Unclassified **ENV/EPOC/GSP/BIO(2001)6/FINAL**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development **28-Mar-2002**

English - Or. English

ENV/EPOC/GSP/BIO(2001)6/FINAL
Unclassified

ENVIRONMENT DIRECTORATE
ENVIRONMENT POLICY COMMITTEE

Working Party on Global and Structural Policies
Working Group on Economic Aspects of Biodiversity

THE DEVELOPMENT OF MARKETS AND ECONOMIC INCENTIVES FOR SUSTAINABLE FORESTRY: APPLICATION TO THE BRAZILIAN AMAZON

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JT00123345

English - Or. English

FOREWORD

This report was prepared by James R. Kahn of Washington and Lee University, Lexington, VA, USA.

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ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. Vicente Nogueira and the Instituto Proteção Ambiental - Amazonas (IPAAM). Many of the insights presented in this paper were developed in research sponsored by the IPAAM. The report submitted to IPAAM has not been released and none of the recommendations made in this paper should be viewed as recommendations of IPAAM. I would also like to thank my co-authors on previously authored papers on sustainable forestry, including James Casey, Jill Caviglia-Harris, Dina Franceschi, Frank McCormick, Vicente Nogueira and Alexandre Rivas, for insights that they helped me to develop. Most importantly, I would like to thank Dan Biller and his colleagues at OECD for their ongoing support and for helpful comments on this paper.

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EXECUTIVE SUMMARY

Although direct markets for biodiversity have been discussed as a way of preserving environmental resources, these types of markets are not likely to create significant economic incentives for environmental preservation. However, markets for ecological services that are jointly produced with biodiversity may have greater potential for preserving our critical environmental resources. This paper looks at the potential to develop markets and related economic incentives in the Amazonian rainforest. The concepts developed in this study can also be applied to other regions and other types of ecosystems.

The first challenge that the paper examines is the challenge of improving the economic viability of sustainable forestry. The paper suggests a variety of ways to structure leases to give firms an economic incentive to harvest in a sustainable fashion that allows the forest to recover quickly to its natural state. Of particular importance are schemes for rewarding firms for success in obtaining high levels of key ecological parameters that are functionally related to the speed of recovery.

The paper also examines the challenge of developing new markets, not only for underutilized tree species, but also for non-timber forest products, agro-forestry products, and eco-tourism. Demand augmentation and ecological certification programs are discussed, and policies are suggested to implement this process.

Finally, the paper examines the potential for rewarding land-owners for preserving the carbon that is sequestered in the forests on their landholding. The paper demonstrates that this may be the largest source of transferable value of the tropical rainforest.

1. INTRODUCTION

Sustainable forestry is a phrase that has become universally accepted by proponents of sustainable development. However, just as sustainable development has many different definitions, so does sustainable forestry. Many definitions of sustainable forestry focus on the continued ability of the land to produce wood that can be harvested into the indefinite future. The other set of definitions of sustainable forestry focuses on the maintenance of the existing ecosystem and its continued ability to provide a full suite of ecological services (including but not limited to production of wood for potential harvest). Accordingly, conversion to a forest plantation (if successful) would qualify as sustainable forestry under the first set of definitions, but not the second.

This paper focuses on the second definition of sustainable forestry, and its application to the Amazonian rainforests of Brazil. The paper specifically addresses the question of how a profitable harvest can take place in a forest, and leaving the forest in a position that it recovers quickly into a forest ecosystem approximating the original, that continues to provide the flow of ecological services similar to that of the original undisturbed ecosystem.

A critical aspect of the analysis will be an examination of the role of markets in stimulating the development of sustainable forestry. In addition to an examination of policies that create a market for sustainably produced timber (such as the development of leasing systems for sustainable forestry) the paper will examine policies that are designed to stimulate existing markets for forest products or generate new markets for non-timber forest products. Examples of these types of market-enhancing policies include demand augmentation policies, ecological certification, non-timber forest products and the utilization of already degraded lands. In addition, markets for sequestered carbon are also discussed.

Although this paper uses the Brazilian Amazon as its case study, many of the concepts developed in this paper are applicable to sustainable forestry in a wide range of settings. It should be pointed out that since sustainable forestry in the Brazilian Amazon is in its infancy, the case study aspects of the paper are more conceptual than empirical.

2. ECOLOGICAL CRITERIA FOR SUSTAINABLE HARVEST[1]

The forestry economics literature that looks at timber production, the capture of resource rents and the optimal rotation has made particular assumptions about regeneration and environmental damages. Since the economic models that are used to examine these issues are calibrated in terms of volume of wood or the length of the rotation, environmental damage is often modeled as a function of the volume of wood harvested, the area of the forest, which is harvested, or the length of the optimal rotation. In terms of temperate forests, for which these models were developed, these relationships may or may not hold. However, it is clear that they are inappropriate for tropical rainforests.

First, the concept of a rotation as a cycle of clear-cutting and replanting makes no sense for tropical forests, particularly those in the Amazonian basin. Clear-cutting destroys the regenerative capability of the forest, and because the soil is destroyed, nutrients are lost, and mycorrhizae[2] disappear, replanting is usually not successful. Although a clear-cut area can often be replanted into a palm plantation or other type of forest plantation, the diverse natural forest will not regenerate and cannot be replicated by replanting.

Second, the ability of the forest to regenerate (and the level of ecological services associated with the regenerated forest) is not related so much to the amount of trees which are cut (volume or area) but to the manner in which they are cut. It is true as a general proposition that the greater the amount of clearing, the less regenerative capability and the more environmental damage. However, the manner in which the clearing and harvesting takes place is important as well. Some simple examples of the importance of the manner of harvest are choosing techniques that avoid damage to young trees, avoid soil compaction by heavy machinery and avoid erosion and soil loss. Further discussion of this is contained in Section 4.

Sustainable harvesting of tropical rainforests should focus upon two fundamental and functionally related ecological determinants, the severity of the disturbance and the capability to recover. Important variables that influence both of these ecological determinants include spatial scale of disturbance, intensity of disturbance, intensity of other stressors at the time of (or preceding the disturbance), age and health of the rainforest ecosystem, and the degree to which human disturbances mimic natural disturbances.

Probability of recovery is inversely related to the severity of the disturbance, while the time required for recovery is directly proportional to the severity. Extended recovery time contributes to secondary and delayed impacts such as soil erosion or compaction, nutrient or water depletion, loss of mycorrhizae and extreme temperature and light regimes. Severely altered micro-environments favor invasions of exotic species, which may significantly alter paths of rainforest recovery. Severity of disturbance is a measure of how extensively biotic and abiotic components are altered. If disturbance does

1 This section is based on Kahn, McCormick and Nogueira (2000).

2 Fungal organisms which have a symbiotic relationship with the roots of trees, enabling them to absorb nutrients more efficiently.

not extend to extensive alteration of geological substrate and soils, residual populations of plants, animals, microbes and humans may survive in micro habitats. Recovery by residual populations is relatively rapid, predictable and dependent upon intrinsic ecological properties. If the disturbance is so severe that micro habitats are destroyed and colonization is required from distant sources, recovery is slow and stochastic (or even chaotic). If the disturbance is sufficiently severe to diminish populations of reproductively mature individuals, pollinators or seed dispersers, ecosystem recovery can also be significantly altered or delayed.

The degree to which human disturbances mimic natural disturbances is the single most significant determinant of ecosystem recovery. Natural stressors such as wind, hurricanes, disease, old age and extreme weather events contribute to tree mortality. Dead and weak trees fall to the forest floor as frequently as one tree per hectare per year. Tree falls create gaps ranging from 30-50 meters in width. Various tree species are pre-adapted to invade gaps of different sizes. This "intermediate" level of natural disturbance is beneficial and necessary to maintain high species biodiversity and ecosystem health. Rainforest species are also well adapted to larger disturbances such as floods, fire, drought or hurricanes if the disturbances are rhythmic, cyclic or periodic in occurrence. Strategies for sustainable tropical forestry should be based upon an understanding of these types of ecosystem responses to various scales and intensities of disturbance. These strategies require long range planning based upon principles of ecological science and field experiments which transform theory into practice. In the absence of long range planning, extraction (disturbance) of forest products is too often episodic, of unnatural scale, and characterized by excessive environmental damage[3].

It is possible to develop operational indicators of the ability of the forest to recover. First, as the research from a joint Instituto Nacional de Pesquisas da Amazonia (INPA-National Institute for Research on the Amazon)/Smithsonian Institute project[4] indicates, disturbed areas should be small in comparison to the undisturbed area. As Thomas Lovejoy [5] indicated, the only workable configuration is "islands of development in a sea of forest". Therefore, one operational measure of the recoverability of a harvested forest would be the ratio of undisturbed area to disturbed area. This is illustrated in panels A and B of Figure 2, where A has a low ratio and B has a high ratio. The higher the ratio of undisturbed area to disturbed area (hereafter referred to as the undisturbed area ratio), the greater the recoverability of the forest. This is because lower undisturbed area ratios will result in loss of many important ecological characteristics. In particular, as the undisturbed area ratio shrinks, animals that fulfill the roles of both pollinators and seed dispersers leave the area, which drastically inhibits the return of the forest to its original state.

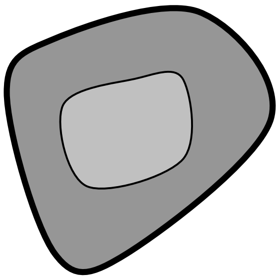
A second operational measure of the recoverability of the forest is the ratio of the edge of the disturbed area to the surface area of the disturbed area (hereafter referred to as the edge ratio). Areas of high edge ratio (as depicted in Panels C and D of Figure 1) are long-narrow strips that mimic the clearings created by the natural falling of emergent trees. Since many of the regenerative processes operate at the edge of the clearing, the greater the edge ratio, the more potential for these processes to operate. Also, with lower edge ratios, the cleared area is more square or circular in configuration (Panel A or B) and more soil is exposed to the sun and the negative effects of compaction, erosion, and loss of leaf litter, mycorrhizae and nutrients. An important aspect of a harvested area with a high edge ratio is that the roots of neighboring trees will underlie the narrow strip of cleared area, so nutrients are re-absorbed and not lost to this system. In contrast, in a larger and more circular area, much of the nutrients will be lost to run-off.

3 See Kahn, McCormick and Nogueira (1998) for further discussion of the relationship between forest characteristics and forest recoverability.

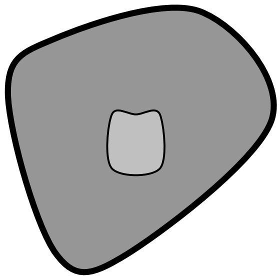
4 This work examines the critical size of tropical forest ecosystems. See Lovejoy et al (1986b)

5 Presentation at the Environmental Sciences Division, Oak Ridge National Laboratory, 1993. Also see Lovejoy (1986a)

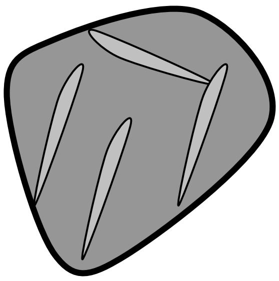
Figure 1. Operational measures of forest sustainability



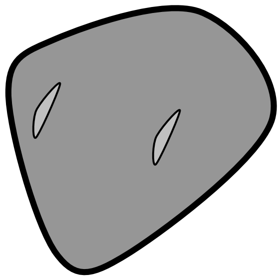
Panel A (worst case): Low ratio of edge of disturbed area to surface area of disturbed area and low ratio of undisturbed area to disturbed



Panel B: High ratio of undisturbed area to disturbed area, but low ratio of edge of disturbed area to surface area of disturbed area



Panel C: High ratio of edge of disturbed area to surface area of disturbed area, but low ratio of undisturbed area to disturbed area.



Panel D (Best case): High ratio of edge of disturbed area to surface area of disturbed area and high ratio of undisturbed area to disturbed area.

Undisturbed Forest

Disturbed area of harvesting activity

3. SUSTAINABLE FORESTRY AND MARKET FAILURE

There are several types of market failure, which may be important in the case of forestry management. First, there is the ubiquitous problem of imperfect information, in which case logging firms or households do not know the appropriate technology for sustainable forestry. Second, there is the problem of insecure property rights. If people do not have long term security in the property rights of their land, there is no incentive to engage in long-term optimization. Related to the problem of the insecurity of property rights is the granting of short term timbering leases by either private or public owners of forest land. Short term leases do not provide an incentive for the harvesting firm to treat the forest gently and conform to the ecological principles, which are described above.

One may ask why land owners voluntarily agree to short term leases, even though these lead to degradation of the forest and a loss in long term income. The answer is that both public and private owners of forests may face constraints which force them to make decisions to maximize short run economic gain, rather than long term economic gain.

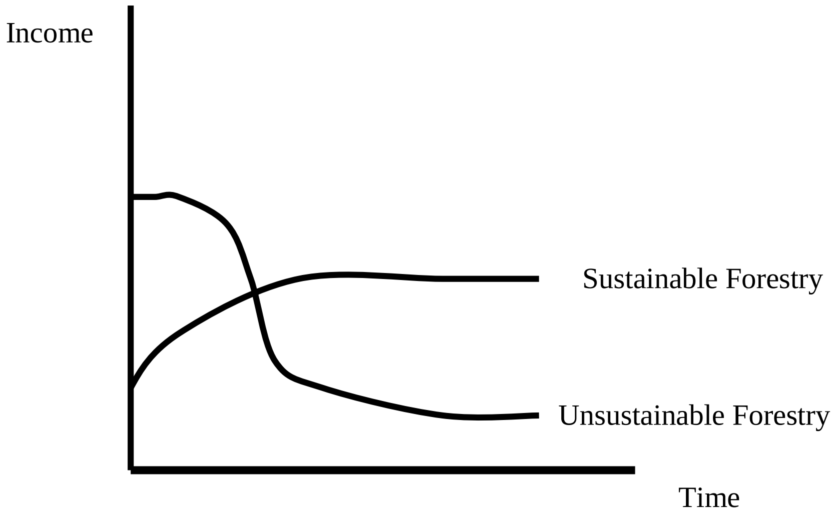
Governments may be forced to focus on short run economic gains because of immediate needs for income. This may be because of macroeconomic problems such as large external debt that requires servicing, or because of pressing needs to maintain or increase current consumption.[6]

Individual landowners will, in general have a greater rate of time preference than society as a whole, for both the usual reasons,[7] and because of short term concerns with feeding their families. In particular, it is likely that the income paths of unsustainable and sustainable forestry take the shapes depicted in Figure 2. If unsustainable forestry has higher initial levels of income than sustainable forestry, and if credit is unavailable to small landowners, then they have an incentive to engage in unsustainable forestry or to write short term harvesting contracts with forestry firms.

6 See Kahn and McDonald (1994 and 1995) for a discussion of how external debt and other economic pressures can cause countries to engage in more myopic economic strategies.

7 There are a number of arguments why the social rate of time preference should be higher than individual rates of time preference. These arguments include the ability of society both to invest in a more diversified portfolio of investments and spread the risk over more individuals. In addition, there are ethical reasons for a higher social rate of time preference including responsibility to future generations.

Figure 2. Alternative time paths of income



Of course, there is also a general market failure because of the global public good nature of tropical forests. Even if the within-country market failures could be addressed by policy, harvesting is likely to be less sustainable than world community would prefer, because the global benefits of forest preservation cannot be captured by local landowners without an international agreement to transfer resources based on forest preservation.

An examination of market failure in the context of Figure 2 provides some interesting insight into the importance of improving existing markets and creating new markets. The traditional approach to environmental market failure is to utilize the "producer pays principle" and increase the marginal private cost of the producer to the level of marginal social cost. In terms of Figure 2, this would represent a downward shift in the income stream associated with the unsustainable activity, making the sustainable path relatively more attractive. However, it is not clear that this would cause firms to adopt the sustainable forestry alternative, and they might shift to a different activity such as farming or cattle ranching which is even more environmentally destructive than traditional forestry.

In contrast, if the problem is attacked by trying to shift up the income path of the sustainable forestry option, then this will not only make sustainable forestry more attractive relative to unsustainable forestry, but also to alternative activities such as cattle ranching. In addition, this augmentative approach is better than the punitive approach, because an upward shift in the sustainable forestry income path will contribute more to regional economic growth than would penalizing the unsustainable forestry.

This paper explores market alternatives for shifting up the income path associated with sustainable forestry. The first market alternative that is examined is the development of leasing (concessionaire) agreements that allow the harvesting companies to share in the resource rent associated with the forest. This is quite a departure from the traditional forestry management literature that argues that the government should extract all the resource rent as part of the leasing agreement. If the sharing of the resource rent is linked to ecological preservation, this will serve to create a market for the ecological services. The next set of market alternatives which are examined are programs to increase the demand for sustainably produced timber, including marketing programs to increase the demand for a diversity of species, and ecological certification programs. The third set of programs would be to develop markets for non-timber forest products (fruit, nuts, dyes, fibers, latex, etc.) that can be produced without significant disturbance to the Amazonian ecosystem. Finally, the possibility of developing markets for the forest's sequestered carbon is examined. Following the discussion of models of sustainable forestry in Section 4, the remainder of the paper is devoted to discussing these methods for making sustainable alternatives more profitable.

4. MODELS OF SUSTAINABLE FORESTRY[8]

Unfortunately, sustainability (McCormick, 1998) has not been a prerequisite for the majority of development projects undertaken in the Amazon. However, over the past two decades sustainable forestry has become the focal point of a steadily growing number of development projects in the Amazon. Three models of sustainable forestry in the Amazon are discussed. The first of these, "selective harvesting", involves the harvest of widely separated individual trees of numerous species. Disturbance is held to a minimum, enhancing natural forest regeneration. A very different approach, "the strip method", involves clear cutting long narrow areas in the midst of larger undisturbed areas of forest. The dimensions of these long fingers of clear-cut are intended to mimic those resulting from natural disturbances. If the mimicking is successful, natural ecological processes can be expected to contribute to regeneration of the forest. The "strip shelter belt" method contains elements of each of the preceding methods, and represents a strip method with additional ecological constraints on harvesting activity that mimic natural disturbance, minimize anthropogenic disturbance and enhance natural regeneration.

The selective logging method is heavily dependent upon scientific research and technology to guide selection of individual trees for harvest. The strip method is heavily dependant upon the ecological theory of gap dynamics and intermediate disturbance hypotheses. The strip shelter belt method shares dependencies of the other two methods.

4.1 The Selective Logging Method of sustainable tropical forestry

The selective logging method of sustainable forestry requires a significant amount of scientific knowledge to be conducted properly. A good example of the selective logging method can be found in the activities of Precious Woods, Ltd., a Swiss owned-Brazilian operated sustainable forest management enterprise.

Precious Woods owns 81,000 hectares of primary forest located approximately 250 km east of Manaus (capital city of the state of Amazonas) and 40 km West of Itacoatiara, an Amazon river town of 80,000 people. The most distinguishing feature of this project is the extent of research, forest inventory and long range planning. Management plans focus upon minimizing damage to forest understory and the area to be harvested, and upon maximizing biodiversity and sustainability. Approximately 25,000 hectares (30%) are placed in permanent reserve to serve as a source of seeds, pollinators, seed dispersers and wildlife, as well as providing baselines against which other sites may be compared. Approximately 5,000 hectares (6%) are dedicated to infrastructure such as roads and the mill site. Each year, a different work unit of approximately 2000 hectares (2%) is selectively harvested, on an expected rotation cycle of approximately 25 years. Thus, at any one time, 92% of the rainforest is in permanent or temporary reserve. The Celos Management System, used by Precious Woods, is based on research at Waginengen Agricultural University and was field tested in experimental plots in Suriname. Pre and post harvest plots

8 See Kahn, McCormick and Nogueira (2000) for further discussion.

($100m^2$) are established in each work unit and are monitored to estimate the severity of disturbance during extraction and recovery thereafter. Prior to extraction, all trees greater than 50 cm (dbh) are identified, measured and located on a geographic information system (GIS). As work progresses, smaller trees will be similarly inventoried and data entered into forest growth models to estimate available wood volume of each species at future dates. Traditional forest practices in the region have typically only utilized one to four species of trees. In contrast, this sustainable forestry operation extracts 40 species of trees (with an eventual goal of 60 species) to minimize the area disturbed annually and to avoid high-grading (harvesting only high-valued species such as mahogany) and associated reduction of biodiversity.

Specific procedures include the following:

1. Access into work units and extraction of trees is confined to trails 3.5 m in width and 80 m long which are located at 100 m intervals. Accordingly, no tree is more than 50 m from a trail. Disturbance of the forest understory is minimized.

2. Prior to cutting, all vines are removed in order to minimize the collateral damage to other trees and to minimize gap size.

3. Direction of tree felling avoids trees that are of economic or ecological value (such as palms which provide food and shelter for many plant and animal species.)

4. No more than 80% of reproductively mature individuals are removed from a work unit in order to insure a nearby source of seed for recruitment of new individuals and to provide a continuing food source for dependent animal species.

5. Only 10% ($40m^3$) of wood volume per hectare is removed, to ensure that nutrient and carbon loss are within sustainable limits.

6. Track skidders used to extract trees are restricted to trails. Logs are trimmed and transported to trails by cable (winched) in order to minimize disturbance.

7. Prior to extraction by cable, logs are cut to 7 m lengths to minimize sway during extraction. This further reduces disturbance.

8. Once logs are on the trail, they are removed by wheeled vehicles in order to minimize disturbance of trails.

The selective harvesting method of forestry requires a significant investment in information in order to implement it properly. As discussed above, its implementation requires a complete mapping of trees, and the implementation of an optimization program, with constraints on the distribution of trees, temporal distribution of fruit, presence of pollinators and seed dispersers, and other ecological factors. Because of this, it is also a method for which it is more difficult to develop encouraging policy instruments, because the implementation, monitoring and enforcement of the instruments would have correspondingly high information requirements for the regulatory agency. The selective method is probably most effectively utilized by firms whose objective is sustainable forestry and who have the technical ability to implement it.

APLUB Agroflorestal is a new entrant to the sustainable forestry industry, with the first harvest cycle in 2001. It is located in the varzea (flooded forest system) along the Rio Juru near the small city of Carauari in western Amazonas State. The total project size is a 210,000 hectare concession from the federal government, but with only 30,000 hectares of the concession designated as areas to be harvested. Of the 30,000 hectares, 1000 are sustainably harvested each year, with similar ecological constraints to the

Precious Woods project. However, for APLUB Agroflorestal, only six percent of the volume of wood in each 1000 hectare unit is extracted. Since the river rises into the forest during the high water season each year, trees are felled during low water and then floated out during the high water season. This leads to minimal disturbance to the soil and potentially vulnerable trees and other plants.

An interesting aspect of the APLUB project is that it combines sustainable forestry with sustainable agriculture, as they restore previously degraded agricultural land near the city of Carauari. The sawdust from the sawmill is combined with the waste from chicken, swine and cattle rearing operations to restore the soil and generate fruit tree plantations in previously degraded areas. The sustainability and profitability of the combined operations seems to be greater than the sum of the separate operations. However, this project is still in its infancy and more experience must be gained to thoroughly evaluate the implications of its procedures.

4.2 The Strip Method of sustainable tropical forestry

In contrast to the selective harvesting method, the strip method requires less information, as it is based on clear-cutting, but of small areas. The disturbances associated with harvesting can most closely mimic natural disturbances if the clear cut areas are appropriately configured as discussed in Section 2 of this paper, where Panel D of Figure 1 is shown to be the appropriate configuration. It is even possible that this type of activity could be monitored with remote sensing techniques, such as satellite imagery or aerial overflights of downward-looking radar. If operational measures of the appropriate configurations are defined and can be monitored, a deposit-refund or performance bonding system can be developed to encourage this type of sustainable forestry. These systems would reward firms for attaining certain ecological recoverability characteristics of the areas that they are harvesting. These systems are discussed more fully in Section 6.1.

4.3 The Strip-Shelter Belt Method

The strip shelter belt method combines the characteristics of the strip method and the selective logging method, and can be interpreted as an extension of the strip method. In essence, it is the strip method with added ecological constraints such as those employed by Precious Woods in their selective harvesting operation. The Central Selva Resource Management (CSRM) Project (Tosi (1981), Hartshorn (1981) in the Pal Cazu Valley of the Peruvian Amazon is an excellent example of the commercial implementation of these theories of sustainable forestry, providing a field test of the importance of mimicking these natural disturbances through the edge/surface area and undisturbed/disturbed area factors.[9]

9 This project illustrated the importance of public participation, education and other social factors in developing sustainable economic activities, but as important as these factors are, they are beyond the scope of this paper.

5. LEASE SYSTEMS TO GENERATE SUSTAINABLE FORESTRY

The use of contractual leases to promote sustainable forestry is an interesting concept, but in order to be successful, it must be based on a radical departure from traditional forest economics recommendations. Traditionally, forest economists have recommended that the leasing country structure the lease so as to capture all the resource rents associated with the forest plot, where the resource rent is equal to the difference between the cost of cutting the tree and the market value of the cut tree. It should be noted that the definition of cost used in this computation includes a normal profit, which is a rate of return on the investment comparable to the typical investment elsewhere in the economy. Thus, if resource rent is positive, then the forestry investment is a better investment than those typically available in the economy.

The forestry management literature has generally suggested that leasing contracts be structured so that the national (or state) treasury capture as close to 100% of the resource rents as possible. There are two arguments supporting this position. First, the timber represents a national asset, so society should be the one to capture the surplus value associated with the asset. Second, since many developing nations are in dire need of foreign exchange, this represents an excellent opportunity to earn more foreign exchange.

In response to these arguments, it should be noted that the asset value ascribed to the forest in this literature tends to be solely the value of the extractable wood, and does not include the value of the ecological services provided by the forest. Society should seek to maximize the total value of the forest and not the timber value of the forest. Since many of the ecological values are public good values, market will not promote the maximization of the total benefits from the forest. However, if leases are structured so that a portion of these rents are shared with the timbering firm if they promote the flow of ecological services, then a market can be created that sends signals to maximize the total net benefits of the forest. Before discussing how the leasing system can be structured to include a quasi-market for these ecological services (Sections 5.4, 5.5 and 6.0), the paper will discuss properties of leases related to timber values.

5.1 Definition of Resource Rent

Before beginning the analysis of alternative forest concession systems, it is important to define and clarify the concept of resource rent. Resource rent refers to the value of the trees in timber production, above their cost of production. For example, if the wood in a tree sold for $50, but the cost to the firm of harvesting the tree was only $10, the resource rent associated with the tree would be $40. The resource rent is distinguished from profit as it is due to the productivity of nature and not the efforts of humans[10]. A normal economic profit (return on investment) is included when measuring the cost of harvesting the tree.

A central issue in developing forest concession issues is who should receive the resource rent on the trees. Typically, the answer to the question is that the landowner should receive the resource rents. The

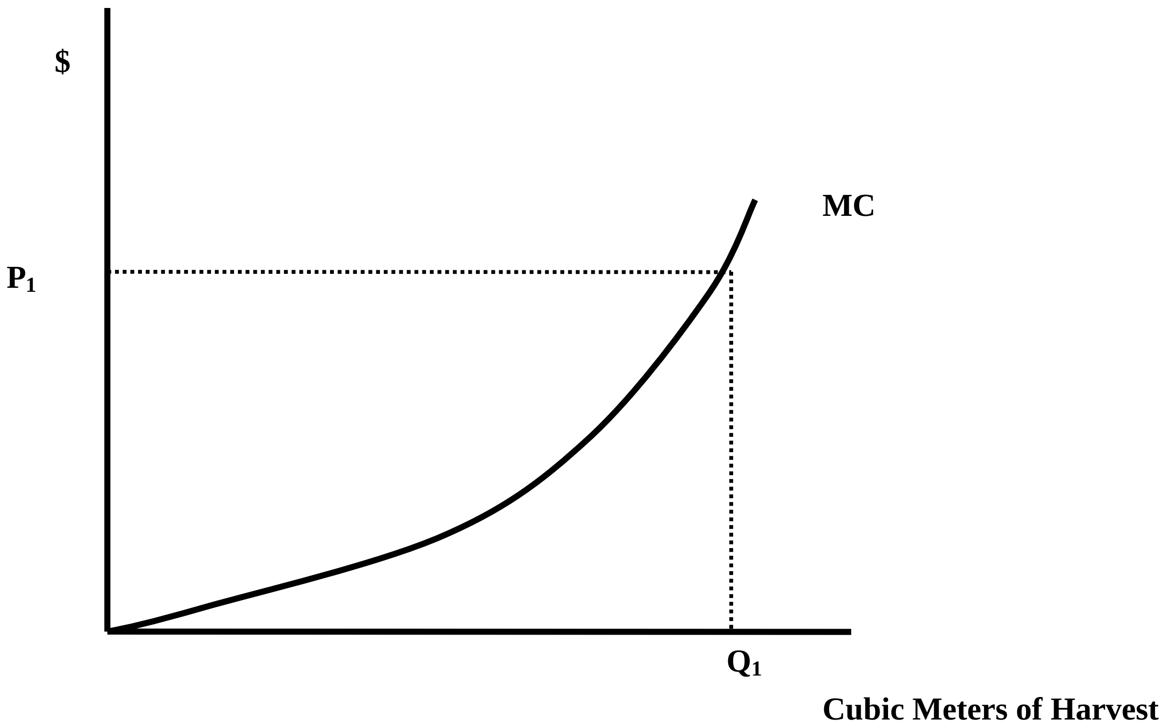
10 The resource rent is also referred to as "stumpage value" in the forestry economics literature. This report uses the term resource rent to emphasize that it is a value created by the forest itself, not a value resulting from human endeavor.

major reason for this is that the resource rent can be regarded as the return for not cutting the forest and allowing it to grow. Often, if the forest land is purchased on the market, the resource rent will be capitalized into the purchase price of the land. Of course, if the landowner is society as a whole, as would be the case for state or federally owned forests, then an additional reason for the landowner collecting the rents is that the forests are a public resource and the public, not the timbering companies, should benefit by receiving the resource rents associated with the trees.

A complicating factor associated with resource rents is that they are not constant but vary with several important factors. First, the greater the value of the wood, the greater the resource rent. This implies that since different species of trees have different market prices, different species will be associated with different levels of resource rents. Second, and perhaps less obvious, the same trees in different sectors of the forest will have different resource rents associated with them, because there will be different costs associated with harvesting the trees. For example, the more accessible the trees, the lower the cost of harvesting and the higher the resource rent.

This implies that even for a given species, the marginal resource rent (the resource rent associated with the incremental tree which is harvested) will be a decreasing function of the quantity of harvest, since the marginal cost of extracting that tree will be rising. This is shown in Figure 3, where P_1 represents the constant price of the wood, and MC represents the marginal cost function for harvesting the wood. The distance between P_1 and MC represents the resource rent and is declining up to the point where marginal cost of harvest is equal to price. The area between the price line (P_1) and the marginal cost function represents total resource rents for the entire forest.

Figure 3. Resource rent with no environmental costs



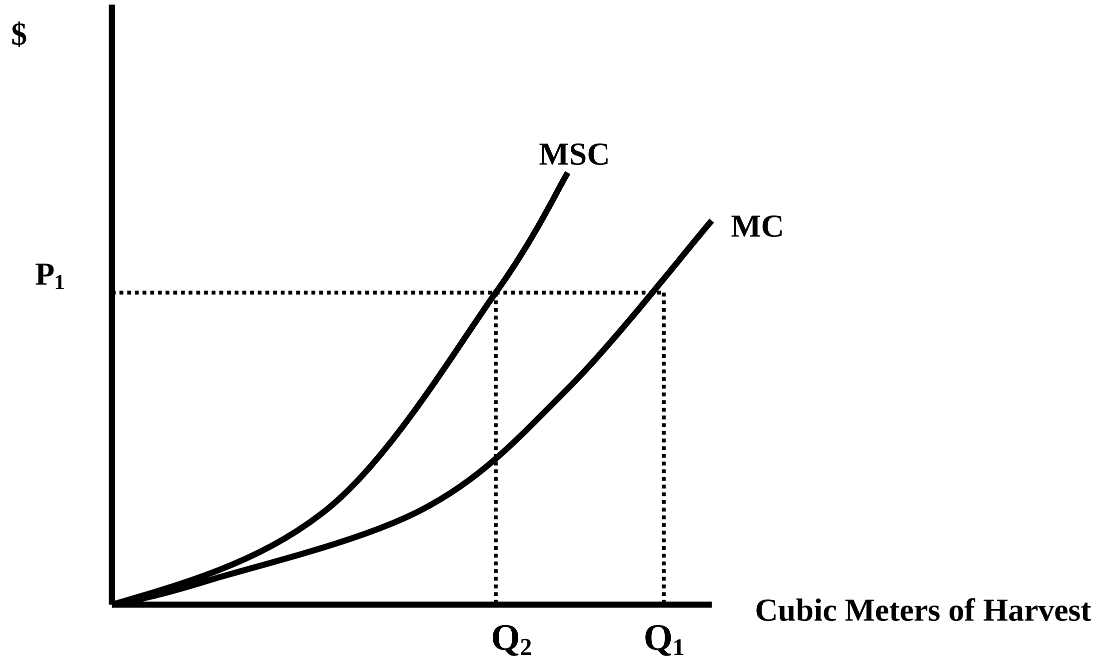
The first few units of harvest have a low marginal cost of harvesting and a high marginal resource rent. As the level of harvest increases, the marginal cost of harvesting increases and marginal resource rents fall. As Figure 3 demonstrates, the marginal resource rent will be changing as the level of harvest increases. The marginal resource rents also change as the price increases. If the price of a cubic meter of wood were to increase, this would increase marginal resource rents for every level of harvest. Also, since different species of wood have different market prices, marginal resource rents would be expected to vary across species of trees.

Social welfare is maximized when the benefit of harvesting (price) is equal to the marginal cost of harvesting (MC). This occurs at Q_1. This level of harvest also maximizes total resource rent.

The magnitude of resource rents will change when one considers the environmental costs of harvesting trees. If there is an environmental cost[11], the marginal social cost curve (MSC in Figure 4) will by higher than the private marginal cost curve, and the marginal resource rents will be the distance between MSC and the price line, while total resource rents will be the area between MSC and the price line. The level of harvest which would maximize social welfare would fall from Q_1 to Q_2.

11 In Figure 3, environmental cost is solely related to the volume of harvest. The method of harvest would shift MSC up or down, depending on the environment impact of the harvesting method.

Figure 4. Resource rents in the presence of environmental costs



5.2 Concession Fees

Concession fees are frequently suggested as a mechanism by which the resource owner may collect the resource rents associated with the trees. Four general types of concession fees have been suggested in the literature. The first is an area-based fee, where the harvesting firm pays according to the area of the forest concession, and the fee is independent of the amount of timber harvested. The second-type of fee is a uniform revenue-based fee, where the fee is a fixed percentage of the revenue (price multiplied by quantity) of the timber which is harvested. The third major type of fee is an undifferentiated volume-based fee, where the fee is a flat charge per cubic meter of wood harvested. The fourth major type of fee is a differentiated volume-based fee, where more valuable species of trees have a higher fee than less valuable species. Several economists (Gray (1997), for example) have also suggested an initial bid fee, as a means of collecting some public revenue before the harvesting begins. No matter which type of concession fee is adopted, if foreign firms are expected to be participants in the concession, then fees must be denominated in terms of an internationally sought currency, such as US dollars. Otherwise, domestic inflation or devaluation of the domestic currency will seriously erode the real value and effectiveness of the concession fees.

Each type of fee has an impact on the amount of revenue that the government can collect, the future timber values associated with that stand of forest, and the ecological services that are produced by the forest after the harvesting period is over. Each type of fee will be analyzed in detail below.[12]

12 For a more detailed technical discussion of these issues see Gillis (1988), Vincent (1994), and Hyde and Sedjo (1992).

Area-based fees

In theory, area-based fees are designed to capture the total resource rent. The total market value of the trees in a stand of forest is estimated, as are the total costs of harvesting the wood (including a normal profit as a cost of harvesting). The difference between the two is the resource rent and is charged as the area-based concession fee for the stand of forest in question.

Many people advocate area-based fees because they are easy to implement and administer. Unlike volume-based fees, they do not require any monitoring and measurement of the volume of wood which is cut. Once the value of the wood and the cost of harvesting are estimated so that the fee can be determined, there is little work required of the forest ministry other than the collection of the fee. For national or sub-national governmental units without a scientifically and administratively sophisticated forest ministry, this administrative ease and low monitoring requirements are very important.

The area-based fee gives the harvesting company an incentive to harvest all the wood possible in its concession area. This occurs because the fees that the harvesting company incurs are independent of the amount harvested, so there are no additional fees associated with additional harvesting. As long as the marginal cost of extracting the wood is greater than the price of the wood, there is an incentive to harvest.

This incentive to harvest the greatest amount of wood possible has both advantages and disadvantages. The primary advantage is that it creates the maximum possible amount of economic activity in terms of employment and sale of timber. Economically valuable wood is not left uncut in the forest, but put into productive use. The primary disadvantage is that it provides incentives for extreme harvesting of the wood and ecological damages which reduce both the ability of the forest to regenerate and the ecological services arising from the forest.

In addition to these incentives for maximum harvest, the area-based fee system will encourage a form of high-grading. High-grading refers to the practice of taking the most valuable trees (e.g. teak, mahogany, rosewood, and ebony) and leaving the least valuable trees, which fundamentally changes the composition of the forest and reduces its future timber and ecological values. Area-based fees encourage this practice since the fee which is paid to the government is independent of the volume or value of wood which is harvested. In the case of area-based fees, the harvesting company will take the highest value trees first and wait until later periods to take the less valuable trees.

As will be shown to be the case with the other types of forest concession fees, the area-based fee does not lead to protection of the future viability of the forest, or to the protection of its ecological values. Separate provisions must be taken to prevent environmental damage from overly intensive harvesting, and from harvesting methods which lead to excessive environmental damage.

Uniform revenue-based fees

Uniform revenue-based fees are designed to capture resource rents by collecting a fixed percentage of the revenue that is generated by the sale of wood. The total value of the wood is estimated, and total costs are subtracted to estimate total resource rent. The total resource rent is then divided by the total value of the wood to arrive at a percentage fee that is levied against the revenue generated by the sale of wood.

This system still retains many of the incentives to high-grade, since it encourages the harvest of trees which have a high ratio of value to harvesting cost. Trees which have a low ratio of value to cost may be uneconomical to harvest because the uniform revenue based fee could cause the firms total cost (harvesting cost plus fee) to be greater than the value of the wood.

Although monitoring and administrative costs are greater than the area-based fee system, they are lower than for the volume based systems described below. The reason for this is that the only data which need be collected are the dollar sales of the wood, and there is no need to measure the volume or the weight of the wood.

Undifferentiated volume-based fees

Undifferentiated volume-based fees are designed to capture resource rents by computing the average resource rent associated with a cubic meter of wood, and assessing this as a fee for every cubic meter that is harvested. As is the case for the area-based fee, the first step is to calculate the value of the wood and then from this subtract the cost of harvesting to compute the total resource rent. This is then divided by the amount of wood that is expected (or allowed) to be harvested, to calculate a fee for each cubic meter of wood which is harvested.

An advantage of this system is that it removes the incentive (found in the area based system) to harvest every tree that is economically feasible. However, it increases the incentives to high-grade. Since the fee is the same for each cubic meter of wood, the harvesting company will have an incentive to harvest the most valuable trees and leave the least valuable trees standing in the forest. The system also is associated with higher administrative costs than either the area-based system or the uniform revenue-based fee, because it requires measuring the volume of wood that is sold.

Differentiated volume-based fees

Differentiated volume based fees are designed to take into account the variation in resource rents across species of trees. The value and cost of harvesting of each tree species is computed and the resource rent is then calculated per cubic meter for each species of tree. In tropical forests, where hundreds of tree species are present, trees can be placed in groups of similar species and the average resource rent is computed for the group and levied per cubic meter of wood harvested from that group of species.

The advantage of this method is that if the species-specific resource rent is calculated correctly, harvesting companies should not have an incentive to high-grade, as the species with higher prices also are associated with higher resource rents and higher concession fees. The higher valued trees should not be disproportionately removed from the forest. Also, like the undifferentiated volume-based fee, the differentiated fee does not provide the incentive to harvest overly intensively, as does the area-based fee.

The disadvantage of the differentiated volume-based fee is that monitoring and administrative costs are likely to be higher than other types of fee systems. First, the forest ministry must acquire the information to estimate resource rent by tree species (or by group of tree species). Second, the wood that is harvested must be measured to implement the volume-based fees.

5.3 Auctions

The literature in forestry concessions (e.g. Gray, 1997, Sizer and Rice (1995), Sizer (1996), Repetto and Gillis (1988)) is very forceful in calling for the auction of concessions rights. It is felt that this type of market mechanism will lead to social efficiency, and a much higher collection of resource rents. Since the concession fees charged by many countries collect only a small fraction of resource rents, it is argued that an auction (that would require harvesting firms to bid against each other) for the rights to harvest a particular stand of forest would maximize the revenue collection by the government.

Although this argument has much intuitive appeal, this literature in forest concessions fails to discuss the limitations of auctions. For example, it is a well-established fact that the efficiency properties of auctions fail to hold in the presence of imperfect information, and that asymmetric information leads to larger problems. Imperfect information would occur when the value of the forest is not known with certainty. Asymmetric information problems occur when one participant in the market has a different amount of information than other participants. This asymmetry in information can be between the government and the harvesting firms, or among the harvesting firms.

The problem of imperfect information can first be analyzed by assuming that every firm has the same information (although imperfect). It will also be assumed that on average, firms guess correctly about the value of a forest concession, but there is a random error associated with each guess that arises from the imperfect information. Under these relatively unrestrictive assumptions, half the firms will underestimate the value of the forest and half of the firms will overestimate the value of the forest. The larger the overestimate of the value of the forest, the more the firm will bid for the forest concession. This means that the forest concession will be granted to the firm that overbids by the most, and that the firm will most likely lose money on the forest concession, because they made their bid thinking that the value of the forest was higher than it actually was. This problem of firms winning bids, but losing money because they overestimated the value of the opportunity is known as the "winner′s curse" and has been cited in many applications, including bidding on off-shore oil leases, and signing star athletes to professional contracts.

Of course, firms are not stupid and they will realize that the potential exists for being awarded a contract that will result in them losing money, rather than making profits. This will give risk-adverse firms an incentive to understate their estimate of the value of the forests when making bids. The greater the uncertainty about the value of the forest, the more incentive the firms have to understate their value estimates when they make bids. This risk adverse behavior could lead to governments receiving substantially less than the value of the resource rents, despite the existence of a competitive auction for forest concessions.

The problem becomes even worse if firms have asymmetric information. For example, if one firm has more information about the value of forests in a particular area than other firms do. This could easily happen as firms which begin harvesting in a general area have more information than firms that are not currently harvesting in that area. Firms with less information will be very hesitant to bid against firms with more information, because if the firms with less information make a winning bid, they will have almost surely overbid and lose money. This means that the knowledgeable firms will have little competition in the auctions and should be able to secure the concession with a bid that is lower than the true value of the concession.

Additionally, auctions give incentives similar to area-based concession fees. This means that one would expect to see both intense harvesting and high grading, unless environmental regulations were put into place to counteract these incentives.

The above discussion shows that auctions do not necessarily generate economic efficiency, and can result in the government receiving a low proportion of the true value of the resource rents. An obvious solution to this problem is to increase the information by conducting rigorous inventories of the forests in question. This inventorying should be conducted by the government, or by third party firms who make the information available to the government. The inventorying should not be conducted by the firms who will be making bids, as this will increase the problems with asymmetric information.

It should also be noted that as information about forest inventories increases, the need for auctions diminishes. The reason that this is true is that if the government knows the true value of the forest, it can set concession fees (such as differentiated volume-based fees) to capture as high a percentage of resource rent as the government desires. Nonetheless, auctions represent a convenient and fair mechanism for allocating concessions among harvesting companies. For example, the government could set concession fees to extract 80% of the resource rents, and then ask firms to bid on the concessions. The harvesting firms would bid to pay something less than 20% of the resource rents, with the concession awarded to the firm that made the largest bid[13]. If the largest bid was less than 20%, the firm would capture some of the resource rents, but the government is assured of capturing at least 80%, plus the amount of the bid. It should be noted that there are some important incentive properties associated with allowing firms to retain even a small fraction of the resource rents. If they are able to do this, they will regard participating in forest concessions as a very desirable activity and thus have an economic incentive to follow environmental regulations to maintain their eligibility. This can create a pseudo-market (economics incentives similar to those found in an actual market) for the environmental resources and associated ecological services.

5.4 The impact of the time duration of the concession on environmental protection

A potential problem that has been discussed (see Repetto and Gillis (1988), Kahn (1998)) with forest concession systems is that independent of the type of concession fee, the short term nature of the concession systems does not give firms an incentive to be conservative of forest resources. Since the harvesting firms do not own long term rights to harvest trees on a given concession, they have little economic incentive to leave the forest in a condition where it will regenerate quickly or maintain the original forest characteristics.

Many people have argued that forest concessions must have a long term orientation to prevent excessive environmental damage (see Gillis, for example), while others have argued that differences between social and private rates of time preferences imply that there will always be an excessive level of environmental deterioration. In other words, since private firms are always less future-oriented than society as a whole, they will always operate in a fashion that is less sustainable and less future oriented than society as a whole. If private rates of time preference are greater than social rates of time preference, then the private owner of a forest would harvest it more quickly and intensively and be less concerned about regeneration than society as a whole. Gray (1997) argues that this is a potentially large problem and that lengthening the duration of the concession is insufficient to protect the forest.

Even if the harvesting companies were as future oriented as society as a whole, and had long-term interests in harvesting the concession area, there will still be more environmental damage than is socially optimal. The reason for this is the harvesting firm will be interested in preserving the future timber value of the forest, but not the future ecological values.

For example, under certain soil and climatic conditions, it might be ecologically feasible and economically profitable to clear-cut a forest and replant it in a monoculture (such as eucalyptus). While this might be profit-maximizing, it is unlikely to be social welfare maximizing because forest plantation monocultures are associated with notoriously low ecological services.

5.5 Can concession fees be used to reduce environmental degradation of the forests?

It should be noted that concession fees are only an indirect means of promoting environmental protection and maintaining the ability of the forest to regenerate itself, as concession fees are designed to

13 Other factors would also be important in deciding which firms will be awarded concessions. This is discussed further in Section 6.

capture resource rents and are not specifically designed for environmental protection. Nonetheless, the type of concession fee and other characteristics of the concession system can have important implications for environmental protection and sustainability.

In section 2, it was noted how individual types of concession systems give incentives for greater harvesting and for high grading. It should also be noted that if concession fees are set far below the actual level of marginal resource rents, this will also provide an incentive for over harvesting. The environmental impacts of alternative fees are discussed below.

Area-based fees may have the worst environmental impact, as they provide the greatest incentive for intensive harvest. Although they do not provide incentives for high grading, area-based fees will lead to the must cutting per unit area, as the amount of fees paid does not increase with the volume of wood. It should also be noted that there would be no environmental benefit in increasing the magnitude of the area-based fee, as the decision of how much wood to cut would still not effect the firm′s required payment to the government. Also, increasing the fee would have no impact on the method by which the wood is cut, so manipulation of the fee would not impact the environmental damages associated with the harvesting method.

One environmental advantage that is associated with area-based fees which Gray discusses in his summary of the Indonesian experience, is that area based fees discourage firms from holding excessively large concessions, because their fee is based on area. Excessively large concessions can cause firms to be wasteful of forest resources, as the holdings are so large in relation to their harvesting patterns that they have little incentive to avoid wasteful or environmentally damaging practices.

An increase in uniform revenue based fees will not eliminate (and will actually aggravate) the high grading problem, but it will reduce the overall amount of harvesting. As with the area-based fee system, an increase in uniform revenue-based fees will not alter the method of harvest and induce harvesting firms to use less environmentally damaging methods. Undifferentiated volume-based fees will perform exactly in the same fashion as uniform revenue-based, with respect to the potential to limit environmental damages by increasing the magnitude of the fee.

Differentiated volume-based fees have the greatest potential to protect the forest from environmental degradation, as they limit the high grading problem. Proportionate (across species) increases in the magnitude of differentiated volume-based fees will reduce the amount of harvest and will not lead to high grading. Thus, as far as the individual fee systems are concerned, the undifferentiated volume-based fee offers the greatest potential for protecting the forest from environmental degradation.

6. SHARING RENTS TO CREATE A MARKET FOR ECOLOGICAL SERVICES

As illustrated in the discussion of the previous section, leasing systems can create some protection for the rainforest ecosystem, but the choice of the type of concession fee and the length of the concession fee cannot fully protect the ecosystem or the ability of the harvested area of a forest to recover to something approximating the original forest ecosystem. In particular, none of these variables will affect the manner in which forests are harvested such as minimizing collateral damage to trees that are not commercially valuable, or to generating a pattern of disturbance with a high edge to surface area ratio and a high undisturbed area to disturbed area ratio. As mentioned, it is possible to create economic incentives to maintain these types of ecological parameters, which is essentially creating a market for the ecological services. The pseudo-market for ecological services can be generated with performance bonds and other contractual stipulations

The ability of a forest concession system to promote environmental protection of the forest is quite limited without additional requirements for environmental protection. Earlier sections of this report have made two major points with respect to environmental protection in a forest concession. These are:

- At best, long-term forest concessions will only protect future wood values, and not the whole range of ecological services. Some evidence suggests that even the protection of future wood values will not occur, as private rates of time preference are too low.

- To the extent that environmental protection of the forest is inversely related to the volume of wood that is harvested, increasing concession fees will increase environmental protection. However, concession fees will not influence the manner in which trees are cut, which has a dramatic influence on the ability of the forest to regenerate and to maintain ecological values that approximate the forest's original ecological values.

Taken together, these two points imply that a forest protection plan must be developed which is independent of either the duration of the concession or the magnitude of the concession fees. The environmental economics literature suggests two broad categories of policies to protect the environment. These are direct controls and economic incentives.

Direct controls specify the type of behavior that is legal, and then impose penalties on violations of this type of behavior. Examples of direct controls which are in actual use include requiring pollution control devices on cars, requiring that hazardous waste be disposed in licensed waste facilities, banning the use of chlorofluorocarbons (CFCs) and requiring the use of electro-static precipitators in the smokestacks of coal burning power plants.

Economic incentives make no specific requirements for behavior, but give firms an economic reason to act in the socially desired fashion. In the economics literature, pollution taxes, marketable pollution permits and deposit-refund systems are the most frequently cited examples of economic incentives.

Of course, direct controls cannot create a pseudo market. Nonetheless, it is interesting to examine how a direct control can be implemented before moving to the case of economic incentives.

An illustrative example of a system of direct controls is established below. Harvesting firms would be expected to meet the stipulations below, and if not they would be subjected to penalties, such as a fine. It is important to note that the *regulations below are listed as an illustrative example and are not recommendations*.

- No more than 15% of the land area may be used for harvesting.

- On this area, no more than 10% of the volume of wood may be removed.

- Cleared areas can be no more than 30 meters wide.

- No more than 80% of the trees of a particular species may be removed from a particular plot of land.

Firms that violated any of the above stipulations would be considered to be in violation of the law and would be required to pay a punitive fine.

In terms of economic incentives, environmental taxes could be developed. For example, a tax could be structured based on the percentage of land area used for harvesting. Concession fees themselves could be considered a tax on the volume of wood harvested. In general, it would be difficult to configure a tax to account for factors such as width of cleared areas, the percentage of trees cut of a particular species, compaction of the soil, damage to unharvested trees and so on.

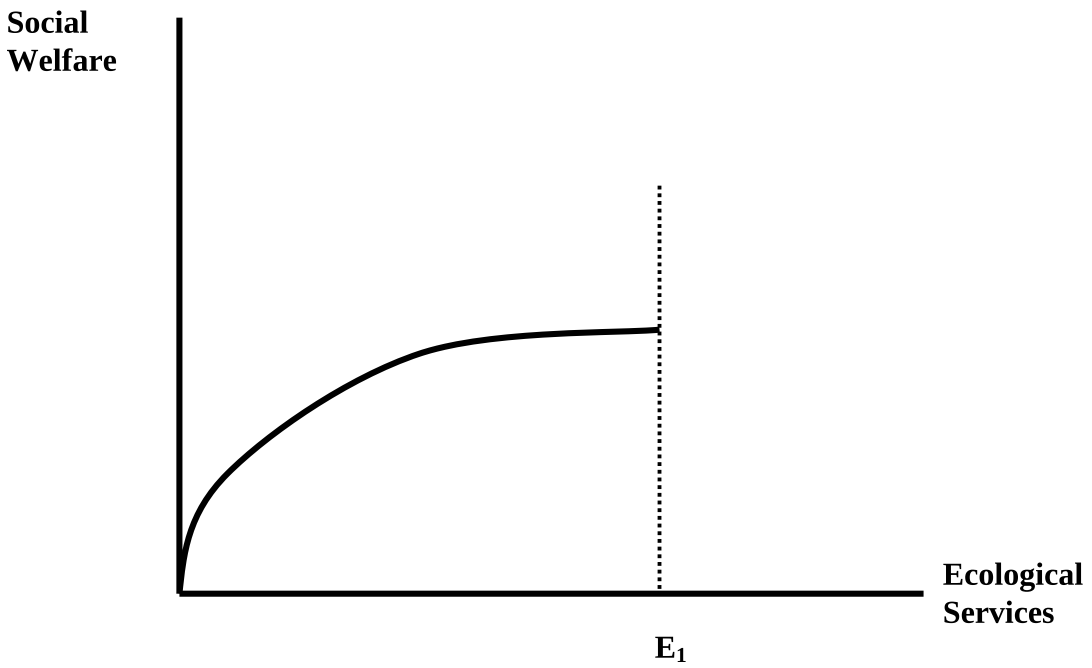
These factors could be incorporated into a performance bonding system. A performance bonding system stipulates a set of regulations on firm behavior, such as those in the above example of direct controls. However, instead of fining the company, an alternative incentive is created. Before beginning operations, the firm is required to give a large deposit of money to the government. If the firm follows the regulations, the deposit is returned, if not, part or all of the deposit is kept by the government. There is a much greater certainty of compliance with performance bonding than with direct controls, because the money is collected in advance and only returned if behavior is compliant with regulations. This eliminates difficulties associated with collecting a fine, because the company simply disappears, or because they are able to delay the imposition of the fine in the judiciary system.

A third type of economic incentive is what economists refer to as "continuous recontracting". Under continuous recontracting, all economic contracts have a very short duration and can only be renewed (and will be automatically renewed) upon satisfactory performance during the previous period(s). The best way to illustrate the incentive properties of continuous recontracting is by example. Imagine that you are the owner of a football team, and interested in signing a very talented player, but one who does not always put forth full effort when he is on the football field. If you were to sign him to a long-term contract (such as a five year contract) you would have no ability to induce him to play his hardest. However, if you only sign him to a one year contract, he must play well in order to ensure that he receives a large salary next year (either from you or from another team).

6.1 Structure of a Performance Bonding System[14]

The proper structure of a performance bonding system will be predicated on the relationship between social welfare and ecological services.[15] A reasonable interpretation of this relationship occurs in Figure 5, where social welfare increases at a decreasing rate as the level of ecological services are increasing. An important observation is that most of the social benefits of increasing the level of ecological services occurs before one reaches the level of services associated with a pristine ecosystem, which is E_1 in Figure 5.

Figure 5. The relationship between ecological services and social welfare



14 This section of the report is based on Franceschi and Kahn (2002)

15 Ecological services are functions produced by ecosystems such as nutrient cycling, soil formation, carbon sequestration, maintenance of atmospheric chemistry, biodiversity, watershed protection, and so on.

A similar relationship exists between ecosystem health and ecological services. This relationship is depicted in Figure 6. However, from a policy perspective one might want to focus on key ecological characteristics which contribute to ecological health, since ecosystem health is an outcome rather than a choice or control variable. The relationship between an ecological characteristic and ecosystem health is contained in Figure 7. Note that in this depiction, the ecosystem crashes as the level of the ecological characteristic approaches a low, but positive level.[16] The three relationships in Figures 5-7 can be linked to derive a functional relationship between social welfare and a key ecological characteristic. This is done in Figure 8, forming the basis for structuring a performance bonding system. It should be noted that the functional forms from which Figure 8 is derived can be argued to be reasonable, but are simply assumed for the sake of illustration. Specific ecosystems could behave differently.

The relationship in Figure 8 can be viewed as measuring the total social benefits (TB) of the ecological characteristic. TC represents the total costs of obtaining the ecological characteristic, and is presented in this graph as a linear function. The linearity of the cost function is chosen solely for ease of exposition, and does not represent a hypothesis concerning the shape of the function.

16 See Kahn and O’Neill (1999) for a discussion of the policy relevance and ecological origins of this type of bifurcation or threshold.

Figure 6. The relationship between ecosystem health and ecological services

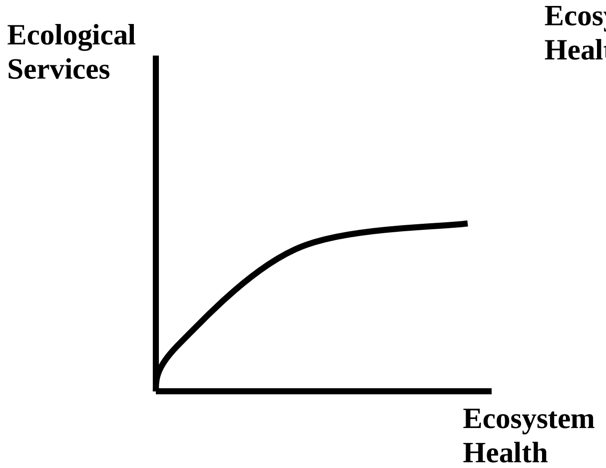


Figure 7. The relationship between an ecological characteristic and ecosystem health

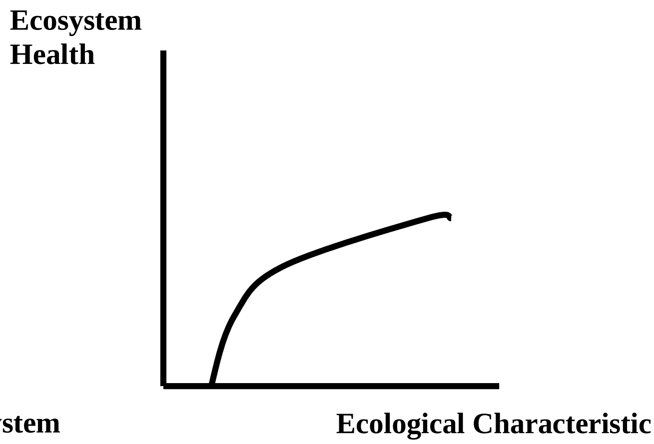
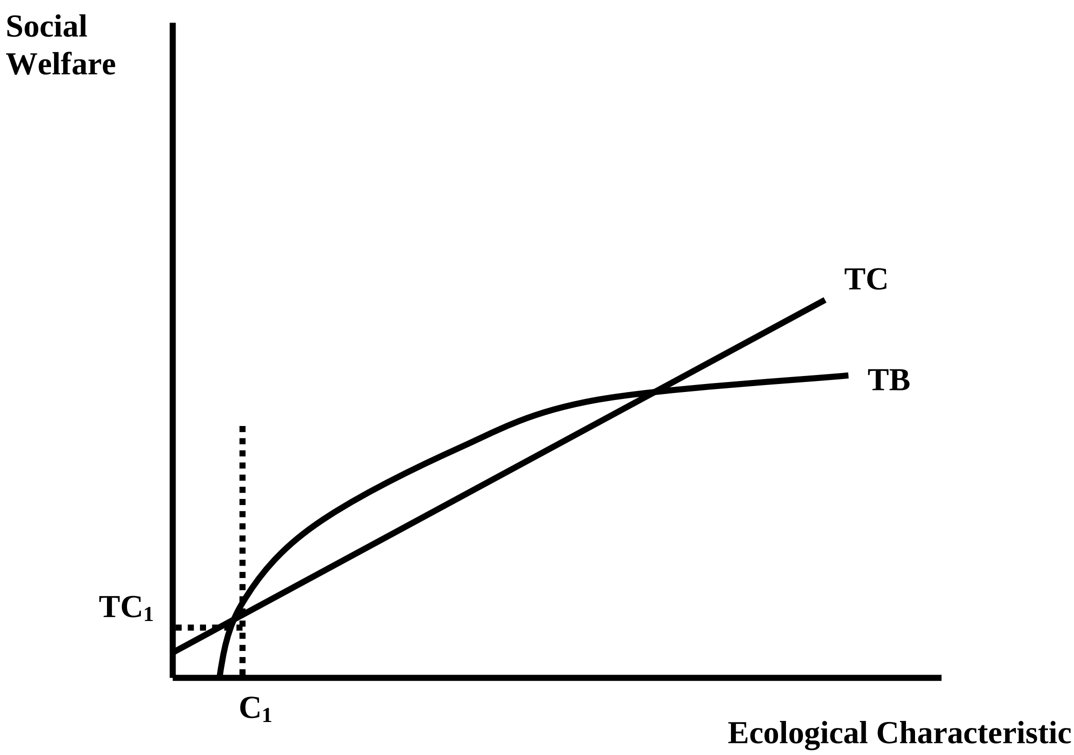


Figure 8. The minimum acceptable level of the ecological characteristic

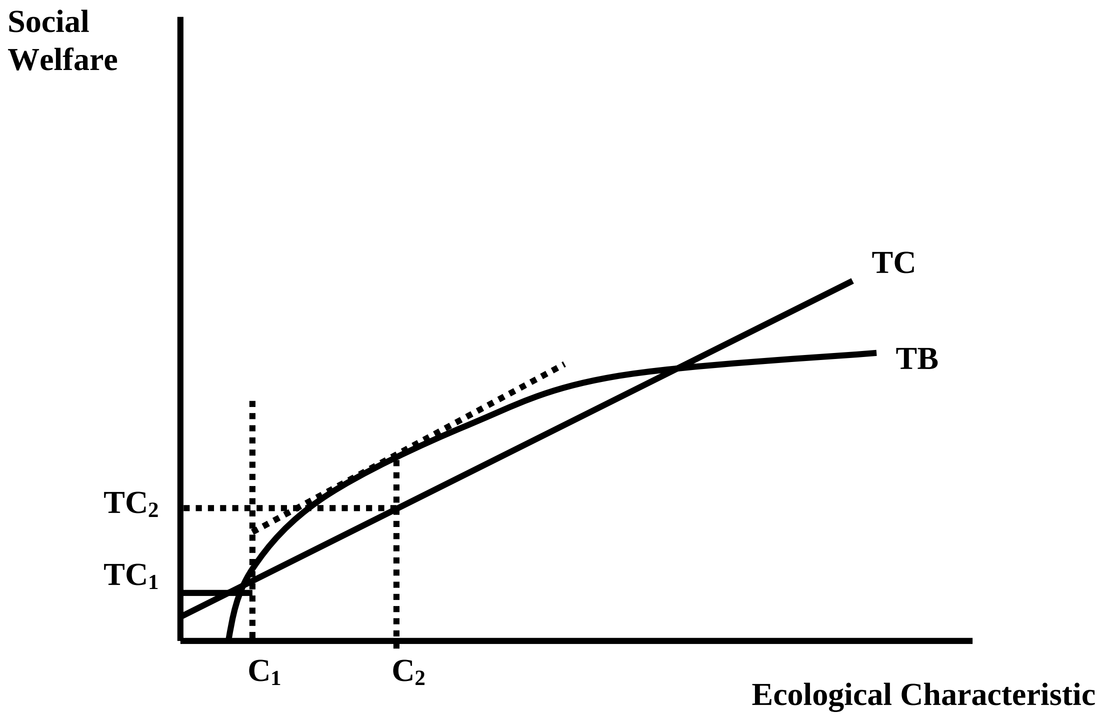


In the traditional performance bonding system, where one seeks to stay above a minimum acceptable level of environmental quality, C_1 would make a good candidate for the definition of the standard. The definition of a level such as C_1 allows one to remain above the collapse point, with an adequate margin of safety to guard against uncertainty associated with either measurement error or stochastic events.[17]

To assure that the level of the ecological characteristic remains above C_1, the magnitude of the performance bond must exceed TC_1, the cost to the firm of maintaining the ecological characteristic at a level of C_1. The amount by which the performance bond should exceed TC_1 will be a function of the firm's perception of the probability of forfeiture from violating the standard (the expected value must exceed TC_1) and also will be related to the existence of random variables or measurement error in the total cost function.

However, this type of system does not move society towards the optimal level of the characteristic. The optimal level of the ecological characteristic would be C_2 in Figure 9, where the marginal cost of obtaining the characteristic is equal to the marginal benefit of the characteristic. In this case, the magnitude of the performance bond must exceed TC_2 in order to generate the optimal level of the characteristic.

Figure 9. The optimal level of the ecological characteristic



17 See Bishop (1978) for a discussion of the safe minimum standard.

Returning the performance bond

If one is only interested in maintaining the minimum acceptable level of environmental quality the procedure for returning the performance bond is relatively straightforward. The bond is returned if the minimum acceptable level is exceeded, and forfeited if the minimum acceptable level is not attained.

Unfortunately, a corresponding procedure will not work well if the optimal level of the characteristic is the policy target. The reason for this is that if the whole performance bond is forfeited for missing the optimal level of the characteristic, the firm will have no further incentive to maintain environmental quality, and will allow it to decline towards zero. When focusing on the optimal level of quality, there should be a small penalty for being slightly below the optimal level, and large penalties for being far below the optimal level. This structuring of penalties is very important given that the total benefit function is increasing at a decreasing rate, and is likely to be relatively flat in the vicinity of the optimal level of the ecological characteristic. In other words, missing the optimal level by a small amount is not likely to create large social damages, so the firm should not receive a large penalty for this. If the total benefit function is known (or if an estimate of the total benefit function is available) then a continuous function of returning the performance bond can be developed as in Equation (1). This function specifies the fraction of the performance bond which is returned, where TB_2 is the level of total benefits associated with the optimal level of the ecological characteristic, TB_1 is the level of total benefits associated with the minimum acceptable level of the ecological characteristic, and TB_x is the actual level of the environmental characteristic at which the firm leaves the effected area.

$$P = \frac{TB_x - TB_1}{TB_2 - TB_1} \qquad (1)$$

If $TB_x = TB_1$ (where TB_1 equals the total benefit associated with the minimum acceptable level of the ecological characteristic), then the numerator of Equation (1) will be equal to zero, and all of the performance bond will be forfeited. If $TB_x = TB_2$ (where TB_2 equals the total benefit associated with the optimal level of the characteristic), the numerator of Equation (1) will equal the denominator, and all of the performance bond will be returned. As one moves from C_1 to C_2, the proportion of the performance bond which is returned increases at a decreasing rate, according to the slope of the benefit function, as illustrated in Equation (2).

$$\frac{dP}{dC} = \frac{dTB_x}{dC}\left(\frac{1}{TB_2 - TB_1}\right) \qquad (2)$$

It is important to note that even though the total benefits are used to generate the proportionality function (P), the variable which is measured and to which the firm responds when optimizing its decision making is the ecological characteristic, C. The purpose of converting C to TB when calculating the proportionality function is to create a proportionality function which is increasing at a decreasing rate. Note that if the proportionality function is comprised of the levels of ecological characteristics that form the explanatory variable of the total benefit function, the proportionality function will be not be increasing at a decreasing rate, but linear, as in Equation (3).

$$P_c = \frac{C_x - C_1}{C_2 - C_1} \qquad (3)$$

While a performance bonding system based on Equation (3) has an advantage over traditional discrete performance bonding systems in that it allows continuous incremental return of the performance bond, it suffers in comparison to Equation (1) because it is not increasing at a decreasing rate. This is quite unfortunate, because in most cases the total benefit function (or even a reasonable estimate) is not available, leaving Equation (3) as a potentially second best proportionality function.

In some cases, it may be possible to formulate a proportionality function which is increasing at a decreasing rate, even if the total benefit function is not known. If the functional relationship between ecological health and the ecological characteristic can be estimated, then a performance bonding system can be structured based on the functional relationship developed in Figure 8. This Figure is reproduced in Figure 9, with levels of ecological health associated with

C1 and C2 noted, as H1 and H2, respectively. The proportionality function can then be structured as Equation (4). Note that this proportionality function (P_h) will be increasing at a decreasing rate as one approaches H2 from the left, and decreasing at an increasing rate as one approaches H1 from the right. This means that the amount of the performance bond that is forfeited for diminishing H2 by one unit will be greater the further Hx is from H2 and the closer it is to H1. Notice that as with the case of the proportionality function of Equation (3), there exists no explicit benefit function to guide the identification of the optimal level of the characteristic, and more subjective methods must be used to choose H2, the target level of environmental quality.

$$P_h = \frac{H_x - H_1}{H_2 - H_1} \qquad (4)$$

In the case of the Amazonian rainforest, the ecological characteristics used to structure the performance bond could be the area ratio (AR) and edge ratios (ER) discussed earlier in the paper and re-specified in equations (5) and (6).

$$AR = \frac{area\ of\ undisturbed\ area}{area\ of\ disturbed\ area} \qquad (5)$$

$$ER = \frac{length\ of\ edge\ of\ disturbed\ area}{surface\ area\ of\ disturbed\ area} \qquad (6)$$

The return of the performance bond could then be structured according to the following proportionality functions

$$P_{AR} = \frac{AR_x - AR_1}{AR_2 - AR_1} \qquad (7)$$

$$P_{ER} = \frac{ER_x - ER_1}{ER_2 - ER_1} \qquad (8)$$

If the area ratio and the edge ratio are equal to the minimum acceptable level, then the numerator of the fractions are equal to zero and none of the performance bond is returned. If the ratios are equal to their optimal levels, then the numerator of each fraction is equal to the corresponding denominator and the full performance bond is returned. Franceschi and Kahn (2002) talk about more sophisticated versions of these proportionality functions, including multiplicative combinations of equations (7) and (8).

6.2 Continuous recontracting

One potential problem with performance bonding is that if the area of the lease is large, the magnitude of the performance bond must be correspondingly large. This can pose financial constraints for some firms, particularly smaller domestic firms that have less access to capital in comparison with larger multi-national corporations. One way to avoid this problem and still provide incentives for environmental compliance is a continuous recontracting system. A continuous recontracting system subdivides the forest concession into much smaller geographic units. While the firm bids, and receives rights to the larger unit, it is only allowed to operate in one of the small units in the initial time period. Upon meeting all the concession requirements in the small unit during the initial period, the harvesting firm would be entitled to begin operations in the second small unit. As long as requirements were met, this process would continue. However, if the firm violates its concession agreement in the first small unit (or in subsequent small units), it would lose all rights to operate in the entire forest concession. It would also lose its rights to bid on further forest concessions in new areas. Obviously, if the firm is sharing in the resource rent, it has great incentives to comply with the environmental regulations and not lose its recontracting rights. The greater the sharing of resource rent, the more likely the contracting system to protect the forest ecosystem and the flow of ecological services. The desirability of a continuous recontracting system is dependent on the ability of the forest ministry to evict firms who violate the concession agreements. In countries where the legal system allows the harvesting firm to stay in operation while they fight the eviction order in the judicial system, performance bonding would provide more protection than continuous recontracting.

Consequently, this report recommends the utilization of a combination of a continuous recontracting system and a performance bonding system to maintain the ecological characteristics of the forest that the forest ministry deems important. This combination provides a comprehensive set of economic incentives and intentional redundancy of incentives which will ensure that the firm has an incentive to maintain these important ecological characteristics. Obviously, the characteristics must include those ecological characteristics that allow the forest to regenerate. The characteristics should also include the set of ecological characteristics that are related to the flow of ecological services that are provided by the forest. The target levels of these forest characteristics that should be maintained will vary substantially form one forest system to another, so the definition of the characteristics and their desirable levels is beyond the scope of this report.

6.3 The implementation of a leasing system with pseudo-markets for ecological services

The first step in the development of a forest concession management plan for public forests is the development of ecological zoning. Each area of the forest must be zoned according to its comparative advantage. Some regions may be kept in their pristine wilderness state, while other areas may be zoned for sustainable harvesting. Some areas should be preserved as zones for indigenous forest peoples to maintain their way of life, other areas may be opened for settlement and sustainable agro-forestry, while mining or industry may be the best land use in other areas.

The second step in the process would be a complete and detailed inventory of the areas set aside for forest concessions. A traditional suggestion has been the mapping of the marketable trees on a large scale map, but this is old technology. Each tree should be marked with a plastic strip containing bar-coded information on the location of the tree (as measured by Global Positioning System (GPS) coordinates), the species of the tree, and the size of the tree (both diameter breast high (dbh) and estimated volume of marketable wood). This information should then be inputted into a Geographic Information System (GIS) program to facilitate planning by potential harvesting firms and to aid the government in future monitoring, environmental regulation and collection of forest concession fees. While this is a more expensive method of inventorying than traditionally employed, the information gathered not only facilitates knowledge of the forest resources, but it is exactly the same information which is required to monitor and enforce environmental regulations and to collect concession fees. The hardware for this system (laptop computer, GPS system and bar-code printer) should cost less than US$6,000 per set (exclusive of import duties.)

Inventorying should be conducted either by government agencies or by independent third parties who are contracted by the government. Inventorying should never be conducted by the harvesting firms, as they have too much incentive to behave strategically and bias their estimates. This also creates problems with asymmetric information in auction processes. The inventories should be conducted before concession rights are allocated. This reduces the possibility of corruption through bribing of the people conducting the inventories. If the inventories are conducted before the concessions are awarded, firms will have little incentive to bribe people to understate inventories (which would lower the price of the concession) as a particular firm only has a probability of obtaining the concession, not a certainty.

The third step in the process is to define the level of volume-based concession fees, differentiated by tree species. With the information already created by the forest inventory system (bar coding and GIS storage of data on GPS location, species, and volume of wood), differentiated volume-based concession fees become the preferable fees, as this system would require no additional information beyond that created by the inventory process. Differentiated volume-based fees do not encourage high grading, as do area-based, undifferentiated volume based, or uniform revenue-based fees. The fee for a cubic meter of wood from each species should be equal to something less than 100% of the resource rent, but greater than 80% of resource rent. Resource rent is computed as the difference between the cost of harvesting and the market value of the wood. In addition to varying by species, this may vary by the size of the tree. Bigger trees may have a higher resource rent per cubic meter than smaller trees.

The fourth step in the process is to specify the characteristics which would define a sustainable forestry management plan. In Section 2, some general characteristics were defined which related to sustainable forestry practices and the ability of the forest to regenerate. These characteristics include a relatively high ratio of unharvested area to harvested area, and in the harvested areas, there should be a high ratio of the edge of the harvested area to the surface area of the harvested area (see Figure 1). It is beyond the scope of this paper to suggest values for these parameters, or even to suggest which additional ecological characteristics should be incorporated into an environmental management plan. This will vary according to the ecological properties of the forests in question, and according to the goals of the government. Therefore, the forest ministry must develop an appropriate environmental management plan, and translate this into regulations on harvesting firm behavior that can be monitored and enforced. One way of doing this is to translate the environmental restrictions into a plan based on the bar-coded trees. If each tree is bar-coded, then the trees which are appropriate to harvest (meet the environmental standards) can be defined. Since the Global Positioning System coordinates for each tree will be stored in the data base, field audits will be effective in determining if firms are meeting the environmental regulations. It is recommended that performance bonds and continuous recontracting be used to give firms an incentive to obey the environmental regulations.

The fifth step is to define the length of the forest concession. There is some controversy in the literature over the benefits of long-term concession leases. This report recommends that long-term leases be established, but the harvesting firm only granted the rights to harvest in one small sub-unit of the forest concession system per three month period. At the end of the three month period, the firm is only allowed to move into the next small sub-unit if they met all requirements during this three month period. It is critically important that the magnitude of the performance bond be greater than the profits that the firm would make during the three month period. The combination of performance bonding and continuous recontracting should ensure environmental protection.

The sixth step is to establish other regulations (social and labor) for the harvesting firm. These could be related to employment, work-place safety, level of economic investment, level of community development, and so on.

These first six steps define the parameters under which harvesting may take place and thus influence the level of profitability to the harvesting firm. If the steps are conducted correctly (particularly the definition of forest concession fees), then the system should be beneficial to both the harvesting firms and to society as a whole. Many harvesting firms will be interested in obtaining forest concessions. The government will need to make decisions regarding who receives the forest concessions.

Once the concessions are awarded, the government must continually monitor the operations of the harvesting firms to make sure the provisions of the concession agreement are satisfied and that goals of the system are met. The two primary goals from the perspective of the government are most likely the collection of revenue through the concession fees, and the protection of the environment so that the forest continues to provide the opportunity for future harvests, other benefits such as non timber products, and ecological services. The proposed system of bar-coding of trees, identifying their location with the Global Positioning System, and storing the data in a geographic information system (GIS) will greatly facilitate this process.

The harvesting firm will be required to generate a sustainable harvesting plan in accordance with the guidelines that constitute part of the concession agreement. This plan will identify the specific trees to be cut. In a selective cutting management plan, individual trees to harvest would be identified. In the strip method of sustainable forestry, the boundaries of the area to cut would be identified by marker trees along the boundary. The GIS system would then be able to specify all the trees that are located within this boundary. In either case, an exact measure of the concession fees would be available, since the trees to be cut are identified and an official estimate of the volume of wood in each tree has been made. Trees which are brought to the saw mill would be required to be accompanied by the plastic bar-code placard associated with them. Attempts to cheat this process and pay less than the official concession fee or cut unauthorized trees can be stymied by field audit. There must be a one-to-one correspondence between the trees that are brought in and the stumps in the forest. Since the exact position in the forest is known for each tree, it can be determined if trees are brought to the saw mill or loading dock for which corresponding stumps do not exist. In addition to preventing cheating on the payment of forest concession fees, this system can be used to regulate the implementation of each firm′s environmental plan. Cutting or damage to the forest outside of the indicated areas can be easily detected by field audit. Also, since the trees and proposed harvesting areas are identified by GPS coordinates, the auditing can occur either by on the ground inspection or through satellite/aerial surveillance. These evaluations will form the basis for deciding whether performance bonds will be forfeited, and whether the firm receives permission to begin operations in the next concession sub-unit.

6.4 Demand development and eco-certification

Since the conduct of sustainable forestry requires restraint in the harvesting of trees, both revenue and rent are lower (at least in the short run) than they otherwise could be. With typical discount rates, it is also likely that the net present value of the sustainable income is less than the corresponding unsustainable stream. These deficiencies create a substantial disincentive to engage in sustainable forestry. Although the sharing of the resource rent can make sustainable forestry more attractive, it can be made even more attractive (an even greater upward shift of the sustainable forestry income path in Figure 2) by increasing total rent. Total rent can be increased if either costs are diminished or if price is increased. This discussion will focus on two methods to increase price. The first method is to further promote and develop eco-certification programs. The second method is to increase the demand for less well-known species of wood.

Eco-certification allows consumers to express their preferences for wood that is produced in a sustainable fashion, allowing the consumers the opportunity to support the protection of the rainforest with their consumer expenditures. If consumers are willing to pay more for sustainably produced wood, then an eco-certification program will help to support sustainable forestry. An eco-certification program will also increase the demand for sustainably produced rainforest wood products, by dispelling a potential misguided consumer perception that *all* rainforest wood products contribute to the destruction of the rainforest.

SmartWood is currently the most recognized certification program, and has certified several sustainable forestry operations in the Brazilian Amazon, including the Precious Wood facility discussed previously in the paper. This certification program has already had an important impact on the profitability of the Precious Wood operations. Recently, Home Depot, the world's largest chain of home improvement stores, agreed to only sell eco-certified wood products. An initial impact of this on Precious Woods was a huge order by Home Depot for short narrow strips of wood with which to build the shelves on propane gas barbecue grills. This was important to Precious Woods not only because of the size of the order, but because it provided a market for small pieces of wood that normally go unsold, and because they could use species of wood for which there was not a large demand for other purposes.

Eco-certification can be further developed by a public relations or advertising campaign. This campaign could talk about the importance of sustainable forestry to the preservation of the rainforest. In addition, the campaign could help to identify which eco-certification programs are credible.

Eco-certification is not the only demand-side policy that is necessary to improve the profitability of sustainable forestry. Both the strip method and the selective harvesting method require the harvesting of more than 40 species to be sustainable, yet world markets for tropical wood focus on only a few species such as teak, mahogany, rosewood and zebrawood. Many other species have similar properties as these woods in terms of density, durability, ability to receive a finish, and beauty. However, because consumers are not familiar with these species, furniture makers will not utilize the species and so little demand exists for these species.

An advertising program that focused on increasing the demand for these species, in conjunction with an eco-certification program, could dramatically increase the profitability of these sustainable operations. In the absence of an increase in the exports of these under-utilized species, sustainable forestry operations must rely on domestic markets for these under-utilized species, where the price is very low because of saturation by wood produced in an unsustainable (and sometimes illegal) fashion.

One particular set of applications that have a lot of potential is outdoor furniture, patios and decks. Currently, wood for these applications are temperate conifers (such as fir, pine or spruce) that are pressure-treated with an insect, mold and rot resisting compound of arsenic and copper. However, many rainforest species that have evolved in the flooded-forest igapo regime have a natural resistance to rotting and insects, allowing for outdoor uses with wood that has much greater aesthetics than the traditional pressure treated conifers.

7. NON-TIMBER FOREST PRODUCTS

Non-timber forest products refer to a group of products that can be extracted from the forest without cutting down the trees. In the Amazon region, these products include rubber (latex), nuts, shade-tolerant coffee, honey, fruits, fiber, fish, palm hearts, palm oil and skins and meat from rainforest fauna. Non-timber forest products can be produced under three different types of management regimes:

1. an agroforestry regime
2. an extraction reserve regime
3. a sustainable forestry regime

Non-timber products can be produced by small farms in an inter-cropping fashion. Farmers clear narrow strips of the forest (from which the forest quickly recovers) and plant a mixture of annual crops and perennial tree crops. The forest quickly moves back (several growing seasons) into the cleared area, and prevents the further production of annual crops (without further clearing), but the fruit trees and other perennial crops remain productive. In addition, farmers can gather fruits and nuts, rubber and fiber, catch fish, and engage in other collective activities in the forest. This type of activity is sustainable, and can actually produce a higher steady-state income than slash and burn activity that results in larger clearing and permanent deforestation. (see Caviglia and Kahn (2001), Caviglia (1999))

In the Brazilian Amazon, particularly in the states of Acre and Roraima, the federal government has established extraction reserves. These are protected areas, under local community management (such as by a collective of rubber tappers), where certain extraction activities are permitted. All extraction reserves allow rubber tapping and gathering of fruits, nuts and honey, and some allow fishing and/or selective harvesting of timber. The State of Amazonas has established Sustainable Development Reserves, where communities who have lived in the rainforest for many generations become part of the protected area, and scientific research is conducted to help make sustainable production techniques yield a higher return.

These extraction activities can also take part in conjunction with a sustainable forestry operation, either directly by the forestry company, or by allowing people who live in the region to conduct gathering activities in the lease area. In fact, this may be a provision that a government might want to put into the lease agreement.

While non-timber products seem like a marvelous way to produce income while maintaining an intact forest, non-timber products do not provide a magical solution to the problem. In fact, there are many obstacles that need to be overcome before markets for non-timber products develop to the point that they really become useful in contributing to the sustainable development of the rainforest region.

The first problem that needs to be overcome is a problem of logistics. Although navigable rivers connect all the parts of the Amazon, and connect the Amazon to the rest of the world, river transportation is generally too slow to conduct perishable products such as fruits and fish to the large markets in southern Brazil or to North America, Asia or Europe. If better ways can be found to move the products to places such as Manaus, where they can be shipped from an international airport or by road to Caracas (and then on to Houston, New Orleans or Miami), this would facilitate the process. One potential transportation mode that has not been adequately explored is the hovercraft, a large boat that does not rest directly on the water, but is suspended on a cushion of air. Hovercraft can travel at much greater speed than conventional boats, particularly because they do not face the drag of the mighty currents when traveling upstream, and because they are not vulnerable to collision with submerged/partially floating timbers.

Another potential logistical problem is found in quarantine regulations of industrial countries. Imports of plant products face restrictions because of dangers of introducing agricultural pests. Pest-risk analysis has not yet been done on many rainforest fruits (nuts are not as big a problem because they can be roasted first). Before projects to expand the exports of rainforest fruits, these issues of pest-risk analysis must be addressed, and inspection stations must be established to facilitate the export process.

The second major problem faced in the development of markets for non-timber products is a lack of familiarity with the rainforest products. For example, there are many remarkable fruits in the rainforest. Açai is a palm fruit that is among the highest known biological sources of iron. It has long been a breakfast food in the Amazon region, as well as being used to make a delicious ice cream. However, until very recently, this fruit was largely unknown outside of the Amazon region, although lately it has become a favorite food among surfers and exercise aficionados in Southern Brazil. Acerola is among a group of rainforest fruits that have more Vitamin C than the typical orange. Although juices from these rainforest fruits are popular throughout Brazil, they are largely unknown in North America, Europe and Asia.

The lack of current demand creates a “chicken and egg” type of obstacle to further developing exports of these fruits and other products. Supermarkets in the OECD countries do not stock rainforest fruits in their aisles, in part because the average cost is high. However, average cost remains high because economies of scale have not been realized. A potential policy to overcome this problem could be to subsidize the export of these fruits to expand the size of the market so that lower average costs can be achieved.

Lack of familiarity has many dimensions other than simple demand issues. For example, watches are manufactured in the free trade zone (Zona Franca) in Manaus. These watch factories are largely operated by Asian firms, who associated inexpensive watches with plastic watch bands. Consequently, that is the way the product line is established. However, there is a large fish market in Manaus, and the skins of many species of the fish (the fish are large, sometimes over 100 kgs) can be easily and inexpensively fashioned into a beautiful leather. This leather could be used to create watchbands that are just as inexpensive to manufacture and just as durable as plastic, but much more beautiful. However, it is not done, because this is not the habit of the manufacturing companies. The same thing is true for televisions and plastic television cabinets. Rather than manufacturing the cabinets out of cheap (and ugly plastic) the factories could use beautiful wood (particularly the underutilized species), but this is not done.

A potential danger that must be guarded against is that policies to increase the demand for non-timber products could make plantations financially viable, and then economies of scale and increase in supply that could develop might lead to a reduction in price, making sustainable gathering or sustainable agroforestry uneconomical. The worst of all possible scenarios would see pristine rainforest converted into fruit or nut plantations. This danger can be avoided with an eco-certification program that differentiates between products produced sustainably and products produced in an unsustainable fashion. An interesting issue here would be how to treat fruits produced in plantations that are established on rehabilitated land (land that was deforested, degraded to waste land, and then restored to productivity in a plantation).

8. CARBON MARKETS AND CARBON SEQUESTRATION[18]

One of the most important values of the rainforest is the value of its sequestered carbon. If an international agreement for limiting carbon emissions gave credit for sequestered carbon, then this would make sustainable forestry relatively more attractive, as firms could earn money from the standing stock of trees.

One way of doing this is with a carbon annuity system. An annuity equates the value of an asset to a set of perpetual annual payments. If the asset value is equal to V and the annuity payment is equal to P, then the annuity payment can be computed as $P=Vr/(1+r)$, where r is the relevant interest rate. For example, if the asset value was \$1000 and the interest rate was 5%, one would be indifferent between \$1000 now and a payment of \$47 per year, every year, forever.

It is relatively easy to see the potential impact of carbon annuity payments on sustainable forestry by looking at the amount of carbon on a hectare of rainforest land, and then using alternative values of carbon (based on damages or the potential magnitude of the price of carbon permits) to compute the asset value of the sequestered carbon.

Estimates of carbon storage in tropical regions vary substantially, as soils, climates and other environmental factors fluctuate across the tropical world. Fearnside (forthcoming) estimates that a fully forested hectare in the Amazon stores approximately 157.1 t ha^{-1} (with a lower boundary of 96.2 and an upper boundary of 218.2). Additionally, he calculates that secondary forest stores 13.3 t ha^{-1} and pasture stores 3.4 t ha^{-1}. Fujisaka et al. (1996) estimate that the standing forest in Theobromia, Rondônia stores about 200 t ha^{-1} carbon, that secondary forest stores 76 t ha^{-1}, and pasture 28 t ha^{-1}. According to their estimates, about 78 percent of the stored carbon is found in the living trees, 16 percent is in the soils and 4 percent of the total carbon is stored in the roots. Since the goal of our paper is to illustrate the potential impact of a carbon annuity system on the peasant farmer in Rondônia, and we don′t want our results to be peculiar to a specific location, we will use several values of carbon sequestration. We will use Fearnside′s lower bound, mean and upper bound estimates and estimate the impact of the system with these alternative values. Note that Fearnside′s confidence interval spans Fujisaka′s central estimate. It is also important to note that since our focus is on the preservation of primary forest, we do not propose sequestration credit for secondary forest, crop land, or pasture. Therefore, differences in the estimates of the carbon storage of these land uses are irrelevant.[19]

In combination with these three values for carbon storage, we develop (admittedly arbitrarily) low range, moderate range, and high range values for the damages from a ton of carbon release, based on the information presented on Table 6.1 of the IPCC report. These values are presented in Table 1 along

18 This section is based on Caviglia-Harris and Kahn (2002)

19 The carbon storage estimates of these land uses were listed solely for the purposes of comparison, not because we propose giving credit for these land uses.

with the estimates of carbon storage, to calculate the asset value (based on carbon sequestration only and not other ecological services) of a hectare of tropical forest in Rondônia.

Table 1. Asset values of a hectare of rainforest (based on alternative assumptions) (2000 US$ per ton)

Estimates of Damages from a Ton of Carbon	Fearnside lower bound estimate of quantity of carbon storage: 96.2 t/ha^{-1}	Fearnside mean estimate of quantity of carbon storage : 157.1 t/ha^{-1}	Fearnside upper bound estimate of quantity of carbon storage: 218.2 t/ha^{-1}
Low range estimate: $10	$960	$1,571	$2,182
Moderate range Estimate: $50	$4,800	$7855	$10,910
High range estimate: $200	$19,200	$31,420	$43,640

Even if one took the lowest value of this table ($960) and then computed annuity payments using a low interest rate (5%) the annuity payment per hectare would be approximately $45. When multiplied by the typical small farmer holding of 100 hectares, this roughly equals the cash value of farm income from the plot. Larger values for a ton of carbon or larger estimates of the amount of income per hectare would imply even larger payments.

Of course, in the case of either forestry or agroforestry, some of the carbon would be removed, so payments would be less than suggested by the asset values of Table 1. However, these still would give a large incentive to maintain forest cover. However, since there is a difference between the ecological services provided by forest plantation, and the ecological services provided by healthy rainforests, care should be taken to construct a carbon annuity system that is only applicable when the full suite of ecological services are being produced. In other words, the carbon annuity system is seen not as an end in itself, or solely a means to reduce atmospheric carbon concentrations, but primarily as a means to encourage the preservation of rainforests.

9. CONCLUSIONS

A properly constructed lease system, with performance bonds and continuous recontracting can create a pseudo-market for the ecological services provided by the rainforest. This market can be strengthened and augmented by developing eco-certification programs, increasing the demand for non-timber forest products, and developing appropriately constructed markets for carbon sequestration. Although many implementation issues must be resolved, a portfolio of policies can give economic incentives to sustainable forestry and the simultaneous sustainable development and environmental preservation of rainforest regions in areas such as Amazonas.

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