The state of forest genetic resources in the world: feasibility study and work options

by

Michel Bariteau
INRA-Avignon, France

December 2004
Background

This paper was prepared for and presented at the 13th Session of the FAO Panel of Experts on Forest Gene Resources, 10-12 November 2003, Rome, Italy. The report of the Panel is available on line at www.fao.org/forestry/site/3484/en.

Disclaimer

The Forest Genetic Resources Working Papers report on issues and activities in related to the conservation, sustainable use and management of forest tree genetic diversity. The purpose of these papers is to provide early information on on-going developments in the field, and to stimulate discussion.

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. As a Working Paper, this document does not necessarily reflect the views of FAO.

Comments and feedback are welcome.

For further information please contact:

Pierre Sigaud, Forestry Officer (Forest Genetic Resources)
Forest Resources Division
Forestry Department
FAO, Viale delle Terme di Caracalla
00100 Rome, Italy
Fax: + 39 06 570 55 137
Email: pierre.sigaud@fao.org

For quotation:

Executive Summary

The objective of this report is to study the feasibility of an evaluation of the state of the world’s forest tree genetic resources (FTGR). As the project only covers trees, the talk will be about FTGR. FTGR represent not only an intersection between science and techniques but also epitomize global concerns about biodiversity, particularly in the framework of the Convention on Biological Diversity (CBD). There are various reasons why a project on the state of FTGR would be desirable.

FTGR are defined as the set of forest trees that has an effective or potential value as a reservoir of genetic diversity. Genetic diversity is the genetic variation within a population or a species, and it is knowledge of genetic diversity that allows differentiation between FTGR and forest resources as a whole.

The technical feasibility of the project thus depends on the availability of indicators and estimators of genetic diversity. Various authors have underlined the scant information available on indicators of forest trees. Two broad categories of methods exist, however:

- Direct methods that allow evaluation of genetic diversity in the field through comparative trials, or comparison tests in semi-controlled conditions (nursery, greenhouse …) and/or with the aid of molecular markers.
- Indirect methods that use ecological indicators to help understand genetic diversity, including:
  - Genegeological zonation, which uses variability in ecogeographical origin to define populations a priori differentiated at the genetic level within species; and demo-genetic indicators, which are obtained by comparing demographic parameters with data resulting from molecular analysis, and allow the evaluation of human impacts on the genetic evolution of forest populations.

The outputs from FAO’s initiatives to assess the world status of genetic resources for cultivated plants and domestic animals show that they deal with heavy and formal intergovernmental processes. They are accompanied by a worldwide action plan. In these sectors, resources and genetic resources are the same. The processes involved in assessing genetic resources serve de facto to support the evaluation of resources in the wider sense and to focus attention on conservation and sustainable utilization of all resources, including genetic diversity, at the international level. In these two cases, information systems exist to support the process.

The economic and political stakes associated with genetic resources are considerably weaker for forest trees than for cultivated plants or domestic animals. A huge project equivalent to the one that evaluated the status of the world’s plant genetic resources for food and agriculture would be hard to justify. However, a process of evaluation already exists for world forest resources involving the participation of more than 160 countries, to which the FTGR evaluation project could be valuably coupled.

Various technical options are listed to aid in planning future work on FTGR. With regard to assessing the status of genetic diversity, the central role of traditional methods is underlined (defining populations within-species with the help of ecogeographic variation, estimating adaptive genetic diversity with the help of comparative trials), in addition to the potential role of new methods (using through-put genotype screening, demo-genetic modeling).

Information on FTGR already exists and is provided by a number of international and national agencies, including FAO, particularly through the REFORGEN database. The planned project would allow subsequent development in this field. However, problematic issues should be addressed in a multidisciplinary way, rather than using approaches centered on forest genetics. Concerns relating to biological diversity, the environment and sustainable development, in addition to developments in the cultivated plants sector, should be taken into account, because the forestry sector is not alone in influencing FTGR in a perceptible manner. In fact, a strategic approach involving many players is necessary to generate an over-arching vision and to create policies that are no longer purely forestry-focused but are largely inter-sectoral.
# TABLE OF CONTENTS

1. Introduction ....................................................................................................................................1  
   1.1 General objective......................................................................................................................1  
   1.2 Specific objective and expected outputs of the document ....................................................1  

2. How are forest tree genetic resources defined? ...........................................................................2  

3. For what and for whom should the state of forest tree genetic resources be established? ....3  

4. Is the production of a global status report on forest tree genetic resources feasible? ..........5  
   4.1 Lessons from the development of status reports for cultivated plants and domestic animals ............................................................5  
   4.1.1 Cultivated plants ...............................................................................................................5  
   4.1.2 Domestic animals ..............................................................................................................6  
   4.2 Any lesson? ...............................................................................................................................6  
   4.3 Comparisons with the forestry sector ....................................................................................8  
   4.4 What about fish resources? .....................................................................................................9  

5. What are the work options? ........................................................................................................10  
   5.1 Global strategy .......................................................................................................................10  
   5.2 Content of the product to be developed ...............................................................................11  
   5.3 Information to collect.............................................................................................................12  
   5.4 Priority species .......................................................................................................................12  
   5.5 Levels of genetic diversity ......................................................................................................12  

6. General conclusions .....................................................................................................................13  

Annex I: Selected references ...........................................................................................................15  

Annex II: Consulted websites .........................................................................................................17  


Annex IV: Recommended Plan for National Reports in the framework of the development of a State of the World’s Animal Genetic Resources ..........................................................19  

Annex V: Relationships between forest and genetic processes and their indicators ...............20
1. INTRODUCTION

This study was carried out 15-25 July 2003 at the request of FAO. The mandate was as follows:

1.1 General objective

The objective of this study was to assist in the preparation of the next session of the FAO Panel of Experts on Forest Genetic Resources (which deals with forest tree genetic resources or FTGR), which will take place in Rome in November 2003. FAO’s plan is to propose to the group the feasibility of a project to evaluate the state of the world's FTGR.

The aim of this worldwide evaluation would be to produce as factual a global status report as possible by collating accurate data from countries, and reorganizing and formatting this by geographical regions and by species.

Thematic studies would complete this assessment (on biotechnology, genetically modified organisms (GMOs), international trade in forest seeds ...). The intended results of the project would be:

- To provide decision makers with statistical concrete data on the current status of FTGR, and also indications of future possible changes;
- To highlight the field of FTGR and help define possibly broad strategies for utilization and conservation (and perhaps research), while taking into consideration global concerns, especially those defined in international conventions (on biodiversity, sustainable development ...);
- To carry out monitoring and risk evaluation;
- To strengthen the interest of the international community in FTGR through the provision of reliable data.

1.2 Specific objective and expected outputs of the document

- To study the feasibility of a worldwide evaluation project by comparing data and experiences drawn either from the forest sector or from other fields (cultivated plants, fish and domestic animals ...).
- To outline different options for the development and formulation of the intended project for consideration by the expert group at its meeting in November 2003.

This document constitutes neither a thorough study of the issue of FTGR, nor a feasibility study in the classical sense of the term. Its purposes are:

- To describe briefly the framework in which the project would be formulated;
- To examine some elements of comparison drawn from experiences in other sectors (cultivated plants, domestic animals)
- To propose technical work options (excluding costs of conducting the project and organizational problems).
2. HOW ARE FOREST TREE GENETIC RESOURCES DEFINED?

The following definitions are taken from Article 2 of the Convention on Biological Diversity (CBD) ([2] and www.biodiv.org).

| Genetic resources: | “Genetic material of actual or potential value.” |
| Genetic material: | “Any material of plant, animal, microbial or other origin containing functional units of heredity.” |
| Biological diversity: | “Variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” |

The genetic material is sometimes considered as the hereditary message itself, transmitted by DNA in plants, but this is generally equated to the plants that carry the message.

The study will talk about FTGR (i.e. forest tree genetic resources) to prevent confusion about the objective of the project, which is not intended to describe the status of biological diversity in forest ecosystems. FTGR are defined here as the set of trees having an actual or potential value as a pool (reservoir) of genetic diversity. The IUFRO-FAO definition of forest genetic diversity says: “The genetic variability within a population or a species is an aspect of biological diversity. Genetic diversity can be assessed at three levels: (a) diversity within breeding populations; (b) diversity between breeding populations; and (c) diversity within the species.” ([http://iufro.boku.ac.at/silvavoc/glossary/](http://iufro.boku.ac.at/silvavoc/glossary/))

The notion of value has to be considered in a very broad way, all the more so since economists underline the importance of option values in the case of forest trees. “Economists recognize two main types of value: use values and non-use (existence) values. Use values may be further sub-divided into those available for known and immediate uses and those, which might become available in the future (option values). While the direct use value of the genetic diversity in forests can be best measured with respect to the few most marketable species, the option value of species not currently in demand may be quite high” [3].

Beyond the known or unknown economic values of use, FTGR also encompass ecological, ethical and religious values. Economists talk about ‘total value’ to integrate the set of values within a single concept. Finally, forest resources as a whole have an actual or potential value, and it is the knowledge of genetic diversity that allows FTGR to be differentiated from forest resources.

Various key elements can be deduced from this definition:

- The concept of species is the key entry point to establish the status of FTGR; given that we cannot reasonably work on the whole set of forest species recorded (there would be more than 100 000 according to the World Conservation Monitoring Centre [WCMC; www.unep-wcmc.org]), it would be more appropriate to explain the concept of ‘important’ or ‘priority’ species explicitly.

- We can talk about FTGR as distinct from forest resources only when knowledge on the diversity within species is available; there has to be consideration of the availability, pertinence and applicability of estimators or indicators of genetic diversity within species.

- FTGR are not limited to improved species (of which there are few in the forest environment), and resources are essentially present in natural and less-human exploited ecosystems (in comparison with agrosystems); this ecosystematic dimension should be taken into consideration.
3. FOR WHAT AND FOR WHOM SHOULD THE STATE OF FOREST TREE GENETIC RESOURCES BE ESTABLISHED?

Forest ecosystems contain a large proportion of the biological diversity found in terrestrial ecosystems. Forest trees belong to the structural species of these ecosystems and their genetic diversity is a guarantee of stability and continuity against multiple biotic and abiotic pressures generated by a changing environment. They are also the origin of diverse goods and services for the human populations, being utilized either directly (where diversity is expressed as worthwhile characteristics for immediate use: size of grain or fruit, characteristics of bark and wood ...) or indirectly (the resource is extracted in the form of material for reproduction, which will eventually be used in forest plantations, after genetic improvement).

While not directly generating substantial economic benefits at the level of the planet in comparison to agricultural production, forest resources are at the heart of huge planetary concerns (biodiversity, desertification, water management ...) [16]. However, no assessment of the state of the world’s FTGR exists. The State of the World’s Plant Genetic Resources for Food and Agriculture, published in 1998 by FAO [5] excluded forests from its field of investigation. It is thanks to the work conducted by FAO, with the participation of more than 160 countries, that an evaluation of the world’s forest resources is conducted regularly and illustrates the status of biological diversity indicators. However, this initiative does not give information on the genetic diversity of forest trees [15, 20], and a number of reports has underlined the scant information available on the genetic diversity of forest trees [21, 23, 24, 26].

The CBD covers forest genetic resources. It adopted a work program on forest biological diversity in 1998, which integrates the issue of genetic resources in the more global framework of concerns about sustainable management of forests and conservation of biological diversity.

The three fundamental objectives of the CBD are:

- Conservation of biological diversity
- Sustainable use of its components
- Fair and equitable sharing of the benefits arising from the utilization of genetic resources

During the 6th Conference of Parties to the CBD held in The Hague in April 2002, decisions were adopted with recommendations for sustainable utilization of forest biological diversity [2]: in particularly, Decision VI/22 - Expanded program of work on forest biological diversity; Program Element 1: Conservation, sustainable use and benefit-sharing; Goal 4: To promote the sustainable use of forest biological diversity; Objective 4: Develop effective and equitable information systems and strategies and promote implementation of those strategies for in situ and ex situ conservation and sustainable use of forest genetic diversity and support countries in their implementation and monitoring:

a. Develop, harmonize and assess the diversity of forest genetic resources, taking into consideration the identification of key functional/keystone species populations, model species and genetic variability at the deoxyribonucleic acid (DNA) level.

b. Select, at a national level, the most threatened forest ecosystems based on the genetic diversity of their priority species and populations and develop an appropriate action plan in order to protect the genetic resources of the most threatened forest ecosystems.

c. Improve understanding of patterns of genetic diversity and its conservation in situ, in relation to forest management, landscape-scale forest change and climate variations.

d. Provide guidance for countries to assess the state of their forest genetic resources, and to develop and evaluate strategies for their conservation, both in situ and ex situ.

e. Develop national legislative, administrative policy measures on access and benefit-sharing on forest genetic resources, taking into account the provisions under Articles 8(j), 10(c), 15, 16 and 19 of the Convention on Biological Diversity and in conformity with future decisions of the Conference of the Parties, as appropriate.
f. Monitor developments in new biotechnologies and ensure their applications are compatible with the objectives of the Convention on Biological Diversity with respect to forest biological diversity, and develop and enforce regulations for controlling the use of genetically modified organisms (GMOs) when appropriate.

g. Develop a holistic framework for the conservation and management of forest genetic resources at national, sub-regional and global levels.

h. Implement activities to ensure adequate and representative in situ conservation of the genetic diversity of endangered, overexploited and narrow endemic forest species and complement the in situ conservation with adequate ex situ conservation of the genetic diversity of endangered, overexploited and narrow endemic species and species of economic potential.

It is interesting to compare the goals included in this Objective with those listed by FAO during the development of a study on the state of animal genetic resources ([11] and K. Hammond, FAO-AGAP, personal communication):

- to analyze data related to animal breeds in order to determine the state of the world’s animal genetic resources;
- to assess the state of each country’s policies and traditional and new technologies in relation to its capacity to manage, develop and protect these essential resources;
- to identify national priorities for immediate action;
- to strengthen the capacity of each country to manage its resources.

In the global evaluation of animal genetic resources, the developmental nature of the study is seen as an effective approach to be implemented at the country level: developing awareness of the value of resources, then building new capacities for the evaluation of these resources, and ultimately being able to define new strategies and policies, etc. This same ethos is clear in the Decision VI/22 of the CBD, above, and could serve as a framework for the implementation of a project on the state of FTGR.

The forest project has, however, to be simpler (the available means and the strategic stakes are not really of the same order). However, a project not just conceived \textit{per se} but formulated as a process seems to be a useful and effective approach. The first clients of this project would also be the principal actors, in other words the participating states. The dynamics created by such a project could serve most of the objectives listed above in Decision VI/22 of the CBD: updating reference data of countries in order to gain a clear picture of FTGR, stimulating awareness in member states of the issues linked to the management and conservation of FTGR, reflecting on existing policies and assisting in the definition of new strategies and their implementation.

In addition to the political decision makers, the community of researchers in forest genetics should also show marked interest in FTGR. It should help in adapting research strategies to the reality and needs of development, considering the position of modern forest genetics, particularly in the context of the major challenge presented by the rapid development of biotechnologies.

Finally, information of this kind delivered by FAO should be widely distributed beyond the country level to reach the individual citizen. A new opportunity for developing public awareness of issues concerning the protection of the living heritage should be envisaged.
4. IS THE PRODUCTION OF A GLOBAL STATUS REPORT ON FOREST TREE GENETIC RESOURCES FEASIBLE?

It is always possible to produce a status report, so long as the measures invested are related to the objectives of the project. It is also true that current efforts involved in this type of study depend on the economic stakes involved, which depend more or less directly on the economic values of the resources. The annual global trade in agricultural seeds is estimated at about US$ 45 000 million [5]. The equivalent figure for the forest sector has not been calculated at the international level, and is probably not as significant; some specialists even doubt the commercial viability of the trade in forest seeds [22]. As we have already noted, FTGR are at the heart of a number of global concerns, and generate goods and services for humanity with very high total values (could we but calculate them). The cost of the project will not be addressed here, but it is reasonable to suppose that a country’s stakes in FTGR are such that means could be tapped to finance it.

Comparisons with how status reports have been produced in other fields such as the State of the World on Plant Genetic Resources for Food and Agriculture (SoW-PGRFA) (www.fao.org/ag/) and the State of the World’s Animal Genetic Resources Process (SoW-AnGR) (www.fao.org/DAD-IS/) could provide useful lessons.

4.1 Lessons from the development of status reports for cultivated plants and domestic animals

4.1.1 Cultivated plants

The FAO Conference, at its 26th Session, agreed that a first report on the state of the world’s plant genetic resources for food and agriculture should be developed, as part of the Global System on the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture. At its 27th Session, the Conference agreed that this should be done through a country-driven process under the guidance of the Commission, in preparation for the Fourth International Technical Conference on Plant Genetic Resources, held in Leipzig, Germany, in June 1996. The preparation of a report on the state of the world’s plant genetic resources, and its adoption at an international technical conference, were also recommended by the United Nations Conference on Environment and Development in its ‘Agenda 21’ and supported by the Conference of the Parties to the CBD.

The report was to describe the current state of plant genetic resources for food and agriculture, at the global level, and identify gaps and needs for their conservation and sustainable utilization, as well as for emergency situations, thereby laying the foundation for the Global Plan of Action to be adopted by the International Technical Conference.

The report on the state of the world’s plant genetic resources was developed through a participatory, country-driven process. This process resulted in the preparation and submission of 151 country reports by governments. Eleven sub-regional meetings were held at which 143 governments and a number of international and non-governmental organizations were represented.

FAO had access to the World Information and Early Warning System (WIEWS) on Plant Genetic Resources for Food and Agriculture (PGRFA) during the preparation of the report (http://apps3.fao.org/wIEWS). FAO also used data on plant genetic resources obtained from questionnaires and the results of a number of scientific workshops held in support of the preparatory process for the International Technical Conference.
FAO established its first ‘electronic conferences’ on the Internet, enabling scientists and others to provide technical inputs and discuss numerous matters of relevance to this report. FAO also benefited significantly from the assistance of individual centres of the Consultative Group on International Agricultural Research (CGIAR), in particular, the International Plant Genetic Resources Institute (IPGRI).

FAO had access to data from a separate questionnaire on forest genetic resources, which was sent to all heads of forest services in member countries. However, having reached no consensus on integrating forest trees in the process (N. Murthi Anishetty, personal communication), data obtained from questionnaires returned to FAO were used as a principal source of information on forest genetic resources for the database REFORGEN.

4.1.2 Domestic animals

The State of the World’s Animal Genetic Resources (SoW-AnGR) process is currently in development. The national reports, which it will include, are intended to contain strategic policies for use in the planning and implementation of national priority activities and the identification of a country's needs, in terms of resources, in order to undertake effective action. Moreover, the national reports will serve as reference documentation for the development of a report on strategic priority actions at the regional and global level and subsequently for the first global report on SoW-AnGR. The national reports should follow the Directives for the Development of National Reports, which have been agreed upon, and call for consideration of the state of all important genetic resources relating to animal breeding in each country, the state of understanding and national capacity to manage these resources, and national priorities and needs for action to be undertaken. The preparation of the national reports will facilitate the development of a complete data bank for use in planning and action implementation, and in the formation and strengthening of capacities for each country.

The long term goal of the SoW-AnGR process for countries and regions is to use the analyses included in the national reports to plan and implement appropriate management strategies to understand the role, value and use of the development and conservation of genetic resources for breeding animals, the responsibility for which lies within each country.

A Training Manual serves also as a source of reference for documents including those developed during regional and national workshops in the framework of the SoW-AnGR process. Finally, the process of report preparation relies on the information system DAD-IS (Domestic Animal Diversity Information System; www.fao.org/DAD-IS). A module of the system was created to assist in the preparation of national reports.

An outline report for SoW-PGRFA is presented in Appendix 3, and the plan recommended for the national reports in the framework of the SoW-AnGr process is presented in Appendix 4.

4.2 Any lesson?

In these two experiences, we can see how heavy, intergovernmental processes rely on an international convention, namely the CBD, whose fundamental principles (conservation of biological diversity, sustainable use, fair and equitable sharing of benefits) they repeat. A strategic dimension is added because the information obtained is to be used to determine/direct action: the report on the state of genetic resources is thus a document that exists to back up the implementation of a global action plan. In the case of SoW-AnGR, it is the process of development itself which is conceived as a vehicle for the implementation of policies and strategies within each country.

The development processes start at the national level, once the countries’ agreement to participate has been secured; they provide for a standard for training, harmonization and cooperation through seminars at the regional level, expert intervention at different levels and finally the drafting of successive synthesis reports by ad hoc secretariats of FAO.
The documents are submitted to the Commission on Genetic Resources for Food and Agriculture (CGRFA) and for the approval of participating states at intergovernmental conferences. In the fields of both cultivated plants and domestic animals, there is a similarity between resources and genetic resources and this focuses the attention of the countries, to the point at which they reach international commitments. The economic stakes underlying this whole process are likely to be determinant in the dynamics.

In both cases, an information system is used. This is generated by reorganizing the assembled information, but this also becomes a source of information for the development of reports, which eventually become modules adapted to the needs of the project.

The content of the ‘states’ documents is very similar (for SoW-AnGR, the directives of national reports define the final product). The key elements are the following:

- State of genetic diversity;
- Threats and biosecurity;
- Conservation (*ex situ* and *in situ*);
- Use; genetic improvement; economy of networks;
- Local, national and international policies and cooperation;
- Access rights; fair and equitable sharing of benefits.

The descriptors of genetic diversity are global and allow countries to complete their inventories without any need for sophisticated scientific thinking. The evaluation levels are, respectively:

For plants:
- Wild species
- Landraces/old cultivars
- Advanced cultivars/breeding lines
- Other types

For animals:
- Locally adapted breeds
- Recently introduced breeds
- Long-established imported breeds

National reports could certainly contain more information. In the case of animals, the information system DAD-IS is used and expanded during inventory completion.

A key feature (N. Murti Anishetty and K. Hammond, personal communications) lies in the clear definition of concepts from the outset of the process (establishing common terminology, definitions ...) together with the necessity of these being shared by each set of countries (training and harmonization at the national and regional level). In the case of domestic animals, major efforts have been made during this phase [9, 11]. The quality of databases is thus fundamental, in addition to their standardization, for ease of information assembly and to obtain credible results. It is always preferable to have fewer well documented data than many less credible data at the international level.
Finally, the process for establishing the state of these genetic resources appears to take a heavy and mainly political intergovernmental rather than technical approach. However, in order to conduct successfully such complex processes, adequate technical inputs are as important as the will of each country to participate in and finance such endeavor.

4.3 Comparisons with the forestry sector

Notions of genetic resources for forest trees and cultivated plants are not homologous. The status of genetic resources in agricultural systems and in forest practices have been compared by F.T. Ledig (see: 'Agricultural models and forestry practice' in [26]):

- Forest trees, even partially domesticated ones, are less differentiated from their populations of origin than are cultivated plants, whose origins are lost in prehistory;
- Forest trees and ecosystems have values other than usage values;
- The very long forest cycles give weak returns on investment, in terms of both cultivation and protection;
- Forest management is conducted *in situ* (it is essentially based on natural regeneration); agriculture systems are models of culture and conservation *ex situ*;
- The domestication of forest trees started with the evaluation of genetic resources (by comparative trials) while in agriculture it started with the collection, distribution and accumulation of resources.

In cultivated plants, resources and genetic resources are identical. Implicitly, while compiling an inventory of different cultivated varieties, we establish categories of genetically homogeneous material within each variety that can be differentiated. Taken to the extreme, this means that no supplementary information on genetic diversity is necessary for a variety to be added to the inventory of genetic resources (this could be the case for local varieties which have high value as genetic resources but for which we have limited information, or even for wild relative species (‘wild relatives’), which we know are genetically different *a priori* from cultivated species1). In the case of domestic animals, the situation is comparable, the base inventory being that of ‘races’.

Only 5% of the world’s surface consists of forest plantations [6]. The rest, in other words by far the majority, is a reservoir of genetic diversity of forest tree species that could be considered to be in a state close to that of wild species, governed by the general rule of natural regeneration. Thus for forest trees there is a difference between resources and genetic resources, but the distinction between them is limited, unlike cultivated plants, by knowledge of genetic diversity. In this sense, all reports on the state of forest resources that do not explore diversity within species cannot be considered to contribute to knowledge of the state of genetic resources (see the discussion in the first section of this document on the definition of FTGR); this is the case for the report on the state of forest resources (FRA) published by FAO.

This realization makes clear the necessity of ascertaining the state of FTGR. But the obstacle to achieving this is the fact, unanimously acknowledged, that indicators and estimators of genetic diversity are inadequate. The simpler methods that have been suggested assume that the level of genetic diversity is directly proportional to the area occupied by the species. This reasoning is very pragmatic because it would allow the inventory of FTGR to be extrapolated from the inventory of forest resources. Unfortunately, there are numerous examples in scientific literature to show that this hypothesis does not correspond to reality.

**Given these conditions, the technical feasibility of the project relies entirely on the availability of indicators of genetic diversity.**

---

1 Recent publications have shown, however, that a very small number of genes could differentiate the domesticated varieties from ‘wild’ varieties.
F.H. McKinnel [23] reviews the different types of indicators of genetic diversity proposed in the literature. He underlines the quality of scientific work conducted in this subject, particularly that of Namkoong et al. [24]. However, he criticizes the applicability of these indicators in the field, arguing that human action influences the genetic evolution process by ecological mechanisms essentially of a demographic nature: phenology, seed dispersion, etc. (see Appendix 5). The use of these parameters requires complex and costly parameters of verification ('verifiers'), which in turn demand high level scientific competencies and laboratories of molecular biology (parameters of verification are of two types: demographic and molecular). McKinnel also underlines the fact that recent studies generally omit to include the genetic diversity of forest plantations.

Graudal et al. [21] proposes a very pragmatic method largely calling for comparative studies to crossing-reference results obtained using genetic markers with those from characterizations of ecogeographic variation and 'genecological' zonation. The authors underline the potential of comparative plantings for evaluating adaptive diversity, although the molecular markers used until now have been 'neutral'. They describe the methods that could be used to establish defined genecological zones, areas that are uniform enough in terms of ecological conditions for it to be presumed that genetic and phenotypic characters are homogeneous within each zone.

This concept of a species consisting of a series of populations adapted by selection to local and edaphic conditions is well established [26]. It has stimulated the development of experimental methods since the 18th century based on planting trees of different origins in the same environment, so that the genetic component of variation is revealed. The high level of differentiation observed in the adaptive genetic diversity among populations, especially for growth capacity, largely justified the development of forest genetics in the 20th century, by adding to foresters' awareness of the necessity of conserving the genetic diversity of forest trees – and this was before the Rio Conference. It would seem now that traditional experimental techniques have been largely replaced by those of molecular genetics in research laboratories, such that the level of knowledge of diversity in situ (of ecogeographic origin) and adaptive diversity (assessed in comparative trials) has tended to stagnate, and even to regress where such knowledge is not passed on, or only partially so, from one generation of researchers to the next.

The methods used to test diversity in semi-controlled conditions also detect valuable indications of adaptive genetic diversity. In particular, modern methods of ecophysiology, such as isotopic methods, allow large numbers of samples to be tested and thus representative samples of entire populations can be screened; for example, this method can be used to discriminate between carbon isotopes to evaluate the genetic variability and geographical origin of efficient use of water.

4.4 What about fish resources?

The issues linked to fish and forest resources are paradoxically similar. The two sectors contain resources that are mainly ‘wild’ and non domesticated, including a large number of species with economic, social and very different ecological values, for which technical and political problems of sustainable management are posed. The systems of artificial culture (aquaculture, forest plantations) have evolved rapidly and contribute increasingly to the creation of standardized products demanded by industry. Biotechnologies offer many potential applications in both sectors but also raise environmental questions. It should be noted that in the area of protection against biological risks (biosecurity), the fishing sector is way ahead of the forest sector.

A report on the state of the world’s fisheries and aquaculture is published every two years by FAO (SOFIA = State of the World Fisheries and Aquaculture; www.fao.org/sofia/). A surge of growth in knowledge on the genetic diversity of aquatic animals is taking place. Consultancies have been conducted by FAO to study the feasibility of creating an information system on the genetic diversity of aquatic animals [25].
In fact, databases already exist in this field, which include such information on genetics as is available. It is ultimately a meta-database that would be necessary because these subjects are well studied. The database FishBase is particularly well documented (with information on more than 25,000 species) and user-friendly (www.fishbase.org/). The cross-referencing of species × countries is facilitated by synthesis tables. A table of genetic data is also available for each species, and information on the availability of genetic markers is backed up by literature references.

This system of providing literature references for genetic information is in the process of development for FAO’s forest databases (Foris), with which REFORGEN is being progressively integrated (Magnus Grylle, FAO-FONL, personal communication). This process allows effective validation of data contained in the databases.

5. WHAT ARE THE WORK OPTIONS?

Options could be envisaged for the establishment of the FTGR inventory task:

- At the level of global strategy
- At the level of document content development
- At the level of information collection

5.1 Global strategy

Two types of approach are possible:

- The ‘top down’ strategy: this consists of mobilizing a number of experts to reorganize all existing information and establish an ‘expert’ synthesis. This is simple to implement in theory, and is actually used in the case of FAO Expert Panel of Experts on Forest Genetic Resources (even though the information generated is not necessarily statistically documented and is produced at the level of eco-regions rather than countries. In the framework of a global evaluation, such a strategy does not necessarily include the participation of states, which could considerably weaken it, either because the document would not be welcome to certain countries or because it would not raise significant interest and, consequently, would not lead to the planned capacity building.

- The ‘bottom up’ strategy: consists of starting in the field; in other words, using information gathered at the country and regional levels; one variation of this approach would be to associate the process with an evaluation of the world’s forest resources, a forest resource assessment (FRA); the alternative would be to uncouple the two processes. In both cases, the ‘bottom up’ process is more arduous than the ‘top down’ option. However, it has all the advantages of a participatory approach. The ‘bottom up’ approach coupled with FRA appears to be the most pragmatic/feasible option. It would allow a focus on technical aspects, while benefiting from the political dimension of FRA, especially the policies and strategies of protection and conservation addressed by FRA in the framework of conservation and biological diversity.
Table 1. Analysis of weak and strong points of strategic approaches.

<table>
<thead>
<tr>
<th></th>
<th>Ease of technical implementation</th>
<th>Political weight of the process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top down</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Bottom up coupled with FRA</td>
<td>+ or –</td>
<td>++</td>
</tr>
<tr>
<td>Bottom up not coupled with FRA</td>
<td>–</td>
<td>+</td>
</tr>
</tbody>
</table>

5.2 Content of the product to be developed

The content could be global, correspond to that presented in the ‘states’ produced for cultivated plants and domestic animals:

- State of genetic diversity;
- Threats and biosecurity;
- Conservation \((ex \, situ \, and \, in \, situ)\);
- Use; genetic improvement; economies of the sectors;
- Local, national and international policies and cooperation;
- Access rights; fair and equitable sharing of the benefits.

According to which strategy is chosen, the ‘political’ part could be linked to FRA, or not. We could therefore imagine two scenarios:

- The state of FTGR as one chapter of an FRA product
- The state of FTGR as a stand-alone document

Producing a ‘state’ of FTGR may entail more than a single product; it could include a set of documents and other media materials. In any case, a study on FTGR could expand FRA and other FAO synthesis publications (such as that on the state the world’s forests). The subject seems important enough (see section 3) to justify a ‘state’ of FTGR as a comprehensive set of resources. In addition, the experience gained from evaluating cultivated plants and its evolution show that many real concerns about current trends exist, beyond the inventory aspect, and some themes would benefit from special consideration [7]: biosecurity, biotechnologies, indicators of diversity, human heath...

Thus an evaluation of the state of FTGR could address more issues than the themes listed above, including:

- The role of biotechnologies; prospective;
- The importance of GMOs in modern forestry;
- Forest plantations and genetic diversity;
- The role and future of forest seed centres;
- Indicators of genetic diversity; knowledge to gain;
- Insecurity: genetic pollution, invading species, phytosanitary protection.
5.3 Information to collect

Numerous data already exist at FAO, especially due to the work conducted by the Division of Forest Resources with the support of a panel of experts on forest genetic resources. The information systems Foris and REFORGEN, to be merged later, capitalize on a section of this data; they are in the process of being modernized and updated. No matter what the chosen strategic options are, the information already available should be taken into consideration, at least to avoid unnecessary requests to the states for this information. The harmonization and validation of data are essential to ensure the credibility of the synthesized product. The role of experts and the work to be conducted at the regional level is therefore equally important. This has added importance because the biological scale used to consider priorities concerning FTGR is based on the area of natural distribution, which is very often compatible with a region or sub-region of the world.

The key entry point for genetic diversity is the species, but information gathering should aim at the level of intraspecific diversity. It is therefore necessary to define priority species and the levels of diversity to be targeted.

5.4 Priority species

The diversity of forest tree species at the global level is such that we do not possess a precise figure of their number. This is thus another difference compared to the agriculture world: only 30 species of cultivated plants feed the world and 120 have an importance at the national level [5].

Lists should be established of priority species in relation to FTGR. Different methods exist. The FAO expert panel used, as an interim measure, a non-defined criterion of ‘expert’ importance. A definition proposed by Graudal et al. allows a more formalized approach. The criterion emerging from their definition (and which is accepted by other authors as well) is the actual or potential use of the forest tree species. Graudal et al. define three ways of assessing the priorities:

- By inventory of planting areas and value of products;
- By inventory of marketed products;
- By evaluation of user preference.

They add three other categories of species that are potentially useful:

- Precious species with high value but which contribute little to the global economy simply because they are rare;
- Locally used species that are not traded at high prices on international markets;
- Endangered species.

5.5 Levels of genetic diversity

Given what has been set out in the previous section, various work options are possible:

1. **Option 1**: Collect available information using the traditional information network for forest genetics: number of improved varieties, selected and/or tested forest populations, inventory of actions for *in situ* and *ex situ* conservation, commercial flow of forest seeds, on going research, existing training ...

2. **Option 2**: Option 1 strengthened by an evaluation of the geographical variability based, at the minimum, on the concept of the geneecological zone for each priority species.
3. **Option 3:** Option 2 strengthened by the evaluation of principle threats to diversity at the level of populations and species with the help of the method developed by Namkoong *et al.* [24]. This option would probably best be tested in a limited number of countries with the capacity to conduct this type of complex inventory.

Lastly, the global evaluation of FTGR could consist of cross-referencing and compiling information from many sources and at different levels:

- Geographical information at the national, eco-regional, regional and global levels;
- Genetic and genecological information at specific and intraspecific levels;
- Thematic information, with specific studies on biotechnologies, biosecurity, seed dispersion ...

6. **GENERAL CONCLUSIONS**

The principal conclusion of this feasibility study is that there are various reasons to think that a project on the state of the world’s FTGR, coordinated by FAO, in close collaboration with national and international partners, would be desirable. The feasibility of the project relies on the existence of intraspecific genetic diversity indicators with an acceptable applicability level for a global study of this type, and not requiring huge financial investments.

One of the proposed options consists of turning to genecological zonation in order to distinguish the variability within species. This method was the foundation for forest genetics. A set of empirical, traditional, geographical, climatic, ecological and soil data has been integrated and allowed foresters in the last century to trace the origin of populations tested subsequently by other researchers. Should not this method for identifying variability based on genecological zonation be the starting point for activities targeting genetic resources, and be generalized to the set of species considered as priority in the world? Forest geneticists seem to move away from these concerns, but the field of FTGR naturally requires horizontal approaches. Expert skills in disciplines other than genetics are probably called for in order to help define these zones at the national and eco-regional levels.

This approach would have the additional advantage of placing knowledge of species diversity in a broader ecological context, through knowledge of the ecosystems that provide their habitat. An eco-regional approach would be necessary to allow the comparison of information between neighboring countries. This step would be compatible with the ecosystem approach recommended by the CBD and would allow synergies to begin to be developed between forest genetics and environmental sciences.

On the other hand, geneticists are making significant progress in producing non-neutral markers and high discharge marking methods. These molecular tools would allow better targeted research on the genetics of adaptive diversity in the near future.

Research methods have been developed that allow simulation of genetic evolution of forest populations on the basis of forest interventions, thanks to demogenetic models. These could assist in transforming the methods currently aimed at describing how ecological processes lead to changes in genetic diversity to become more effective in forecasting directly the consequences of human interventions in different types of situations.

Finally, the community of forest geneticists owns an extraordinary heritage in the form of networks of comparative trials in a number of countries in the world.
This treasure is being progressively forgotten and interest is declining into indifference, even though it is the only tool capable of evaluating adaptive genetic diversity under natural conditions for the potential utilization of forest resources and thus ultimately domestication. An immediate priority would be to stimulate the interest of the international community for this type of experimental tool, whose ultimate objective is to characterize genetic resources, regardless of the potential for the use of forest products in planting programmes. The information from these trials constitutes a precious information source for conservation activities. They are themselves very often remarkable *ex situ* conservatories, yet there is no information system that collates this field trial data anywhere in the world. Databases should be developed (region by region) and initiatives stimulated to facilitate the maintenance of comparative trials, and to ensure the regular analysis and collation of data. Unfortunately, the general tendency of forest research organizations in numerous countries tends towards a progressive disuse of experimental methods, whilst managers and owners of forested land are not always aware of the importance of such collections.

In conclusion, FTGR are at an intersection between science and techniques, but also at the crossroads between global concerns on biodiversity and sustainable management of renewable resources. The issues should be addressed in a multidisciplinary way, because forestry is not the only sector influencing the development of FTGR. In fact, a strategic approach is necessary to define the vision of a group of actors and their policies, which are not purely forestry-focused, but largely inter-sectoral.
ANNEX I: SELECTED REFERENCES


ANNEX II: CONSULTED WEBSITES

FAO: www.fao.org

Commission on Genetic Resources for Food and Agriculture (CGRFA): www.fao.org/ag/cgrfa/


The State of World Fisheries and Aquaculture (SOFIA): www.fao.org/sof/sofia/


Convention on Biological Diversity (CBD): www.biodiv.org


FishBase, a global information system on fish resources: www.fishbase.org

www.millenniumassessment.org/
Millennium Ecosystem Assessment, an evaluation of ecosystems at the beginning of the millennium

Multilingual Glossary on Forest Genetic Resources (FAO and IUFRO [International Union of Forest Research Organizations]): http://iufro.boku.ac.at/silvavoc/glossary/

Danida Forest Seed Centre (DFSC): www.dfsc.dk

International Plant Genetic Resources Institute (IPGRI): www.ipgri.cgiar.org

Consultative Group on International Agricultural Research (CGIAR): www.cgiar.org


Bureau des Ressources Génétiques, France (BRG) [French Genetic Resources Board]: www.brg.prd.fr
ANNEX III: OUTLINE OF THE REPORT ON THE STATE OF THE WORLD’S PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

www.fao.org/ag/cgrfa/

Chapter 1: The state of diversity

Chapter 2: The state of in situ management

Chapter 3: The state of ex situ conservation

Chapter 4: The state of utilization

Chapter 5: The state of national programmes, training needs and legislation

Chapter 6: The state of regional and international collaboration

Chapter 7: Access to plant genetic resources, sharing of benefits derived from their use and the realization of farmer’s rights

Annex 1: State of the art

Annex 2: State of diversity of major and minor crops

Appendix 1: Status by country of national legislation, programmes and activities for PGRFA

Appendix 2: List of major germplasm accessions by crop and institute

Appendix 3: Regions of diversity of cultivated plants
ANNEX IV: RECOMMENDED PLAN FOR NATIONAL REPORTS IN THE FRAMEWORK OF THE DEVELOPMENT OF A STATE OF THE WORLD’S ANIMAL GENETIC RESOURCES

(source: http://dad.fao.org/)

Section 1 aims to assess the state of genetic resources in the domestic animals sector, and deals with *in situ* and *ex situ* conservation, resource use and techniques connected to many production systems and socioeconomic conditions for each country.

Section 2 should analyze the evolution and growth of demand in the sector of animal rearing and determine the incidence of future policies and national programmes concerning conservation and use of genetic resources in animal rearing as well.

Section 3 should examine the state of national capacities in management of genetic resources of rearing animals and establish a global evaluation of capacity building, taking into consideration future policies and programmes exposed in Section 2.

Section 4 should identify priorities for the development of better national programmes for sustainable conservation and use of genetic resources in the sector of animal rearing. The national priorities could cover many fields of action, species and animal races, as well as long and short term needs in the area of creation of research institutions, information system conception, and definition of general policies, legislations and regulations.

Section 5 should include recommendations of countries in the area of international cooperation and show fields, levels and methods for desirable cooperation, proposed contributions, as well as identified needs.

At the end of the five sections, it would be desirable to include a summary.
**ANNEX V: RELATIONSHIPS BETWEEN FOREST AND GENETIC PROCESSES AND THEIR INDICATORS**

(According to Namkoong *et al.*, 2002 [24])

<table>
<thead>
<tr>
<th>Forest Events</th>
<th>Logging</th>
<th>Grazing</th>
<th>Fire</th>
<th>Non-timber Harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic Processes</td>
<td>Drift</td>
<td>Selection</td>
<td>Migration</td>
<td>Mating System</td>
</tr>
<tr>
<td>Indicators</td>
<td>Levels of Variation</td>
<td>Directional Change</td>
<td>Migration Between Populations</td>
<td>Reproductive System</td>
</tr>
<tr>
<td>Verifiers: Demographic</td>
<td>Census Number</td>
<td>Phenotypic Mean</td>
<td>Physical Isolation</td>
<td>Parental Pool Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coefficient of Variation</td>
<td>Age/Size Class Distribution</td>
<td>Mating Isolation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Seed Germination</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Seed Dispersal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pollinator Abundance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pollen Dispersal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sexuality</td>
</tr>
<tr>
<td>Genetic</td>
<td>No. of Alleles</td>
<td>Genotypic Frequency</td>
<td>Gene Flow</td>
<td>Outcrossing Rate</td>
</tr>
<tr>
<td></td>
<td>Gene Diversity</td>
<td>Marker Frequency</td>
<td></td>
<td>Correlated Mating</td>
</tr>
<tr>
<td></td>
<td>Genetic Variation</td>
<td>Genetic Mean</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---