A COMPUTER EXPERT SYSTEM FOR MANAGING FORESTS IN THE AMAZON

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ABSTRACT:

Brazil's Amazon region contains the largest tropical forest resource in the world. About 1,300,000 ha has been exploited each year without planning. To improve the current practice, a computer program has been developed to investigate various management operations. BRAMA - an interactive expert system, simulates management activities and stand growth for timber production. The system agrees very closely with the existing knowledge of tropical forest management, that requires complex and extensive data. This software is written in VS FORTRAN as a forest management planning tool.
KEYWORDS: Tropical Forest, Simulation,Amazon, Uneven-aged Management, Computer System.

Amazonia exhibits the world's largest tropical forest. More than 80% of native forests of BRAZIL are located in the Amazon region.The colonos, immigrants to Amazonian rainforests, are subsistence farmers from resettlement schemes promoted by government agencies. The majority of them see the rainforest when they first arrive in the Amazon and treat the forest as an enemy rather than a resource (Dufour,1990). Kengen (1991) has summarized the consequences of policies adopted by the government of Brazil after 1964 to promote economic growth at any cost.

The program of regional development contributed to the expansion of Brazil's agricultural frontiers towards the Amazon basin. Fiscal incentives encouraged many entrepreneurs to establish cattle ranches in the area. A deforestation process was initiated since only 5% of the land is fertilized to sustain agrosystems. The destruction of forests in the Amazon has received a worldwide attention. In response to international pressure, the Brazilian Government has suspended the fiscal incentives. There is now a growing trend to develop an internationally recognized code of conduct to regulate the harvesting in tropical forests. The emergence of this best-practice code of forestry implies that the word "tropical" will be soon eliminated. Quidelines will take the form of a code for international, sustainable forestry practice (Jagels,1990).

The main product of Brazil'Amazon is timber (IBAMA,1991). An understanding of the complex ecological interrelationships of the forest, and the full range of values will be realized only through proper management (Lima and Mercado,1985). One of the goals in managing the Amazon forest is to encourage the maximum yield per unit area, consistent with product quality. A second objective is to improve growing conditions of certain native and exotic species when grown in plantations (Lima,1990).

Timber management essentially involves decisions on temporal and spatial scheduling of harvest during a planning period,as well as the reforestation strategy following harvest. The philosophy of uneven-aged management was developed mainly in France and Switzerland (Hann and Bare,1979). An uneven-aged forest stand, as a tropical forest, is a heterogeneous dynamic spatial arrangement of trees varying in age, size, and species. Utilization of solar energy, nutrients, and water affects the size of living trees. Mortality, either from natural or man-induced causes, eliminates individual trees that are competing for growing space. Ingrowth, the movement of trees above an arbitrarily defined lower size limit, presents a threat to existing trees that compete for a niche in a stand. BRAMA prescribes an evolving system that consist of several components relevant to net forest growth.

The management of forest resources has proven challenging throughout the tropics due to physical, socio-economic and political constraints.

The aim of our study is to assist forest managers in developing a sound strategy for tropical forest management. Basically, the study has two objectives:

First, to simulate a process of predicting growth and yield of the forest after harvesting, in order to achieve sustained yield of the Brazilian Amazon Forest. More specifically, BRAMA simulates the behavior of growth and yield along with economic values at different stages of the forest.

Second, to identify the important elements of this process for inclusion into a model for planned change.

It is anticipated that this study will lead to improvements in managements strategies for Amazon forest.

METHODOLOGY

The approach involves a dynamic process based on TAPAFOR (Lima,1990), in which the changing distribution of the number of trees in a forest is modified by initial and cyclic harvest intensity of trees, and silviculture. To avoid error of aggregation, it is expected to point to an optimum treatment consistent with a particular stand and its environment in each simulation, rather than for all forest.

BRAMA is structured to depict the forest at a prescribed condition as a result of specific treatments. Monte Carlo simulation is employed in different phases of this study in order to simulate naturally occurring variations. The model, was developed only for high forest (productive forest) growing on level ground. The stand is divided into 15 DBH classes, with a minimum DBH of 15 cm. The class interval is 10 cm, based on the work of Lima (1990). Three groups of species were considered: exportable trees, local commercial trees, and non-commercial trees. Stand treatments include:

a) natural regeneration;

b) artificial regeneration (line plantations);

c) artificial regeneration by enrichment planting; and

d) artificial regeneration by close plantating following clearcutting.

The prime purpose of BRAMA is to present an open-ended system designed for the management of an Amazon basin forest. In designing BRAMA, the prediction of the effects of harvesting and silvicultural treatments on growth and yield in the tropical forest is based on integration of the following modules:

"HARVESTING"

Basically, this module deals with a single tree selection process by identifying trees to be cut, time of cut, and intensity of cut. Because Amazon species are unsuitable for pulp and paper products,under existing manufacturing technology the output is sawlogs (Lima and Mercado,1988). Thus, only commercially valuable trees with a DBH greater than 45 cm will be removed.

Under a close plantation alternative treatment, planting following clearcutting in small patches is used. Residues from forest harvesting operations are expected to decompose in about three years. Cutting cycle and cutting intensity are important components of the system.

The principal parameters utilized in this process are:

a) Average log intensity. This depends on basal area per hectare and determines the damage to residual stand. Ranges of damage for each DBH class in relation to logging intensity are based on data from tropical forest literature.

b) Removed volume. The volume to be removed is estimated for each DBH class by an equation developed for the model. This equation predicts volumes for exportable trees and local commercial trees; planted trees are considered exportable commodities. A conservative estimate of losses from felling, breakage and natural defects is approximately 39% of the volume.

"SILVICULTURE"

Silvicultural operations affect the growth rate of trees, damage to the residual stand, and cost. BRAMA handles two alternatives: natural regeneration and/or artificial regeneration. Artificial regeneration utilizes selected species with a good growth rate that produce valuable timber and are free from insect damage. Enrichment planting, close plantation, and line planting are alternatives to artificial regeneration. The maximum number of valuable for commercial purposed trees to be planted is 126 per hectare. Trees planted in an enrichment or line plantation are expected to compete effectively in the natural cycle. A regression equation from current literature on tree competition over time has been used to calculate total commercial trees to be planted under enrichment or line plantation.Close plantations are established after clearcutting. Four hundred trees per hectare, spaced 5 x 5 meters, are to be planted. In practice, clearcutting is limited to stands with high density of mature commercial trees and low survival of seedlings on the ground. Non-commercial thinning or silvicultural treatments to favor valuable trees may be applied in years when no planting is done and where trees with DBH greater than 15 cm exceed 300 per hectare.

"GROWTH"

Our approach to predicting growth is based on the work of Abkin and Wolf (1993). This procedure divides the DBH classes into kth order continuous delay processes and projects the trees into the future through diameter class distribution as affected by ingrowth, growth, and mortality. The trees in a stand are divided into 15 DBH classes, by species groups according to their commercial value.

To quantify the delay process, the model considers the average delay, which is based on the average growth rate by DBH class and treatment. Available data in the literature, indicate growth from 1.5 to 2.5 cm per year for planted trees. In BRAMA, the change in delay is based on the density of the stand and/or the basal area growth. In line and enrichment plantings the delay in DBH movement for trees less than 25 cm, where the competition is greater, will double if the number of trees exceeds 400 or basal area exceeds 45 square meters per hectare. In a plantation treatment following clearcutting, the delay is also expected to double for trees with DBH less than 25 cm, when total trees exceed 500 or basal area exceeds 70 square meters per hectare.

The time increment (DT) in BRAMA is one year. DT strongly influences model stability. If the model is unstable, its validity and usefulness are impaired. Since the delay routine computes a smaller increment for stability and non negative flow, if this is necessary, additional DT adjustments are not necessary.

The damage losses in each simulation run depend on the silvicultural operation of a specific year. The Proportional Loss Rate utilized in the delay process, is a stochastic variable based on the normal distribution. Inputs in the Delay Process are mainly from the natural process of ingrowth and/or artificial regeneration. A line or enrichment planting is expected to produce natural regeneration of 100 trees per hectare when at least ten trees have DBH greater than 45 cm.

"ECONOMICS"

Present net worth calculations are a routine operation in BRAMA, based on sawlogs as the final product. The present value of expected future returns over the simulated cycle, minus the present value of expected future costs (with costs and returns discounted at a specified rate of interest) are the economic criteria for analyzing profitability.

The opportunity cost of capital is an alternative that can be used in BRAMA. The user has the option of using different rates of return in alternative treatments. If the rate of value growth falls bellow the best alternative, the user must choose the next most appropriate treatment.

Costs are expressed in any monetary unit per hectare, because they are an input option. Sawlogs are assumed to be the final product; in general, two cubic meters of commercial volume are necessary to produce one cubic meter of sawlog material.

Cost variables are:

a. Harvesting, logging and transportation percubic meter of sawlog,
b. Non-commercial thinning, independent of output per ha,
c. Weed control and maintenance,
d. Planting cost per tree, for close plantation, line planting and enrichment planting.

The revenue at any point in time is obtained by multiplying the output by a unit price. The output is two cubic meters of valuable tree for each cubic meter of sawlog.

Prices are an input option, as follows: price of local commercial trees per cubic meter of final product or per two cubic meters of commercial volume, and price of exportable trees or artificially regenerated species per cubic meter of sawlog or per two cubic meters of commercial volume.

The predictive equations of BRAMA were derived from available data for each component. Successful mathematical model building depends in part on the analyst's experience, trial procedures, and a considerable amount of luck (Naylor,et.al. 1968). When tested against actual data, mathematical models were considered successful.

INPUT DATA

Input data for BRAMA are provided in three sets: forest data, management-decision variables and financial variables.

Forest Data:

The system accommodates 15 DBH classes and three initial species groups: exportable, locally commercial, and non-commercial trees. For every DBH class of each group of species, the number of trees must be specified. The initial number of seedlings provided by the user, if not known, must be between 50 and 150, due to the assumption that the forest is in equilibrium with few seedlings surviving. Another input variable is the area of the stand in hectares.

Management-Decision Variables:

This set of variables includes: a) the initial cutting intensity (from 1% to 100%) and b) stand treatment: natural regeneration, line plantation with natural regeneration, enrichment planting with natural regeneration, and close plantation.

Financial Variables:

The price and cost variables for each operation and interest rate for discounting future costs and revenues are input variables specified by the user.

OUTPUT

Detailed output includes:

Year after the first harvest, total basal area per hectare; total mortality per hectare for a specific year; present net worth per hectare; accumulated value of removed trees per hectare; present net value per hectare for residual stand; and total present net value per hectare.

General output includes:

Year after the first harvest; present net worth per hectare; present net value per hectare for residual stand; total present net value per hectare; total number of trees with minimum 15 cm DBH per hectare; total number of commercial trees with minimum 15 cm DBH, and total number of commercial trees with minimum 45 cm DBH.

RESULTS

The BRAMA computer expert system follows the forest management rules. The results of applying BRAMA to five stands over a 40 years period for treatment combinations of prescriptions, cutting intensities and cutting cycles aimed at bringing the forest to a sustained yield basis. Optimum volume removed over a 40 year period resulted from removing all commercial trees in years 0, the year of initial disturbance, and 40, with an enrichment planting at year 1.

The advantage of enrichment planting over line planting is small even though the latter causes less stand damage at treatment implementation. In practice, line plantation may present an advantage over enrichment planting when PNW is to be maximized because the planting is concentrated and permits more control of valuable species than enrichment planting.

Optimum residual stand value and basal area, without the close plantation option, is realized when 70 percent of commercial trees are removed in years 0 and 40, and enrichment planting takes place in year 1. Similar results were obtained by line plantation. Volume is maximized if a constant annual harvest is not maintained. The average volume removed from each hectare annually, after treatments, ranged from one to nine cubic meters.

According to Dufour (1990), restoration of the forest in terms of biomass and species diversity, will take 100 years or even longer in sites which have been greatly disturbed. With BRAMA, natural regeneration results look reasonable in the absence of frequent interference of the forest growth process.

Our computer simulation suggests that in order to achieve maximization objectives (PNW and/or Volume) in an Amazon forest area, are needs to combine different prescriptions, cutting cycles and intensities, for different stands that vary in size and site characteristics.

DISCUSSION

Intelligent management practices in the Amazon basin must take into consideration the diminishing productivity of the forest with the increasing frequency of harvesting. In such cases, PNW will be maximized, but the structure and quality of the residual stand will deteriorate.

According to FAO (1991), in the tropics management implementation at less than 5 percent of closed forest areas is light. This low rate, coupled with the lack of incentives and benefits for local residents derived from forest management contribute to deforestation. Without appropriate policy and dynamic rational management it is unlikely that forest areas under sustained management will increase in the forescable future. Sustainable management is possible only if the allowable cut is considerably less than what is presently realized. Also, the proper balance between economic and the silvicultural aspects has to be readdressed if forests are to be managed on a sustained basis.

BRAMA results strongly suggest that while wood production must continue as management priority, the efficiency of utilization could be increased at least over some period of time, if alternative treatments are used for different stands based on initial stand distribution. Small, irregularly-shaped clearcut areas with close plantation are also an attractive management option for long- term planning in low productivity areas.

Determination of the best cutting cycle is among the oldest and most important problems in forestry. For the Amazon region, maximization of the value of wood production may be the most desirable approach. Other non-timber benefits of the forest should also be considered where they are important.

In the early stages of Brazilian colonization the need for labor led Portuguese settlers to penetrate the Amazon basin to capture Indians. These incursions led to exploitation of the forests (Furtado,1982). A survey by the Smithsonian Tropical Research Institute found 835 different species of trees in one 125- acre (50.625 ha) plot in a tropical rain forest (Cook,1990). Planning for the Amazon forest must be a truly dynamic process for realizing the best possible adjustments over time between man and the environment.

Simulation approaches, such as BRAMA, hold great promise for studding the impact that new policies are likely to have on the forest over time. In its simplest form, BRAMA is a process designed to provide guidelines for the efficient management of a tropical forest in the Amazon basin.

As new reliable data become available, calibration of BRAMA through successive runs with varying number of growth stages in each DBH class and other parameters will improve its effectiveness. The program suggests that residual stands are extremely sensitive to the cutting intensity, as well as the year that silvicultural treatments are applied.

Simulated results from BRAMA can be used as a starting point. The tremendous potential of the Amazon forest offers unique opportunities and challenges. However, exploitation without protection and concerted efforts for reestablishment must be avoided to prevent total forest destruction (TCA,1992).

Simulation models are at best, abstracts of the real world. As such, they can not depict fully the complexities of natural systems (Arvanitis and Reich 1989). However, BRAMA, as a forest management planning tool, may prove effective in demonstrating many approaches and the respective outcomes. It offers the possibility of exploring alternative management strategies and could be of great value to the management of Amazon forest by knowledgeable persons. It is anticipated that this would lead to a more rational infrastructural and economic development in the Amazon region while enhancing the uniqueness of the area, its environment and natural resources. Ultimately, the results of a sustained forest management in the Amazon will benefit all of Brazil.

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