAMF) in Saskatchewan. PAMF is a partnership of seven stakeholders, representing various levels of the government, industry and the First Nations people. The area under the jurisdiction of PAMF is small, only 315 326 hectares. In spite of the small size, the forest provides both timber and non-timber products. The goals of the model forest programme were to ensure sustainable and predictable supply of forest-based benefits (ecological, social and economic) through the management of forest ecosystems and people, and to raise awareness of the concept of sustainability, integrated resource management and ecosystem management among forest users, researchers, and managers of the forests.

The success of the model forest concept can be viewed in terms of the continuation of a working partnership among the seven stakeholders. The very fact that the original seven members decided to continue with the partnership, and added three new members in Phase 2 of the project, is enough evidence to support such a claim. In addition, during this phase, several cooperating activities were initiated. The model forest acts as a forum for bringing forth concerns of other stakeholders. However, it cannot be said with any degree of certainty whether the philosophy of forest management would change if the entire Forestry Management License Area (or the entire northern part of the province) were to be managed on these lines. Sustainable and integrated forest management also requires good information. Although significant strides have been made in collecting the missing information, many gaps persist which prevent the application of scientific knowledge that would help sustainable forest management in the region.

In Chapter 9, Olman Segura considers forest policy in Costa Rica. One of his main findings is that in the past government policies have supported mainly agriculture, cattle ranching, non-traditional products and, lately, tourism, and that the sustainable development of forestry has not been a priority. Furthermore, he finds there is very little integration between forest and industry, and even in industry there are very few examples of integration. The development of forest activities has not taken into account the intellectual, technical, cultural and economic contribution of indigenous communities and women, which could strengthen it and make it competitive.

The application of forest incentives, in spite of their importance in the development of the reforestation of the country, has not taken advantage of the opportunity to motivate the rural population to take a more active role in forest management. There are no policies to render technical assistance for the exploitation, storage and marketing of timber and non-timber products. Finally, environmental services have positive externalities for any forest, including the Costa Rican forests. In the Costa Rican case, there appears to be little recognition of these services. The predominant view of the use of natural resources is biased towards agricultural production.

In the final chapter, Sebastiao Kengen and his co-authors consider the socioeconomic importance of forest management in a semi-arid region in Brazil. They argue that the semi-arid forests of the northwest of Brazil are just as fragile as the tropical Amazon, and therefore deserve attention. The main tree found there is the 'caatinga', which, if harvested in a sustainable manner, could be valuable both as a source of timber and as a source of firewood. Its conservation would also help conserve the biodiversity of the region. While its management is still in its initial phase and still requires more research, it offers a viable alternative to forest plantations. Recognizing its potential, the 'Banco do Nordeste' has started to offer a line of credit for farmers and companies to promote forest management of the 'caatinga'. This is a great advance when one considers that traditionally the emphasis has been on forest plantations, most of which fail due to the rough climatic conditions of the northeast.

In summary, this book attempts to throw light on the various dimensions of sustainable management of forestry in North, Central and South America. The authors also argue that the economic and social value of the ecological services provided by the forests must be taken into account, as a forest is more than just timber. The authors represented in this book draw on a large number of case studies in the Americas, ranging from the boreal forest of North America and the forests of the humid tropics to the forests in the arid regions of South America.

REFERENCES

- Brown, S. and A. Lugo (1982), 'Aboveground biomass estimates for tropical moist forests of the Brazilian Amazon', *Interciencia*, 17, 8–18.
- Brown, S., A. Gillespie and A. Lugo (1989), 'Biomass estimation methods for tropical forests with applications to forest inventory data', *Forest Science*, 35 (4), 881–902.
- Brown, S., J. Sathaye, M. Cannel and P. Kauppi (1996), 'Mitigation of carbon emissions to the atmosphere by forest management', *Commonwealth Forestry Review*, 75 (1), 80–91.

- Canet, B. (1986), 'Características del sistema silvopastoral jaul (Almus acuminata) con lechería de altura en Costa Rica', in R. Salazar (ed.), *Simposio sobre técnicas de producción de leña en fincas pequeñas y recuperación de sitios degradados por medio de silvicultura intensiva*, Turrialba, Costa Rica, 24–8 June 1985, pp. 241–9.
- FAO (1995), 'Forest resources assessment 1990: Global synthesis', *FAO Forestry Paper*, 124, Rome.
- Fassbender, H., J. Beer, J. Heuvelink, A. Imbach, G. Enriquez and A. Bonneman (1991), 'Ten year balances of organic matter and nutrients in agroforestry systems at CATIE, Costa Rica', *Forest Ecology and Management*, 45, 173–83.
- Godoy, J., M. Kanninen and O. Ramirez (1998), 'Análisis de los Programas de Incentivos a la Reforestación Implementados en Costa Rica', *Ponencias del Primer Congreso Latinoamericano de IUFRO*, Valdivia, Chile.
- Grace, J., J. Lloyd, J. McIntyre, A. Miranda, P. Meir, H. Miranda, C. Nobre, J. Moncrieff, J. Massheder, Y. Malhi, I. Wright and J. Gash (1995), 'Carbon dioxide uptake by an undisturbed tropical rain forest in southwest Amazonia, 1992 to 1993', *Science*, 270, 778–80.
- Houghton, R., D. Skole and D. Lefkowitz (1991), 'Changes in landscape of Latin America between 1850 and 1985, 2: Net release of CO₂ to the atmosphere', *Forest Ecology and Management*, 38, 173–99.
- IPPC (1995), *Climate Change 1995. The Science of Climate Change*, ed. J. Houghton, L. Meira Filho, B. Callander, N. Harris, A. Kattenberg and K. Maskell, Cambridge: Cambridge University Press.
- Kauppi, P., K. Mielikäinen and K. Kuusela (1992), 'Biomass and Carbon Budget of European Forests, 1971 to 1990', *Science*, 256, 70–74.
- Kuersten, E. and P. Burschel (1993), 'CO₂ Mitigation by Agroforestry', *Water, Air and Soil Pollution*, 70, 533–44.
- Lugo, A. and S. Brown (1992), 'Tropical Forests as Sinks of Atmospheric Carbon', *Forest Ecology and Management*, 48, 83–90.
- Martínez, H. (1989), 'El componente forestal en los sistemas de finca de pequeños agricultores', CATIE, Série Técnica, Boletín Técnico No. 19.
- Nilsson, S. and W. Schophauser (1995), 'The Carbon-sequestration Potential of a Global Afforestation Program', *Climatic Change*, 30, 257–67.
- Picado, V. (1986), '*Mimosa scrabella*, especie con potencial para sombra y producción de leña en cafetales de Costa Rica', in R. Salazar (ed.), *Simposio sobre técnicas de producción de leña en fincas pequeñas y recuperación de sitios degradados por medio de silvicultura intensiva*, Turrialba, Costa Rica, 24–8 June 1985, pp. 227–86.
- Salazar, R. (1984), 'Producción de leña en árboles de *Gliricidia sepium* usado como sombra en cafetales de Costa Rica', *Silvoenergía*, no.2 (CATIE).
- Salazar, R. (ed.) (1986), *Simposio sobre técnicas de producción de leña en fincas pequeñas y recuperación de sitios degradados por medio de silvicultura intensiva*, Turrialba, Costa Rica, 24–8 June 1985.
- Sedjo, R. (1992), 'Temperate Forest Ecosystems in the Global Carbon Cycle', *Ambio*, 24 (4), 274–7.
- Trexler, M. and C. Haugen (1995), *Keeping it Green: Evaluating Tropical Forestry Strategies to Mitigate Global Warming*, Washington, DC: World Resources Institute.
- UN-ECE/FAO (1992), *The Forest Resources of the Temperate Zones. Main Findings of the UN-ECE/FAO 1990 Forest Resource Assessment*, ECE/TIM-60, UN-FAO, New York.
- Young, A. (1989), 'Agroforestry for Soil Conservation', *ICRAF Science and Practice in Agroforestry*, 4, CAB International, Wallingford.