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DESFIL
Development Strategies for Fragile Lands

FINANCIAL CONSTRAINTS TO "SUSTAINABLE" SELECTIVE HARVESTING OF FORESTS IN THE EASTERN AMAZON: BIOECONOMIC MODELING OF A FOREST STAND IN THE STATE OF PARA, BRAZIL

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SECTION I
ABSTRACT

"Sustainability" relies upon a clear definition of appropriate levels of timber extraction as well as an understanding of regional economic and ecological constraints to tropical forest management. We present a general methodology to assess the feasibility of long-term forest management considering natural timber growth rates, mortality, and changes in timber prices and interest rates. We use a simulation model to project the bioeconomic response of a 100 hectare forest stand in the Paragominas region of Para, Brazil, to various harvest selection criteria. We compare the potential returns from forest management with the returns on accessible financial instruments, such as 30-day CDs, to determine the opportunity cost of holding mature stands of commercial trees between cutting cycles. In the Paragominas case, financial returns on forestry improve as a function of increasing harvest intensity due to the high discount rate in Brazil. Though the relationship between biodiversity and harvest intensity is not yet fully understood, financial motivations in forestry in the Eastern Amazon may not correspond with the international conservation community's goals for "sustainable" forestry without strict legal enforcement of cutting limits.

SECTION II
INTRODUCTION

"Sustainable" forest management is poorly defined within the policy arena, but most definitions stress the use of natural forests to continuously yield timber while protecting forest ecology and biodiversity (Johnson & Cabarle, 1993). It is largely believed (1) that if forest resources are used in a "sustainable" fashion, long-term economic benefits will outweigh the short-term gains that would be accrued by aggressive timber exploitation, and (2) that given the appropriate economic incentives, long-term management plans will prevail (Godoy, 1992; Burgess, 1993). Non-sustainable forestry practices are attributed to uncertainty about land tenure or resource rights, market externalities, undervalued forest resources, and imperfect information about the economic potential of the forest and its value as an environmental resource (Repetto, 1988).

The ecological parameters for "sustainable" forest management are not widely agreed upon, and extraction intensity is central to the debate. Many supporters of biodiversity maintenance tend to see low-intensity extraction as a compromise between conservation and commercial forestry interests. The actual correlation between biodiversity and harvest intensity remains unknown, but is assumed to be negative and tied to regional geography and ecosystem characteristics (McArthur and Wilson, 1967; Lugo, *et al*, 1993). The impact on biodiveristy of high-intensity harvesting may be negative, but the notion of managing old-growth forests for timber production in Amazonia may be economically unrealistic (C. Uhl, pers. comm.) What is clear is that regional economic and ecological constraints to tropical forestry must be examined more closely in order to approximate viable long-term forest management.

A. Significance of Opportunity Costs in Forestry

The opportunity cost of allowing mature timber stands to remain intact, as may occur in a sustainably managed forest, has long been a consideration in forestry (Faustman, 1849). A growing forest stand with normal mortality generally represents a positively yielding investment. A stand of immature commercial trees increases in value as the total tree volume increases, as long as the prices of the species that comprise the stand experience stable real prices. In very simple terms, the value of a growing stand is expressed as the sum of each species' volume, multiplied by its current market price. The annual increment in commercial volume of a stand is a function of the growth rates of the species, less the mortality of commercial-sized individuals. In the absence of alternative investments, the return from a stand with well known growth and mortality rates is maximized by harvesting when annual volume increments are determined to be to declining.

Where alternative investments are available such as other land use options or the investment of harvest returns in financial markets, the decision to harvest a stand will be

made when the increasing value of the stand is lower than the net returns on the competing investments (Clark, 1976). As interest rates increase, the incentive to extract timber in the present will increase. This assumes that forestry is always perceived as the extraction of a renewable resource and that cutting may be postponed at the liberty of the forest manager.

Economies that exhibit very high interest rates may force foresters to practice methods that run counter to conventional methods practiced in economies with low and stable interest rates (Buongiorno & Lu, 1990). High interest rates in many developing countries, for causes of monetary policy and a high time preference for capital by members of those economies, brings the issue of opportunity costs to the forefront of considerations in long-term investments in land use in these regions (Schneider *et al.*, 1993).

B. The Role of the Timber Market

If the combination of annual timber growth rates and the annual increase in timber prices is greater than the return on competing investments, it is best to leave the stand appreciate as harvesting incurs an opportunity cost. When the combination of growth rates and timber price increases does not exceed the rate of return on competing investments, it is best to harvest, as leaving the stand incurs an opportunity cost.

Though tropical timber is an exception to the falling real prices of tropical commodities on the World Bank commodity index, with an average annual real price increase of 1.2% from 1950 to 1992 (Varangis, 1992), many argue that the supply of temperate wood is large and diverse enough to substitute for tropical timber in the event of a more aggressive price increase (Sedjo and Lyon, 1990; Vincent 1992). Arguably, data from many developing regions is incomplete and the market behavior of some currently known or previously unmarketed hardwoods may experience a more rapid price increase. Furthermore, economic projections are hindered by the instability of developing economies and long-term projections of interest rate behavior may vary dramatically. Cognizant of such uncertainties, analysis must consider the broad range of possibilities of price and interest rate behavior.

SECTION III
AREA OF STUDY

This study focuses on a 100 hectare forest stand located near the municipality of Paragominas (3 degrees S, 50 degrees W) in the state of Para, Brazil. This area is characterized by intensive mill activity, intensive timber harvest, and agricultural expansion. The 100 ha forest plot used in this study is the site of investigations of logging damages and long-term forest management (IMAZON, unpublished reports).

The vegetation is evergreen lowland rain forest with a canopy height of 25-40 meters, and an aboveground biomass of approximately 300 tons ha^{-1} (Uhl *et al.*, 1988) and is representative of the forest currently experiencing intensive extraction in central Para (C. Uhl, pers. comm.). The seasonal rainfall (1700 mm yr^{-1}) restricts logging activity to a seven month period between June to December (Verissimo *et al.*, 1992).

SECTION IV
METHODOLOGY

Based on inventory data from our experimental forest stand, ecological data from the region, and observations of logging operations in Para, we make a series of assumptions about growth rates, mortality, and extraction costs. We use the data to simulate the costs and returns associated with various harvest intensities and tree selection criteria and compare them with the return on 30 day CDs, invested over 25 years within Brazil. In order to estimate the volume and composition of harvests, costs and revenues, we developed a computer simulation model in the C programming language. The model is designed to calculate costs and revenues and to integrate ecological functions in order to project long-term responses to varying selection criteria in extraction.

A. Extraction Costs

Using a mapping algorithm for the tree extraction is fundamental in the calculation of extraction costs as it quantifies the amount of machine time necessary to complete the job, damage to the residual stand, and the resulting mortality. After actual field experimentation with the mapping techniques suggested by Gullison and Hardner (1993), it was determined that evenly spaced rectilinear placement of primary roads within the stand better accommodated the high harvest intensity (Barretto *et al.*, unpublished). Adhering to the mapping algorithm in our simulations is important for keeping constant the extraction costs for a given extraction intensity. The cost function of timber extraction is primarily determined by the construction of roads, the skidding of stems to patios, and the loading and subsequent transport of the logs. The use of constant parameters in road building, patio building, and skid trail construction provides a grounding upon which to construct the cost analysis.

B. Growth

We maintained a record of each stem in the management area above 25 cm dbh. The record holds data on the location of the tree within the harvest area, the species of the stem, a physical condition divisor (value/1 = good, value/2 = damage or bole problems), and diameter at breast height (dbh). The species is cross referenced to an aggregated growth rate table. Growth rates are determined by species alone, no other factors are considered. Our growth-rate table is grouped into three classes which may be the most efficient means to implement modeling where ecological data remains sparse and biodiversity is high (Vanclay, 1991), though precision is undoubtedly lost.

Each stem is tracked throughout the simulation period, and its diameter increases each year in accordance with its growth class. The species are aggregated into three growth classes: slow growth, 0.5 cm per annum; moderate growth, 0.8 cm per annum; and rapid

growth 1.5 cm per annum. The aggregation is based on data from Surinam (DeGraaf, 1981) and the state of Para (Martini et al, in press). Trees left after harvest experience a temporary increase in growth rates due to a decrease in competition (Silva, 1989; DeGraaf, 1981) Again, as data is lacking on growth rates, they are subject to error, and may be considered high for the given stand (C. Uhl, pers. comm.)

C. Mortality

The rate of stem mortality within the harvest area varies according to the level of unnatural disturbance experienced by the forest. A natural mortality rate of 1.5% yr^{-1} (DeGraaf, 1981 and Silva, 1989) is experienced by all stems above 25 cm dbh that lie a distance of at least thirty meters beyond harvest activity. All stems within the thirty meter disturbance boundary suffer a mortality rate of 15.0% during the first year after a logging disturbance, and a 2.0% mortality rate in the following years. These figures are extrapolated from studies of mortality in disturbed forest conducted by IMAZON (unpublished), though these studies do not express mortality as a function of distance (this parameter was devised for the simulation). Mortality is calculated on an annual basis. Each stem is subjected to a random chance of mortality determined by its proximity to past logging activity.

D. Management Costs

The management costs generated by the simulation model are based on a management plan developed by the Instituto de Homem e Meio Ambiente (Barreto, 1993). The management plan has three fundamental elements: an initial pre-harvest inventory and mapping of the distribution of trees; periodic vine eradication to reduce felling damage caused by vines which interconnect tree crowns; and periodic ringing of non-marketable species to reduce competition for commercial species. The total cost for these activities for one harvest rotation is US$ 169 ha^{-1}.

E. Harvest Volumes

Harvest volume is controlled by the selection criteria for harvestable stems. A variety of criteria may be considered in the selection of stems for harvest but only two are simulated in this study: 1) extraction of all species above a given diameter threshold; 2) an extraction of all stems above a given stem value threshold. A harvest is first simulated in the present and the remaining stand of trees above twenty-five centimeters dbh is passed through the growth and mortality functions for a twenty-five year period. The gross revenues of the second harvest are determined by the annual price increase for roundwood. The second harvest includes all stems above fifty centimeters, the legal cutting limit, in order to demonstrate the maximum possible gross revenue from the second rotation (for more than two harvest rotations, the cutting limit should remain consistent if it is desirable to maintain a steady timber output).

SECTION V
RESULTS

Table 1 compares the two systems of harvest selection; based on value or diameter of the individual trees. The costs, revenues and profits of each harvest intensity are displayed, as well as the value of the residual stand (which provides the basis of the second harvest). I is notable that when stems are selected by value criteria instead of diameter criteria, fewer stems are required to generate comparable profits.

Chart 1 displays the revenue potential of the second harvest at various real annual roundwood price increases. Each line, or data set, on the graph represents a different harvest volume as a function of the remaining standing volume left behind by the first harvest. As the intensity of the first harvest increases, with the 100 centimeter dbh threshold being the least intensive and 50 centimeters the most intensive, the gross revenue of the second harvest diminishes, and the revenue curve lies lower on the graph. Along the X axis the real annual roundwood price increases, causing the revenue curve to climb as gross revenues grow. Chart 3 displays the second rotation revenue potential when the forest is harvested using the value criteria.

A range of interest rates is provided to project the opportunity cost of holding the stand between harvests. Chart 2 displays the costs incurred by both holding the stand for twenty-five years and reentering the forest for a second harvest. Again, eleven data sets are displayed, each representing a different harvest volume as a function of the remaining standing volume after the first harvest. Along the X-axis, the real annual rate of interest increase causes the opportunity cost component of the total cost function to increase. The opportunity cost of leaving trees below fifty centimeters dbh is null as it is not legal to extract those stems, hence the cost curve does not rise with interest rates for that data set. Less intensive first harvests leave commercial-sized stems standing. As the post-harvest volume of mature commercial trees increases, the opportunity cost rises correspondingly. Chart 4 displays the opportunity costs when the forest is harvested using the value criteria.

Given a conservative harvest intensity of approximately 4.3 trees ha-1 the immediate net financial return is US$ 46,310 using the diameter criteria for selection (all stems above 65 cm dbh) and US$ 52,716 using the value criteria for selection (all stems above US$ 80 gross roundwood value). The residual commercial value of the stand immediately after the first harvest is US$ 24,082 using the diameter criteria and US$ 17,676 using the value criteria.

During the period of July 1990 to November 1993, 30-day CDs had a net nominal return of 23.85% per month. During this same period the official monthly monetary correction rate was 21.57%. Hence the real monthly rate of return of 30-day CDs in Brazil was 2.28%, or 27.36% per year (Goldman Sachs, pers. comm.). Based on these rates, we

asses the opportunity cost of holding a residual stand of timber at a real interest rate of 20% and a more conservative rate of 10%.

Table 1
Finances of Increasing Harvest Intensities in the Present for a 100 hectare Forest Stand.

Harvest Criteria Diameter Based (dbh)	Stems Harvested	Cost	Revenue	Profit	Residual Stand Value
>50 cm	844	$22,469	$92,861	$70,392	0
>55 cm	693	19,484	82,640	63,156	7,236
>60 cm	**560**	**18,001**	**73,650**	**55,649**	**14,743**
>65 cm	428	16,566	62,846	46,310	24,082
>70 cm	644	15,458	55,114	39,656	30,736
>75 cm	238	14,652	44,648	30,296	40,096
>80 cm	193	12,260	38,645	26,385	44,007
>85 cm	137	11,730	31,278	19,548	50,844
>90 cm	109	12,746	26,441	13,695	56,697
>95 cm	78	12,133	21,134	9,001	61,391
>100 cm	61	11,835	17,495	5,660	64,732
>105 cm	7	10,696	47,92	(5,904)	76,296

Value Based	Stems Harvested	Cost	Revenue	Profit	Residual Stand Value
Stems>$80	**433**	**16,624**	**69,340**	**52,716**	**17,676**
>$85	415	16,419	67,856	51,437	18,955
>$90	383	15,991	65,062	49,071	21,321
>$95	363	15,840	63,217	47,377	23,015
>$100	331	15,520	60,124	44,604	25,788
>$105	297	15,100	56,652	41,552	28,840
>$110	268	14,693	53,500	38,807	31,585

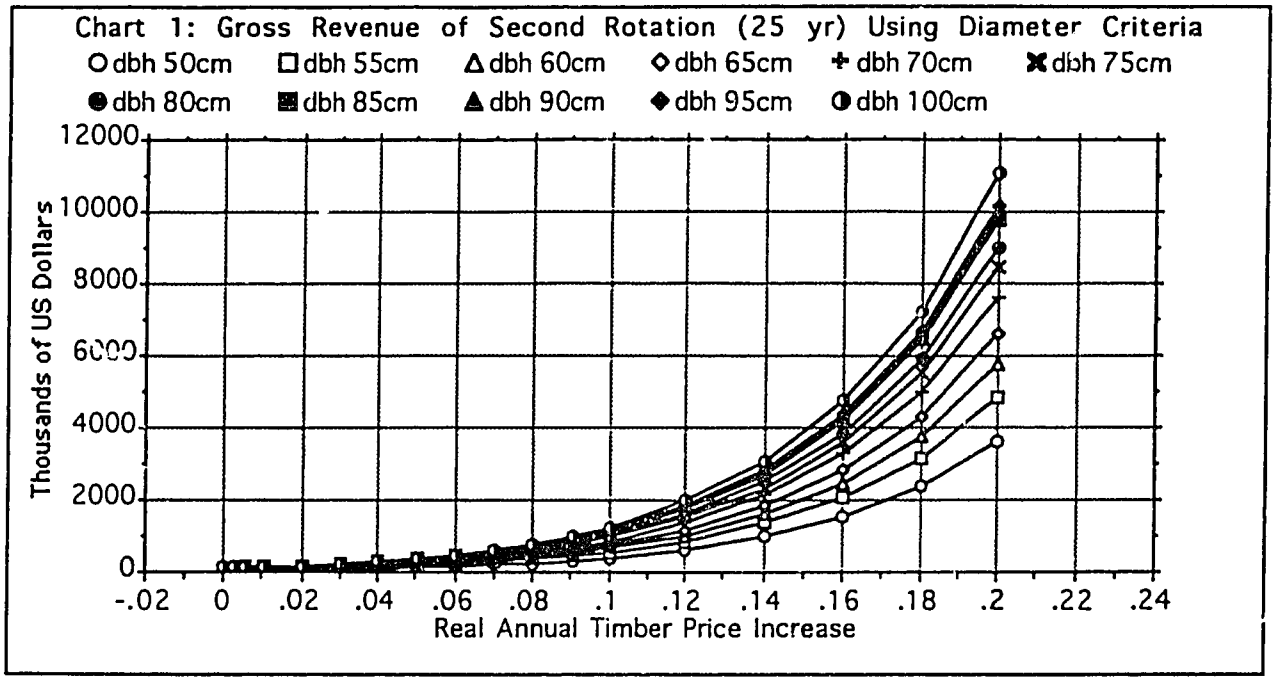
Chart 1: Gross Revenue of Second Rotation (25 yr) Using Diameter Criteria
dbh 50cm
dbh 55cm
dbh 60cm
dbh 65cm
dbh 70cm
dbh 75cm
dbh 80cm
dbh 85cm
dbh 90cm
dbh 95cm
dbh 100cm
Thousands of US Dollars
12000
10000
8000
6000
4000
2000
0
-.02
0
.02
.04
.06
.08
.1
.12
.14
.16
.18
.2
.22
.24
Real Annual Timber Price Increase

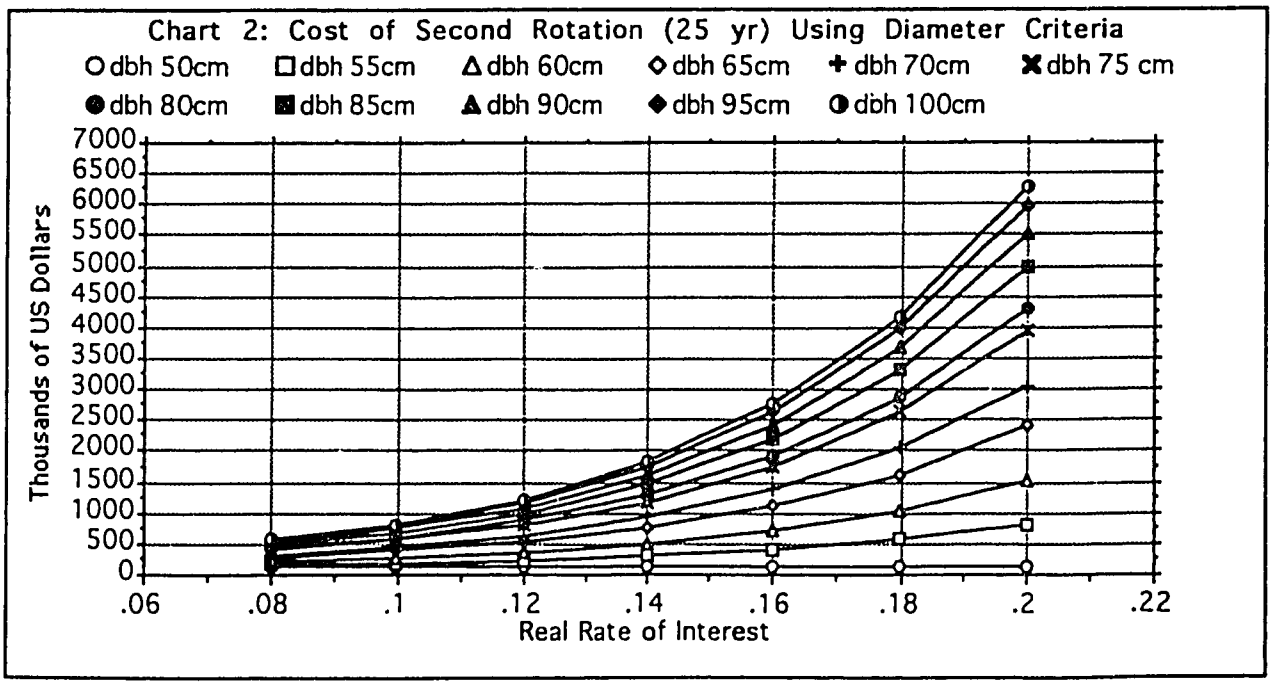
Chart 2: Cost of Second Rotation (25 yr) Using Diameter Criteria
dbh 50cm
dbh 55cm
dbh 60cm
dbh 65cm
dbh 70cm
dbh 75 cm
dbh 80cm
dbh 85cm
dbh 90cm
dbh 95cm
dbh 100cm
Thousands of US Dollars
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
.06
.08
.1
.12
.14
.16
.18
.2
.22
Real Rate of Interest

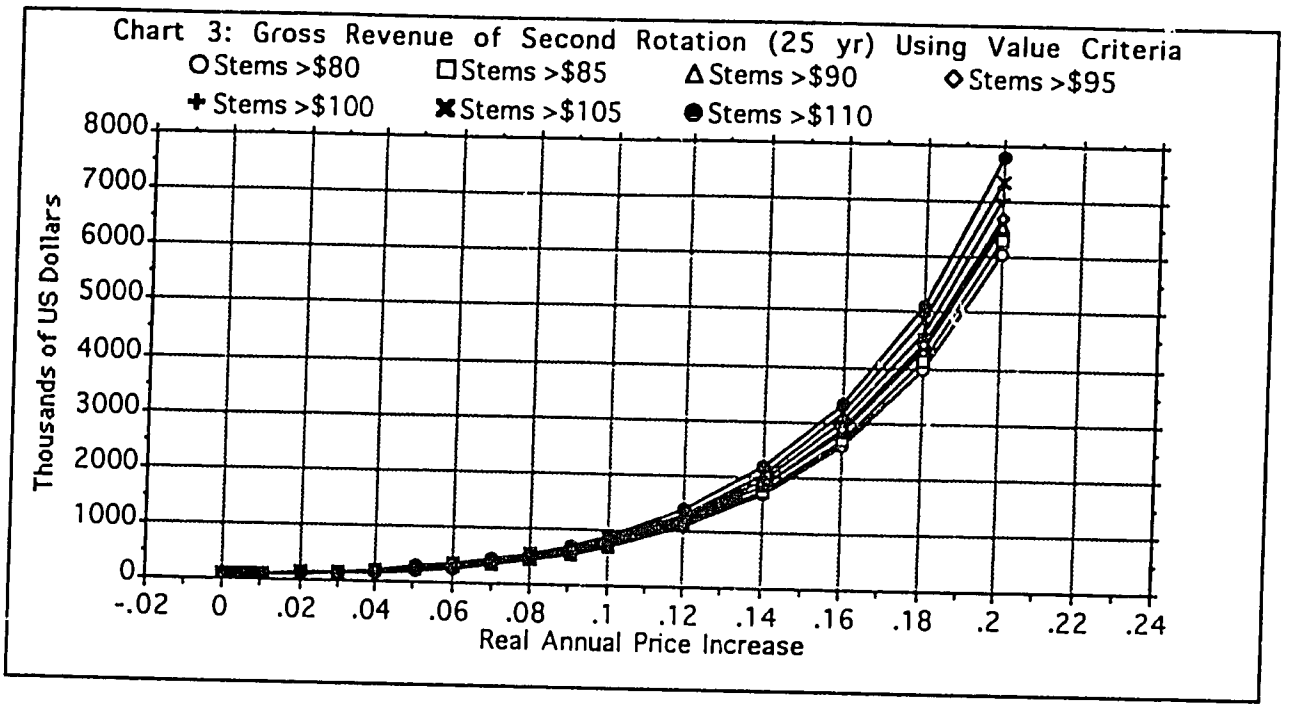
Chart 3: Gross Revenue of Second Rotation (25 yr) Using Value Criteria
O Stems >$80
□ Stems >$85
Δ Stems >$90
◇ Stems >$95
✚ Stems >$100
✖ Stems >$105
● Stems >$110
Thousands of US Dollars
8000
7000
6000
5000
4000
3000
2000
1000
0
-.02
0
.02
.04
.06
.08
.1
.12
.14
.16
.18
.2
.22
.24
Real Annual Price Increase

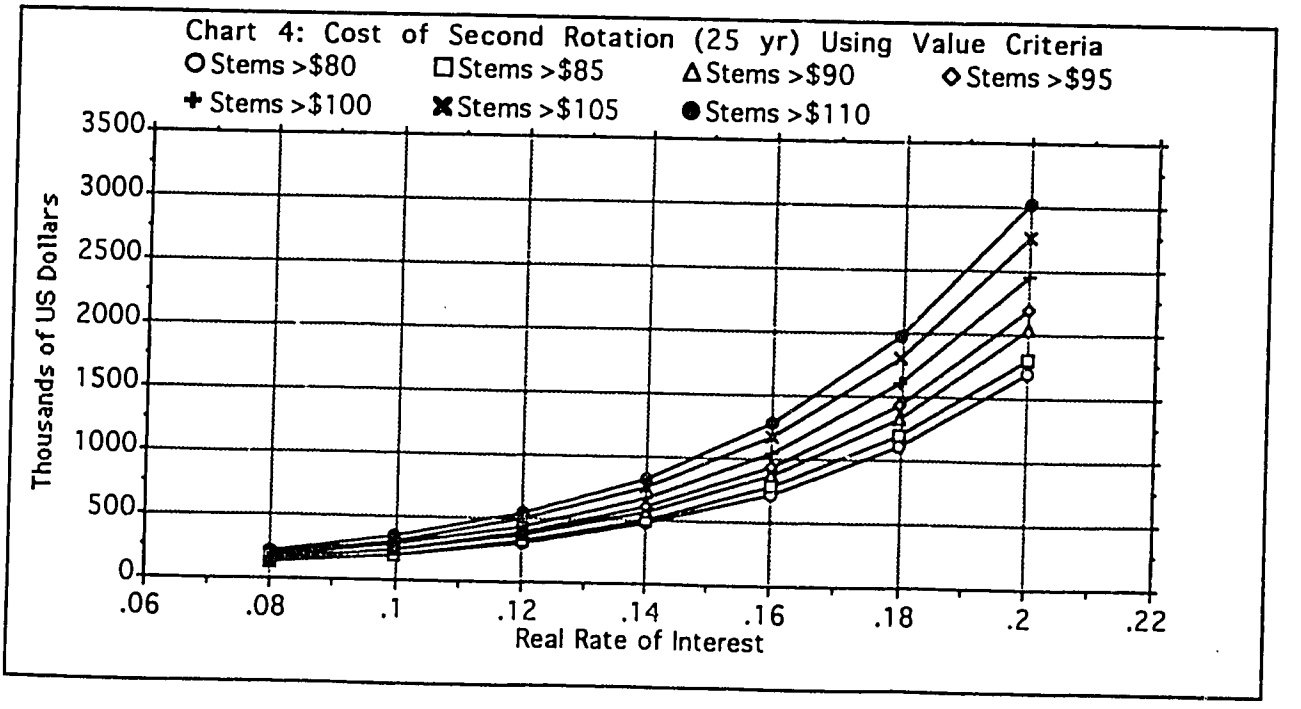
Chart 4: Cost of Second Rotation (25 yr) Using Value Criteria
O Stems >$80
□ Stems >$85
Δ Stems >$90
◇ Stems >$95
✚ Stems >$100
✖ Stems >$105
● Stems >$110
Thousands of US Dollars
3500
3000
2500
2000
1500
1000
500
0
.06
.08
.1
.12
.14
.16
.18
.2
.22
Real Rate of Interest

At a real annual interest rate of 20% the opportunity cost of holding a residual 100 ha stand is US$ 2,297,331 using the diameter criteria and US$ 1,686,223 using the value criteria. Using the more conservative long-term estimate for real annual investment yield of 10%, the opportunity cost of holding a residual 100 ha stand is US$ 260,921 using the diameter criteria and US$ 191,514 using the value criteria. The real annual increase in roundwood prices required to offset the cost of extraction and the opportunity cost of the second harvest would be approximately 16% and 14% for the diameter and value criteria, respectively at an interest rate of 20%, and approximately 7% for both criteria at an interest rate of 10%. If real roundwood prices continue to increase at the current annual rate of 1.2% (Varangis, 1992) and interest rates of 20% continue for the duration of the harvest cycle, stand owners will suffer a loss of approximately US$ 2,324,900 using the diameter selection method at an intensity of 4.3 trees ha-1 and US$ 1,721,000 using value selection methods. At a real interest rate of 10%, the stand owner will suffer a loss of approximately US$ 288,506 using current diameter selection methods and US$ 226,328 using value selection methods. Evidence of the presence of this opportunity cost is seen in current extraction behavior where all stems above the legal cutting limit are removed.

SECTION VI
DISCUSSION

A. Managing Opportunity Costs

The opportunity cost of leaving commercial-sized trees (above the legal cutting limit) in the forest is significant in the Paragominas case. To some extant the opportunity cost can be minimized through the selection of species to be left in the residual stand. Stem selection for harvest in the present should heavily exploit species with the least potential for a real value increase in the future. Stem value may increase in two ways, growth and real price increase over time. Those species whose projected real value increase is below projected interest rates represent an opportunity cost to the stand holder. Using selection criteria more sophisticated than a simple diameter threshold may serve to lower opportunity costs and increase future revenues. Given more information regarding individual mortality rates, growth rates, propensity to develop bole problems, regeneration, and price in the future, a forest manager can maximize long term economic performance of the stand. The residual stand would include the most ecologically robust species that incurred a low opportunity cost but were projected to experience a significant price increase in the future. Such species might be identified for their ability to substitute current precious woods such as mahogany that may become scarce in the future. Unfortunately, even if an optimal forest stand is selected, a formidable opportunity cost may result.

B. Policy Implications

The foremost policy implication is the imperative to define "sustainable" forest management with attention to regional economic and ecological constraints. If "sustainable" management guidelines include high-intensity extraction, they will correspond with the financial realities of many timber producing regions. If it is determined that very low-intensity extraction corresponds more closely with the conservation community's notion of "sustainability" and biodiversity maintenance, then a method for offsetting high opportunity cost will be necessary.

A legal cutting limit is one method of alleviating the opportunity cost of leaving all stems that, in effect, become illegal to cut. The 50 cm dbh limit currently enforced in Paragominas removes from the opportunity cost calculation all stems in the residual stand that lie below this limit. Without a cutting limit, a private firm does not have a financial motivation to hold a forest stand intact while discount rates exceed the combination of growth rates and real price increases.

Offering land tenure to loggers does not alleviate this financial concern. Land tenure and long-term timber concessions are considered vehicles for promoting a vested interest in the long-term productivity of a land-holding (Repetto, 1988). Assuring land tenure and

long-term timber concessions will not necessarily alter resource use without strictly enforced cutting regulations. The opportunity cost of sustainable management will continue to exist and secure access to a forest may encourage more capital intensive investment in extraction equipment and milling facilities as the risk of losing such an investment will be diminished. The increased harvest capacity may allow a more intensive and efficient non-sustainable extraction of timber.

C. Green Labeling

Market initiatives, such as green labeling of sustainably produced timber, must not only cover the costs of tropical forest management, they must offer a substantial annual real price increase for tropical woods. Presumably, consumers in developed countries will bear a price increase in order to aid in the preservation of tropical ecosystems. If producers are to voluntarily reduce harvests, it is questionable whether price premiums could increase at a rapid enough pace to offset high discount rates. In our example, an annual price increase of between 13% and 15% would be required to offset costs if interest rates run at 20%. At interest rates of 10%, a real annual price increase of 7% would be necessary. The majority of roundwood and commercially finished wood products from developing tropical countries is consumed domestically or by other developing countries (Vincent, 1992). Passing the costs of sustainable production on to domestic consumers in these countries may be difficult or even impossible.

D. Refining the Debate on Sustainability

Public debate over the future of tropical forest management is mired in vague definitions of sustainability and a poor understanding of regional constraints to long-term management. We have demonstrated that financial constraints in Paragominas do not encourage voluntary reductions in harvest intensity. Though there is no conclusive evidence that this is necessary for biodiversity maintenance, conservationists should re-examine the potential of voluntary low-intensity harvesting as an economic solution to deforestation.

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