CHAPTER 9

INTERNATIONAL POLICY ISSUES ON CARBON FLUXES AND FORESTS IN THE SOUTH

Carlos Eduardo Frickmann Young[*]

1. ABATEMENT OF CO_2 EMISSIONS AND THE DEVELOPING WORLD

The differences in historical cumulative share of carbon dioxide (CO_2) emissions among countries reflect their unequal patterns of economic development. Developed countries benefit today from the accumulation of man-made assets made mainly possible by the industrial revolution and the subsequent pattern of high levels of fossil fuels consumption and CO_2 emissions. In contrast compared to the developed countries, the economic performance of developing countries was relatively poor, as was their energy consumption. According to estimates, developing countries were responsible for only 15 per cent of the total CO_2 emissions between 1870 and 1986 (Sathaye and Reddy 1993).

Unfortunately, technology has not yet advanced to the stage where economic development could be achieved without fossil fuels consumption. As a former secretary-general of UNCTAD acknowledges:

> Although there is no reason to believe that completion of this process (of industrialization) requires other countries to follow step by step the paths established by developed countries, the broad characteristics of the process of development are clear enough: development means industrialization; and industrialization entails the systematic application of controlled mechanical energy to an ever-widening range of productive activities (UNCTAD 1992: ii).

In other words, there is an apparent conflict between the objectives of reducing CO_2 emissions and closing the socioeconomic gap between developed and developing countries. Developing countries need to increase their average energy consumption at faster rates than the developed world if the gap between their respective production and consumption patterns is to be reduced. However, the costs of abatement of greenhouse gases (GHG) emissions are considerably smaller in the developing countries. Moreover, their share in total emissions is increasing with time, and some developing countries are among those most affected by possible damages introduced by the climate change—thus, developing countries are an essential component of any effective international strategy aiming at emissions abatement.

The biggest challenge presented by the GHG abatement agreements is to conciliate *equity* and *efficiency* in a common strategy. The principle that has been used so far in similar agreements (for example, the Montreal Protocol), based on 'grandfathering' rights (i.e., future levels of emission should be determined as a function of the current level), cannot be accepted under these terms. Equal percentage reductions are intrinsically unfair since they freeze the *status quo* of energy and resource consumption (which is widely recognized as an unfair distribution between rich and poor countries). This would also penalize the economies that are presently investing to reduce the emission intensity of their production (emissions per unit of output)—these economies could be 'giving away' future emission rights through current abatement measures. Finally, emissions abatement based on uniform cuts does not respect the efficiency principle since the associated marginal costs of emission reductions vary considerably among countries.

There are also 'altruistic' proposals which emphasize that only developed countries should be penalized by their past and present higher levels of emission. However, these proposals would face two main problems. First, there would be great resistance from developed countries to accept the idea that massive transfer payments, without reciprocal efforts, could be sent to developing countries, which makes the proposal unacceptable in political terms. Second, the impacts of the reduction in economic activities in the developed world would have considerable social costs, affecting the welfare of the entire human population. For instance, a reduction in the production of goods would affect exports to the third world, making them more scarce and expensive, while at the same time, imports from the developing countries would be considerably reduced. The experience of the 1970s illustrates this problem: the economic retraction of the developed countries induced a world recession with dramatic consequences to developing countries (reduction of primary goods exports combined with the external debt crisis), some of which are still paying the costs of adjusting to the new world order.

Therefore, the establishment of international instruments to limit CO_2 emissions should be considered in a context of open economies—that is, recognizing that international flows of income have background effects to national economies. This can be exemplified in a very simple situation. Consider two countries (A, B) with different costs of abatement, but the one with higher costs of abatement (A) being politically interested in the control of greenhouse gases. It is possible that a deal between both countries is reached: country A is willing to pay compensation to reduce emissions in country B up to a point where the marginal contribution equals the benefit of reducing GHG emissions (for country A); similarly, country B is willing to accept compensation to reduce its economic activity up to a point where the marginal compensation equals the marginal cost of sacrificed production. The use of economic instruments allows these transfers to take place in a flexible, cost-effective way. The options currently discussed to implement them are examined in the next section.

2. REDUCING CO_2 EMISSIONS: THE EXISTING PROPOSALS

The Framework Convention on Climate Change was signed in June 1992 in Rio de Janeiro. Since the divergence among the participant countries at the time was considerable, the terms of the Convention were left mostly unspecified in order to allow negotiations to take over the coming years. The most important target, the 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (Article 2), has been disconnected from detailed targets and timetables. Only developed countries and a small number of emerging developing countries have committed themselves to the 'return by the end of the decade to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases' (Article 4), which is commonly associated with stabilizing CO_2 emissions by the year 2000 at the 1990 level. However, national targets for CO_2 abatement adopted voluntarily by some European countries are more strict than these (for example, Denmark has an ambitious target level of 20 per cent CO_2 reduction of the 1988 level by the year 2005; see Svendsen 1996).

The Convention also establishes the Global Environmental Facility (GEF) as the financial mechanism for the provision of resources on a grant or concessional basis. The programme priorities and eligibility criteria were left to be determined by the Conference of the Parties, and there was also a vague reference to financial resources related to the implementation of bilateral, regional, and multilateral channels between developed and developing countries.

The flexibility of the terms used in the Convention reflects the uncertainty about the real commitment and political willingness of each participant country to deal with the adjustments imposed by the need for emissions reduction. This also means that there is a wide range of implementation options if developed countries effectively decide to pay financial compensations to developing countries in order to 'import' CO_2 abatement from developing countries.

The literature has emphasized economic instruments: carbon taxes, external offsets and tradable permits. These mechanisms respect the 'polluter-pays' principle, internalizing pollution costs, but providing flexibility to the economic agents to minimize costs in the adjustment to lower levels of emissions, so that:

> they separate the question of where abatement can be undertaken (hopefully, at the lowest cost), from the question of who should pay, which is determined by the initial allocation/targets, or tax redistributions' (Grubb 1992: 11).

Nevertheless, there are important differences in their implementation. A system of international emission taxes can be established with revenues from carbon taxes being collected in countries with high levels of emission, and transferred to countries which preserve carbon sinks. The essence of the tax is to encourage tax-avoiding behaviour, through the permanent incentive of energy conservation, substitution of non-carbon energy for carbon energy, and any other innovation that reduces pollution (Pearce 1992).

Special allowances can be made to prevent poor countries from becoming net payers of carbon taxes, respecting the equity principle.

Current experiences show that the establishment of international carbon taxes is not problem free. One point in particular deserves special attention: there is considerable uncertainty about the effective reduction in emissions related to a certain tax level. Therefore policy makers have to guess the tax level necessary to achieve the desired target in emissions reduction. Moreover, if this tax level is high, there will be strong resistance from penalized economic agents to accept the increase in their costs (creating the risks of unemployment and declining competitiveness). This problem is highlighted by Svendsen (1996) in the analysis of the Danish experience: the CO_2 tax implemented in 1992 (households pay US$ 16 per ton of CO_2 emitted, and VAT-registered firms pay half the tax) is considered too low to achieve the politically-decided target of 20 per cent reduction by the year 2005—it is estimated that this target can only be achieved if the tax is raised to US$ 50.

Finally, at the international level, penalizing countries that do not respect the agreements (for example, not paying the stipulated tax amounts) is a formidable problem. An international agency responsible for monitoring and enforcement would not have the necessary power to obligate all countries to adhere to its decisions and, as agreements are voluntary, too much pressure could induce the withdrawal of the transgressor country (a worse-off solution).

In any case, even if emission targets are not achieved, carbon taxes are a very efficient system to obtain revenues earmarked for environmental action. For instance, Svendsen (1996) argues that the main motivation behind the Danish initiative of taxing CO_2 emissions is to 'justify'—through 'green' objectives—higher levels of taxation relative to the European Union standards. Therefore, conventional taxes could be lowered without affecting the total tax revenue (that is, a double-dividend strategy).

This property is very important if carbon taxes are to be coupled with funding abatement schemes in other countries. Indeed, this is the main idea behind external offsets: a country can meet its own national emission target by reducing emissions domestically or 'offset' this by investments to reduce emissions in equivalent amounts elsewhere, so that the total of national emissions minus the external 'savings' would meet the target (Grubb 1992).

The implicit assumption is that developing countries have a large stock of economically inefficient CO_2 sources (that is, economic returns per unit of CO_2 are lower than in developed countries) with cheap abatement options. This would bring flexibility to developed countries in the process of reducing their own CO_2 emissions, while at the same time create an economic value for the forestry carbon fixation capacity preserved in developing countries. In other words, the CO_2 abatement services currently provided freely from the south to the north would be considered as a kind of export service, thus to be paid for.

The establishment of an international system of CO_2 emissions reduction offset would require that countries commit themselves to emission reduction targets which are mutually respected, accepting the principle that emission savings can be obtained through abatement investment in other countries. The responsibility to meet the abatement commitments can be transferred onto public and private entities within these countries. This means that abatement services can also be provided by private entities, not necessarily requiring interstate agreement. In fact, there are already examples of jointly implemented forestry offset projects funded by private US electricity utilities which invested in carbon fixing reforestation in developing countries (Hayes 1993; IPCC 1996).

From the analysis above, it is clear that external offsets have great potential as a transfer mechanism to compensate the developing countries which decide against depleting their natural forests (or, at least, to reduce the deforestation process). In the long term, however, one problem remains. The system is based on transfers to developing countries independently of the efforts being made to reduce emissions outside the abatement projects. For example, one country may receive compensation because it has preserved natural forests, but at the same time, other emission sources have been accelerated (in the energy, industry or transportation sectors). Since these other sources of emissions are expected to increase in developing countries, the external offsets cannot be considered a long-term global solution. Furthermore, it is expected that the volume of resources to be transferred from developed countries to developing countries could be substantial, arousing strong opposition from net payers in the north (the situation in some industrialized countries could be worse off after the transfers than before; see Pearce 1992). Therefore, many authors consider that external offsets can only be the first stage of the implementation of international tradable emission permits.

Tradable permits have the advantage of directly establishing a maximum amount of emissions for the system as a whole (taxes, for example, can only affect the total level of emission indirectly). At the same time, relevant agents have the freedom to adopt their own cost structures, thus assuring economic efficiency.

The experience of the United States is an obligatory reference with regard to the feasibility of tradable permits (for a review, see Svendsen 1996). Some of the permit programmes were established at the federal level by the US Environmental Protection Agency (EPA), all of them dealing with air pollution. The first programme was the Emission Trading Programme (started in 1974), aiming for the industry to achieve national air quality standards on sulphur oxides, nitrogen oxides, particulates, carbon monoxide, hydrocarbons, lead and ozone. In the 1980s, two similar programmes were established to phase-out leaded gasoline (1982-87); and chlorofluorocarbons (CFC) and halons (1989-96). The most recent experience is already considered a successful example of cost-effective pollution control strategy: the Acid Rain Programme, aiming at the reduction of sulphur dioxide emissions by electrical utilities (50 per cent reduction of the 1980 level by the year 2000). Other programmes, managed by state agencies, deal with air and water pollution control. An important feature of all US programmes is the initial concession of permits based on past emission levels (grandfathering).

The advantages of tradable permits include the flexibility to reduce emissions at low costs, and the permanent incentive for users to invest in technological innovation that reduces the need to pay for additional permits. At the international level, a permit market can be considered as a system according to which one country reduces its emissions in favour of compensation paid by another that continues to emit, provided that the sum of emissions of the two countries do not exceed their combined quotas. Such a system would allow net transfers to developing countries if credits are provided for the preservation of native or new forests as carbon sinks.

However, the implementation of tradable permits is the subject of much criticism. First, as in the case of carbon taxes, the need of an agency to oversee the trade in permits does not solve the problem of penalty enforcement for countries exceeding their emission quotas. Second, the international permit market would be subject to many imperfections, since there is a great imbalance between the size of the potential buyers (large economies) and sellers (mostly small economies). Third, and probably the most crucial, is the virtual impossibility of reaching a consensus over the definition of initial quotas. There is considerable debate about the best way of distributing the permits. On the one hand, the proposal of 'grandfathering' the permits according to the existing levels of emissions (as in the US experience) would not be acceptable to the developing countries, since this approach does not respect the equity principle (in the sense that it benefits the currently high-pollutant countries). On the other hand, proposals aiming at 'fair' allocation, such as granting quotas proportionally to the number of inhabitants (the idea of an equal, individual right to emit) would face great resistance from the largest industrialized countries.

It should be noted that the experiences reviewed above refer to domestic programmes, so there is no assurance that some of their successful aspects can also be achieved in the international context. Also, as argued by Pearce (1994), most studies assume implicitly that costs of carbon emission controls vary significantly between trading parties, and that transaction costs do not represent an obstacle. The first point is challenged by the fact that developed countries with better availability of capital and technology, may face equal or even lower abatement costs than poorer countries. The second point refers to the problem that the 'thinner' the market the higher the transaction costs, leading to a paradox: an effective joint implementation programme requires large-scale trading; however, large-scale trading cannot occur until it has been demonstrated the efficiency of joint implementation.

Another institutional problem emphasized by Pearce (1994) refers to the definition of what can be considered 'genuine' compensation for CO_2 emissions reduction. The Climate Change Convention (and the Montreal Protocol) considers that emission control obligations can be jointly implemented by developed countries and other parties. Joint implementation can be obtained through compensations from donors to countries that host carbon abatement programmes, and compensation values should be determined by the 'agreed full incremental costs' of these programmes. However, there is no proper definition of 'full incremental costs'. It is understood that incremental costs should compare actual results against a counterfactual baseline (what they would have done if the emission control programmes did not take place). This is a particularly complicated task, especially because the Convention did not establish reduction targets for developing countries. Pearce (1994) argues that there is no real need for an explicit set of guidelines on how to estimate incremental costs since 'donor' and 'host' will agree a price, each of whom will know whether or not the arrangement is in their advantage. Nevertheless, as discussed before, the 'market' for CO_2 transactions is far from a perfect competition hypothesis. It is possible that a few industrialized countries, acting in cooperation, will have much more power in the negotiations than a large number of indebted and atomized developing countries. A possible result is that opportunity costs would be omitted from these negotiations, thereby reducing compensation values and creating an implicit subsidy to developed countries. The relevance of opportunity costs is discussed in the next sections.

From the discussion above, it is clear that difficulties in the implementation of economic instruments to control CO_2 emissions at the global scale will require a long process of negotiation. An effective system will probably combine some of many different proposals, mixing command-and-control and market-oriented tools. National strategies in developed and developing countries might contemplate carbon emission taxes in order to encourage a permanent stream of innovations that strive for the reduction of marginal costs of abatement for all concerned. Offset investments in abatement might be considered by developed countries to take advantage of lower marginal abatement costs in developing countries. Finally, tradable permits might be used to consolidate the system operation once it has reached a mature stage when the costs and rewards of reducing CO_2 emissions are relatively clear to most nations.

Time will certainly be needed for the elaboration of a joint framework whereby the historical responsibility of developed countries can be matched by their willingness to pay, and the current pattern of deforestation in developing countries can be reversed by the potential benefits of conservation. Nevertheless, this does not mean that initial steps cannot be taken. One of these steps is the establishment of compensation schemes for developing countries that effectively invest in forest preservation, thus averting an increase in CO_2 emissions. The next section deals in more detail with the great potential of abatement schemes based on north-south transfers.

3. TROPICAL FORESTS AND CO_2 EMISSIONS

The future of tropical forests will be decisive in the expansion or reduction of the concentration of CO_2 in the atmosphere. Forests are natural sinks of carbon, and the current trend of forest depletion and degradation in the tropics is a substantial source of CO_2 and other GHG emissions—in these areas, deforestation is usually associated with the burning of biomass, which liberates gases into the atmosphere. The International Panel on Climate Change (IPCC 1996) estimates that low-latitude forests were responsible for an annual increase of approximately 1.6 Gt of carbon to the atmosphere by 1990. Considering that the annual rate of deforestation is about 15.4 million hectares, this corresponds to one hectare of deforestation in a low-latitude country producing, on average, a net flux of around one hundred tons of carbon.

Therefore, slowing down the current rates of tropical deforestation would represent a significant contribution to controlling carbon dioxide and other GHG emissions. In the medium term, if forest management options are economically feasible, the role of the tropics in the balance of GHGs can be reversed through the expansion of forestry activities with net gains in the storage of carbon. In forestry expansion, two elements should be considered: the potential capacity for carbon storage and the costs of mitigating options.

According to IPCC (1996) estimates, the potential of low-latitude forests to conserve and sequester carbon ranges between 45 to 72 Gtons, more than half of which would result from promoting forest regeneration and slowing down deforestation. This is considerably larger than the potential of temperate and boreal zones: about 13 Gtons and 2.4 Gtons, respectively. Tropical America has the largest potential for carbon conservation and sequestration (46 per cent of tropical total), followed by tropical Asia (34 per cent) and tropical Africa (20 per cent).

TABLE 9.1
COSTS OF FOREST PROTECTION OR REDUCTION DEFORESTATION

Country	Cost ($/t C)	Source and notes
Brazil	2.3 [(a] - 4 [(b]	[(a] Darmstadter and Plantinga (1991) [(b] Cline (1993)
Côte d'Ivore	8	Darmstadter and Plantinga (1991)
Indonesia	15	Darmstadter and Plantinga (1991)
Thailand	0.4 - 0.8	Based on Wangwacharakul and Bowonwiwat (1995), which includes government budget for protection and opportunity cost of land for agriculture production
Mexico	1 - 6	Based on data in Masera *et al.* (1995); lower bound on cost of protection of tropical evergreen forest of Tabasco
India	0.5	Based on $5/ha cost for a tiger sanctuary and 50t C/ha of biomass density
Central America	1 - 3	Swisher (1991) estimate, based on cost of protected areas reported in the Tropical Forest Action Plan (TFAP) proposals for Cost Rica, Honduras, and Panama
Russia	1 - 3	Krankina and Dixon (1994)

Source: IPCC (1996)

The potential gains in carbon storage are considerable. The IPCC (1996) baseline scenario (under current climate conditions and assuming no change in the estimated available lands over the period of interest) estimates that the cumulative amount of carbon that could potentially be conserved and sequestered over the period 1995-2050 by slowing deforestation (138 million hectares) and promoting natural forest regeneration (217 million hectares) in the tropics, combined with the implementation of a global forestation programme (345 million hectares of plantations and agroforestry), would be equivalent to 12-15 per cent of the cumulative fossil fuel emissions of carbon over the same period, projected according to the IPCC (1992) scenario.

The other relevant dimension refers to the (reportedly) low costs of carbon conservation and sequestration projects in the tropics. These costs usually consider only the direct costs of forest projects (protection, management, etc.) but not the opportunity cost of the land. Therefore, there is a bias to present mitigating strategies in developing countries considerably cheaper than in developed countries. The consequences of this problem are discussed later.

The IPCC review on the costs of forest protection and deforestation reduction followed the pattern of considering only direct costs of carbon sequestration—the opportunity cost of land was omitted (Table 9.1). The results ranged from about US$ 8/ton carbon for afforestation and reduction of deforestation in the tropics, increasing to about US$ 28/ton carbon for afforestation in non-US OECD countries. The costs for establishing a forest plantation (opportunity cost of land excluded) were estimated to range between US$ 230 and US$ 1,000 per hectare, with an average cost of US$ 400 per hectare.

The 1996 IPCC report surveys more recent studies estimating the costs of preserving and expanding carbon sinks, including the benefits that forestry options would present for dwellers. Opportunity costs of land, however, remained omitted. The consequence is that most of the initial costs of expanding carbon sinks are smaller than the ones presented in the previous report (Table 9.2).

TABLE 9.2
INITIAL COST OF EXPANDING CARBON SINKS
BY DIFFERENT REGIONS AND PRACTICES

Region/country	Practice	Cost (a (US$/t C)	Source
Boreal	Natural regeneration (b	5 (4-11)	Dixon *et al.* (1994)
	Reforestation	8 (3-27)	
Temperate	Natural regeneration (b	1	Dixon *et al.* (1994)
	Afforestation	2 (1-5)	
	Reforestation	6 (3-29)	
Tropical	Natural regeneration (b	1 (1-2)	Dixon *et al.* (1994)
	Agroforestry	5 (b-11)	
	Reforestation	7 (3-29)	
Central America	Regeneration	4	Swisher (1991)
	Agroforestry	4	
	Plantations	13	
Argentina	Reforestation	31	Winjum *et al.* (1993)
	Afforestation	18	
Australia	Reforestation	5	Winjum *et al.* (1993)
Brazil	Reforestation	10	Winjum *et al.* (1993)
	FLORAN	3-8 (c	Andrasko *et al.* (1991)
Canada	Reforestation	11	Winjum *et al.* (1993)
	Regeneration	6	

Table 9.2 (con't)

Region/country	Practice	Cost [a] (US$/t C)	Source
China	Reforestation	10	Winjum *et al.* (1993)
	Forest management	3-4	Xu (1995)
	Eucalyptus plantations	8	
	Agroforestry	6-21	
Germany	Reforestation	29	Winjum *et al.* (1993)
India	Reforestation	15	Winjum *et al.* (1993)
	Regeneration	2	Ravindranath *et al.* (1995)
	Teak plantation	3	
	Agroforestry	9	
Malaysia	Reforestation	5	Winjum *et al.* (1993)
Mexico	Reforestation	4	Winjum *et al.* (1993)
	Plantations	5-11	Masera *et al.* (1995)
	Forest management	03-3	
South Africa	Reforestation	9	Winjum *et al.* (1993)
Thailand	Teak plantations	13-26	Wangwacharakul and Bowonwiwat (1995)
	Eucalyptus plantations	5-8	
	Agroforestry	8-12	
USA	Reforestation	5	Winjum *et al.* (1993)
	Afforestation	2	
	Various options	5-43 [d]	Moulton and Richards (1990)
	Various options	19-95 [e]	Adams *et al.* (1993)
Former Soviet Union	Reforestation	6	Winjum *et al.* (1993)
	Regeneration	5	
Russia	Plantation	1-8	Krankina and Dixon (1994)

Source: IPCC (1996)

Notes: [a] Forest components for sequestering carbon vary by source: Dixon *et al.* (1994), Krankina and Dixon (1994), and Winjum *et al.* (1993) include only carbon in vegetation; Xu (1995), Ravindranath and Somashekhar (1995), Wangwacharakul and Bowonwiwat (1995), and Masera *et al.* (1995) include vegetation and soil carbon; Swisher (1991), Moulton and Richards (1990), and Adams *et al.* (1993) account for C in vegetation, soil, and litter.

[b] Values in parentheses are interquartile ranges.

[c] Figures vary depending on land rental costs per ha from US$ 400 to US$ 1,000; Floram=Florestales Amazonia.

[d] Marginal costs include planting and land rental costs.

[e] Includes land rental costs.

The IPCC reports and other studies suggest that land prices should be used as *proxies* for the opportunity cost of land. In many areas across developing countries, this price would be close to zero, as in the case of degraded land suitable for reforestation. Unfortunately, however, land productivity is not the only factor affecting land prices. Uncertainty concerning property rights, abundant supply of 'quasi-open' access land in the frontier between the forest and agricultural areas, lack of capital to invest in proper management, non-existent credit schemes for small farmers and many other factors negatively affect land prices (for an overall analysis of the causes of deforestation in developing countries, see Palo and Mery 1996). The consequence is that land prices do not accurately represent the opportunity cost of land: if a system of international transfer payments for arresting agricultural development in tropical forests is based on existing land prices, there would be an implicit subsidy from developing countries to developed countries because land prices underestimate the opportunity cost of land. The discussion of this problem in the context of the Amazon is analysed in the next section.

4. THE OPPORTUNITY COST OF FOREST CONSERVATION: EVIDENCES FROM THE AMAZON

According to the theory of economics, if there are no market distortions, actual prices are the proper measure of the opportunity cost of an asset. Based on this principle, many studies consider land prices as a proxy for the opportunity cost of land (as in the case of the IPCC report, discussed above).

In a similar way, a World Bank dissemination paper (Schneider 1993) argues that there could be considerable gains from the trade in carbon emissions between industrialized countries and landowners and governments in the Amazon. The methodology was based on a comparison of the global benefit per hectare of forest as a store of carbon (combining the amount of carbon sequestered in a hectare of forest and the per-ton value to society of reducing carbon emission) and its value as agricultural land, assuming that:

> The value of forest land in agricultural use is best estimated by the selling price of forest land' (Schneider 1993: 1)

This approach assumes implicitly that any positive difference between the benefits of carbon sequestering (which allows extra economic activity in the north) and the compensation payments based on actual forest prices in the south would accrue as consumer surplus to the payers (developed countries). Indeed, it is the disparity between these values that Schneider (1993) considers an encouragement to the proposal of compensation schemes. In his estimates, the value of one hectare of Amazonian forest land range from US$ 600 to US$ 7,000 (based on the value that industrialized societies have actually demonstrated as their willingness to pay for carbon sequestration) while actual land prices vary from US$ 2.5/ha to US$ 300/ha.

However, there are considerable distortions in land markets in the Amazon. Among other factors, the abundance of quasi-open access land in the frontier, coupled with the insecurity over property rights of land already occupied, produces a negative bias to land prices as an indicator of the opportunity cost of land. Hence, payments to arrest the existing patterns of economic development in the Amazon based on current land prices represent an implicit subsidy to the developed world, since developing countries would not get decent 'value for their money'. In other words, Amazonian countries could be selling the services of CO_2 sequestration at a price smaller than the flow of future benefits they could expect from the land, had the forest not been preserved. This would not respect the equity principle, since most of the developed world is already receiving economic benefits from higher patterns of CO_2 emissions.

In order to illustrate the problem of undervaluation, a few valuation studies in the Amazon are reviewed in this section. The selected studies estimate the economic returns of alternative land-use options that can be considered as better proxies of opportunity costs of land than land prices. These include Peters *et al*. (1989) whose study concerns the valuation of one hectare of forest reserve in Mishana, Peruvian Amazon; Pinedo-Vasquez *et al.* (1992) who analyse the local population's land-use options in one hectare of forest reserve in San Rafael, Peruvian Amazon; Toniolo and Uhl (1992) who deal with commercial agriculture options in Uraim, a state of Pará (southeastern Brazilian Amazon) and Uhl *et al.* (1991) on land-use options in Tailândia, a state of Pará.

TABLE 9.3
NET PRESENT VALUE ESTIMATES OF ONE HECTARE OF LAND
(discount rate: 5 per cent)

Peru (Mishana)	selective logging plus extractivism	6820,00
Eastern Amazon [a]	commercial agriculture plus dairy herd	3974,07
Peru (San Rafael)	one-time timber removal plus swidden agriculture	2997,88
Eastern Amazon [b]	one-time timber removal plus dairy production (intensive)	1385,19
Peru (San Rafael)	one-time timber removal plus extractivism	741,90
Eastern Amazon [b]	one-time timber removal plus dairy production (extensive)	624,92
Eastern Amazon [c]	one-time timber removal plus beef production (extensive)	282,20
Eastern Amazon (Pará)	average forested land price (1989) [d]	252,30
Eastern Amazon [e]	selective logging	214,07

Notes: [a] Based on the average composition of a farm in Uraim (Toniolo and Uhl 1992).
[b] Combining data for one-time timber removal in the Paragominas region (Veríssimo *et al.* 1992) and dairy herd productivity in Uraim (Toniolo and Uhl 1992).
[c] Combining data for one-time timber removal in the Paragominas region (Veríssimo *et al.* 1992) and extensive ranching in Paragominas (Mattos and Uhl 1994).
[d] Based on land prices data collected by Fundação Getúlio Vargas.
[e] Based on data from Tailândia (Uhl *et al.* 1991).

Valuation studies are carried out according to different assumptions and methodologies. Moreover, each site presents many ecological and socioeconomic specificities (for example, soil quality, topography, biodiversity, economic infrastructure, location, migration flows, etc.), making the comparison of results not an easy task. The choice for these studies was based on the possibility of comparing relatively closely-located sites (Mishana and San Rafael; Uraim and Tailândia) and data availability that allows the adoption of a standard methodological approach.

The exercise was based on the estimate of net present values of alternative land-use options in one hectare of forested land, assuming a 5 per cent discount rate. Prices are expressed in 1989 US dollars. Table 9.3 above presents the results for the selected studies.

It is clear that the returns from sustainable extraction of timber and non-timber products obtained by Peters *et al.* (1989) in Mishana (Peruvian Amazon) are exceptionally high. This study is the most referred to valuation exercise for the Amazon forest, probably because the high returns from forestry and extractivist activities appear to justify the widespread optimism among environmentalists that greater profit can be achieved with sustainable activities which retain the forests than with the conventional agricultural practices. The high returns are explained by the unusual composition of tree species: the Mishana forest reserve presents a concentration of high value species that is not representative of other areas in the Amazon. Indeed, the data would suggest a process of forest 'enrichment', with very high incidence of commercial fruits and high value timber species. For example, in only one hectare, there are 83 trees of the *Iryanthera, Virola* family, a high commercial value timber, and 36 trees of the *Jesenia batava (mart.) Burret* species, a fruit tree with high productivity. Another unusual characteristic of the site is its proximity to Iquitos, a major urban centre, thus considerably reducing transportation costs.

The net present value expected (NPV) from fruit extraction was estimated at US$ 6,300, and US$ 490 for the NPV from selective logging, for a total NPV of US$ 6,820 for economic activities not requiring forest depletion. According to this result, since local net benefits from the conservation of the forest are higher than from any activity associated with deforestation, there is justification for transfer payments based on carbon conservation and sequestering. In other words, the current deforestation process cannot be explained by rational economic behaviour, as net returns from preserving the forest are higher than those obtained by its depletion.

Pinedo-Vasquez *et al.* (1992) used the same approach—inventory of tree species in one hectare of forest, but in a site resembling more closely the average situation of Amazon forests. San Rafael is not located as advantageous to an urban centre (Iquitos) as Mishana, and there is no spectacular concentration of species with high commercial value. The results indicated a conflicting conclusion: current agricultural practices (NPV=US$ 2,516.94) coupled with one-time harvesting of all merchantable timber (NPV=US$ 480.94) are considerably more attractive to local dwellers than collection of fruits and latexes (NPV=US$ 399.40) or selective timber (NPV=US$ 342.50). Two important findings were the observations that only half of the dozen commercial fruit and latex species inventoried in Mishana were available in San Rafael, and there was no harvesting of fruit or latex from the reserve for the Iquitos market, even though additional species with potential markets similar to those identified in the Mishana reserve were present. These results would justify the behaviour of local populations in economic terms, given their capital endowment and time-horizon:

> Examining the actual land-use choices made by the San Rafael population emphasizes the logic of their decision making within the current context in which rural population prioritize their economic activities. Within that context, *ribereños* can be expected to continue converting forested land to swidden agriculture unless alternative land uses become more attractive economically (Pinedo-Vasquez *et al.* 1992: 172).

A better comparison of alternative land-use options is provided by a number of valuation exercises in the Paragominas region, state of Pará (Brazilian Eastern Amazon). The studies covered different production conditions, from capital-intensive agriculture and dairy production activities to extensive ranching and timber extraction, reproducing the economic rationality of distinct land-use decisions.

The highest productivity was obtained in Uraim. The site is located in a region where the first settlers established themselves as small- and medium-sized farmers in the early 1960s, and is close to the town of Paragominas and the Belém-Brasília road. These special features resulted in a process of agricultural intensification and diversification that is not typical in other Amazon areas (Toniolo and Uhl 1992). Therefore, the returns from agriculture are considerably higher than the Amazonian average. The distribution of productive land in Uraim is as follows: 59.77 per cent for cattle (dairy herd), 12.77 per cent for shifting cultivation, 0.25 per cent for vegetable cropping, and 27.21 per cent for perennial crops. The relevance of perennials (black peppers and oranges), which require a time lag between investment and harvest, leads to the importance of the discount rate option for ultimate results. Both perennial crops require high investments at the beginning; moreover, the first harvest is available only after two or three year. Higher discount rates mean that the net present value of future benefits is reduced (or, symmetrically, higher capital costs per unit of output), thus reducing the profitability of cultivation.

This point illustrates the relevance of capital availability in valuation exercises. Usually, all measures are calculated as per unit of area (hectare). Nevertheless, this equals to considering that land is a scarce resource—indeed, in order to properly assess differences among land-use options which are more or less intensive in each production factor, proper valuation exercises should also consider measures per unit of labour and per unit of capital invested. The high returns obtained for Uraim are the consequence of previous investments that necessitated some sort of capital endowment or access to credit facilities. These usually do not exist for most small farmers in the Amazon. Therefore, the opportunity cost of land is a function of credit access, and the true potential of future revenues should be considered in a context that has solved this market failure.

Combining data obtained from Uraim (which include land clearance and other investment requirements) to the net returns from one-time timber harvesting in the Paragominas county (Veríssimo *et al.* 1991), it was possible to estimate the net returns from deforestation followed by intensive or semi-intensive dairy ranching. A similar exercise was carried out for extensive beef production (using data from Mattos and Uhl 1994). All obtained results were above the average price for forested land in the state of Pará, showing that actual land prices underestimate the economic potential of the land. This problem is more important in capital-intensive activities, and suggests that the opportunity cost of reducing agricultural expansion is considerable for the local economy.

The only activity that remained below the average land price was selective logging. The data, extracted from sites near the town of Tailândia and a paved highway (Uhl *et al.* 1991), are based on a 20-year cycle. No data were available for non-timber forest products, therefore it was not possible to estimate the proper NPV of extractivism. Nevertheless, the absence of information suggests that non-timber forest products are not financially relevant to local farmers. Therefore, compensations to locals are justified if agricultural expansion is reduced in the region for the purpose of abating the global CO_2 emission problem.

5. THE OPPORTUNITY COST OF CURBING AGRICULTURAL ACTIVITIES IN THE BRAZILIAN AMAZON: A SIMULATION EXERCISE

The previous section shows that reducing commercial agricultural expansion in the Amazon would result in a positive opportunity cost for the local economy. However, it is somewhat questionable to use values obtained from a limited number of site studies for evaluating the entire Amazon region because the particularities of the sites examined may introduce major biases into the analysis.

In order to provide some figures for considering the Brazilian Amazon as an entity, some projections were obtained by a simulation model based on the DESMAT database. The simulation model was originally elaborated by Reis and Margulis (1991) to estimate global warming impacts of deforestation in the Amazon, and then reviewed to estimate the deforestation impacts of the Carajás iron project in the Northeastern Brazilian Amazon (Reis 1996). DESMAT consolidates economic, social and ecological data at municipal and state levels for the Brazilian Amazon, from censuses and other surveys being applied in many empirical exercises.

TABLE 9.4
AGGREGATE RESULTS OF THE SIMULATION MODEL (REFERENCE SCENARIO)

	1990	1995	2000	2005	2010
Agriculture GDP (US$ millions)	2,832	3,469	4,116	4,689	5,149
Total GDP (US$ millions)	20,549	24,467	29,141	34,898	41,627
Accumulated carbon emissions (tons, millions)	5,697	7,033	8,226	9,255	10,090
Agricultural land (hectares, millions)	56.6	68.4	79.3	88.7	96.6

Source: Reis (1996)

The simulation model combines projected changes in road structure to demographic, economic and ecological variables that are time-lagged.[1] Total increase in the road network is determined exogenously according to plans for road expansion in each municipality. However, the distribution between paved and non-paved roads is determined endogenously by a function considering (lagged) economic, demographic and ecological variables. Similar procedures are used to estimate demographic and economic variables. For example, population growth is a function of the previous trend in population growth itself, plus economic growth and other socioeconomic variables. Deforestation is defined by the net changes in agricultural areas (including fallow lands).

Carbon emissions are estimated according to expected changes in land use (including average fallow time), biomass and carbon content parameters. The most important results are shown in Table 9.4.

It is assumed that the opportunity cost of land is determined by the potential agricultural product to be sacrificed if forest areas were reserved for carbon conservation. Therefore, (average) opportunity costs can be estimated by dividing the changes in carbon emissions and the changes in total GDP for each period. Two estimates are provided: agricultural GDP and total GDP. Total GDP is considered in the analysis because agriculture has important multiplier effects in urban activities—a large part of urban GDP probably could not be generated without accompanying land clearance (Andersen 1996). The 'true' opportunity cost for the entire Amazon economy lies between these two values. The results are shown in Table 9.5.

TABLE 9.5
OPPORTUNITY COSTS AND CARBON EMISSION CONTENTS

	1990	1995	2000	2005	2010
Agricultural GDP: US$/ton C	7.1	12.0	16.2	21.7	29.8
Agricultural GDP: US$/ha	959	1,359	1,772	2,359	3,160
Total GDP: US$/ton C	51.8	84.3	114.8	161.9	240.9
Total GDP: US$/ha	6,958	9,586	12,548	17,555	25,548
Emission per area (ton C/ha)	134	114	109	108	106

It is clear that the strategy of conserving carbon in forestlands would result in increased opportunity costs over time: the value for the year 2010 (US$ 29.8/ton for the agricultural GDP only, and US$ 240.9 for the total GDP) is more than four times the initial value of US$ 2.79/ton. These costs increase with GDP, indicating that the opportunity cost is a function of the level of economic growth. Net emissions per hectare are close to Schneider's estimates (ranging from 134 tons/ha to 106 tons/ha), indicating a declining trend. The combination of both results provide the opportunity costs per hectare: the opportunity costs start at US$ 959 for 1990 when only the loss of agricultural output is considered and reach US$ 3,160 by 2010—even the lowest value exceeds, by far, the best land price considered by Schneider (1993).

Note that the annual rate of growth of the opportunity cost of forest land, measured in terms of expected agricultural output growth, is 6.1 per cent per annum (6.7 per cent if total GDP is considered). This value exceeds the usual range assumed for the social discount rate (2 per cent to 5 per cent), showing that, even in present value terms, the opportunity cost of the foregone output would still increase in time (Table 9.6).

In other words, even if discounting is considered,[2] the main point remains valid: north-south compensations should not omit the opportunity cost of land, measured in terms of foregone income that local economies would have to sacrifice if the current trend of land clearing is halted for global reasons.

TABLE 9.6
DISCOUNTED VALUES OF CARBON CONSERVATION OPPORTUNITY COSTS (T_0=1990)

	1990	1995	2000	2005	2010
Discount rate 2%					
Agricultural GDP (US$/ton C)	7.1	10.8	13.3	16.2	20.1
Total GDP (US$/ton C)	51.8	76.4	94.2	120.3	162.1
Discount rate 6%					
Agricultural GDP (US$/ton C)	7.1	9.4	10.0	10.5	11.2
Total GDP (US$/ton C)	51.8	66.1	70.5	77.9	90.8

On the other hand, these results do not eliminate the main motivation of north-south transfers—avoiding either the damages caused by global warming or the more expensive strategies of carbon emission abatement. Fankhauser (1994), for instance, considers a benchmark of US$ 20/t C for the social costs imposed by carbon emissions in the period 1991-2000 (ranging from US$ 6/t C to US$ 45/t C). Existing carbon taxes in Europe vary from $ 6.1/t C to US$ 45/t C (Shah and Larson 1992), and other studies present upper-limit values of more than US$ 100/t C for the 1991-2000 period (for a review, see Andersen 1996). These values clearly show that at least in a huge number of cases, total costs of carbon conservation in tropical forests (direct and opportunity costs) will be lower than the global benefits.

6. CONCLUSION

Global warming is a problem for everybody—the rich and the poor, the north and the south. Cooperation and participation aiming at the control of carbon emissions are essential, and solutions should not be restricted to a specific group of countries. Nevertheless, equity principles cannot be ignored. Therefore, the north-south agenda for cooperation should be based on fairness. There is no positive advancement if the problem of greenhouse gases is controlled at the cost of increasing disparity between developed and developing countries.

This chapter discussed the use of economic instruments (carbon taxes, offsets and tradable permits) in the control of CO_2 emissions. Economic instruments have a crucial role in an efficient cooperation between developed and developing countries. The preservation of tropical forests as carbon pools can be encouraged if the industrialized countries provide economic incentives to 'import' these environmental services which today are given for free.

However, there are important limitations to be considered. Allocation of emission rights, definition of compensation values, the possibility of free riding by non-cooperative countries, enforcement, settlement of disputes and other concrete problems are important institutional difficulties in the implementation of multilateral programmes. In spite of the considerable advances made in recent times, research of these topics remains a crucial issue.

Among them, one specific topic was developed more carefully in this chapter. To be effective, any compensation instrument should be based on proper valuation of the economic potential of the forest areas to be preserved. Nevertheless, some of the current proposals are based on the hypothesis that land prices reflect the true opportunity cost of land. One important finding of this study is that such a procedure does not respect the equity principle. The implementation of compensations based on actual land prices result in benefits to industrialized countries which may largely exceed the benefits to the countries that effectively act in the control of carbon emissions. This is shown in the exercises carried out using data for the Amazon. The risk of such a situation is that, instead of a true win-win solution, the result is a perpetuation of the wealth concentration problem on a global scale.

NOTES

* I am grateful to Eustáquio J. Reis and Fernando Blanco, for their valuable comments, Marcia Pimentel, for computational help, and José R. Fausto, for research assistance.

1 A methodological description is presented in Reis (1996).

2 Discounting is a complex issue, given the complexity of greenhouse gases discounting and the controversy about intergenerational equity.

REFERENCES

Adams, R. *et al.* (1993). 'Sequestering Carbon on Agricultural Land: Social Cost and Impacts on Timber Markets'. *Contemporary Policy Issues*, 11: 76-87.

Andersen, L. E. (1996). 'The Economics of Deforestation'. Rio de Janeiro: IPEA.

Andrasko, K., K. Heaton and S. Winnett (1991). 'Evaluating the Costs and Efficiency of Options to Manage Global Forests: A Cost Curve Approach'. Paper prepared for the Technical Workshop to Explore Options for Global Forestry Management, in Bangkok (International Institute for Environment and Development), 216-233.

Cline, W. (1993). 'The Economics of Global Warming'. Washington, DC: Institute for International Economics.

Darmstadter, J. and A. Plantinga (1991). 'The Economic Cost of CO_2 Mitigation: A Review of Estimates for Selected World Regions'. Discussion Paper ENR91-06. Washington, DC: Resources for the Future.

Dixon, R. K. *et al*. (1994). 'Integrated Systems: Assessment of Promising Agroforestry and Alternative Land-Use Practices to Enhance Carbon Conservation and Sequestration'. *Climatic Change*, 30: 1-23.

Fankhauser, S. (1994). *Valuing Climate Change: The Economics of the Greenhouse Effect*. London: Earthscan.

Grubb, M. (1992). 'Options for an International Agreement', in UNCTAD (ed.), *Combating Global Warming: Study on a Global System of Tradable Carbon Emission Entitlements*. New York: United Nations.

Hayes, P. (1993). 'North-South Transfer', in P. Hayes and K. Smith (eds.), *The Global Greenhouse Regime: Who Pays?*. London: Earthscan.

Hayes, P. and K. Smith (eds.) (1993). *The Global Greenhouse Regime: Who Pays?* London: Earthscan.

IPCC (1996). 'Climate Change 1995: Impacts, Adaptation and Mitigation of Climate Change: Scientific-Technical Analyses'. Contribution of Working Group II to the assessment report of the IPCC. Cambridge: Cambridge University Press.

Krankina, O. N. and R. K. Dixon (1994). 'Forest Management in Russia: Challenge and Opportunities in the Era of Perestroika'. *World Resources Review*, 6: 88-101.

Masera, O. *et al*. (1995). 'Response Options for Sequestering Carbon in Mexico's Forests'. *Biomass & Bioenergy*, 8 (4-5) (quoted in IPCC 1996).

Mattos, M. M. and C. Uhl (1994). 'Economic and Ecological Perspectives on Ranching in the Eastern Amazon'. *World Development*, 22 (2): 145-58.

Moulton, R. J. and K. R. Richards (1990). 'Costs of Sequestering CO_2 through Tree Planting and Forest Management in the United States'. General Technical Report WO-58. Washington, DC: USDA Forest Service.

Palo, M. and G. Mery (eds.) (1996). *Sustainable Forestry Challenges for Developing Countries*. Environmental Science and Technology Library 10. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Pearce, D. W. (1992). 'Economics and the Global Environmental Challenge', in A. Markandya and J. Richardson (eds.), *The Earthscan Reader in Environmental Economics*. London: Earthscan, 391-406.

Pearce, D. W. (1994). 'Joint Implementation: A General Overview'. CSERGE Working Paper GEC 94-19. London and Norwich: CSERGE.

Peters, C. *et al*. (1989). 'Valuation of an Amazonian Rainforest'. *Nature*, 339: 655-6.

Pinedo-Vasquez, M. *et al.* (1992). 'Economic Returns from Forest Conversion in the Peruvian Amazon'. *Ecological Economics*, 6: 163-73.

Ravindranath, N. H. and B. S. Somashekhar (1995). 'Potential and Economics of Forestry Options for Carbon Sequestration in India'. *Biomass & Bioenergy*, 8 (4-5) (quoted in IPCC 1996).

Reis, E. J. (1996). 'Os impactos do Pólo Siderúrgico de Carajás no desflorestamento da Amazônia Brasileira', in IPEA (ed.), *A Economia Brasileira em Perspectiva 1996*, volume 2. Rio de Janeiro: IPEA.

Reis, E. J. and S. Margulis (1991). 'Options for Slowing Amazon Jungle-Clearing', in R. Dornbusch and R. Portera (eds.), *Global Warming: Economic Policy Responses*. Cambridge, MA: MIT Press.

Roland, K. (1992). 'From Offsets to Tradable Entitlements', in UNCTAD, *Combating Global Warming: Study on a Global System of Tradable Carbon Emission Entitlements*. New York: United Nations.

Sathaye, J. and A. Reddy (1993). 'Integrating Ecology and Economy in India', in P. Hayes and K. Smith (eds.), *The Global Greenhouse Regime: Who Pays?* London: Earthscan.

Schneider, R. (1993). 'The Potential for Trade with the Amazon in the Greenhouse Gas Reduction'. LATEN Dissemination Note No. 2. Washington, DC: World Bank.

Shah, A. and B. Larson (1992). 'Carbon Taxes, the Greenhouse Effect and Developing Countries. Background paper to World Bank: World Development Report. New York: United Nations.

Svendsen, G. T. (1996). 'Public Choice and Environmental Regulation: Tradable Permit Systems in the United States and CO_2 Taxation in Europe'. Aarhus, Denmark: Aarhus School of Business. PhD dissertation.

Swisher, J. N. (1991). 'Cost and Performance of CO_2 Storage in Forestry Projects'. *Biomass & Bioenergy*, 1: 317-28.

Tietenberg, T. (1992). 'Relevant Experience with Tradable Entitlements', in UNCTAD (ed.), *Combating Global Warming: Study on a Global System of Tradable Carbon Emission Entitlements*. New York: United Nations.

Toniolo, A. and C. Uhl (1992). 'Potential for the Intensification of Agriculture in the Eastern Amazon: A Case Study'. Belém, Brazil: IMAZON.

Uhl, C. *et al*. (1991). 'Social, Economic and Ecological Consequences of Selective Logging in an Amazon Frontier: The Case of Tailândia'. *Forest Ecology and Management*, 46: 243-73.

UNCTAD (United Nations Conference on Trade and Development) (1992). *Combating Global Warming: Study on a Global System of Tradable Carbon Emission Entitlements*. New York: United Nations.

Veríssimo, A. *et al.* (1992). 'Logging Impacts and Prospects for Sustainable Forest Management in an Old Amazonian Frontier: The Case of Paragominas. *Forest Ecology and Management*, 55: 169-99.

Wangwacharakul, V. and R. Bowonwiwat (1995). 'Economic Evaluation of CO_2 Response Options in Forestry Sector: Thailand'. *Biomass & Bioenergy*, 8 (4-5) (quoted in IPCC 1996).

Winjum, J. K. *et al*. (1993). 'Forest Management and the Economics of Carbon Storage: An Analysis of 12 key Forest Nations'. *Water, Air and Soil Pollution*, 70: 239-57.

Xu, D. (1995). 'The Potentiality of Reducing Carbon Accumulation in the Atmosphere by Large-Scale Afforestation in China and Related Cost-Benefit Analysis'. *Biomass & Bioenergy*, 8 (4-5) (quoted in IPCC 1996).