International Union of Forest Research Organizations

Science and Technology - Building the Future of the World's Forests

Planted Forests and Biodiversity

Contributions to the Third Session of the United Nations Forum on Forests in Geneva, Switzerland, 24 May - 6 June 2003

IUFRO Occasional Paper 15
ISSN 1024-414X

IUFRO

International Union of Forest Research Organizations
Union International des Instituts de Recherches Forestières
Unión Internacional de Organizaciones de Investigación Forestal
Internationaler Verband Forstlicher Forschungsanstalten

IUFRO Occasional Paper No. 15
ISSN 1024-414X

Printed in Austria/Imprimé en Autriche/Gedruckt in Österreich/Imprimido en Austria:

By Eigner Druck
A-3040 Neulengbach

This publication may be ordered from/Ce livre peut être obtenu de/Dieses Buch kann bezogen werden bei/Se puede pedir este libro en:

IUFRO Headquarters
c/o Federal Office and Research Centre for Forests (BFW) - Mariabrunn
Hauptstrasse 7
A-1140 Vienna-Hadersdorf
Austria
Tel: +43-1-877 0151-0
Fax: +43-1-877 0151-50
E-mail Secretariat: iufro@forvie.ac.at
Web site: http://iufro.boku.ac.at

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Science and Technology - Building the Future of the World's Forests

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Contributions to the Third Session of the United Nations Forum on Forests in Geneva, Switzerland, 26 May – 6 June 2003

Edited by
Alexander Buck, John Parrotta and Gerda Wolfrum

IUFRO Headquarters
Vienna, Austria, 2003

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- is an international scientific body founded in 1892;
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Our Vision is ...

- of science-based sustainable management of the world's forest resources for economic, environmental and social benefits.

Our Mission is ...

- to promote the coordination of and the international cooperation in scientific studies embracing the whole field of research related to forests and trees.

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Part I:

Science and Technology - Building the Future of the World's Forests

Expanded version of the Discussion Paper of the Major Group "Scientific and Technological Community" submitted to the Third Session of the United Nations Forum on Forests[1]

Prepared by the International Union of Forest Research Organizations (IUFRO), the International Council for Science (ICSU) and the Centre de Recherche et d'Action pour le Développement Durable en Afrique Centrale (CERAD) as organizing partners of the Scientific and Technological Community for UNFF-3

[1] Including the full, revised versions of the authors' contributions to the Discussion Paper

Summary

The international forest policy deliberations have made progress over the past decade in fostering political commitment for sustainable forest management. In the effective implementation of these commitments the role of science and technology (S&T) is crucial.

Policy and decision makers should take into full account the potential of markets as means for expressing the full range of values and for distributing the multiple benefits. To this end, it is of vital importance to determine appropriate absolute and relative values for the many benefits provided by forests and to include real costs of production and distribution in market prices. For this purpose, S&T should provide, and further develop, its substantive scientific knowledge on the valuation of forest goods and services, the provision of market and trade related data and information, and on market-based policy instruments.

There is a great need for policy and decision makers to adopt a universally accepted definition on forest health. In addition, more appropriate approaches should be used for monitoring and assessing forest health over the medium- to long-term in response to the various natural and anthropogenic stresses that affect forest health. S&T should provide and further improve scientific knowledge and technology addressing the broad range of factors involved in degrading forest health and productivity.

In order to be able to maintain forest cover for present and future generations, policy and decision makers need to address more effectively the various anthropogenic stresses for forest ecosystems and forest biodiversity by means of strengthened dialogue and cooperation with other sectors. In addition, impacts of forestry practices on the roles and functions of forest ecosystems should be addressed. S&T has an important role in generating substantive scientific knowledge about the role and functions of forests and the impacts of stresses, as well as new technologies for monitoring, assessment and reporting of forest resources, including remote sensing.

All these efforts require adequate institutional and human resource capacity. Therefore, the transfer of technology, improvement of education, and capacity-building continue to be important tasks.

1 Background: Science and Technology as a Basis for Sustainable Forest Management[1]

The international forest policy dialogue since the United Nations Conference on Environment and Development (UNCED) in 1992 has given shape to the multi-dimensional concept of sustainable forest management (SFM). Policy instruments have been developed in order to operationalize and further promote this multi-dimensional concept. Ten years after UNCED, the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg reiterated the important role of SFM for achieving overall sustainable development and the eradication of poverty.

However, actual implementation of SFM remains a daunting challenge, and achieving it requires that fundamental issues be addressed without delay at local, regional and global levels. Most notably, deforestation and forest degradation have continued at a rapid rate in several regions of the world, the loss of natural forests in the tropics being estimated to exceed 15 million ha every year. Moreover, concerns about the conservation of forest biological diversity have further increased over the past decade. These developments invariably also affect the availability of forest goods and services and the livelihood of people.

In order to effectively address these urgent problems, a better integration of the three dimensions of SFM, i.e. the ecological, economic and social dimension, has to be achieved through participatory and cross-sectoral deliberation mechanisms that integrate the values and needs of different stakeholders and incorporate existing and new scientific knowledge.

At all scales, the role of science and technology (S&T) is crucial. The S&T community can make a major contribution to tackling the economic, social and environmental problems connected with SFM. At the WSSD, the S&T community offered its commitment to: (i) make research more policy-relevant, (ii) include other stakeholders in broad-based, participatory approaches for a new research agenda, (iii) develop research that integrates the environmental, social and ecological pillars of sustainable development, (iv) assist in improving science education and capacity building, (v) develop strategies to bridge the North-South divide in scientific and technological capacity, and (vi) to help ensure long-term strategies and data needs. If these commitments are implemented and supported, S&T will be a basis for sustainable development. These general points are also highly relevant for UNFF-3 and the sustainable management of the world's forests.

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[1] This chapter has been prepared by Alexander Buck who co-ordinated the preparation of Part I of the IUFRO Occasional Paper and served as editor.

2 Substantive Element "Economic Aspects of Forests", Including "Trade"

Colin Price
University of Wales, Bangor, United Kingdom

Ewald Rametsteiner
BOKU - University of Natural Resources and Applied Life Sciences, Vienna, Austria

Richard Guldin
USDA Forest Service Research & Development, Washington D.C., United States

2.1 Background: Role of economic aspects of forests

Forests create multiple economic, social, environmental and other benefits for society. Forests offer food, fiber and fuel for large populations. Forests are thus central for rural development and the livelihood of people. For others, forests are important for recreation and tourism. The 2002 WSSD emphasized the importance of SFM often as a critical means to eradicate poverty. On the other hand, forests are influenced by other sectors and policies in various ways, including industry, energy, tourism, transport and trade policies.

Comprehensive SFM policies affect all three major components of sustainability - ecology, economy, and society. The linkages among these components of forest systems as well as other sectors are a complex web of interactions. Activities affecting one component invariably affect the others. In economic terms the characteristics of SFM are the recognition of diverse and dynamic preferences of people, the incorporation of various sources of value and utility from the forests, their transformation into the many products and services desired, and their consumption. This all requires multiple allocation decisions by many actors in and outside the forest sector across space and time – and sufficient information to make appropriate decisions.

The supply of forest goods and services is not without limits, nor can these goods and services to be distributed equally to all. The production and allocation of these benefits requires trade-offs and creates costs. Economics offers help in making trade-offs, whether via the market mechanism or through cost-benefit analysis. The means by which it does so is by giving an equivalent value to costs and benefits in a common, monetary unit. There is widespread skepticism about monetary valuation, particularly in relation to distributional issues and the inclusion of non-market benefit and costs. Two schools of thought are:

(a) to leave these issues to be incorporated by an overarching political process,
(b) to bring them explicitly into the economic calculus.

Markets and cost-benefit analyses may also be regarded as a means of facilitating participation since stakeholders' values can be included in the balance. Information and transparency are important aspects in this respect.

Economics also provides guidance on the means of achieving the desired balance of output: there is much written about incentives, rather less recognition that incentives structures themselves have policy implications (e.g. distributional changes) as well as policy outcomes.

2.2 Crucial issues

Given the complexity of the issues involved in forest related matters, and the differences in contexts and situations across the globe, the international forest policy dialogue has made remarkable progress over the last decade, including a widely shared understanding of SFM as overall goal, the main thematic elements that constitute this goal, and a policy deliberation mechanism, national forest programmes, to include the multiple views on forests in policy making. However, with the help of S&T, a number of key areas can be identified which seem critical for further consideration in forest policy concerning the effective, efficient and equitable allocation of costs and benefits of forests.

All values, including nature conservation, should be included in the production of goods and services. It is necessary to enhance efforts aiming at the determination of appropriate absolute and relative values for each of the many benefits, and some disbenefits, that forests provide (market and non-market). Further, the real costs of production and their distribution should be integrated and reflected in the price as far as possible, so that products are not traded where full costs of production exceed market values.

It is important to review, and if needed devise or adjust mechanisms and rules that guide the adequate allocation of the benefits provided by forests within society, and over time. This includes many aspects, mechanisms and trade-offs. It is essential to clarify property right issues and mechanisms, especially related to common property resources or open access resources and land tenure rights. At last, also adequate information bases and mechanisms for decentralized decision making, as well as adequate price building mechanisms on markets, and mechanisms for allocating non-market exchanged goods and services are of high relevance for a more effective, efficient and equitable allocation of benefits.

Another important challenge is to address trade and environment issues and to assure that trade occurs in ways that promote SFM. Here forest certification has successfully been taken up and further developed by the private sector, often with support from governmental bodies. Further work is necessary and possible to develop the full potential of this instrument for promoting trade in sustainably produced goods. However, this voluntary instrument is one amongst other voluntary economic and information instruments for strengthening SFM through market mechanisms.

There is a need to address the issue of governance, illegal harvesting and associated trade of forest products. Illegal logging occurs on all continents. It directly affects forests on their ecological, economic and social bases. The question is not only theft of goods from the rightful owner, which has an economic impact, but more broadly, the ecological and social impacts of harvesting at places (e.g., fragile soils) or times (e.g., before financial maturity) or of species (e.g., *Swietenia spp.*) inconsistent with long-term sustainable management objectives. However, unless good governance and poverty are addressed directly, little progress will be made.

Significantly more efforts are required also in the light of the commitments made at the WSSD concerning the relation between forests and poverty issues. In this context, also the socio-economic and ecological role of agro-forestry should be further considered by policy and decision makers. Reference can be made to a number of successful projects and studies addressing agro-forestry and involving the use of S&T.

2.3 The role and contribution of the S&T community

Important contributions of the S&T community so far

The S&T community has contributed substantially to make progress on several of the issues addressed by the IPF/IFF proposals for action.

An economic interpretation of sustainability and how it links with the definition of capital and with investment appraisal led to significant advances in the understanding of the sustainability concept. For example: Many economists tend to perceive sustainability not in terms of maintaining a particular ecosystem indefinitely, but in terms of maintaining a capacity for satisfying human wants indefinitely, with the possibility that the basket of wants may change through time. This may involve the replacement of natural capital (including forests) by human-made capital (such as industrial capacity). However, economists are not in agreement about how capital can be measured, other than in terms of its productive capacity, and there are also disputes about whether human-made capital is capable of replacing or displacing supplies of raw materials, and particularly of environmental services. This resulted in different conceptions of the term sustainability ranging from strict to strong to weak to metaphorical sustainability.

For the valuation of forest goods and services a scientifically sound methodical basis has already been established and further developed. Research has increasingly helped to identify the values of non-timber forest products and services. Regarding products, there is more information available today on medicinals, fungi, greenery, and items of spiritual or ceremonial interest to indigenous peoples. There has also been a substantial increase in the knowledge available about recreation and tourism values of forests and the value of clean water flowing from forested watersheds. These values should be reflected in designing and evaluating management options. However, it seems that outcomes of these valuations have not been taken up widely by policy makers. This is despite the now considerably well developed methodological toolbox of cost-benefit analysis, which includes stated preference methods (contingent valuation etc.), hedonic pricing (applied to house prices, travel costs and wages), costs of replacement or restoration of functions, and financial costs or benefits arising for third parties, to name but a few. Some of these can be used in the analysis of the role of forests and other land use forms to poverty eradication, food, water and energy supply. However, there remain unresolved disputes about methods and results. For example, the highest values suggested for carbon fixing may make it the dominant benefit of forests, while the lowest values make that role quite trivial.

When discussing the economic valuation of environmental goods and services, adequate attention also has to be given to defining the spatial and temporal scales of interest. For example, if the roles of forests for carbon sequestration or biodiversity are to be valued, one needs to consider the economic costs of climate change and biodiversity loss over the longer-term and at a global scale. At the same time, benefits derived from "watershed protection", such as the prevention of soil erosion and the modulation of downstream flooding, have to be considered in a more local context.

The Millennium Ecosystem Assessment, co-sponsored by ICSU and many other governmental and non-governmental bodies, has prepared a report on "People and Ecosystems: A Framework for Assessment and Action". In addition, ICSU is co-sponsor of four global change programs which form a basis for determining the role of forests in the global climate system and the assessment needs of the United Nations Framework Convention on Climate Change.

On the issue of market data and other information related to wood and non-wood forest products, the S&T community is strongly involved in several efforts in setting up or improving existing information systems for data collection, assessment and reporting. IUFRO has been working with a specifically assigned Task Force on the establishment of the Global Forest Information Service (GFIS), together with EFI, CIFOR CABI, FAO and other organizations. The scientific and technical community is also strongly involved in several other efforts in setting up or improving existing information systems for data collection, assessment and reporting, including in forest resources assessments, in climate change policies, biodiversity protection and other areas. ICSU is a co-sponsor of the International Global Observing Strategy which includes the Global Terrestrial Observing System. Furthermore, the S&T community is contributing significantly to the development of Outlook Studies in different regions of the world through econometric modelling and scenario techniques. Recent scientific advances in price reporting have helped improve the fairness and equity of transactions between private landowners selling products and buyers. Many private landowners still only sell products infrequently, so lack of knowledge about current markets and prices remains a serious impediment to their negotiating a fair price for their goods.

The S&T community has been very active in assisting policy makers in relation to forest certification. Scientists have likewise been key in devising instruments and mechanisms related to common property regimes; they have made major contributions to climate change mitigation policies, the efficient use of wood as a renewable resource for bio-energy, to incorporating forest aspects into rural or community development or tourism, including eco-tourism, and to devising economic or market instruments for biodiversity protection. It seems important that the scientific and technical community continues and enhances its contribution in these areas, including the analysis of costs and benefits of different options for policies and mechanisms, including for participation and community development, and revenue collection systems. An issue of rising importance is how taxation and subsidy (linked to internalizing non-market effects) conflict with free trade imperatives.

The need for further contributions of the S&T community in the future

Further contributions are needed by the S&T community in the future. Comparatively few efforts were made to document the contribution of forests to the eradication of poverty, e.g. in the context of the "Water, Energy, Health, Agriculture and Bio-diversity" (WEHAB) framework agreed upon at the WSSD in Johannesburg.

Further contributions are also needed in addressing illegal logging as well as trade and environment related issues. In this area, science can help to assure that remedies do not impose hidden costs or disincentives, compounding the adverse impact of illegal logging. For example, regulations that simply ban illegal logging may inhibit research and adoption of new forest management and reforestation techniques that have significant potential to provide a long-term remedy for the underlying issue by seeking possibilities to enable the sustainable supply of a scarce, valuable product. Trade and environment related issues constitute a complex web of values and interactions.

The result of increasing wealth and public participation in developed countries has been a move towards greater emphasis on environmental objectives. In the participatory decision framework of today environmental benefits are included in the decision making evaluation in many developed countries. Timber production is increasingly seen as an additional, but not the core value of forests. This is because few people make their living from forestry, and consumers assume that wood products will be supplied, regardless of what happens in their “local forest”. Thus not only is timber production external to the list of costs and benefits considered: it may impose externalities elsewhere, because that is where the timber is produced (perhaps by intensive and not-sustainable methods) and where negative environmental externalities (including costs of transportation) may fall.

Future supply and demand of wood and how that is (and should be) affected by environmental, economic and social constraints is an important topic area where the scientific community can make significant contributions. The problems of predicting supply and demand (or availability and needs) are well known; however, they still form the basis for a wide range of long-term investment decisions in forestry. Recent predictions of supplies have been optimistic, in line with increasing inventories in many temperate regions as well as through plantations. Nevertheless, there are new factors such as the potential effect of environmental regulations on realizable supplies, and the effect of expanding demand from such players as China in world markets. The situation is different in many tropical countries, with deforestation and degradation of natural forest ecosystems continuing, and uncertainty prevailing about whether, given technical and political constraints, plantations are capable of replacing, quantitatively and qualitatively, the range of goods and services supplied by natural forests.

The ongoing and unresolved debate about discounting (reducing the economic significance attributed to future costs and benefits) has a bearing now not just on the economics of timber production, but on the economics of long-term effects such as those of biodiversity and climate change. On the face of it, discounting is actively hostile to sustainability, and its inclusion as an analytical tool within the context of SFM should only follow on careful and particular justification.

Overall, it seems important that the scientific and technical community continues and enhances its contribution in addressing economic aspects of forests, including the analysis of costs and benefits of different options for policies, mechanisms for participation and community development, and revenue collection systems.

2.4 Proposed actions for policy and decision makers

Policy and decision makers are called upon to:

- *take into account the valuation of forest goods and services in developing forest policies. The scientific and technological community should provide scientific knowledge and technical support, and carry out further research in support of these aims;*
- *improve mechanisms to collect, store and disseminate SFM and market related data. The scientific and technological community should generate and provide scientific knowledge as well as technical support for the enhanced provision of information available to all;*
- *make best use of, and further enhance the role of research in relation to the use of economic and policy instruments to facilitate progress toward sustainable forest management as well as on trade-related aspects, especially in relation to poverty eradication, biodiversity and water protection, renewable materials and renewable energy provision, and climate change mitigation;*
- *devise policies and instruments that increase the transparency of transactions and promote sustainable production and consumption of forest products. This is critical to improving fairness and equity in markets for forest products while at the same time contributing to the overall goal of sustainable development. The scientific and technological community can help to design different policies options that are aimed at improving the current situation in both key areas.*

3 Substantive Element "Forest Health and Productivity"

Kevin Percy
Natural Resources Canada, Maritimes Region, Fredericton New Brunswick, Canada

3.1 Background: Multiple factors influence forest health and productivity

There are numerous natural and non-natural disturbances involved in altering forest capital in ecological, economic and social terms. Climate change is modifying temperature and precipitation patterns affecting species and ecosystems at the extremes of their ranges. Increasing storm frequency and intensity may result in greater loss through blow-down. The world's forests are increasingly being exposed to air pollution. Changes in fire frequency have caused changes to forest structure and carbon sink strength. Fire suppression programs in temperate/sub polar forests have often inadvertently resulted in more-intense, stand-destroying fires. In the tropics, the opposite trend is occurring. Changes in climate and air pollution levels may act alone or often interact to weaken trees rendering them more susceptible to insect attack and/or disease infection. Invasion of alien species has in the past decimated native plant species and increasing globalization is likely to increase this. Consequences of increasing fragmentation of forests may range from gene pool modification to species loss. Furthermore, past and present management activities influence future forest health and productivity.

The relevant proposals for action of the Intergovernmental Panel on Forests (IPF)/Intergovernmental Forum on Forests (IFF) give particular emphasis to air pollution as a major threat to forest health. Among air pollutants affecting forest health at supra-national scales, ozone is the most pervasive, being toxic to plants at the surface and an important greenhouse gas at higher altitudes in the troposphere. Half of the world's forest may be exposed to damaging ozone levels by 2100. While man-made emissions of sulphur dioxide have declined in North America and Europe, emissions have increased in certain countries of Asia, Africa, South and Central America. Man-made emissions of nitrogen oxides have decreased only slightly, remained constant or increased depending upon region. Therefore, rainfall acidity has not generally been reduced and acidification potential remains nearly the same. Increasing atmospheric carbon dioxide is a main driver of climate change, and is generally predicted to increase forest productivity in the absence of other disturbances, such as air pollution and insect outbreaks.

Against the backdrop of changing atmospheric chemistry, there is clear evidence that the world's physical climate is changing. The consensus view amongst international experts is that man-made influences originating from outside forestry are strongly implicated.

Air pollution and climate change (global change) have induced changes in tree condition, physiology, phenology, and in biogeochemical cycling. Air pollution, acting to lower tree resistance to insects and disease, and climate change, acting to change insect population cycles, have altered the function of diverse forest types. However, retrospective analysis shows we have not always been successful at relating forest health to air pollution (with or without consideration of climate change). One of the disadvantages of national and supra-national monitoring schemes is "averaging" across large areas of forest. There has been an increasing trend towards reporting at such scales, thus minimizing regional and local scale changes in forest health.

3.2 Critical issues

Forest health has been defined in terms describing the condition of forest ecosystems which provides for human needs. However, it is well accepted that forests respond to stressors in a dynamic and multi-directional way. Stress responses typically start with sensitive individuals and can cascade from the gene expression level all the way to ecosystem productivity. Underlying responses are changes in the uptake and allocation of carbon, water and nutrient resources. Current definitions of forest health are likely inadequate to measure these responses. Therefore, there is a need for a definition of forest health incorporating essential processes with measurable endpoints related to productivity.

During past decades, developed countries have instituted control programs to reduce air pollutant emissions. Progress is also evident in regional co-operation in monitoring air pollution and its forest effects among countries in South and South East Asia. Limitations to the strength of national and supra-national forest health monitoring programs usually accrue from sampling design adopted. The systematic nature of plot selection may not provide a representative sample of the forests. Data quality is also an issue of concern in crown condition assessment and the spatial/temporal comparability of data. In addition, it is clear that such programs must be accompanied by supplemental process-oriented investigations that more thoroughly test cause and effect relationships between the disturbances and the responses of forests and the processes that sustain them.

Finally, it should be re-emphasized that apart from air pollution there are many other natural and non-natural disturbances of global or regional significance degrading forest health and productivity. These disturbances should receive further attention by forest policy and decision makers in the future.

3.3 Role and contribution of the S&T community

Considerable effort has been devoted to enhancing understanding of forest responses to air pollutants by means of international S&T co-operation, through state-of-science reports and sponsorship of workshops on forest health and productivity. Much work, however, remains to be done in scaling up to landscape in the context of multiple stressors, and in the transfer of knowledge.

The role of the S&T community must continue to be, first and foremost, to accelerate understanding of system response through investigation of essential processes sustaining health. Secondly, the community must use knowledge from case studies to develop scientifically-defensible indicators. Thirdly, effort put into risk assessment and modeling of outcomes must be enhanced. Fourthly, against the background of decreasing funding levels, the community must demonstrate cost-benefit (improving forest health) from the investments made in emission control and monitoring.

3.4 Proposed actions for policy and decision makers

Policy and decision makers are called upon to:

- *adopt a universally accepted definition for forest health, one that incorporates essential processes and for which quantifiable endpoints can be measured. To this end, the following definition is proposed for consideration:*
  "Forest heath is a measure of its capacity to supply and allocate water, nutrients and energy in ways that increase or maintain ecosystem productivity while maintaining resistance to biotic and abiotic stresses";
- *use appropriate approaches to assess forest health in order to improve detection of change over the medium- to long-term in response to natural and anthropogenic stressors. To this end, the scientific and technological community should generate and provide scientific knowledge and technology, addressing the broad range of factors involved in degrading forest health and productivity.*

4 Substantive Element "Maintaining Forest Cover to Meet Present and Future Needs"

Alain Franc
INRA Department of Forestry and Natural Environment, Paris, France

Alex Mosseler
Natural Resources Canada, Canadian Forest Service, Atlantic Region, Fredericton New Brunswick, Canada

John Parrotta
USDA Forest Service, Research & Development, Arlington, United States

4.1 Background

With a total estimated area of 3869 million ha worldwide (FAO, 2001), forests cover about one third of the Earth's land area. They shelter a major part of terrestrial biological diversity and play important roles in providing both a potential sink and source for the carbon cycle and in regulating the global climate system through water cycle. Net primary productivity of forests and other wooded land is estimated to be over half of global terrestrial net primary productivity. As a renewable resource, forests provide a multitude of goods and services to the socio-economic wellbeing of society, contributing to the livelihood of the rural poor and the eradication of poverty.

International policy deliberations in recent decades have fostered development of the multi-dimensional concept of sustainable forest management, aiming at a balanced approach to the diverse and dynamic societal preferences related to forests and their management, including forest conservation. This multi-dimensional concept has also provided a strong impetus to the international scientific community to continuously expand its research focus. For instance, maintaining and/or enhancing forest cover addresses a multiplicity of environmental, social, and economic concerns, including maintaining habitat for protecting biodiversity, enhancing carbon sequestration, climate regulation through evapotranspiration, watershed protection, maintaining air, soil, and water quality, combating desertification, providing livelihoods for people, etc. In this regard, it is important to recognize that our collective forest sector expertise in plantation forestry can be used to facilitate the process of ecological restoration with the aim of realizing the benefits of maintaining forest cover to meet present and future needs.

When considering the issue of maintaining forest cover to meet present and future needs, forest biodiversity conservation emerges as a key element to be deliberated. Appropriately, the relevant IPF/IFF proposals for action emphasize the development and implementation of strategies to protect forest biological diversity. In general, biodiversity has been defined in the Convention on Biological Diversity (CBD) as "the variability among living organisms from all sources …[including] diversity within species, between species and of ecosystems" (1992).

Research and experience indicate that forests are the terrestrial ecosystems where human impacts are most extensive and pervasive. Furthermore, forests serve as important refuges for many species and communities that are unable to survive in agricultural, pastoral, urban or industrialized areas. Overall, forest ecosystems shelter an estimated 80% of all terrestrial species. Although some of these species and communities are known, many others have yet to be identified.

In many parts of the world, forests constitute one element in fragmented landscapes. Several groups of animals (insects, birds, etc.) move between the so-called "wild" forest compartment and the "cultivated" agricultural and pastoral compartment of such landscapes. Destruction of these forest compartments not only impacts these movements, but can also disrupt the biological equilibrium in agriculture, such as the ecological dynamics between agricultural crops and their pest and disease organisms. Hence, research in these areas underlines the need to preserve forests as ecosystems for both the conservation of forest biological diversity and the sustainability of the surrounding landscape mosaic.

At the same time, it is important to understand the effects and impacts of forestry practices (e.g., harvesting and silvicultural practices, rotation lengths, etc.) on maintaining forest biodiversity. For instance, clear-cutting normally has a detrimental effect on late-successional forest cover types composed of long-lived, shade-tolerant trees and their associated/dependant species. These late-successional and old-growth forest types represent the main area of concern with respect to species and forest types at risk. These species and forest types are recognized as an important component of forest biodiversity. Therefore, maintaining viable areas of such forest cover types and populations of their associated species should be seen as a key objective of maintaining forest cover to meet present and future needs.

4.2 Main problems, progress achieved, and challenges ahead

When considering the main problems, progress achieved, and challenges ahead in maintaining forest cover to meet present and future needs, natural limiting factors for the development of forests as well as anthropogenic factors that influence forests, must be considered.

In general, there are two climatic factors that constitute natural limiting factors to the development of forests, namely cold (frost) and drought. These two limiting factors determine the broad distribution of forest types found on the globe, including tropical rain forests (no limiting factor), tropical dry forests (drought: moderate to severe), Mediterranean forests (drought: light), temperate forests (frost: light), and boreal forests (frost and drought).

The world's varied forest types are subject to diverse human influences and substantial anthropogenic pressures. Reference can be made in this context to the continuing expansion of agricultural and pastoral land into tropical rain forests and the strong pressure created by the need for fuel-wood in tropical dry forests. Furthermore, the increasing urbanization and mobility of society create new pressures, particularly on temperate forests, such as commuter traffic from suburban areas into urban centers, tourist activities in alpine forests, etc. Forests are often particularly sensitive to anthropogenic factors at the limits of the different biomes, such as forest savannah limits, savannah/desert limits, the ecotones between temperate and boreal forests, at the upper limits of trees in mountains, and at the northern limit of boreal forests (permafrost). Even low human population densities and industrialization rates can have important impacts on forests at these boundaries. Therefore, special emphasis should be given to maintaining forest cover at the limits of biomes.

When considering the need to maintain the forest cover in order to meet the needs of present and future generations, particular emphasis should be given to maintaining viable populations of tree species and forest cover types at risk, thereby ensuring the protection of forest-associated and dependent wildlife. Considerable knowledge has already been generated about the identity of species and forest types at risk and about the impacts of various forestry practices on these species and forest types. However, there remains a major challenge to develop and implement harvesting and silvicultural practices that protect these vulnerable species (e.g., long lived, shade tolerant) and forest types (e.g., late-successional and old growth) in order to maintain the natural diversity of native forest cover types. Further research and development support is needed to provide policy-relevant information on forest structure, composition, and ecological processes as affected by different management practices to ensure the long-term (intergenerational) potential of forests to provide the diverse array of goods and services required by society.

Greater attention needs to be paid to understanding the impacts of forest fragmentation and landscape-level interactions between forest and non-forested land cover and land uses. A deeper understanding of these processes is needed to develop land-use planning and management strategies to help ensure that present and future generations will have forests of sufficient size, quality, and distribution across landscapes capable of providing the environmental goods and services required to support sustainable development within and outside of forests, without jeopardizing longer-term biodiversity conservation objectives. In this context, greater recognition and support for promotion of sustainable agroforestry practices (both traditional and new) holds promise for resolving complex issues (and conflicts) between forest and agricultural sectors in many countries. This understanding may become even more important as we seek to develop natural resource management strategies to adapt to, or mitigate adverse environmental and societal impacts arising from global environmental (particularly climate) change.

Finally, due consideration should be given to questions of how the expertise developed by the forest sector in plantation forestry, forest restoration, and agro-forestry can be used in the specific context of creating forest environments that serve as "nurse crops" to accelerate ecological restoration of naturally regenerating native species and forest types. Considerable progress has been made in understanding how to establish forest cover on barren lands (e.g., which species are suitable/amenable/adapted to plantation establishment) and how to nurture these plantations to maturity and eventually, through the process of natural succession, toward original, native forest cover types. Based on this expertise in plantation forestry, it is a major challenge to develop restoration protocols aimed at re-establishing native species and forest types in order to develop self-sustaining (e.g., late-successional) forest types that meet present and future needs. Forest research contributes significantly to the development of a better understanding of the use of planted forests as a tool for forest ecosystem restoration.

4.3 Implication for forest policy

The international forest policy dialogue has fostered more widespread understanding of the multi-functional concept of sustainable forest management. In accordance with this concept, forest policy aimed at maintaining forest cover for present and future generations should, in particular, accommodate both the objective of forest biodiversity conservation and the objective of providing forest goods and services, including the provision of wood. Adequate consideration must be given to the full range of native biological diversity occurring in native forest types.

In order to meet this objective effectively, suitable approaches to forest policy formulation, implementation, monitoring, and evaluation have to be applied at different levels. Depending on each country's social and legal system, particular emphasis should be given to policy deliberation and negotiation processes that build on mechanisms involving the diverse range of stakeholders and that support decentralized decision-making.

4.4 Role and contribution of scientific and technological community

The scientific and technological community facilitates and supports the international forest policy deliberations aimed at maintaining forest cover for present and future generations by various means. It should also be noted that it is often the science community that has first raised the issues that become the focus of public attention and concern and that, subsequently, become the focus for policy development.

The scientific and technological community constantly improves scientific knowledge about the role and function of forests (e.g., in relation to biodiversity conservation) through its various activities and promotes the transfer of such knowledge to policy and decision-makers as well as practitioners. Reference can be made, for example, to the most recent scientific contributions of IUFRO to the UNFF Intersessional Experts Meeting on "The Role of Planted Forests in Sustainable Forest Management: Maximizing planted forests' contribution to sustainable forest management" (March 2003, Wellington, New Zealand). As mentioned above, a task of particular relevance is the development of an improved understanding of the impacts of forest management practices on forest ecological functions of necessary for maintaining species and forest types at risk.

Based on this scientific understanding about the roles and functions of forests, the scientific and technological community also contributes to the development and further improvement of forest resource monitoring and assessment tools and mechanisms. By this means, forest-relevant science also contributes to informing stakeholders about the state of forests and forest cover in terms of both quantity and quality. In this context, IUFRO has been particularly active in bringing together scientists to evaluate new developments in the field of natural resource management and assessment.

Finally, science assists policy and decision-makers as well as forest practitioners in the development and application of tools and mechanisms for participatory deliberation and decision-making.

4.5 Proposed actions for policy and decision makers

Policy and decision makers are called upon to:

- *support the expansion of multi-disciplinary research and the enhancement of dialogue and scientific cooperation with other sectors, such as water and agricultural resource management, energy, transportation, and tourism, in order to develop a better understanding about the diverse human influences creating substantive anthropogenic pressures on forests as well as strategies to prevent or mitigate their adverse impacts;*
- *make best use of, and support the further development of, scientific knowledge about the role and function of forests and the impacts of forestry practices on these functions, in particular, support the further development of scientific knowledge about the impacts of forestry practices on maintaining forest biological diversity;*
- *support further development and improvement of monitoring and assessment methods and programs for forest resources, particularly in those regions where there is a lack of reliable forest data; for this purpose, make best use of research and technology, including remote sensing technologies in conjunction with ground-based measurements, and make strong commitments to build and further develop the capacity needed for forest resource monitoring and assessment.*

5 Means of Implementation – Technology Transfer and Capacity Building for Sustainable Forest Management

Cynthia Miner
USDA Forest Service, Pacific Northwest Research Station, Portland Oregon, United States

Michael Kleine
IUFRO Special Programme for Developing Countries (SPDC), Vienna, Austria

5.1 Introduction

New information and technology are generated by universities and forestry research organizations throughout the world. As scarce resources for forestry research are allocated, clear articulation of the benefits of research is imperative. A growing trend is to measure the success of organizations based on outcomes and benefits of innovations generated by scientists. Technology transfer is a process towards assuring that innovations are used.

Various approaches are taken in transferring technology and information. One-way dissemination occurs as those who generate innovations communicate or deliver them to forest land managers and policymakers. Publications and other one-way media are very effective in creating awareness of an innovation. Frameworks that facilitate communication among stakeholders of researchers, developers, potential users, and community members create a more fluid process that can be highly effective. The commonality that drives the process is a desire for a benefit or outcome associated with forest policy or management. Outcomes draw communities and indigenous peoples into the process as related to particular forests, geographical regions, or sets of resources such as special forest products or species of special interest.

5.2 Users of technologies and information

Whether land managers in a private or public organization, policymakers, indigenous people, or members of a community, people come to use a concept, set of knowledge, method, or technology through becoming aware of such an innovation, deciding if they will adopt it, and perhaps eventually incorporating it into regular use. People who go through this process may modify the innovation to fit their specific needs and that of their organization. Potential users may provide input very early as partners with scientists during the development of research projects. The common goal is to generate information and technology that is relevant and easily used in addressing complex policy and management issues. Key research questions are considered in the context of issues described by potential users, and technologies are developed and diffused by combined effort of the many stakeholders.

Users can be categorized as innovators, early adopters, early majority, late majority, and laggards. Understanding the diffusion process and types of users helps identify the most effective use of limited resources to reach the goals common among the stakeholders. Expenditures to bring late majority or laggards into the process early will not yield significant results.

Paradoxically, the types of people who use scientific information related to forests is expanding despite downward trends of support for forest research. Increasingly users of forest-related innovations are very interested citizens or community members who may not have a forest-related education, yet are very knowledgeable about key issues and may be in position to influence policy and management. Forest research organizations can disseminate information in formats that place scientific information in context of issues so that these individuals and their organizations are aware of the scientific information, its relation to key forest issues, and the relevancy of the research organization's work. There is a strong link between technology transfer and public relations.

A question for forest-related technology transfer efforts is “What is the interplay among individuals; research, management, and other forest-related organizations; and communities connected to forests?” These interactions can be approached at various scales, and therein difficulties arise as needs may be very different within and between geographic areas. Despite the frequently onerous task of bringing together disparate interests, this approach brings great advantages when it works and is well recognized as beneficial. For example, an outcome of the World Summit on Sustainable Development in Johannesburg in 2002 called for accelerating collaborative partnerships on forests.

Technologies and information from developed countries can be adapted and diffused to developing countries by building capacity for development and extension. And, technologies and information from developing countries can be adapted and diffused to developed countries through awareness and understanding of benefits. For example, developing countries have created innovative partnerships at the community level that have potential application in developed countries.

5.3 Scientific information and knowledge as innovations

Forest-related innovations are made up of complex sets of information. Scientific credibility is a defining characteristic of such information. Before innovations are adopted, they must be understood by potential users. One way to help understand complex information is to define the information itself as a product in the context of issues. Information should be described in terms of its forest management or policy implications. Related products should be developed and packaged so that they are readily understood and support each other toward effective applications.

The transfer of scientific information can be facilitated when potential users serve as advisors and participants in the research process. Users have a vested interest in assuring that research products meet their needs and can help develop, test, and demonstrate innovations. They also can be included in research projects in a way that will help them understand and apply scientific findings. The challenge in this participatory process is for the scientific and technology community to maintain its integrity and objectivity in close proximity to the desires of potential users. It may occur that the user perceives a course of action to be heading toward a desired outcome, but at the end of a study or group of studies the scientific information may indicate a different outcome.

Scientific knowledge related to forests is often built over many decades, and information that is generated today does not necessarily lead to where one might have gone based on initial findings from a decade or more ago. As unintended consequences of innovations emerge, an adaptive approach to implementation can be crucial. The challenge for transfer of scientific information is to develop on-going continuity and context setting, requiring significant dedication on the part of research organizations and innovation users to overall benefit for forests and society.

5.4 Technologies and intellectual property rights

Technologies, such as remote sensing and satellite data, are used to monitor and assess forest-related economic trends, forest health and productivity, and forest cover. Users can enhance the diffusion of technologies, particularly if they are involved in product development, demonstration, testing, and training. Developers have added incentive for assuring the application of their innovations when they can be patented. Private industry can assure widespread use of products through licensing agreements. The protection of intellectual property rights needs to be understood in accordance with relevant international and domestic laws. As appropriate, concessional and preferential terms as mutually agreed upon can be used to facilitate the transfer of technologies among countries, with particular benefit to developing countries. However, the rights of indigenous peoples must be acknowledged and the value of traditional knowledge recognized.

The Internet has increased awareness about new technologies, concepts, scientific findings, and information about forests including, economics, forest health and productivity, and forest cover. The Internet also provides means to involve users in development and delivery of innovations. The technology allows various ways to obtain feedback directly from users. A challenge for forest-related organizations is to provide easy access, navigation, and searching capabilities for users to locate the information and technologies they need. Efforts to develop Internet-based global information systems and networks, therefore, need to be well recognized and supported.

Workshops and courses are learning events that allow participants to receive information in a way that provides context and detail. Electronic media can be used for such training and to share presentations after the events. One-on-one communication and consultation is often the most effective way to help potential users to decide to use an innovation. Time-intensive consultations by scientists and extensionists with potential users are highly effective and provide for feedback that can benefit all. People respond strongly to visual and experiential learning; demonstrations are particularly important in transferring innovations related to forest management and policy.

5.4 Building capacity

Given the importance of technology transfer activities to successfully apply innovation and new knowledge at field level, considerable capacities are needed on the part of scientists and researchers to make meaningful contributions to technology transfer processes. Although basic science education must remain as the foundation of research, greater emphasis is now being given to skills and capacities required for technology transfer in all its aspects. Exemplary reference can be made in this context to the work of CERAD which aims to promote the development of scientific knowledge on natural resource management and the use of that knowledge to improve the conditions of the rural poor forest communities in the field.

In line with these developments, the forest related S&T community has been carrying out various activities aiming at expanding and fostering research capacity in developing and economically disadvantaged countries. IUFRO's Special Programme for Developing Countries (IUFRO-SPDC) – aiming at expanding and fostering research capacity in developing and economically disadvantaged countries – currently develops and offers training modules that are intended to help in consolidating and increasing scientists' knowledge and skills to participate in technology transfer activities. The training programme includes course work on specific topics with mainly hands-on exercises and collaborative research networking in developing countries, both supported by forestry research organizations in industrialized countries. Some examples are outlined below. CERAD participates in activities on building the capacity of environmental and forestry schools in Central Africa on participatory management of natural resource, indigenous peoples' rights, co-management of forests and fisheries, and the development of forestry research in Central Africa.

With the principal objective to define information as a product that is desired by a specific group of clients, a thematic research network of individual African scientists dealing with the rehabilitation of degraded lands in Africa has been established through the support of IUFRO-SPDC. The aim of this network is to produce a scientific synthesis and state-of-knowledge report on the topic providing the input to various field-based projects that are included in the work as case studies. The information collected and synthesized will be packaged and presented in easy-to-understand language so that potential users are attracted and subsequently use the network as partners in their own field implementation projects.

Transfer of technology can also be facilitated by mixing practitioners and scientists from the very start of a project or technology development process. This is particularly relevant in the field of criteria and indicators (C&I) for SFM, auditing of SFM and forest certification. Currently, training modules in these fields are being developed in the frame of IUFRO-SPDC with special emphasis on skills needed by scientists to successfully participate in C&I processes, act as auditors of SFM or assist in developing forest certification schemes and their implementation. These skills include understanding of problems related to land-use, human welfare and policy frameworks, downscaling of detailed research results into easily assessable parameters at field level, communication, and negotiation and arbitration. Whenever possible the training courses are open to both scientists and practitioners.

Another challenge in technology transfer is associated with the access and dissemination of information. Following the call for greater integration and sharing of information at the global scale, IUFRO in cooperation with various international partners has initiated the development of the Global Forest Information Service (GFIS). In order to enhance participation of developing countries scientists in GFIS, IUFRO-SPDC provides support to research institutions in the establishment of the system and training of staff. In a broader context, new training modules are being developed that focus on the use of modern information technology in forest research and technology transfer so that scientists apply these information technology tools in their day-to-day work.

Overall, capacity building in the area of technology transfer will need to be expanded to allow forest scientists to confidently play their role in the complex process of transferring innovative ideas and knowledge to the field level.

5.5 Proposed actions for policy and decision makers

Policy and decision makers are called upon to:

- *promote the diffusion of key information and technology to the full array of potential users and support efforts to strengthen multiple-way communication, partnership, networking and participation between developers and potential users of innovations in the context of the benefit or outcome desired, including through North-North, North-South and South-South co-operation and partnerships;*
- *expand the definition of potential users to include organizations, communities, and individuals in different countries, including developing countries, and strongly promote the use of global Internet systems related to forests as a key method for disseminating information in order to create awareness of innovations across the world;*
- *further strengthen and support capacity building in forest higher education and research and transfer of technology, including through North-North, North-South and South-South co-operation and partnerships, aiming at a better diffusion of innovative ideas and new knowledge for implementation at field-level.*

6 National Forest Programmes – Procedural Aspects and Supporting Factors

Peter Glück
BOKU - University of Natural Resources and Applied Life Sciences, Vienna, Austria

6.1 Background

The international forest policy dialogue since UNCED 1992 has agreed on actions to promote the sustainable management, conservation and sustainable development of all types of forests, in short: SFM. Many of the proposals for action of the Intergovernmental Panel on Forests (IPF)/Intergovernmental Forum on Forests (IFF) refer to national forest programmes (nfps) for their implementation. FAO's Guidelines on the formulation and implementation of national forest programmes (FAO 1996) and the revised "Practitioner's Guide" published by the Sixth Country Initiative (FAO and UNDP, 1999) facilitated the understanding of nfps and prepared their world-wide acceptance. The Ministerial Conference on the Protection of Forests in Europe (MCPFE) also worked towards a common understanding of nfps in the European context, culminating in the MCPFE Approach to National Forest Programmes in Europe. At the level of the European Union, nfps or equivalent programmes are a prerequisite for acquiring forest subsidies according to the EC Regulation 1257/99 on Support of Rural Areas within Agenda 2000.

6.2 National forest programmes as a new mode of governance

Nfps do not compete with any existing forest policy tool, instead they are meant to complement and supplement them. In its essence, an nfp is a political planning instrument for ensuring sustainable forest management by making substantive contributions to (i) economic aspects of forests; (ii) forest health and productivity; and (iii) the maintenance of the forest cover to meet present and future needs. This is to be accomplished by a new paradigm of governance, based on interconnecting policy networks instead of hierarchical governance by the state; public participation of all relevant actors and stakeholders in the planning and communication process instead of technocratic decision making; adaptive, open-ended and iterative learning processes instead of deterministic goal achievement; and comprehensive, holistic and inter-sectoral coordination of political actors, ensuring that all sectors affecting forestry and affected by forestry are considered and that externalities are internalized.

Essential preconditions for the success of policy networks are communication and trust among the actors. They provide additional informal linkages by information, persuasion, experience, and so on, and thereby help produce the collectively desired outcome. Furthermore, the members agree on specific rules, norms and values for achieving the common goal. There is agreement on 10 basic elements, of which a number serves to resolve of specific coordination problems (e.g., public participation, inter-sectoral coordination, adaptive and iterative planning).

Though there is broad consensus on the desirability of an nfp for anticipatory regulation of conflicting economic, ecological and social interests in forests at the national level, there are many questions left on how to proceed in detail. For voicing and answering these questions, in 1999 the 4-year COST Action E19 "National forest programmes in a European context" was launched, consisting of more than 70 researchers from 21 European countries and the USA.

6.3 Role and contribution of the scientific and technological community

The main objective of COST Action E19 is to provide policy makers in Europe with approved means for formulating and implementing nfps. Target groups for the results are European policy makers dealing with nfps, such as ministries responsible for nfps, stakeholders in nfp processes and European and international organizations dealing with nfps. The more detailed objectives are the (i) formulation of a network of European researchers and civil servants who deal with the socio-economic aspects of sustainable forest management and policy planning in forestry; (ii) specification of the procedural requirements of formulation and implementation of an nfp; (iii) assessment of supporting and impeding factors for the development of substantive nfps. Nfps are substantive if they fulfill the basic elements and contribute to sustainable forest management; otherwise they are symbolic.

As there is no operational definition of an nfp, the COST Action focused on its main essential elements, such as public participation, intersectoral coordination, adaptive and iterative planning and so on. The core piece of work consists in a series of propositions on the impact of various internal factors (characteristics of participants, process characteristics, and content characteristics) and external factors (political culture, ownership structure, financial incentives, legal aspects etc.) on nfps. Some of these factors can be modified by the intervention of relevant policy makers in the short or medium term (e.g., a number of participants in the nfp process), others can not (e.g., the fragmentation of forest ownership or the organization of forest owners). This kind of information enables actors of nfp processes to assess which "screws" can be moved in order to influence nfp processes in the desired direction, e.g. to achieve substantive nfps instead of solely symbolic processes and outputs. The proposed actions for policy and decision makers refer to the influence of external factors as well as actors, procedural aspects and the expected content of nfp processes.

6.4 Conclusions and proposed actions for policy and decision makers

Policy and decision makers are called upon to:

- *make best use of scientific knowledge and the results of recent research when formulating and implementing national forest programmes; in particular, take into due account the results of scientific work concerning influence of external factors as well as actors, procedural aspects and the expected content of substantive nfp processes.*

7 Monitoring, Assessment and Reporting

Alexander Buck
IUFRO Secretariat, Vienna, Austria

Ewald Rametsteiner
BOKU - University of Natural Resources and Applied Life Sciences, Vienna, Austria

7.1 Background

Monitoring, assessment and reporting (MAR) is one of the principle functions of the United Nations Forum on Forests. According to the UNFF, monitoring is to be understood as periodic quantitative or qualitative measurements or observations of a specific parameter. Assessment means the analysis and synthesis of monitoring data and observations, and reporting means the dissemination of the results of assessments. Overall, MAR aims to facilitate informed decision making on forest policy and management. In the particular context of UNFF, "monitoring and assessing progress at the national, regional and global levels through reporting by governments, as well as by regional and international organizations, institutions and instruments" aims to serve as a basis for the identification of future actions needed.

The multi-year programme of work of the UNFF specifies three different areas for MAR: 1) Progress in implementation of the IPF/IFF proposals for action; 2) Progress towards sustainable forest management of all types of forests; and 3) Review of the effectiveness of the international arrangement on forests.

Progress in each of these three areas should, and hopefully will ultimately translate into progress in the field concerning the sustainable management, conservation and sustainable development of the World's forest resources.

7.2 Crucial issues

Experience gained so far has contributed significantly to a more differentiated understanding about the three different areas of MAR, as identified in the MYPOW, and related policy instruments. When further considering this subject in the context of UNFF, a distinction should be made between the three areas of MAR, the various levels to which they apply and the different actors who are addressed.

MAR on progress in implementation of the IPF/IFF proposals for action relates to progress achieved in implementation of international commitments by means of policy-related action, mainly by countries and at the national level, but also by other institutions such as international organizations. Many of the proposals for action of the IPF/IFF refer to national forest programmes (nfps) which thus appear as an important means for their implementation. Countries and the UNFF have taken several initiatives to clarify the issue and finding effective mechanisms for MAR, such as the UNFF inter-sessional expert meeting held in November 2001 in Yokohama, Japan; and the Country Led Initiative "Monitoring, Assessment and Reporting on Lesson Learned in the Assessment of Implementation of the IPF/IFF Proposals for Action" in March 2003 in Viterbo, Italy. This recent initiative emphasized the importance of assessing and prioritizing the IPF/IFF proposals for action at the national level. Furthermore, it underlined the need to streamline and formalize MAR on the IPF/IFF proposals for action and pointed out the importance for governments to collaborate with stakeholders, including the private sector and NGOs, e.g. through national forest programmes.

Consultations and deliberations are still underway to further clarify the issue and to find effective mechanisms for MAR. This is despite the ongoing reporting, e.g. for UNFF-3, and the limited time span that is left for UNFF as such. At least the start of the reporting on progress in implementation of the IPF/IFF proposals for action has therefore been slow.

The current emphasis on reducing reporting burdens for countries by streamlining reporting obligations and by intensifying efforts towards the development of common reporting formats and data collection mechanisms is important. Reference can be made in this context to the Task Force on

Streamlining Forest-related Reporting established by the CPF and the initiatives take by the Commission on Sustainable Development (CSD). Nevertheless, it should be kept in mind that reporting is not an end in itself. It is essential to devise mechanisms to transfer knowledge and experience and to enable learning from lessons made amongst all stakeholders. Furthermore, it is important to note that the follow-up on the implementation of political commitments made, through MAR, should not be confounded with monitoring progress achieved on the ground.

Regarding the second area of MAR, i.e. progress towards SFM of all types of forests, the UNFF stressed the importance of using the framework for criteria and indicators (C&I) for SFM as a basis for reporting. Conceptually, C&I were developed to show, on the basis of repeated measurement of and reporting on indicators, progress made towards sustainable forest management. They are mainly used at the national level, but increasingly also at field-unit level.

The international forest dialogue paved the way for the broad acceptance and application of C&I for SFM as an instrument for monitoring, assessing and reporting on progress towards SFM. Since 1993, a number of national, regional and international initiatives came into existence for the development of C&I for SFM. A range of international conferences were held, including the Intergovernmental Seminars on Criteria and Indicators for Sustainable Forest Management in 1992 and 1996 (ISCI). The recent International Conference on Criteria and Indicators for Sustainable Forest Management (CICI), held in February 2003 in Guatemala City, concluded that, by early 2002, nine major processes related to C&I were in operation involving more than 150 countries worldwide and covering most of the world's forest area. However, the meeting also concluded that countries are at different stages of developing, implementing and using C&I. Nonetheless, the experts identified seven common thematic areas in the criteria that are similar in all nine existing regional or international C&I processes. Furthermore, many countries have already evaluated the indicators identified in their respective C&I process in terms of applicability to their own country. In some cases new national or sub-national indicators have been added in order to better reflect the particular conditions. In a number of countries, the results of monitoring and assessment using C&I for SFM have already been integrated into domestic policy.

The outcomes of CICI-2003 pointed to a number of areas in which further efforts are required with regard to C&I for SFM. It was concluded that the cost effectiveness of MAR activities related to SFM can be significantly enhanced by using existing mechanisms for data collection and reporting, e.g. in the context of the Global Forest Resource Assessment. This aspect is of particular relevance for matching the country-level use of C&I with the international reporting requirements on SFM.

As another major aspect, the need of building capacity for national data collection, analysis and reporting has been underlined in particular with regard to developing countries and countries with economies in transition. It was noted that – despite decade long efforts to compile data from national sources, notably in the context of the Global Forest Resource Assessment of FAO – only few countries are in a position to provide accurate and comprehensive forest related data due to lack of a permanent forest inventory.

Finally, the UNFF identified the review of the effectiveness of the international arrangement on forests as the third area for MAR. For this purpose, UNFF-2 decided on specific review criteria.

7.3 Role and contribution of the S&T community

The S&T community has been at the forefront of developing instruments for sustainable forest management. Following UNCED, it played a central role in shaping the concept of criteria and indicators for SFM at the International Seminar of Experts on the Sustainable Development of Boreal and Temperate Forests, convened in 1993 in Montreal, Canada, and sponsored by the Conference on Security and Cooperation in Europe (CSCE). Through various activities, science has also contributed to further develop the concept of C&I for application at the forest management unit level. Reference can be made in this context to the activities of the former IUFRO Task Force on Sustainable Forestry and various initiatives by CIFOR.

In maintaining this active role, the S&T community continues to facilitate and support progress in monitoring, assessment and reporting by various means. Most importantly, it provides scientific expertise for the development of approved means for monitoring, assessment and reporting at various levels, e.g. the further development and improvement of regional, national and sub-national sets of C&I for SFM. Reference can be made to the scientific advice given by IUFRO's Division 4 "Inventory, Growth, Yield, Quantitative and Management Sciences" to the Ministerial Conference on the Protection of Forests in Europe (MCPFE) concerning the improvement of the Pan-European Indicators for Sustainable Forest Management.

The S&T community also plays an important role in supporting the development of a common understanding of those forest-related terms, concepts and definitions that form the basis for international reporting. IUFRO's "SilvaVoc Terminology Project" serves as a clearinghouse for multi-lingual forest terminology. Together with FAO, the Intergovernmental Panel on Climate Change (IPCC) and the Centre for International Forestry Research (CIFOR) and the United Nations Environment Programme (UNEP), it promotes the development of an enhanced common understanding of forest-related terms and definitions, their possible harmonization and proper use. By this means, IUFRO's SilvaVoc Terminology Project also provides a basis for a more coordinated and streamlined forest-related reporting to international conventions and organizations.

The recent CICI meeting also emphasized the need to improve the capacity of developing countries and countries with economies in transition for national data collection, analysis and reporting. The S&T community contributes to this task through specific training measures. For example, IUFRO's "Special Programme for Developing Countries" (IUFRO-SPDC) is currently preparing the Expert Meeting "Capacity Building for Forest Scientists in Latin America in Criteria & Indicators, Auditing of Sustainable Forest Management and Forest Certification", to be held in May 2003 in Costa Rica, organized by IUFRO, CATIE and CIFOR and in technical cooperation with FAO. The meeting aims to familiarize forest scientists with the approaches to build auditing and certification systems relevant to their region and provide the necessary background and skills to better participate in the various processes of C&I formulation, auditing of sustainable forest management and forest certification. The results of the proposed expert consultation will assist IUFRO-SPDC and its partners to design further training modules that are beneficial to scientists from developing countries and tailored to the regional context.

As another activity facilitating international efforts concerning MAR, the IUFRO Special Programme "Global Forest Information Service" (GFIS) has been established in September 2001. This international initiative, which is carried out in co-operation with FAO, CIFOR and EFI, aims to serve as an Internet-based search machine using metadata to provide access to forest information. The resulting system serves as a resource discovery tool, providing multiple benefits to information users and providers including, facilitating user-friendly access to a greater amount of forest-related information. Particular emphasis is placed on including developing countries into the service. A first prototype of GFIS was successfully developed in 2001, including five GFIS nodes in Africa and the training for webmasters for these nodes with the support of EU. In August 2002 the prototype of GFIS was launched at the Regional Conference in Copenhagen, consisting of 12 nodes in Africa, Asia, Australia and Europe. The multi-host search engine is capable of performing search operations in a distributed network of metadata over available information resources. The conceptual model of GFIS essentially relies on a federated approach to system design with a central Information server and multiple levels of nodes. The number of nodes can be expanded indefinitely with additional layers of sub-nodes as required by the data providers. It can be noted that the multi-year programme of work (MYPOW) of the UNFF explicitly recognizes the IUFRO Global Forest Information Service (GFIS) as an existing activity related to "Monitoring, Assessment and Reporting".

Finally, the S&T community has also been involved in several other multinational initiatives and processes related to MAR. For example, IUFRO Division 4 provided consultancy for the FAO/UNECE Global Forest Resources Assessment 2000, assisted the European Commission in developing a European forest information and communication system, and is supporting the UN-Intergovernmental Panel on Climate Change (IPCC) in setting up Good Practice Guidance for Land use, Land use change and Forestry (LULUCF) in the scope of the IPCC Guidelines for National Greenhouse Gas Inventories. Currently, IUFRO is assisting FAO in developing an On-line Knowledge Reference for National Forest Assessments which is intended to serve as a worldwide knowledge resource for national forest assessment assisting scientists, teachers and other stakeholders, and as a tool to support forest assessments in developing countries.

7.4 Proposed actions for policy and decision makers

Forest policy and decision makers are called upon to:

- *make best use of S&T expertise for the development of approved means for monitoring, assessment and reporting, including the scientific work addressing the concept of national forest programmes, the improvement of regional, national and sub-national sets of C&I for SFM and MAR related to policy commitments;*
- *fully utilize the supporting role of the S&T community in the enhancement of the common understanding and possible harmonization of forest-related terms and definitions; and to recognize the role of science and technology in facilitating the compilation and storage of forest-related data and information and in providing access to forest information;*
- *make best use of, and further support the role of the S&T community in improving the capacity of developing countries and countries with economies in transition for national data collection, analysis and reporting.*

8 Final Considerations and Conclusions[1]

Science and Technology are essential factors for the successful implementation of the IPF/IFF proposals for action as well as UNFF's multi-year programme of work and Plan of Action. Policy and decision makers are therefore called upon to make best use of available science and technology and take into full account the proposed actions related to "economic aspects of forests" including "trade", "forest health and productivity" and "maintaining forest cover to meet present and future needs".

However, enhancing the S&T community's capacity to contribute to sustainable development will also require significant changes. The S&T community is committed to further strengthen its capacity to contribute to SFM and, by this means, to overall sustainable development. There is a need to provide more policy-relevant, problem-oriented research which addresses the social, economic, and environmental dimensions of sustainable forest management and their various linkages and interactions. To this end, the S&T community is committed to further expanding multi-disciplinary research by means of increased networking and collaboration, bridging traditional disciplinary divides and crossing sectoral boundaries.

Furthermore, the S&T community recognizes the need to build, and enhance, strong scientific and technological capacity in all regions of the world, including North-North, North-South and South-South co-operation and partnerships. Sharing of knowledge, information and technology based on widely available and affordable mechanisms constitutes a crucial task to this end. However, this requires adequate support for S&T, especially in the area of scientific and technological capacity building.

Strong partnership between the S&T community and other members of civil society, the private sector and governments is of fundamental importance to further enhance the contribution of science and technology to achieving SFM, and to ensure policy-relevant science. The S&T community is committed to implementing necessary changes and developing appropriate partnerships. Reference can be made in this context to the contributions of the S&T community to the Multi-Stakeholder Dialogues at UNFF-2 and the WSSD.

At the same time, the S&T community needs more stable and sustained financial support if it is to be successful in facing the challenge of the sustainable management of the world's forests. In particular, there is an urgent need to reverse the declining trends in financial support and investment in research and higher education, which is unfortunately observed in an increasing number of countries around the world. Public and private inputs into science and technology should be seen primarily as an investment in forest-related socio-economic development and in preserving forests as natural life-support systems for the present and future generations, rather than simply as research expenditures.

[1] This chapter has been prepared by Alexander Buck who co-ordinated the preparation of Part I of the IUFRO Occasional Paper and served as editor.

Explanatory Remarks and Acknowledgements

Part I of the IUFRO Occasional Paper No. 15 is an outcome of the collaborative efforts by the International Union of Forest Research Organizations (IUFRO), the International Council for Science (ICSU) and the Centre de Recherche et d'Action pour le Développement Durable en Afrique Centrale (CERAD) to support and facilitate the deliberations of policy and decision makers at the third session of the United Nations Forum on Forests (UNFF).

As the three organizations representing the major group "Scientific and Technological Community" in the UNFF process, IUFRO, ICSU and CERAD were invited in autumn 2002 to prepare a "Discussion Paper" for the Multi-Stakeholder Dialogue (MSD) at UNFF-3. IUFRO accepted the task to assume the overall responsibility for the development of the discussion paper.

Following this invitation, numerous experts from within the scientific and technological community have contributed to the preparation of the discussion paper by drawing up – in an individual or joint effort – the diverse thematic chapters of the paper. As part of the preparatory process, various reviewers took a critical look at each of these chapters and helped to further develop them and to include additional aspects of major relevance.

Unfortunately, the prescribed limitation in length did not make it possible to include the reviewed contributions in full length into the official paper submitted to UNFF-3[1] . Therefore, it was decided to make available the full versions of these contributions in an IUFRO Occasional Paper in hand. Hence, part I of the Occasional Paper further expands and complements the contributions included in the Discussion Paper of the Scientific and Technological Community for UNFF-3.

The preparation of part I of the IUFRO Occasional Paper would not have been possible without the dedication and commitment of the following authors who have made their invaluable contributions to this important task: Alain Franc, Peter Glück, Richard Guldin, Michael Kleine, Alex Mosseler, Cynthia Miner, John Parrotta, Kevin Percy, Colin Price and Ewald Rametsteiner[2] . Thanks to all of them.

Thanks also to Alicja Breymeyer, Mark A. Crochane, Ruth DeFries, Sune Linder, Ravi Prabhu, Bob Scholes and Anatoly Shvidenko for providing in-depth and comprehensive review comments[3] . They helped to further enhance the attractiveness of the contributions for policy and decision makers.

Sincere thanks go to Thomas Rosswall (Executive Director ICSU), Patrice Bigombe Logo (Director CERAD), Risto Seppälä (President IUFRO) and Eric Teissier du Cros (Vice-President Science IUFRO), Don K. Lee (Vice-President Policy IUFRO) and Heinrich Schmutzenhofer (IUFRO Executive Secretary), who provided invaluable guidance and leadership. Additional guidance and comments provided by the UNFF Secretariat, in particular by Abigail Sarmac, Luz Aragon and Susan Braatz, are also highly appreciated.

Finally, words of thanks are directed to Niels Bruun de Neergaard (Co-ordinator IUFRO-GFIS), Niels Elers Koch (Coordinator IUFRO Division 6), Renate Prüller (Coordinator IUFRO SilvaVoc), Birger Solberg (Coordinator IUFRO Unit 6.12.00), Kazuo Suzuki (Coordinator IUFRO Division 7), and Gerda Wolfrum (IUFRO Secretariat), who appreciably facilitated the preparation of the paper through their thematic input and critical remarks.

With all this support, it was a pleasure to co-ordinate the contributions of the Scientific and Technological Community to the MSD at UNFF-3. Altogether, these contributions my help to open new avenues at the science-policy interface in support of sustainable forest management.

Alexander Buck, May 2003

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[1] Note by the Secretary General – Addendum: Discussion paper contributed by the Scientific and Technological Community Major Group – "Science and Technology – Building the Future of the World's Forests" (E/CN.18/2003/2.Add.4)

[2] A list of authors and the institutions which they represent can be found in Annex 1.

[3] A list of review commentators and the institutions which they represent can be found in Annex 2.

Annex 1: List of Authors

BUCK, Alexander
International Union of Forest Research Organizations (IUFRO)
IUFRO Headquarters
Vienna, Austria
FRANC, Alain
Coordinator IUFRO Division 8 (Forest Environment)
Institut National de la Recherche Agronomique-France (INRA)
Department of Forestry and Natural Environment
Paris, France
GLÜCK, Peter
University of Natural Resources and Applied Life Sciences (BOKU)
Institute of Forest Sector Policy and Economics
Vienna, Austria
GULDIN, Richard
Coordinator IUFRO Task Force 8 (Science/Policy Interface)
United States Department of Agriculture (USDA) Forest Service
Research & Development
Washington D.C., United States
KLEINE, Michael
Coordinator IUFRO Special Programme for Developing Countries (SPDC)
IUFRO Headquarters
Vienna, Austria
MINER, Cynthia
Coordinator IUFRO Unit 6.06.02 (Technology transfer)
United States Department of Agriculture (USDA) Forest Service
Pacific Northwest Research Station
Portland Oregon, United States
MOSSELER, Alex
Deputy Coordinator IUFRO Units 8.01.01 (Old growth forests and forest reserves) and 8.07.00 (Biodiversity)
Natural Resources Canada
Canadian Forest Service, Atlantic Region
Fredericton New Brunswick, Canada
PARROTTA, John
Coordinator IUFRO Division 1 (Silviculture)
United States Department of Agriculture (USDA) Forest Service
Research & Development
Arlington, United States
PERCY, Kevin
Deputy Coordinator IUFRO Division 7 (Forest health)
Natural Resources Canada,
Maritimes Region,
Fredericton New Brunswick, Canada
PRICE, Colin
University of Wales Bangor
Faculty of Science & Engineering
School of Agricultural and Forest Sciences
Bangor, United Kingdom
RAMETSTEINER, Ewald
University of Natural Resources and Applied Life Sciences (BOKU)
Institute of Forest Sector Policy and Economics
Vienna, Austria

Annex 2: List of Review Commentators

BREYMEYER, Alicja
Polish Academy of Sciences
Institute of Geography and Spatial Organization PAS
Department of Geoecology
Warsaw, Poland

CROCHANE, Mark A.
Center for Global Change and Earth Observations/Michigan State University
East Lansing, United States

DEFRIES, Ruth
University of Maryland
Department of Geography and Earth System Science Interdisciplinary Center
Lefrak Hall, College Park, United States

LINDER, Sune
Swedish University of Agricultural Sciences
Department of Production Ecology
Uppsala, Sweden

PRABHU, Ravindra
Center for International Forestry Research (CIFOR)
Bogor Barat, Indonesia

SCHOLES, Bob
CSIR Division of Water, Environment and Forest Technology,
Pretoria, South Africa

SHVIDENKO, Anatoly
International Institute for Applied Systems Analysis
Forest Resources Project
Laxenburg, Austria

Annex 3: List of Acronyms

BOKU	University of Natural Resources and Applied Life Sciences
C&I	Criteria and indicators for sustainable forest management
CABI	CAB International
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Tropical Agricultural Research and Higher Education Center)
CBD	Convention on Biological Diversity
CERAD	Centre de Recherche et d'Action pour le Développement Durable en Afrique Centrale
CICI Forest	International Conference on Criteria and Indicators for Sustainable Management
CIFOR	Center for International Forestry Research
CLRTAP	Convention on Long-Range Transboundary Air Pollution
COST	European Co-operation in the field of Scientific and Technical Research
CPF	Collaborative Partnership on Forests
CSCE	Conference on Security and Cooperation in Europe
CSD	Commission on Sustainable Development
EFI	European Forest Institute
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GFIS	Global Forest Information Service
ICSU	International Council for Science
IFF	Intergovernmental Forum on Forests
INRA	Institut National de la Recherche Agronomique
IPCC	Intergovernmental Panel on Climate Change
IPF	Intergovernmental Panel on Forests
ISCI	Intergovernmental Seminars on Criteria and Indicators for Sustainable Forest Management
IUFRO	International Union of Forest Research Organizations
IUFRO-SPDC	IUFRO's Special Programme for Developing Countries
LULUCF	Land use, Land use change and Forestry
MAR	Monitoring, assessment and reporting
MCPFE	Ministerial Conference on the Protection of Forests in Europe
MSD	Multi-Stakeholder Dialogue
MYPOW	Multi-year programme of work
nfps	National forest programmes
SFM	Sustainable forest management
SPDC	Special Programme for Developing Countries
S&T	Science and technology
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
UNFF-2	Second session of the United Nations Forum on Forests
UNFF-3	Third session of the United Nations Forum on Forests
USDA	United States Department of Agriculture
WEHAB	Water, Energy, Health, Agriculture and Bio-diversity
WSSD	World Summit on Sustainable Development

Part II:

Planted Forests and Biodiversity

An IUFRO contribution to the
UNFF Intersessional Expert Meeting on

The Role of Planted Forests in Sustainable Forest Management: "Maximising planted forests' contribution to SFM"

Wellington, New Zealand,
24-30 March 2003

Planted Forests and Biodiversity

J-M Carnus[1], J Parrotta[2], EG Brockerhoff[3], M Arbez[4], H Jactel[1], A Kremer[1], D Lamb[5], K O'Hara[6] & B Walters[7]

Abstract

Forest ecosystems shelter a major part of terrestrial biological diversity, and over the past decades, conservation of biodiversity has become a key element in national forest policies and planning. Plantation forests are cultivated forest ecosystems established primarily for wood biomass production but also for soil and water conservation or wind protection. During the past decade, the global forest plantation area has increased by an estimated 32 million ha while the area of natural forests has declined by 126 million ha.

Biodiversity is an issue of increasing relevance to the development and management of plantation forests and their long-term sustainability. Plantations can and do play a vital role in forest conservation by providing a substitute for wood from unsustainable harvesting of natural forests. In many parts of the world plantations also play a key role in restoring local ecosystem services and by reducing runoff and erosion on previously degraded sites. Despite these positive attributes, plantation forests are widely viewed in a negative light in relation to biological diversity conservation, especially when intensive monocultures of exotic species are involved.

*While a plantation stand will, in general, support fewer native species than a native forest at the same site, plantations are increasingly replacing other human-modified ecosystems (*e.g., *degraded pasture) and often support a greater diversity of native species, particularly in understorey communities. As such, plantations can play an important role in conserving or even restoring native biodiversity in production landscapes. As well as providing habitat in their own right, plantations play particularly important roles in buffering native forest remnants and in enhancing connectivity between areas of native ecosystems. In doing so, these plantation forests may help foster the overall sustainability of agriculture and other land uses across these landscapes.*

However, to sustain health and productivity of planted forests, managers need to preserve genetic diversity through adapted breeding strategies and controlled deployment of improved genetic material, and enhance interspecific diversity using a greater variety of planted species (exotic and native) and alternative forest management regimes and practices, such as the extension of rotation lengths in some stands, and adoption of a variety of harvesting approaches.

1 INRA Bordeaux Pierroton, 33610 Gazinet Cestas (France); carnus@pierroton.inra.fr
2 USDA Forest Service, Research & Development, 1601 N. Kent Street, Arlington VA 22209 (USA); jparrotta@fs.fed.us
3 Forest Research , PO Box 29237, Christchurch (New Zealand); Eckehard.Brockerhoff@ForestResearch.co.nz
4 IEFC– EFI Regional Project Centre, 69 route d'Arcachon, 33 610 Cestas (France); aquitaine@iefc.net
5 Department of Botany, University of Queensland, Brisbane, Queensland 4072 (Australia): d.lamb@botany.uq.edu.au
6 Division of Forest Science, 145 Mulford Hall #3114, University of California, Berkeley CA 94720-3114 (USA); ohara@nature.berkeley.edu
7 Department of Geography, Mount Allison University, 144 Main Street, Sackville, New Brunswick, E4L 1A7 (Canada); bwalters@mta.ca

I Introduction

Plantation forests, or planted forests, are cultivated forest ecosystems established by planting or/and seeding in the process of afforestation and reforestation, primarily for wood biomass production but also for soil and water conservation or wind protection. Though the total area of plantation forest (187 million ha) represents only 5% of the global forest cover (FAO, 2001), their importance is rapidly increasing as individual countries move to establish sustainable sources of wood fibre to meet the increasing demand for wood and pulp. This is particularly the case in Asia, where an estimated 62% of the global plantation forest estate is located. Industrial plantations (supplying industrial wood and fibre) account for 48% of the global plantation estate; these typically consist of intensively managed, even-aged and regularly-spaced stands of a single tree species (indigenous or exotic), often genetically improved, and are characterised by relatively short rotations when compared with natural forests. Non-industrial plantations, established for fuelwood, soil and water conservation (e.g., watershed rehabilitation), and wind protection, account for 26% of the world's plantation forests, while an additional 26% of plantation forests are established for other, unspecified, purposes (FAO, 2001).

During the past decade, while natural forest and total forest areas have continued to decline at the global level, forest plantation areas have increased in both tropical (+20 million ha) and non-tropical (+12 million ha) regions. In both tropical and non-tropical regions, the conversion of natural forests and reforestation of non-forest areas have contributed in roughly similar proportions to these increases in forest plantation areas during this period (FAO, 2001). It is worth noting that between 1990-2000, the rate of conversion of natural to plantation forests in tropical regions was about equal to the increase in natural forest resulting from natural reestablishment (i.e., forest succession) of non-forest areas, and only 7% of the area of natural forest converted to non-forest land uses. In non-tropical areas the net increase in natural forest areas was more than three times the rate of conversion of natural to plantation forests.

About 60 % of plantation forests are located in four countries (China, India, Russian Federation and the United States). Species in the genera Pinus and Eucalyptus are the most commonly used in plantations (30%), though the overall diversity of planted tree species is increasing (FAO, 2001). Table 1 provides a summary of plantation forest areas and their geographic distribution.

Table 1: *Plantation forests area by region, 2000 (from FAO, 2001)*

Region	**Total forest area (million ha)**	**Natural forest area (million ha)**	**Forest plantation area (million ha)**	**% of total plantation area**
Africa	650	642	8	4
Asia	548	432	116	62
Europe	1039	1007	32	17
North & Central America	549	532	18	9
Oceania	198	194	3	2
South America	886	875	10	6
World total	**3869**	**3682**	**187**	**100**

What is biodiversity?

Biodiversity is defined as "the variability among living organisms from all sources …[including] diversity within species, between species and of ecosystems" (Convention on Biological Diversity: United Nations 1992). Forest ecosystems shelter a major part of terrestrial biological diversity, including an estimated 80% of all terrestrial species; approximately 12% of the world's forests are presently in protected areas (FAO, 2001). The importance of maintaining biodiversity in forest ecosystems has been emphasised in the past decade at political levels through many international conventions and agreements promoting sustainable forest management (SFM) including the Montreal or Pan European

Processes, and at commercial levels as part of forest certification schemes (e.g., FSC, PEFC). Biodiversity is thus an issue of increasing relevance to plantation forests and their long-term sustainability, and as a criterion for SFM, it is becoming clear that maintenance of biological diversity has direct implications for plantation forests and their management.

Biodiversity in a forest ecosystem is determined and influenced by climatic and soil conditions, evolution, changes in species' geographical ranges, population and community processes, and natural or human-related disturbances. Ecological processes and biodiversity change over time as ecosystems recover from natural or human-caused disturbances. Disturbances can either increase or decrease biological diversity depending on the scales and measures of biodiversity being considered; for many measures, the highest levels of biodiversity are found in forests that have been subjected to intermediate frequencies, scales and intensities of disturbance (Kimmins, 2000).

Four components of biological diversity are of particular relevance to discussions on planted forests and their environmental impacts:

Genetic diversity: the genetic variation within a population or a species.

Species diversity: the number of species in a particular area or community (species richness) or the relative abundance of the species therein (species evenness).

Structural diversity: how forest plant communities are structured both horizontally and vertically, which changes continuously as stand development proceeds and is particularly significant in plantation forests. Structural diversity can be as important for animal species diversity as is the diversity of plant species in the forest plant communities.

Functional diversity: variation in functional characteristics of trees and other plant species, *i.e.*, evergreen *vs* deciduous, shade tolerant *vs* light demanding, deep-rooted *vs* shallow-rooted, etc....

The measures of biological diversity defined above can be applied at various spatial scales (local ecosystem and stand level, landscape level, regional and beyond) and are dynamic, changing over time. This change can be quite rapid as a result of disturbance or slow as a result of climate change or species evolution. Much of the focus in discussions about biodiversity has been at the local ecosystem level; however, biodiversity measures at this level exhibit the greatest temporal variation.

In the following sections we will discuss and attempt to summarize the current state of scientific knowledge regarding the impacts of planted forests and their management on biodiversity. We will consider key issues related to intraspecific diversity, focusing on genetic diversity within tree plantations, as well as the influence of planted forests on interspecific diversity within planted forests and in surrounding landscapes. Further, we will consider the role of biodiversity in planted forests and the strategies for managing planted forests to conserve and/or enhance biological diversity at various spatial scales from the forest stand to the landscape level.

2 Genetic Diversity

Characterisation of genetic diversity in tree plantations

As a fundamental component of global biodiversity, genetic diversity includes the intraspecific variations between individual trees, e.g. genes, within populations and between populations (races, ecotypes and provenances). This genetic diversity largely controls adaptability and resistance to abiotic and biotic disturbances.

In the past decade, the rapid development of tools (e.g. molecular markers) for analysing the genetic variability of forest trees (Petit et al., 1997), has enabled scientists to better characterise and assess pollen fluxes between individuals and populations, spatial distributions of genetic diversity within stands, and to better understand the effects of silvicultural practices on the long-term evolution of genetic diversity of forest trees. Also, the molecular characterisation of the plantation tree populations and improved varieties enable us to better manage and control the movements of forest reproductive materials (FRM). (Ribeiro et al. 2002)

Modification of genetic pools (new species, seed transfer)

Although there is an increasing body of scientific information available to assess the possible impact of plantations on intraspecific genetic diversity of forest trees, there is no single satisfactory answer to this question. This impact is clearly influenced by the type of forest reproductive material (FRM) used in plantations, the quality of available and registered FRM genetic information, and the feasibility of the control applied to it (Ditlevsen, 1993). The impact of plantations on genetic diversity depends on the level of genetic variability of the FRM itself, as well as on the possible gene exchanges between the planted FRM and surrounding forest tree gene pools. The final impact of plantations set up with a controlled FRM, at the regional forest tree diversity level, depends also on the total area afforested with this FRM and duration of its use. There is a real challenge for sustainable forest management to take into consideration what would happen if highly selected FRM (especially hybrid, clonal or GM varieties), initially planned to be clearfelled and re-planted, were to regenerate naturally and spread outside plantation areas by lack of control over time.

As has occurred earlier in agriculture, the introduction of genetically improved exotic species in forestry increases productivity and carbon-fixation efficiency but also interspecific diversity at landscape and regional scales (see chapter 3). In France for example, compared to 70 natural forest tree species, 30 introduced species are commonly used in plantation forestry and often help to increase the interspecific genetic diversity of forests at the local level (Le Tacon et al., 2000; 2001). More generally in Europe, the forest flora was very diverse at the end of the tertiary era, and numerous species disappeared during the successive glacial periods. There is no doubt that the introduction of new species has partly restored this species richness.

While popular in the past, introduction of exotic species has been limited more recently because there were and are still risks associated with these introductions. Long-term confirmation of adaptation to local soil and climate conditions is necessary for the use of exotic species in extensive plantation programmes, to avoid severe damage - summer drought and winter frost resistance, tolerance to hydromorphic soil condition, resistance to insects and diseases all require verification. Also, exotic fast-growing species can replace native forest tree species because of their natural invasive potential, as observed for example with eucalypts in northwestern Spain and Portugal.

Impact of using genetically improved FRM

FRM collected from registered seed stands results in plantation forests with a level of genetic diversity most often similar to the wild population from which it originates. The main genetic impacts depend on the level of adaptation of the introduced population to its new environment and the possible gene transfers from it to the surrounding native population; in this respect, the possible undesirable impacts of long-distance seed transfer requires special consideration. With the development of selection programmes for plantation tree species, the level of genetic diversity of the planted material has been progressively restricted, as with single or controlled mixtures of full-sib families, clonal varieties, or genetically modified (GM) trees that may be used in the future. Consequently such FRM could be expected to have a lower adaptability and an increased ecological risk over the same rotation time (Gadgil & Bain, 1999; Evans, 1999; Wingfield, 1999). On the other hand, the genetic information is much greater, allowing the forest-owner to better balance the expected economic gains and the ecological risks, and there are some relevant and known breeding strategies and gene conservation procedures able to maintain the genetic variability of the plantation species over several generations.

Clonal varieties

A major concern arising from the use of clonal plantation forestry is the maintenance of stand adaptability, i.e. the ability to face an unexpected catastrophic perturbation due to biotic or abiotic causes. Does the increased use of clonal planting stock contribute to a decrease in stand viability? These questions have been investigated theoretically by considering simplified situations in which susceptibility to the unknown hazard (Bishir & Roberds, 1999) is controlled by one single diallelic locus. The results varied according to the frequency of susceptible genotypes and the level of acceptable stand mortality. If the former is higher than the latter, then increasing the number of clones will increase the susceptibility of the multiclonal variety. If the former is low, then increasing the number of clones increases the probability of success, but the increase of probability of success occurs mainly up to 10 genotypes. To cover most of the situations, Bishir & Roberds (1999) recommend using clonal mixtures including between 30 to 40 genotypes.

Genetically modified (GM) trees in commercial varieties

Gene transfer is currently being tested in most forest species undergoing intensive breeding activities (Radiata pine, Scots pine, Maritime pine, Sitka spruce, Norway Spruce, Eucalyptus, poplars…). In conjunction with other biotechniques such as somatic embryogenesis, rapid and important genetic gains can potentially be transferred to forestry. Transgenesis has been considered as an attractive tool for genetically improving trees for pest and insect resistance, wood properties and lignin content (Jouanin, 2000). Benefits expected from transgenesis are increased ecological and economic efficiency of wood production by improving and homogenising target traits, increased adaptability and resistance to biotic and abiotic stresses, and reductions in the use of undesirable insecticides and pesticides. For example, poplar, European larch, and white spruce have been engineered for a gene encoding an insecticide toxin from the soil bacterium Bacillus thuringiensis (Bt). To date there are a total of 117 experimental plantations with GM trees belonging to 24 trees species around the world, but no commercial plantation has been reported. The main risks for biodiversity (Kremer, 2002) are related to the dissemination of GM material which might result in introgression with related tree species (Matthews and Campbell, 2000) and in the spread, through natural regeneration, of GM trees that are potentially better adapted to site conditions (Hayes, 2001). As for annual crops, the potential use of transgenic trees in forestry has raised concerns in the public and among foresters and scientists, and has motivated vandalism and other criminal acts. These unfortunate events illustrate the sharp controversy existing between the public and the scientific community, and also within the scientific community. There is an urgent need for an in-depth debate on benefits and risks associated to transgenic technology in forestry, considering scientific, economic, social and ethical aspects. This debate is a motivation for this contribution.

3 Interspecific Diversity

Species diversity in plantation forests versus natural forests and other habitats

It is widely thought that plantation forests are, on average, less favourable as habitat for a wide range of taxa, particularly in the case of even-aged, single-species stands involving exotic species (Hunter, 1990; Hartley, 2002). In support of this notion, the bird fauna of single-species plantation forests has been reported to be less diverse than that of natural or semi-natural forests (Helle and Mönkkönen, 1990; Baguette et al., 1994; Gjerde and Sætersdal, 1997; Fischer & Goldney, 1998; Twedt et al., 1999). Carabid beetles were found to be more abundant and diverse in natural or semi-natural forest than in spruce plantations in Ireland (Fahy & Gormally, 1998) and Hungary (Magura et al., 2000). Similar results were obtained in studies of beetles in South Africa (Samways et al., 1996), dung beetles in Borneo (Davis et al. 2000), and arthropods in general in Brazil (Chey et al., 1998) and New Zealand (Anderson and Death, 2000). The vegetation in conifer plantations was found to be less diverse than that in semi-natural woodlands in Ireland (Fahy & Gormally, 1998) and in Great Britain (Humphrey et al., 2002).

However, such findings cannot be generalised because in some cases the wildlife or other biota in plantation forests may be as diverse as in natural forests. For example, species richness of indigenous birds in New Zealand was only slightly lower in pine plantation forests (Clout and Gaze, 1984), and in some cases bird counts in these plantations exceed those of most natural forests (Brockie, 1992). Bird species richness in a Lophostemon plantation was similar to that in secondary forest (Kwok and Corlett, 2000). In Great Britain, the fungal and invertebrate communities in conifer plantations have been found to be similar to those in natural woodlands (Humphrey et al., 1999; 2000; 2002).

Furthermore, an analysis of the impact of plantation forestry on biodiversity based simply on comparisons with natural forests in the same area is not always appropriate. While the conversion of old-growth forest, native grassland or some other natural ecosystem to plantation forests will rarely be desirable from a biodiversity point of view, planted forests in fact often replace other land uses. Where they are established on abandoned pastures or degraded land, plantation forests are usually more beneficial to biodiversity than such modified agricultural areas. For example, in New Zealand pasture is known to be dominated by exotic species and to be a particularly poor habitat for indigenous species whereas the understorey of pine plantations usually includes many indigenous plant species (Brockerhoff et al., 2001).

Numerous studies carried out during the past 15 years have demonstrated that planted forests can accelerate natural forest regeneration on degraded sites where persistent ecological barriers to succession would otherwise preclude recolonization by native forest species. This facilitative role of planted forests is due to their influence on understorey microclimatic conditions, vegetation structural complexity, and development of litter and humus layers during the early years of plantation growth. Examples of the "catalytic effect" of forest plantings on degraded landscapes (summarized in Parrotta & Turnbull, 1997; Parrotta, 2002) can be found in many tropical and subtropical countries, including India, China, Indonesia, Australia, Uganda, Malawi, Congo, South Africa, Puerto Rico, Costa Rica, and Brazil. In the Mediterranean region, artificial forests created at the end of the 19th century to rehabilitate overgrazed grasslands and for watershed protection, and subsequently thinned and/or harvested, revert naturally to mixed conifer-broadleaf forests similar in structure and species composition to those that existed prior to their degradation caused by overgrazing, overharvesting, and fire. These examples highlight the need for consideration of the land use history when evaluating species richness in plantation forests.

The differences in species composition and diversity between plantations and natural forests can be attributed to a number of factors. The use of exotic tree species in plantations has implications for indigenous forest species (Kholi 1998), which may have certain requirements that are not met by the exotic tree species or the habitat they create. For example, exotic tree species in Britain are inhabited by far fewer herbivorous insects than are found in indigenous forests (Kennedy and Southwood, 1984). By contrast, vascular plant species are generally not as discriminative and can colonise plantation forests regardless of the identity of the canopy species, provided the physical characteristics of the habitat are appropriate. Some plantations can have a surprisingly diverse understorey of indigenous species (Allen et al. 1995, Keenan et al., 1997, Oberhauser 1997, Viisteensaari et al., 2000, Yirdaw, 2001). However, there is considerable variation in the richness and abundance of understorey plants among planted forest stands. Some of this variation can be attributed to the amount of light available to understorey plants (Cannell 1999). Particularly dense stands of spruce and Douglas fir can cast so much shade that they appear to literally shade out the understorey vegetation (Humphrey et al. 2002). Likewise, single-species plantations of Rhizophora may prevent site colonization of other, non-planted mangrove species (Walters, 2000). The harvesting method of clearfelling places a strong constraint on species inhabiting plantations. For example, clearfelling dramatically changes the species composition of understorey plants (Allen et al. 1995), although the subsequent succession often restores the pre-clearfell understorey vegetation (Brockerhoff et al. 2001). Generally, site management practices in planted forests have direct impacts on biodiversity. Fertiliser use can lead to reductions in the populations of some native plant species but increases in the populations of others, especially if the site was degraded prior to reforestation. Fertilisation may also induce an increase in microbial diversity by accelerating turnover of organic matter (Nys, 1999). There is limited knowledge of effects of planted forests on the diversity of soil biota compared to other land uses; it has been shown that longer rotations foster soil biodiversity for loblolly pine plantations in the southeastern U.S. (Johnston et.al. 2002) and also that short-rotation plantations have positive effects on biological soil fertility in the Congolese savanna environment (Bernhard-Reversat, 2001). Herbicide or insecticide application which are often associated with intensive management of plantation forests can also result in a temporary decrease in plant, fungi and insect biodiversity (Dreyfus, 1984). Short rotation management can also reduce the quantity of dead wood that are beneficial to saproxylic insect species (Jukes et al. 2002) or bryophyte species (Ferris et al., 2000) and may decrease the opportunities for colonisation by poorly dispersed, late-successional native plant species (Keenan et al., 1997). Short rotations will also limit the extent to which structurally complex understorey development will occur which can limit the suitability of plantation for some wildlife species.

Characteristics of species that can benefit from planted forests

As a habitat for other species, plantation forests are characterised by some constraints resulting from their more or less intensive management (see above). Clearfelling and comparatively short rotations favour the occurrence of ruderal plant species whereas some long-lived climax species may not be present, and harvesting disturbance may enable invasive exotic plants to invade plantation forests (Allen et al. 1995). However, older stands can provide habitat for indigenous shade-tolerant species that are typical of natural forest understories (c.f., Allen et al., 1995; Brockerhoff et al., 2001). Similar patterns have been observed for birds (Clout and Gaze, 1984), typically for relatively common species. All such species benefit from the additional habitat provided by plantation forests if they have replaced less suitable habitat. Plantation forests can also accommodate edge-specialist species (Davis et al. 2000) and generalist forest species that would benefit from any forest type (Christian et al. 1998, Ratsirarson et al. 2002). "Planting tree monocultures" has even been suggested as a method to restore forest vegetation on degraded land, by providing a sheltered forest environment that allows colonisation of forest tree species (Lugo, 1997).

Rare or threatened species are not often reported from plantation forests, but this is perhaps due to a lack of scientific study. Some notable cases of occurrence of such species exist, and these are often significant findings both as conservation issues and because they can have implications for the management of affected plantations. For example, large populations of threatened kiwi inhabit some pine plantations in New Zealand (Kleinpaste, 1990). The occurrence of these flightless endemic birds and other threatened species challenges plantation forest managers (Brockerhoff et al., 2001).

Spatial considerations

The role of plantation forests in benefiting biodiversity at a regional level depends very much on the location of the plantation within the landscape. In some circumstances, plantation forests can potentially have negative effects on adjacent communities because of invasive natural regeneration of planted trees in adjacent habitats (Engelmark, 2001) or alteration of hydrological properties. On the other hand, they can also make an important contribution to biodiversity conservation at the landscape level by adding structural complexity to otherwise simple grasslands or agricultural landscapes, and fostering the dispersal of species across these areas (Parrotta et al., 1997; Hunter, 1990; Norton, 1998). Even plantation forests that are less diverse than natural forests can increase bird diversity at landscape and regional scales, when they have habitat characteristics that are favoured by some species (Gjerde and Sætersdal 1997). In most tropical regions, wildlife species (especially bats and birds) are of fundamental importance as dispersers of seeds and soil microorganisms. Their effectiveness in facilitating plantation-catalyzed biodiversity development on deforested, degraded sites depends on the distances they must travel between seed sources (remnant forests) and plantations, the attractiveness of the plantations to wildlife (ability of plantations to provide habitat and food), and the condition of the forests from which they are transporting seeds (c.f. Wunderle, 1997). Plantation forests adjacent to exposed remnants of indigenous forest can therefore be beneficial because they provide shelter, reduce edge effects, and enlarge the habitat for some species, and they can also serve to increase connectivity among forest fragments (Norton, 1998). Such effects are most important in regions with sparse indigenous forest vegetation.

Of course not all plantations generate benefits such as these, and there is still much uncertainty about just how these outcomes might be achieved. Little is known, for example, of just how much of a deforested landscape must be reforested to allow biodiversity and self-sustaining forest ecosystems to be re-established. Likewise, little is known of where trees might be re-planted in a fragmented landscape to achieve an optimal biodiversity outcome.

4 Role of Biodiversity in Planted Forests

Biodiversity and ecosystem functioning

It is well known that living organisms, through their metabolism and growth, drive energy and matter flows that contribute to the structuring and functioning of ecosystems. It is more difficult to understand ***how*** the diversity of these organisms, *i.e*., biodiversity, affects these ecosystem processes. This question is a key issue in modern ecology but has also practical implications for agriculture and forest management. It is indeed of great interest to understand how changes in biodiversity can affect ecosystems functions (*e.g*. primary productivity, soil fertility or trophic interactions) that in turn can affect crop yields.

Three main hypotheses have been proposed to link biodiversity to ecosystem functioning (Naeem et al., 2002). The first is the 'species redundancy' hypothesis, which postulates that species lost from a system can be substituted by others and compensate for the functional role of the lost species without affecting the functioning of the ecosystem. The 'species singularity' hypothesis states that each species performs a unique contribution to ecosystem processes and that the loss of any species will cause a potentially significant change in these processes. The 'context-dependent role of species' hypothesis accounts for the unpredictability of the effect of the loss (or the addition) of species on ecosystem functioning, which can be either beneficial or detrimental, depending on the local and temporal context.

Functional role of biodiversity in planted forests

Most of the experimental studies that demonstrated increasing biomass production with richer species diversity involved grassland, wetland or microbial species (Naeem et al., 1994; Yachi and Loreau (1999); Tilman et al., 2002). Due to obvious technical difficulties in manipulating long-lived species like trees, relatively few manipulative experiments have so far addressed this issue in forests, but similar mechanisms are likely to apply in forest ecosystems. One area where manipulative experiments involving forests have been conducted is in the use of nitrogen-fixing trees to overcome nitrogen deficiencies. These studies, mostly involving two-species mixtures, have shown mixed-species stands improve plantation productivity (Binkley et al., 1992; Khanna, 1997, DeBell et al., 1997; Parrotta, 1999). In addition, several observational studies indicate higher growth performances in mixed than in pure stands of oaks (Bartsch et al.,1996) and spruce (Wang et al., 1995).

Diverse forests can be healthier than monocultures, and thus the trophic dimension of the biodiversity-ecosystem functioning relationship needs to be considered. Several reviews indicate that forest monocultures in all climatic regions may experience insect outbreaks that cause considerable damage (Gibson & Jones, 1977; Barthod, 1994). Until recently, the evidence in support of the view that insect pest outbreaks occur more frequently in plantation forests as a result of their poor tree diversity was controversial (Gadgil & Bain, 1999) because, in plantation forestry, confounding factors may occur such as even-age structure (Géri, 1980; Schwerdfeger, 1981), use of exotic species (Watt & Leather, 1988; Speight & Wainhouse, 1989) and intensive silviculture (Gibson & Jones, 1977; Ross & Berisford, 1990; Jactel et al., 1997). However, a recent review, based on a meta-analysis of more than fifty field experiments which compared pure stand vs. mixed stand of the same tree species, demonstrated a significant increase in insect pest damage in single-tree species forests (Jactel et al., 2002). Three main factors related to single-species forestry can predispose forest plantations to insect attack (Jactel et al., 2002). Firstly, the lack of physical or chemical barriers provided by other associated plant species that could reduce access of herbivores to the large concentration of food resources, i.e., the high density of host trees in the forest monoculture. Secondly, the low abundance or diversity of natural enemies often observed in forest plantations can result in limited biological control of pest insects. The third explanation is the potential absence of a diversion process, i.e., the disruption effect on pest insects resulting from the presence in the same stand of another more palatable host tree species.

Because of technical and economic constraints, it is unlikely that plantation managers will convert single-species stands into mixed-species stands simply in order to reduce pest damage that was normally only of minor significance. On the other hand they might if the commercially attractive tree species was especially valuable and the insect damage was significant. Thus Keenan et al. (1995) described the advantages and required trade-offs involved in using a temporary tree cover crop to minimise tip borer attack in red cedar (a member of the Meliaceae) in north Queensland. In this case the multi-species plantation reduced insect damage on the target species to an extent sufficient to make the plantation viable. On the other hand, the overhead cover also reduced the growth rate so that care had to be taken to balance survival against growth increment.

Alternative ways of achieving the functional benefits of diversity might be to increase plant diversity in the plantation understorey, but proper field experiments are needed to test whether this would be effective. A second option might be to consider increasing tree diversity at the landscape level. Growing evidence suggests that enhancing habitat diversity in plantation forest landscapes may prevent the development of pest insect outbreaks. For example, a study on spruce budworm, Choristoneura fumiferana, reported lower balsam fir mortality in stands surrounded by non-host deciduous forest than in stands within large conifer-dominated forest (Cappucino et al. 1998). Similarly, Jactel et al. (2002) demonstrated that pure stands of maritime pines bordered by a mixed woodland of broad-leaved species were less attacked by the stem borer Dioryctria sylvestrella than pure stands among a monoculture of pine trees. These findings indicate that the preservation or restoration of mixed-species woodlands, for example in gaps where site conditions or stand accessibility make timber production less profitable, could provide the basis for a more sustainable management of plantations forests.

5 Managing Planted Forests to Enhance Biodiversity: Suggestions for the Future

Genetic resources

By combining current scientific knowledge in the area of forest and tree genetics with common-sense forest management, general suggestions for preserving and enhancing genetic diversity in plantation forestry can be elaborated (Arbez, 2000):

- ***Monitoring and improving genetic diversity in breeding populations**. The main concerns associated with the use of improved FRM are whether genetic gain and diversity can be simultaneously maintained at reasonable levels over successive generations during the whole selection programme. As many operational tree breeding programs conducted on fast growing species are entering their third or even more advanced generations, these questions have raised theoretical and experimental approaches which provide guidelines to geneticists for maintaining genetic diversity (Namkoong, 1988; Eriksson, 1993; White et al., 1993). Furthermore, conservation strategies can enrich the genetic base at any moment and must be used as a necessary complement of the breeding process.*

- ***Controling quality of Forest Reproductive Material (FRM)**. Quality of a given FRM is directly related to the quality of the genetic information available, allowing its final user to optimally balance expected gains and possible risks. It means precise and reliable information on: (i) geographic origin of the parent gene pool (natural population or selected genotypes), (ii) identities, number, genetic characteristics of the parents and crossing scheme used to obtain the commercial variety, and (iii) selection procedures (description of the mono- or multi-site experimental design, selected traits and levels of genetic superiority assessed by comparison with well known reproducible standards). This information can be used to control quality of FRM and to favour FRM resulting from long term breeding scheme combining recurrent selection and gene resource conservation.*

- ***Diversifying genetic resources at stand or landscape levels** through the parallel development of available genetically improved varieties and limited utilisation of a given variety in space and time in order to prevent genetic uniformisation. The risks associated with improved FRM* *and decreased genetic diversity can be minimised by (a) using multi-clonal mosaic schemes, where genetic diversity within a stand at a given time is replaced by genetic diversity between stands at the landscape level; (b) limiting the monoclonal plantation area at the regional scale as well as the time during which a given clonal variety is permitted to be used.*

- ***Evaluating genetic risks,*** *in particular developing risk simulation methods and secured long-term trials to monitor impacts of introduction of GM trees in forest plantations prior to any commercial deployment and use (Kremer, 2002). Economic and biological constraints limit the number of GM trees created and impose to deploy them through clonal varieties; main recommendations for their use include: (a) male sterility, preventing pollen contamination of the surrounding forest related tree species; (b) testing not only in classical clonal tests (comparing one clone with a limited number of standard other clones, in well controlled conditions of experimental plantation) but also in long-term experimental field trials to evaluate environmental risks .*

Stand management

Enhancing biodiversity in plantations can generally be achieved by increasing variability when plantations are established or tended (Hartley, 2002). The emphasis in the past has been on reducing variability to improve predictive capabilities and efficiency of establishment, tending, and harvesting operations. As a result, there is little experience with enhancing variability in plantation management settings. It seems likely however that many future plantation owners, especially those operating on a small scale, will be seeking more than just timber production from their plantations and might be willing to trade off efficiency and predictability for the sake of ecological services such as enhanced biodiversity.

This increased variability can be achieved in several ways. Perhaps the most obvious is to use multi-species plantations rather than monocultures. Random species assemblages are unlikely to be successful and care is needed to design mixtures that are stable as well as productive (FAO, 1992; Montagnini et al., 1995; Lamb, 1998). The choice of species and the number to use will also be affected by economic considerations. One of the potential advantages of diversity is that it provides insurance against future changes in market values but all potential species must have broadly similar values; if not, the opportunity cost of reducing the stocking of high value species to use lower value species may be too high. Various planting arrangements have been tested but alternate row plantings appear the most common. Plantations with more than one species planted in alternate rows may increase yields and facilitate removal of the slower growing species in an intermediate thinning. These mixed species plantation systems may also provide higher wood quality through mutual shading of lower limbs (Oliver and Larson, 1996).

Another way of achieving enhanced variability and diversity is by taking advantage of the “catalytic effect” referred to earlier. In many areas, single-species stands may be the intention, but natural regeneration of other species is inevitable and adds to diversity (Parrotta & Turnbull, 1997). In these situations, such as in the Douglas-fir region of North America, this natural regeneration could be encouraged during the vegetation control process. Similar biodiversity enhancement could be also achieved favouring a diverse plant understorey (Chey et al., 1998; Lamb, 1998). Given sufficient time this understorey community may grow up and join the canopy layer. This means it could compete with the original plantation trees and reduce their productivity. Some of the management options are reviewed in Keenan et al. (1997).

Even in plantation monocultures there is considerable scope for enhanced variability. Less uniform site preparation treatments, variations in tree spacing and thinning treatments can also enhance stand structure variability. Structural complexity of the planted forest is an important determinant of subsequent biodiversity enrichment due to the importance of habitat heterogeneity for attracting seed-dispersing wildlife and microclimatic heterogeneity required for seed germination for a variety of species (Parrotta et al., 1997). This suggests that broadleaf species yield generally better results than conifers, and that mixed-species plantings are preferable to monocultures, due in part to their increased structural complexity. Two-aged stands may also be a viable alternative in situations where clearcutting is aesthetically unpopular. Extending rotation length could also benefit biodiversity, particularly favouring diversity of soil biota and species associated with dead wood or leaf litter (Ferris et al., 2000; Magura et al., 2000). Maintaining snags, logs and other woody debris on site can also enhance habitat values for a range of species, from fungi to cavity-nesting birds. Management practices that increase soil organic matter content (such as spot cultivation, use of amendments, retention of harvest residues) and decrease soil disturbance during site preparation and harvest are desirable for maintaining the inherent biological capacity of soils and diversity of soil living organisms which are essential for nutrient conservation and cycling (Johnston et.al., 2002). Although management efficiency may be reduced, these more complex stand structures may be as productive, if not moreso, than comparable even-aged plantations (O'Hara, 1996). Whereas the productivity and actual effects on biodiversity of these structures are not well understood, there is additional uncertainty with regard to current tree breeding and the appropriateness of these trees in complex forest structures.

Landscape level

Forest management needs to consider plantations from a landscape perspective in that they comprise a spatial array of different elements that can be arranged in different ways depending on management goals. The key elements within a plantation forest are individual stands or compartments of different age and species composition, remnants of native ecosystems, including riparian strips, and amenity plantings. Observations suggest that managing plantation densities and creating irregularities within the spatial structures, favouring the proportion of borders and clearings, and preserving natural plant communities along rivers and in swampy areas would logically increase the level of associated plant and animal biodiversity. Retention of broad-leaved species among coniferous plantations (Ferris et al., 2000), or preservation of native remnants, have been proposed as a management tool to enhance biodiversity at the landscape level (Norton, 1998; Fisher et al., 1998).

Some of these elements are fixed in the landscape (e.g., native remnants and riparian strips) but others can be arranged in different ways. Humphrey et al. (2000) suggested locating plantations near existing semi-natural woodland fragments. In North America, spatial modelling tools have been used to optimise timber harvesting in native forests to meet biodiversity conservation goals (Bettinger et al., 1997). Similar modelling could be used to optimise the arrangement of different-aged plantation forest compartments, and different plantation species, to maximise timber production, biodiversity conservation and ecosystem stability. The key feature of this approach is that it considers biodiversity conservation at the landscape scale rather than at the stand scale and thus removes the direct conflict between biodiversity conservation and timber production at any individual site. The major potential difficulty, of course, is that land ownership patterns and consequently management decisions are often made at the local rather than landscape scale. Ways must therefore be found to ensure social outcomes as well as ecological outcomes at the landscape level.

In his analysis of the role of industrial plantations in large-scale restoration of degraded tropical forest lands, Lamb (1998) suggests a number of management approaches by which forest productivity (and profitability) and biodiversity objectives may be harmonized at the landscape level. These include: increased use of native rather than exotic species, creation of species mosaics by matching species to particular sites, embedding plantation monocultures in a matrix of intact or restored vegetation, using species mixtures rather than monocultures, or modifying silvicultural management practices to encourage development of diverse understories beneath plantation canopies.

Conclusions

There is no single, or simple, answer to the question of whether planted forests are good or bad for biodiversity. Plantations can have either positive or negative impacts on biodiversity at the stand or landscape level depending on the ecological context in which they are found. Objective assessments of the potential or actual impacts of planted forests on interspecific biological diversity at different spatial scales require appropriate reference points. In this regard, it is important to consider in particular the (biodiversity) status of the site (and surrounding landscape) prior to establishment of planted forests, and the likely alternative, land-use options for the site (i.e., would or could a site be managed for biodiversity conservation and other environmental services or be converted to agriculture or other non-forest uses?). For example, the establishment of an industrial pine plantation on a particular site will clearly have a more negative impact on stand-level biodiversity if it replaces a healthy, diverse, old-growth native forest ecosystem than if it replaces a degraded abandoned pasture system that was the result of earlier forest conversion. Thus, the ecological context of planted forest development, as well as the social and economic context shaping land-use change, must be considered in the evaluation of biodiversity impacts (Romm, 1989; Walters, 1997; Rudel, 1998; Clapp, 2001; Rudel et al., 2002).

The need to pay more attention to biodiversity issues in plantation design and management is supported by observational, experimental and theoretical studies that indicate that biodiversity can improve ecosystem functioning. While plantation monocultures have economic advantages, the need to ensure their long-term sustainability argues for greater research effort to develop design and management strategies that enhance plantation understory and soil biodiversity as well as their functional benefits. Many plantations are being established for the contribution they can make to overcome ecological degradation (e.g. soil salinity, erosion) and improve the long-term sustainability of land uses such as agriculture. Faced with the unpredictable, enhancing species diversity may improve adaptability of all managed forest ecosystems to changing environmental conditions (Hooper et al., 2002).

The primary management objective of most plantation forests has traditionally been to optimise timber production. This will continue to be the primary objective in most (though perhaps not all) industrial plantation programs but it will not necessarily be the case in many smaller scale plantations owned by farmers and other non-industrial groups. In these circumstances the management objectives may place greater weight on the provision of non-timber products and ecological services such as biodiversity. This will require the development of a new range of silvicultural tools to establish and manage these plantations.

Where managers are seeking to produce goods as well as ecological services, there are invariably difficulties in making the necessary trade-offs. These trade-offs operate at all levels of biological diversity. In the case of genetic diversity, for example, a balance must be struck between the need to identify the most productive forest reproductive material to plant at a particular site and the desire to re-establish the biodiversity represented in the original genotypes. Should a manager use highly productive planting material with a narrow genetic base that has been developed from an intensive selection program, clonal material or even genetically modified varieties? Or, should one rely instead on natural seed sources with a wider genetic diversity because these will confer greater resilience to the plantation enabling it to cope better with future environmental changes such as insect attacks or climatic events? Judicious use of relevant, well-known tree breeding strategies and gene conservation strategies can greatly facilitate efforts by managers to maintain genetic variability of plantation species over several generations and thus achieve better balance between economic and environmental benefits and risks.

Likewise, at the species level, should managers establish plantation monocultures or should they give greater emphasis to multi-species plantations? There are, of course, no simple answers to questions such as these because much depends on the fertility of the soils being planted (are they still able to support the original native species and the soil biota required for maintaining soil fertility and nutrient cycling processes?) and on the present objectives of the landowner. Usually some compromise between the two extremes is chosen.

A critical issue for the future of plantation forests is how to combine biodiversity maintenance and wood production at various spatial scales (i.e., stand, forest, landscape). One way to achieve a balance between biodiversity and productivity/profitability is through improved practices at the stand level or alternative silvicultural regimes (species mixture at different scales from individual trees to compartments of different sizes, age and clone mosaic) combined with biodiversity management at landscape level. This would include, for example, modification of extensive clear-felling practices to reduce coup sizes (i.e., plan for smaller compartments of same-aged stands that are dispersed within the plantation landscape) to achieve a better balance between economic and environmental objectives. Thus, it may be possible to achieve a degree of biodiversity at the landscape scale through diversification of plantation landscapes to create mosaics of different planted forest and natural vegetation habitats, even if each of the individual plantation stands within that landscape are established as simple monocultures. In many parts of the world, this will require a reorientation of current practices and, in particular, a shift from a stand-level to a forest- or landscape-level approach to the planning of all aspects of plantation management.

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Explanatory Remarks and Acknowledgements

Part II of IUFRO Occasional Paper No. 15 is an outcome of collaboration between the International Union of Forest Research Organizations (IUFRO) and the organizers of the UNFF Intersessional Experts Meeting "The Role of Planted Forests in Sustainable Forest Management" held in Wellington, New Zealand in March 2003[1]. This meeting, sponsored by the Governments of Argentina, Australia, Canada, Chile, Malaysia, New Zealand, South Africa, Switzerland, the United Kingdom, the United States, and the International Tropical Timber Organization (ITTO), received technical support from IUFRO, FAO, and CIFOR.

The goals of this meeting were: to promote the role of planted forests and identify ways to maximize their contribution to global sustainable forest management; to support countries in implementing actions to promote sustainable forest management; to build on the outcomes of the first Expert Consultation on the Role of Planted Forests held in Santiago, Chile in 1999; to build consensus through informed dialogue among major interest groups; and, to support the United Nations Forum on Forests (UNFF) in implementing its work programme.

IUFRO was invited to prepare and present a paper summarizing the state-of-knowledge on key biodiversity issues related to the plantation forests and their management. On behalf of all of the authors, I would also like to thank Don Wijewardana of the New Zealand Ministry of Agriculture and Forestry, Convenor and Chairman of the Experts Meeting's Steering Committee, for his invitation to contribute IUFRO's expertise to the UNFF Intersessional Meeting, and for his committee's constructive review of an earlier draft of our paper.

A number of experts on different issues covered in this paper were invited to contribute, and the paper benefited greatly from the diverse experience and perspectives of its authors, representing research organizations and universities in France, the United States, New Zealand, Australia and Canada. This task would not have been possible without the excellent collaboration among IUFRO Divisions, particularly between Division 1 (Silviculture) and Division 8 (Forest Environment). I would like to thank Alain Franc (Coordinator Division 8) for his key role in facilitating contacts and communication among authors as we embarked on this task, Jean-Michel Carnus (INRA, France) for his critical coordinating role, and Eckehard Brockerhoff (Forest Research, New Zealand) for his leading role in presenting this paper at the Wellington meeting.

Sincere thanks also go to Eric Teissier du Cros (Vice-President Science) and Don Koo Lee (Vice-President Policy) for their invaluable leadership, guidance and technical input, and to IUFRO Executive Secretary Heinrich Schmutzenhofer as well as Alexander Buck, Judith Stoeger, and Gerda Wolfrum at the IUFRO Secretariat in Vienna for their support and assistance in the production and publication of this paper.

I sincerely hope that this paper will contribute to the UNFF process and other international (as well as national) policy deliberations by helping to clarify and communicate both what is presently known within the forest science community, as well as identify areas of continued uncertainty and research need, in relation to issues surrounding the biodiversity/planted forest debate.

John Parrotta, May 2003

[1] Full information on this meeting, including the text of all papers presented and the meeting's final Report, can be found on the meeting's website:
http://www.maf.govt.nz/mafnet/unff-planted-forestry-meeting/

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c/o Federal Office and Research Centre
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Hauptstrasse 7
A-1140 Vienna, Austria
Tel: +43-1-877 0151-0
Fax: +43-1-877 0151-50
E-mail Secretariat: iufro@forvie.ac.at
Web site: http://iufro.boku.ac.at