Genetic conservation within managed forests in Amazonia: Dendrogene project

M. KANASHIRO[1], I. S. THOMPSON[2] and B. DEGEN[3]

Address: [1]Embrapa Amazonia Oriental, C.P. 48, 66095-100 Belém-PA, Brazil; [2]United Kingdom Department for International Development (DFID), C.P. 48, 66095-100 Belém-PA, Brazil; [3]UMR CIRAD INRA ENGREF, Campus agronomique, BP 709, 9738 - Kourou cedex, French Guiana

Key words: Genetic diversity, harvesting planning, logging impact, reproductive biology, species identification, tropical trees

Abstract: The genetic structure of tropical tree species forms the basis for adaptation to present environmental conditions. Moreover, genetic variation improves the adaptability to future conditions. Hence, conservation of forest genetic resources is an important issue for sustainable forest management in Amazônia. This paper describes an applied research project which will integrate indicators for genetically sustainable management into forest logging plans. The novelty of the project, entitled Dendrogene, is the interdisciplinary approach which results from the integration of different software packages: a simulation model (ECO-GENE) to study temporal and spatial dynamics of genetic structures of tree populations; a database (DENDROBASE) summarizing the ecological and genetic information known for tropical tree species; and tree mapping and forest management utilities (TREMA) using the concept of minimum stock by species to influence harvest tree selection. The DENDROBASE application will identify groups of species with similar genetic systems. For these groups simulation studies with ECO-GENE will help to estimate the dynamics of genetic structures for different logging scenarios. Information on species groups and their responses to different logging intensities will be added to TREMA for further integration into logging plans. Perspectives on implementation of genetic indicators within management plans are discussed.

Parts of this paper represent an extract from the publication of Kanashiro et al. (2002) in Unasylva (Vol. 52), No. 2, (Issue No. 209): http://www.fao.org/forestry/FODA/UNASYLVA/unasyl-e.stm

Introduction

Although tropical lowland rain forests cover only 6 to 7 per cent of the Earth land's surface, they accommodate more than 50 percent (possibly as much as 90 per cent) of all living species (Linsenmair 1997). Amazonia is acknowledged to be one of the richest and most biologically diverse forest ecosystems in the world. In Brazil alone the Amazon forest encompasses 3.5 million km^2. Despite the enormous international pressure due to rates of deforestation and intensive selective logging operations, more than 2500 mills were operating in 1996/97, consuming an equivalent of 27.8 millions m^3 of tropical timber (Nepstad et al. 1999).

In the last two decades the forest legislation for Brazilian Amazon forests has evolved considerably, yet many advances still need to be implemented either at a technical and/or an operational level (Zachow 1996). The current Sustainable Forest Management Plans (SFMP) still do not take into account the characteristics of individual commercially-harvested species, although an understanding of their reproductive traits is increasingly well-studied, at least for some timber tree species.

In a recent evaluation process, IBAMA, (The Brazilian Environmental Agency) determined that, out of 4.204 Sustainable Forest Management projects, only 1759 (41.8%) were properly prepared, and thus approved to continue (www.ibama.gov.br). About the same number were temporarily interrupted, for not presenting appropriate documents, and others were completely cancelled. However, there are few initiatives trying to show that tropical hardwood can be economically harvested and managed on a sustainable basis such as promoting low impact logging and selection criteria (Blate 1997; Silva 1997; Kageyama 1998; Bihun 1999). As noted by Thompson and Yared (1997), in addition to public pressure for sound environmental practices, and in particular sustainable management of tropical forests, there is an increasing demand for practical measures which can be adopted by companies and monitored by regulatory authorities, expecting to move away from destructive logging practices towards sustainable management

More recently timber certification as a means of furthering sustainable forestry has been intensively debated within many countries as well as at the international level. Although the creation of incentives for moving towards a wise and sustainable use of forest resources are positive steps, we still lack much basic information to inform such attempts at sustainable use (Lisenmair 1997). Several initiatives towards discussing, developing, and testing criteria and indicators are under way (van Bueren and Blom 1997; Flinn and Franc 1998). However ecological criteria directed towards processes which maintain genetic variation were recently waived in field testing due to the difficulties of fair assessment in monitoring and auditing activities (Sabogal 1999, personal communication). Forest certification may increase the product value provided the forest operations are approved for certification, but it still may not guarantee genetic sustainability, herein taken as the maintenance of intra-and inter-population species diversity as a basis for future adaptation.

Szaro (1998) reports that there is a considerable body of knowledge available on tropical forests, but it needs to be synthesised and put into a form usable by managers and policy makers. The first step is to ensure that what we know is used, and the second is to prioritise where additional resources for research can make a critical contribution to sustainable forest management and to a global dialogue on forest policy. Namkoong (1998) stressed that forest scientists needed to make special effort to come together and communicate effectively. He noted that forest policy was not interested in complexity and was often based on little scientific information. In that respect, modelling information provided by the adapted version of ECO-GENE and parameter estimates and opportunities for model verification for predictive purposes, will be important to link forest practices to their effects on the parameters of population size, inbreeding, selection and migration that can be experimentally estimated. Forest management decisions can then be made on the basis of the effects of practices on evolution through their effects on genetic processes, and this may represent one of the major contributions of Dendrogene to sustainable forest management decisions.

In this paper we give a general description of the Dendrogene project which tries to integrate indicators for genetically sustainable management into forest logging plans. We introduce the different software packages which are important tools of the integrative approach of the project. Thereafter we comment on some perspectives on implementation of genetic indicators within management plans.

The *Dendrogene* project

Hosted at the Embrapa Eastern Amazon research station in Belém, Pará, Brazil, the Dendrogene project depends on a multidisciplinary approach and multi-institutional participation. The Department for International Development (DFID) of the United Kingdom supports the project (2000 to 2004) through the Brazil-United Kingdom Technical Assistance Programme. Many of the initiatives in Dendrogene are based on earlier activities in the Rainforest Silviculture Research Project (1993 to 1998), also supported by DFID.

The project focus is to develop mechanisms to apply scientific knowledge (species composition, reproductive health and genetic diversity of populations) to promote sustainable rainforest management in the Brazilian Amazon. The idea is to link forest management in the field to ongoing scientific research, as an attempt to contribute to a goal of achieving sustained use and conservation of genetic resources in the region's natural forest.

One of the novelties of this approach is the integration of several software packages such as ECO-GENE, DENDROBASE and TREMA, in order to generate meaningful information to be translated into sustainable forest management at an operational level.

ECO-GENE simulation model

The temporal and spatial dynamics of genetic structures of tree populations are the results of different processes like gene flow, mating system, selection and random genetic drift. Logging and forest fragmentation influence several processes simultaneously. Thus their overall impact on genetic variation of tropical tree species requires the understanding of the dynamic within a complex system. Modelling and simulation studies are very helpful to analyse complex systems. The simulation model ECO-GENE has been developed to study temporal and spatial dynamics of genetic structures of tree populations (Degen et al. 1996). Overlapping or separated generations can be created and different processes like gene flow, mating systems, selection, random drift can be implemented. The model can be run with empirical and fictitious input data. It have been successfully applied to study the impact of different silvicultural practices and the effect of air pollution on the genetic structure of temperate tree populations (Degen and Scholz 1996; Degen et al. 1997; Degen and Scholz 1998; Geburek and Mengel 1998). Since 1998 it have been adapted to the specific conditions of tropical tree species. Modules on pollen and seed dispersal, and a new module on flowering phenology have been added to ECO-GENE. The integration of the forest simulation model Symfor (www.symfor.org) offers improved modelling of growth processes and management impacts.

The ECO-GENE model will be validated through comparison with real data collected on an intensive study plot (500 ha) in the National Forest of Tapajós. Dendrogene is carrying out this work in cooperation with the project "Sustainable Forest Management for Timber" of the Brazilian Institute for Environment and Natural Renewable Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, IBAMA) and the International Tropical Timber Organization (ITTO). Studies on the genetics, reproductive biology and ecology of seven timber species are under way and will continue after the area is logged in 2003. Using the ECO-GENE model, the project seeks to project the impacts of management alternatives on the genetic make-up of tree populations 50 to 100 years into the future. The ECO-GENE model will be used to predict the sustainability of alternative forest management scenarios to support decision-making in the development of public policies that concern forest resources. Some possible uses include testing of:

- the use of alternative criteria for the selection of trees for harvesting;
- the impact of incorrect identification of species;
- the impact of different intensities of logging;
- the impact of different spatial distributions of logging;

- the impact of different layouts of felling coupes within the management unit;
- the impact of riverside buffer zones and permanent reserve areas;
- the impact of different scales of management, from small community forest holdings to large holdings and landscapes;
- the impact of fragmentation of forest areas;
- the usefulness of different management indicators, such as percentage of commercial tree stock retained;
- species vulnerability to harvesting practice and possible species-specific controls.

An example for the application of ECO-GENE to estimate the impact of logging and forest fragmentation on the genetic diversity of Jacaranda copaia (one of the model species) is given in the contribution of Degen et al. (this issue).

DENDROBASE – Database on the genetic system of tropical tree species

The DENDROBASE is a databank which integrates genetic and ecological data as well as results of experimental field plots of tropical tree species (Degen 1999). The basic idea is to bring together existing knowledge in order to determine, for different key species or groups of tree species, the critical thresholds of minimal stock levels after logging. Therefore the data base contains tables with information about the breeding systems, level of inbreeding, reproductive system, agents of pollen and seed dispersal, parameters of genetic variation and genetic differentiation between populations as well as information about species abundance and spatial distribution. Where no experimental data for the simulation model ECO-GENE are available, the databank serves as a basis for the generation of model input data and defines the meaningful range of model parameters.

The efficiency of the database and the significance of data analysis and evaluation of species increase with a greater level of knowledge stored in the different tables. Therefore open access of the database on a network would be the best means to build up the system. Gathering together the knowledge generated by different institutional groups would be an important step forward. Controlled operation of the databank on the internet, maintaining correct usage, is the grand challenge for the future. Even if modelling shows limitations in the future, this database by itself will be of great importance for the generation of indicators and thresholds of genetic sustainability for forest management, as well as for collecting together existing knowledge on genetic systems of tropical tree species. It will also contribute to improve the planning, coordination and prioritisation of research while improving access to existing information.

TREMA – Tree Mapping and Utilities

TREMA is a software tool being developed to manage and map tree data (http://www.trema.co.uk). It can be conceived as managing four basic types of data, species, geographic, tree and log data. It is developed in open architecture so that additional specific modules can be written and interfaced with the TREMA shell and core elements. It has many applications but core functions include the management of species names, planning and monitoring of forest harvesting, and mapping forest stand information. It is an appropriate mechanism to enable genetic and reproductive ecology knowledge to inform operational forest management (Hawthorne et al. 1999).

Field identification by common names, the normal practice in forest management, needs to correspond to scientific species identification, as species is the basis for biological reproduction and for access to technical information such as timber properties, ecology and economic value. To this end TREMA interfaces with the botanical research and the herbarium management software, BRAHMS. Species names need in turn to be related to timber trade names for marketing purposes. Cross-referencing and standardisation of names are complex but necessary steps to improve information use and management ability. The IBAMA Forests Products Laboratory have made their list of tree species of Brazil available for use in TREMA (Camargos J.A.A et al. 2001).

Tropical forest management systems are commonly based on selective logging practices. The ability to plan and monitor this selection in intensity and distribution at the species population level, within economically viable limits, is fundamental for sustainable forest management. The harvest planning module facilitates the application of multiple criteria to the forest stand information to determine selection of trees to be felled (harvested) or reserved.

The criteria used to select individual trees depend on factors such as local logging regulations; the current market for the forest produce, and short and long term economic and ecological considerations. Information on the actual harvest result in terms of which trees where actually felled can be incorporated for the monitoring of operational efficiency. Log production can be related to tree harvesting, creating the potential to evaluate economic results and trace chain of custody to the processing industry. Stand tables and harvest reports for management planning can be produced

Integral to the harvest planning module is the capability to display information spatially using maps. These have many applications e.g., to analyse spatial distribution during tree selection, to plan extraction routes, or as basis for the operational control of tree felling and extraction operations.

Dendrogene impact pathways

Providing tools which offer the potential to take account of genetic and ecological evidence in policy and operational decision-making is the core activity for the Dendrogene project. However the project is also concerned with the pathways by which this potential will be realized. This is conceived in three steps:

- Participatory development of alternative policy and management scenarios
- Analysis of ecological sustainability impacts of alternative scenarios
- Participatory assessment of ecological impacts and examination of trade-offs with social and economic impacts

The success of this effort depends on an effective communication programme based on establishing effective two-way communication channels with key stakeholders. Many of the incentives to establishing effective communication are beyond the project's control e.g. legislative context, but such risks are minimized using a strategy of cooperation allied to a clear vision of the project's role in the broader sectoral and regional development scenario.

Acknowledgements

The authors acknowledge the Organising Committee of the Symposium for the opportunity in presenting this project overview, and for Dr. Namkoong and all participants´ contributions during Dendrogene Workshop in Belém-Pará, Brazil, in May 1998. The first author sincerely expresses his appreciation to Dr. Namkoong for all the growing opportunities he has been exposed to during the doctorate degree (and afterwards) under his guidance. The critical thinking, respect and support for contributions of others, made a tremendous impact on him at the personal and professional level.

The authors also express their thanks to DFID and Embrapa for the financial support of the project as well as to all members of the project team and partners for their participation in the project with special mention to Peter Coventry for his work in establishing the Tapajós field site. We are also grateful to Lyn Loveless for her constructive comments on a former version of this manuscript.