**2004s-12**

# Reinforcing Economic Incentives for Carbon Credits for Forests

*Robert D. Cairns, Pierre Lasserre*

**Série Scientifique**
***Scientific Series***

**Montréal**
**Mars 2004**



CIRANO
Centre interuniversitaire de recherche en analyse des organisations

**ISSN 1198-8177**

# Reinforcing Economic Incentives for Carbon Credits for Forests*

*Robert D. Cairns*[†], *Pierre Lasserre*[‡]

**Résumé / *Abstract***

La plantation de forêts est une manière peu coûteuse pour certains pays de remplir leurs engagements à l'égard du Protocole de Kyoto et de ses extensions éventuelles. Les marchés pour les permis d'émissions peuvent s'assortir de crédits pour la séquestration de carbone. Tant les nouvelles que les anciennes forêts sont exposées aux incendies et aux invasions de parasites, qui peuvent se donner lieu à l'émission d'importantes quantités de gaz carbonique à intervalles irréguliers. Les marchés des permis et les marchés d'assurance, mis en œuvre dans un cadre de comptabilité verte, peuvent rendre plus efficace et plus attrayant un système de crédits pour séquestration du carbone.

**Mots clés** : crédits carbone, forêt, assurance, comptabilité verte, perte accidentelle.

*Afforestation is a cost-effective way for some countries to meet part of their commitments under the Kyoto Protocol and its eventual extensions. Credits for carbon sequestration can be mediated through markets for emissions permits. Both new and old forests are subject to pestilence and fire, which are events that could release substantial, discrete quantities of carbon at irregular intervals. Permits markets, the use of green accounting, and insurance markets for sudden emmisions could increase the efficiency of the scheme and its attractiveness to potential participants.*

**Keywords:** *carbon credit, forest, insurance, green accounting, accidental loss.*

**Codes JEL** : H00, Q280, Q290, Q380, Q390.

---

* We thank the guest editor of *Forest Policy and Economics,* and two referees, for comments that have helped to improve the paper. We also thank the FCAR fund for financial support.
† Department of Economics, McGill University, 855 Sherbrooke St. W., Montréal, Québec, Canada H3A 2T7. Email: robert.cairns@mcgill.ca.
‡ Département des Sciences Economiques, Université du Québec à Montréal, C.P. 8888, Succursale A, Montréal, Québec, Canada H3C 3P8. Email: lasserre.pierre@uqam.ca.

# 1 Introduction

Considerable quantities of carbon are contained in the world's forests. As trees grow, they absorb or fix a quantity of carbon which is proportional to the growth of their biomass. This observation has led many to observe that increasing the area devoted to forests, or the stock of timber in existing forests, could be a method to mitigate the increase of atmospheric carbon dioxide (CO2), a greenhouse gas.

The potential contribution of forests and forest products to the reduction in CO2 emissions will fail to materialize unless actions to realize it are properly rewarded. Any country which increases its forest base, improves its forestry practice, or modifies its forest-product mix should receive carbon credits under the Kyoto Protocol on global warming and its eventual extensions beyond 2012. A simple way to accord such credits could be to observe the net growth of biomass in the country and to credit the current value of carbon fixing to that growth. This value, $p(t)$ at some time $t$, could be determined in various ways depending on policies adopted. If $df/dt$ is the growth of biomass, then the credit for biomass changes could be $p(t)df/dt$.

We would argue that the development of appropriate institutions to make the best use of potential resources in an uncertain world requires that appropriate values $p(t)$, for all future values of $t$, for atmospheric carbon be established. The preferred way to do so is through economic instruments, either a carbon tax covering all emissions of CO2 or tradeable permits for all emissions of CO2 into the atmosphere. Such instruments would provide direct incentives to reduce emissions to societal standards at the least social cost. The determination of such levels would involve the methods of green accounting for carbon, informed by scientific understanding of the effects of atmospheric carbon and of carbon assimilation by forests, as all of these develop. For instance, the setting of a Pigovian carbon tax (a unit tax equal to the marginal cost of emissions to society) would demand the same types of evaluation of the social cost of the marginal unit of carbon as in determining the cost of carbon in the green accounts. Alternatively, the appropriate number of emissions permits would be set in order to balance at the margin the costs of atmospheric carbon and the cost of reducing it in the least-cost way.

As a forest grows, there is a continuing risk of destruction by fire or deterioration due to pests. Such events release carbon immediately into the atmosphere, and should be recognized explicitly as possible results of an afforestation program. The efficient way of minimizing the risks of such events is the provision of appropriate levels of insurance. Indeed, under conditions of uncertainty, two types of economic market would reinforce each other in an international carbon-fixing program: (1) insurance against damages and (2) emissions trading. Since CO2 is widely dispersed from any source on the globe, these two instruments could be organized as globally integrated markets, further increasing their joint efficiency. It is our view that a permits market could most readily be integrated globally, and so we stress this instrument over taxes, which may (be expected to) show international variation. The insurance market would both benefit from and contribute to the improvement of green accounting, and hence from wider environmental policy.

# 2 The Value of Fixing Carbon

We consider an afforestation program in the sense of the IPCC (2000, p. 6), namely, 'the establishment of forest on land that has been without forest for a period of time (e.g., 20-50 years or more) and was previously under a different land use.' Let the program begin at time $t_1$, which we normalize to zero; the $n$th rotation, $n \geq 0$ begin at time $t_n$; and the harvesting age for the $n$th rotation be $T_n$. Thus, the $n$th rotation will be harvested at time $t_n + T_n$.

Any rotation can end either by harvesting at time $t_n + T_n$ or with a destructive event at some time $t < t_n + T_n$. At any instant $t < t_n + T_n$, the destruction of the forest, due to a fire (an example analyzed by Reed 1984) or a pestilence that will totally ruin the forest, can be represented as having a hazard rate, $\rho$. In general, the hazard rate may vary with the age of trees or other factors but, in order to avoid notational clutter, we assume that $\rho$ is constant. In this case, the probability of the $n$th rotation's surviving to time $t$ is $e^{-\rho(t-t_n)}$ and the probability of a fire on the interval $(t, t+dt)$ is $\rho e^{-\rho(t-t_n)}dt$. A *partial* destruction of the forest, by fire or infestation by pests, can also be represented as having the hazard rate $\pi$ on any interval $(t, t+dt)$, with a destruction of a fraction $\phi \in (0,1)$ of the forest, so that $(1-\phi) f(t)$ remains thereafter. Again, the parameters $\pi$ and $\phi$ may vary, but for simplicity of exposition we assume they are constant.

Let the quantity of carbon fixed in the biomass of the forest (an even-aged stand) at time $t$ be $f(t-t_n)$; then the rate of growth is $df(t-t_n)/dt = \dot{f}(t-t_n)$. This rate of growth abstracts from the possibility of partial damages during the rotation. If the forest survives to age $T_n$, it is cut. A fraction $\lambda_n$ is useful and $(1 - \lambda_n)$ is waste, immediately being transformed into carbon dioxide (say by burning or rapid decay); this ratio is determined by the choice of inputs (recovery effort) as well as by the production mix (e.g. the proportion of construction products relative to paper in output). The part which is useful is transformed into a mix of wood products, the proportion of each product $i$ being $\Gamma_{ni}$, and its rate of decay $\gamma_{ni}$ (again, assumed to be constant). In what follows, in order to keep the notation simpler, we assume that output is one-dimensional: $\Gamma_{ni} = \Gamma = 1$ and $\gamma_{ni} = \gamma_n$.

In this analysis we make strong abstractions from reality. We neglect changes in carbon content in soils as forestry operations proceed. We simplify the types of stochastic damages to forests. We consider only one type of final product. The assumptions we are making for the sake of simplicity of presentation do not affect the conceptual basis for our proposals. It is true, though, that the details of the probability distributions and the actual values of parameters would be more complicated than in this presentation, and in turn the formulae to be used in practice and hence the actual accounting for and implementation of credits would be more complicated. In any policy application, the effects of all of these features must be estimated in as great detail as possible and then given economic values.

Green accounting is the method of assigning accounting values to environmental effects that are not mediated in markets. Analyses of the social costs of atmospheric carbon at various dates, as is currently being done by many researchers, will inform the setting of the number of emissions permits at any time. For example, in a life-cycle model, Haripriya

(2001a) discusses how to account for changes in carbon content of various wood products in India, classified into retention periods that are 'very short', 'short', 'medium' and 'long'.

As advances such as this are made, the effectiveness of the policy we propose will increase. We emphasize that any other method of crediting carbon sequestration would also have to deal with all of these complications. Below we shall comment on the implications of our full set of proposals for the evaluation of realistic parameters.

The price of an emissions permit (or the unit tax) is the accounting value, $p(t)$. We write the value as a function of time because the value is expected to increase through time as cumulated emissions increase (Sohngen and Mendelsohn 2001).

It is well-known that the introduction of carbon credits can influence the rotation period (cf. Ariste and Lasserre, 2000). In this paper we assume that the rotation periods $T_n$ are known (decided optimally or non-optimally, given the institutions of society) and we do not analyze the influence of the instruments we are discussing on the rotation period, much less the optimal rotation period. As argued by Dasgupta and Mäler (2000), green accounting can be done even if current social standards do not attain the optimal levels. Indeed, it is in exactly these conditions that green accounting is useful.

The stock of carbon stored in a forest is a type of capital and flows such as $f(t)$ are a type of investment. In this context, Cairns and Lasserre (2001) show that there are two possible ways of evaluating the carbon credit for a country at any time $t \geq 0$, given the value of a unit of emissions $p(t)$. The first method evaluates (1) the interest on (using appropriate risk-adjusted interest rates) and the depreciation of the stock value of the carbon currently sequestered in the forest and (2) the depreciation of the stock value of carbon contained in previously produced forest products. It involves imputing and capitalizing (present valuing) future flows over an uncertain future and then calculating the rates of change of the capitalized values. In the case of carbon sequestration, credit would be given (immediately) for the present value of carbon to be sequestered, through all future rotations, of a reforestation program. As has been pointed out by scholars studying the green accounts, computing the stock values would be a formidable task. Thinking about performing such an exercise does point up that the problem of correctly accounting for the forest involves much more than simply crediting a country for the rate of growth of its forests. Any loss of forest value, such as through forest fires or pests, should be considered a debit to be made up otherwise.

The second method, which is theoretically equivalent to the first but in practice far simpler, involves measuring only *current flows* of value (interest on and depreciation of stocks), at current prices, rather than first computing stock values (as present values of flows evaluated at future prices) and taking a time derivative. This method is what is envisaged in most theoretical treatments of green net product. Let $\delta_m^s$, $m < n$, index those rotations in the past that have survived to maturity and been harvested. That is to say, $\delta_m^s$ is one if rotation $m$ survived and zero if not. Similarly, let $\delta_m^p$ index rotations in which there was a partial destruction (so that $\delta_m^p = 0$ if there was no partial destruction). The credit at time $t \in (t_n, t_n + T_n)$ (i.e., for times strictly between planned harvests) is given by the formula,

$$C(t) = p(t) \left\{ \left[ \dot{f}(t - t_n) - (\rho + \pi\phi) f(t - t_n) \right] - \sum_{m=1}^{n-1} \delta_m^s \lambda_m f(T_m)(1 - \delta_m^p) \gamma_m e^{-\gamma_m (t - t_m - T_m)} \right\}.$$

In this formula the credit $C(t)$ involves only physical changes occurring at the current instant $t$, evaluated at the current price $p(t)$, as determined by the current price of carbon permits, for example. In case of a total destruction occurring at time $t$, there is an immediate release of a quantity $f(t - t_n)$ of carbon to the atmosphere. This event occurs with hazard rate $\rho$, and results in the appearance of the term $\rho f(t - t_n)$ in the formula for the carbon credit. A new rotation starts right after the destruction, so that $n$ is increased to $n + 1$; and the beginning of the new rotation is set at $t_{n+1} = t$. The possibility of a partial destruction is responsible for the appearance of the term $\pi\phi f(t - t_n)$. In this case, a fraction $(1 - \phi) f(t - t_n)$ of the forest remains; for simplicity, we assume that the damaged forest is left to grow but other practices may be possible. The final term, under the summation sign, is the reduction in the credit for decay of forest products in previous rotations, $m < n$.

The green accounting at time $t$ for the carbon credit of a forest, $C(t)$, is different from the two possible ways for accounting for the value of a *harvest* discussed by Cairns (2001). In that model, of a commercial forest in which all benefits were received at the harvest date, the value of the forest could be accounted either (1) as occurring at the point of harvest as is current practice, or else (2) as growing at the rate of interest (not the rate of growth of the biomass) through the rotation period. In the formula, the value of carbon fixation, $C(t)$, is actually obtained by society in each year, and is so evaluated (at the rate of growth of the biomass, $f(t)$) in the green accounts. Distinct types of benefit provided by the forest give rise to different methods of green accounting.

# 3 Carbon Credit Implementation Scheme

The second method of evaluation suggests the following policy for distribution of carbon credits to nations and through them to local decision-making units:

1. At dates $t$ strictly between planned harvests, when the age of the stand is $t-t_n$, impute a credit of the value of carbon fixing through actual forest growth, $p(t)\,\dot{f}(t-t_n)$.

2. At dates $t$ when a complete destruction occurs, impose a debit of $p(t)\,f(t-t_n)$, and when a partial destruction occurs, impose a debit of $\phi p(t)\,f(t-t_n)$

3. At all dates, for each past harvest $m<n$ impute a debit for the value of the current decay of forest products, $\delta_m^s f(T_m)\,\lambda_m(1-\delta_m^p)\,\gamma_m p(t) e^{-\gamma_m(t-t_m-T_m)}$.

4. At the time of harvest, impute a discrete debit for the value of waste, $(1-\lambda_n)(1-\delta_n^p)\,f(T_n)\,p(t_n+T_n)$.

5. Make no imputation for future harvests, $m>n$. Future harvests are not evaluated until they are actually planted.

There is no calculation of present value in any of these steps. Rather, the policy consists in crediting current forest growth while ignoring risks of fire or infestation (item 1), and charging instead the full loss from any fire or infestation when it occurs (item 2). A benefit of this scheme is that there is a very strong incentive to take the optimal actions to reduce the risk of fire and pestilence.

A major problem with the policy is that, unlike for the imputation of the value of waste at time $t_n+T_n$, there is no cash revenue against which the charge for fire or pestilence can be levied. In fact, the country or firm that is liable for the charge would lose the value of environmental amenities and the prospective value of the harvest as well as the value of carbon sequestration. The sudden, discrete cash outflow may entail hardships for some countries or firms, requiring them to go to both capital and permits markets to cover the cost of the release of the carbon. If these countries or firms are risk averse, and the cost of the adverse event is levied on them, the prospect of such a requirement could reduce their incentive to invest in forests to sequester carbon.

If fires and pestilence on the planet are not correlated, however, insurance markets could develop to spread these risks. Being able to insure against sudden, discrete costs would give smaller countries and also firms a greater incentive to maintain forests, and thereby would encourage the use of what we have argued may be a low-cost method of reducing atmospheric concentrations of carbon. Some countries with a large land area may be able to self-insure, but even they may find it efficient to use the insurance markets. The fact that carbon emissions are dispersed fairly uniformly throughout the globe, and are not localized, implies that the price of permits, $p(t)$, will become equalized throughout the world in an international permits market. With an international price, the insurance market can become international, and the resulting international diversification will increase the efficiency of the insurance market by making it 'thicker'.

Implementing an insurance market would entail modifying the above scheme, not from the point of view of global society as a whole but from the point of view of individual decision-making units. Our decentralized method would change item 2 above as follows.

1. An additional deduction, in the form of an insurance premium of $(\rho + \pi\phi)\, p(t)\, f(t - t_n)$, would be imposed at dates $t$ strictly between planned harvests.

2. In case of fire or pestilence, no carbon debit would be imputed to the individual forest. Rather, the insurance company would pay the tax or provide the required permits: in the case of complete destruction, for example, the insuror would pay $p(t)\, f(t - t_n)$ to provide $f(t - t_n)$ permits to offset the release of CO2.

The net gain to the firm (country) at any time $t$ is $C(t)$, exactly as in the green accounting of the formula above.

As we have mentioned above, important issues in this insurance scheme are the treatment of all of the sources of complication of an implemented scheme, from which we have abstracted in our conceptual presentation. In the model, this treatment reduces to the estimation of the parameters $\rho$, $\pi$, $\phi$ and $\gamma$, for different geographical regions, species, end uses and future dates. Estimation is all the more difficult if, as is likely, the values of these parameters depend on global warming and hence on the success of efforts to reduce it, including the credits and insurance we have been discussing. There has also been some question concerning the quantity of carbon a forest can absorb. But insurance companies with a financial interest would have a greater incentive than any disinterested government or international institution to determine more accurate values for those parameters, as well as to anticipate the future values of carbon in the atmosphere, $[p(t)]_{t=0}^{\infty}$. In fact, the insurance companies would have the incentive to contribute to the estimation of these parameters, thereby contributing to optimal management both directly through research directed to their own interest and indirectly through more accurate values of carbon for the green accounts.

Our development points up some further issues. One of the main benefits of our proposal is that the three economic instruments, namely tradeable permits, insurance markets for risk and green accounting, reinforce each other. Better estimations of insurance risk require and lead to better estimates of the value of permits, and a more efficient market for permits leads to better estimates of the costs and value of insurance. Incentives are aligned more effectively. By reinforcing each other, the instruments help to integrate markets internationally as well, further increasing efficiency.

The benefits of insurance are substantial, especially if there are actors inclined not to uphold their agreements. If a private company can go bankrupt or if a country can default on the restitution required by the credit scheme, it may be induced to take on too much risk, investing in forests that are too risky to be socially worthwhile. Having insurance available would reduce such incentives. Inducing transnational insurance companies in the private sector to take part in the mechanism would require a high degree of transparency of the scheme. But, once the companies were confident enough to participate, their presence and actions would increase transparency and likely improve enforcement and stability of the mechanism. Green accounting and the insurance market would also make it easier for outsiders to determine whether a given investment was efficient or not. Even if a firm did not take insurance, in normal years (with no destruction) the clearing house for credits could, at least conceivably, reduce its credit by the value of insurance, thereby offsetting the incentive to invest in overly risky forests in order to benefit from the permits. Thus, green accounting and the insurance market would make any inefficiency (such as an overly risky investment) more obvious.

A problem with the scheme is that, as in any insurance market, there is moral hazard: the very existence of insurance reduces the power of the incentive to manage forests optimally. That is to say, given that it is insured the firm may be induced not to take sufficient steps to avoid the hazard, with the effect of increasing the parameters $\rho$, $\pi$ and $\phi$. Moral hazard afflicts all forms of insurance and forces insurance companies to take steps (such as variable deductibles) to minimize the cost of the risk. In this way, the insurance market is imperfect.

Unfortunately, governments and international institutions are also subject to moral hazard. If firms and countries are to make long-term commitments to planting forests, of the order of several decades, there must be an international commitment to maintaining the scheme – if not to the prices themselves, at least to the methods of computing the prices. A part of this commitment includes one to improving methods of green accounting. Methods of accounting, transparency, credits and insurance feed back upon themselves to produce more credible values of $p$, $\rho$, $\pi$, and $\phi$, and hence to reduce inefficiencies in the system and the ability of actors to take advantage of them.

The insurance scheme provides a different perspective on the use of forests in climate control. Discussion to date tends to be limited to afforestation and not continuing forestation. Since the discussion is of a uniform global problem, of CO2 concentrations in the atmosphere, logically the scheme should not be limited to afforestation. If an ancient forested area, such as the New Forest in England or the Black Forest in Germany, suffered damage due to pest or to fire, the appropriate government should be charged for the additional emissions. Such a requirement would imply, in principle, bringing all forests in the world, not just newly planted ones, into the permits-and-insurance scheme (except possibly for self-insurers). The charges would provide improved incentives to managers of existing forests. In addition, extending the market would imply a reduction in the other form of inefficiency in insurance markets, adverse selection.

# 4 Extent of the Market

In this paper we argue that three institutions, (1) emissions trading, (2) insurance markets for carbon in forests and (3) green accounting, can interact in organizing a system of carbon credits for investment in forestry. We presume that the first of these is functioning well; the novelty is the two others and the interactions. The transaction price in the insurance market would be determined by the general emissions trading scheme, of which we assume forestry's, let alone any forester's, contribution would be so small that it would have no discernible effect on that price. We have presented the insurance market in this paper as if it were competitive and the only imperfections were moral hazard and adverse selection.

We are arguing that the opportunities for earning credits from forestry should be extended to all countries. Our referees remind us that markets are not perfect in developing countries, may have to be developed, and themselves have costs. Extending the opportunities does not eliminate all forms of risk, especially in developing countries. Nor, however, does making insurance available increase any risk or other burden for a developing country.

There already exist many insurance companies in the developed countries that, given a wider emissions trading scheme, could establish the market in developing countries. We feel that the development of insurance markets is less problematic than the prior requirement of emissions trading or, indeed, extension of the Kyoto Protocol to developing countries.

By being able to enter the scheme and obtain credits for their forests, developing countries would benefit directly. Other countries would benefit by the reduction in the price of credits occasioned by the increase in supply. There is a cost to developing a market, as with any product, but that cost will in the first instance be borne by the insurance companies, who will expect to recover it later in the insurance premium. Even with these premia, there will be a net *reduction* in the full cost perceived by participating countries because the market for forest credits will become more credible and the risk less onerous for forest owners as a result of the introduction of insurance. Any forester that doubts that costs are reduced by buying insurance will not buy it. In addition to a gain by those who would participate anyway, the reduction in cost through insurance will make it possible to invest in additional forests that are close to the margin of viability.

Another type of cost is insurance monopoly. However, as markets become thicker monopoly becomes less sustainable. Therefore, as the scheme is extended in time and space, monopoly will be attenuated. In any case, even the monopoly price would be an improvement on there being no insurance (or, in effect, a prohibitively high price for insurance).

We have taken the forest-management regime as given, and have avoided assuming that it is optimal. The forester chooses the rotation period, but not necessarily optimally, just as a commercial forest may be harvested at an inopportune (sub-optimal) time; in that case, profits are not maximized, but the forester obtains the market price for what is harvested and for the credits earned up to then. If the carbon is emitted prior to the expected time, the charge is imposed prior to the expected time. There is room for improvement of management regimes and a consequent increase in sequestration and credits for any given plot of land, as well as other benefits. Haripriya (2001b) discusses the fact that better management of forest lands and forests would provide developing countries with additional benefits, beyond the sequestration of carbon. All countries will surely take into account all aspects of their forestry regime in their decisions, and not solely the benefits to be had from sequestering carbon. A more efficient recognition of carbon sequestration will increase these perceived benefits and lead countries to make more appropriate trade-offs in management.

In a sense, the (value of the) credit is only loaned to the forester while the carbon is still fixed. Sequestration is temporary, since any given, stored carbon molecule will eventually escape to the atmosphere in the form of CO2 in one of the ways we have enumerated. Indeed, our scheme loosens a perceived need for permanence (somehow defined) of storage within a particular forest or limited geographical area. From any planted forest, world society gains a temporary benefit in that there is less CO2 in the atmosphere for a period and the forester gains a temporary credit, paid back when the carbon re-enters the atmosphere. The reason is that intertemporal differences in the value of funds (at market rates of interest) are exploited. The components of our scheme can be compared to (1) bank interest on funds that will eventually be withdrawn, (2) deposit insurance and (3) a readily available estimate of future inflation, taxation and so on. The bank does not hold the funds permanently. Still, there are gains to the bank and to the depositor from the transaction. In the case of carbon fixing, there is a gain to society even if the carbon is stored only temporarily, and the intertemporal pricing helps the parties to realize that gain. It is not essential to the scheme, then, that on a global basis the total stock of carbon sequestered increase until a stationary state is approximated, even though we do expect such a trajectory. Since there is an important role for the future price, detailed green accounting of physical changes and their values as well as the predictions of insurance companies are vital elements of the scheme.

# 5 Conclusion

An efficient afforestation policy can contribute to efforts to mitigate the greenhouse effect. Economic instruments can help to make that policy more effective and to minimize the costs of global warming. The most commonly discussed such instruments are unit carbon taxes or (what we have emphasized) tradeable emissions permits. Other economic instruments discussed in this paper are insurance markets and green accounting. In conditions of uncertainty, all of these instruments reinforce each other as well as encourage more directed scientific and economic research on global warming and environmental policy in general. The reinforcement and strengthening are especially encouraged in global markets for insurance and carbon credits.

# References


[1] Ariste, R. and P. Lasserre (2000), "La Gestion Optimale d'une Forêt Exploitée pour la Valeur Stochastique de son bois et son Potentiel de Diminution des Gaz à Effet de Serre", *Actualité économique* forthcoming.

[2] Cairns, R. (2001), "Seeing the Trees as a Forest: What Counts in Green Accounting", *Ecological Economics* 36, 61-69

[3] Cairns, R. and P. Lasserre (2002), "Carbon Credits for Forests and Forest Products", mimeo., CIRANO, Université de Montréal

[4] Dasgupta, P. and K.-G. Mäler (2000), "Net National Product, Wealth and Social Well Being", *Environment and Development Economics* 5, 1&2, 69-94.

[5] Haripriya, G. (2001a), "A Framework for Assessing Carbon Flow in Indian Wood Products," *Environment, Development and Sustainability* 3, 229-251.

[6] Haripriya, G. (2001b), "Managing Forests in India to Mitigate Carbon," *Journal of Environmental Planning and Management* 44, 701-720.

[7] Intergovernmental Panel on Climate Change (2000) "Land Use, Land-Use Change, and Forestry: Summary for Policymakers" internet: www.ipcc.ch

[8] Reed, W. (1984), "The Effects of the Risk of Fire on the Optimal Rotation of a Forest", *Journal of Environmental Economics and Management* 11, 180-190.

[9] Sohngen, B. and R. Mendelsohn (2001), "Optimal Forest Carbon Sequestration", Working Paper AEDE-WP-0009-01, Ohio State University.