International Union of Forest Research Organizations

Challenges and Opportunities of Forest Research in the Policy-Making Process

A symposium organized jointly by the International Union of Forest Research Organizations and the Chinese Academy of Forestry

May 29th, 2007
Beijing, P.R. China

Edited by John L. Innes

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Foreword

There was a time when researchers considered that they should not be associated in any way with decision makers, policy makers or practitioners. They believed that such associations could bias or otherwise influence the research. As a result, researchers were accused of being confined to 'ivory towers', distanced from reality and from the needs of the general population. In recent years, this situation has changed dramatically, and today researchers are increasingly trying to ensure that their research is both relevant and used. This is particularly true of applied fields such as forest research. Research on forests and the goods and services that they provide has never been more important, and if forest research is to be used by those who could benefit from it, then there is a need to ensure that the research meets the needs of those end users. Forest research has a critical role to play in solving some of the World's most pressing problems, but it will only succeed in doing so if that research is relevant. Making it relevant requires a dialogue between researchers and the end-users of research.

Within this context, the International Union of Forest Research Organizations (IUFRO) has recognized the importance of improving the interaction between research organizations and policy makers. To date, efforts have focused on interactions with international policy groups, as befits an International Union. However, subtle changes are occurring in the field of forest policy and, for example, considerable decision-making power is now wielded by non-governmental organizations. In forestry, we have seen the rise of organizations such as the Programme for the Endorsement of Forest Certification, the Forest Stewardship Council and the Sustainable Forestry Initiative Inc., all of which are setting policies that determine the way that forestry is practiced. Such organizations have major information needs, particularly on issues such as the interaction between forests and water resources.

Thanks to these interactions, much of the research activity coordinated by IUFRO is directly related to the needs of forest policy makers. This is particularly true of IUFRO's Task Forces, which deal with a series of issues of current international concern. These Task Forces are examining complex and controversial topics with a view to summarizing the current state of knowledge related to each. This information is then being translated into policy briefs that will enable both governmental and non-governmental policy to gain insight into the issue from a reliable and unbiased source.

The papers presented at the Beijing Symposium present some of the work being done by the Task Forces. In addition, the opportunity has been taken to gather and present some information form the policy-makers themselves. Some selected regional assessments of research needs have also been presented. Together, these papers provide an overview of some of the more controversial and topical areas of forest science, and provide some hints as to where the interests of policy makers will lie in the future.

Given the rapid increase in the importance of the Peoples' Republic of China in the global forest products industry, and the increasing importance given by the Chinese Government to the role of forests in environmental improvement, it is particularly appropriate that this meeting should have been held in Beijing. I would like to thank our colleagues in the Chinese Academy of Forestry for co-hosting the symposium and for undertaking all the arrangements for what proved to be a very successful day.

Professor John Innes
Vice President for Policy, IUFRO

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The use of genetically modified trees in forests: Opportunities and challenges

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Summary

A substantial proportion of the current global research activities dealing with forest tree biotechnology are dedicated to understanding and manipulating biosynthetic pathways through genetic engineering. These collective research activities cover an array of target traits in several tree species, representing both angiosperms and gymnosperms. Despite these significant efforts, the only large-scale deployment of genetically modified trees is restricted to China, representing primarily pest-resistant *Populus.* At present, global deployment has been restricted due to limitation in accurate assessment mechanisms to ascertain the benefits and risks of such out-plantings due to the absent of multiple generations/sites experiments. Furthermore, the significant global differences in current regulatory systems calls for the development of a unified, global governing system. This report highlights the current global scope of forest trees genetic engineering, and presents the methods for genetic modification as well as alluding to putative procedure for integrations into existing breeding and production populations.

Introduction

Current applications in forestry biotechnology can be classified into five general categories: 1) genetic markers, 2) propagation and multiplication, 3) marker-assisted selection and breeding 4), genetic modification (engineering/transformation), and 5) genomics (functional, structural, comparative, associative, statistical) (see Tables 2.4.1 and 2.4.2 in El-Kassaby 2003). Recent statistics suggest that genetic modifications (defined as the introduction and/or expression of novel genes in host plants using foreign DNA) accounted for close to 20% of all broad forest biotechnology activities (Wheeler 2003). However, due to the potential of genetic modification, apparent feasibility (in select species), and the perceived known and unknown ramifications of its application, it has garnered considerable global attention (FAO 2003; Herrera 2005).

Worldwide, more than 210 registered field trials of genetically modified trees exist in 16 countries (Wheeler 2003), which are largely represented by four genera: *Populus* (51%), *Pinus* (23%), *Liquidambar* (11%), and *Eucalyptus* (7%). Generally, these efforts target commercial applications such as the development of herbicide-tolerant and biotic-resistant trees, manipulation of wood chemistry and ultimately wood ultrastructure, and attempts to control fertility. These commercial tests however only represent a small fraction of the global research efforts, which are restricted to basic research and understanding the fundamental principles underlining biological function and the complex networks involved in plant growth and development. Despite the significant fundamental observations that have resulted from these laboratory-based efforts, the basic research activities are ignored and continue to suffer from limited public funding caused by the controversial views of genetic engineering at large.

At present the commercial release of genetically modified trees has been restricted to China (over 1 million plants on ≈300 ha) following two stages of field trials and attaining the required government regulatory approval (Wang 2003). However, genetic engineering activities in forestry occur in at least 35 countries and *Populus* remains the most commonly studied tree genus (52% of activities) (Walter and Killerby 2003).

In this report we attempt to review the most commonly employed methods of genetic engineering, summarize where genetic modification efforts are under investigation, highlight the species and traits of interest, comment on the current regulatory framework, and highlight recent breakthroughs in genetic containment.

Genetic engineering methodologies

There are two commonly employed methods of genetic engineering used for integrating foreign DNA into forest tree species, namely biolostics (gene gun) and *agrobacterium*-mediated transformation.

Biolostics

This process couples a segment of desired DNA to biologically inert particles such as tungsten or gold, which are subsequently inserted into the target tissue (tissue culture such as somatic embryogenesis (SE) tissue or leaf explants) by acceleration in a partial vacuum chamber (Sanford et al. 1987; Kline et al.1987). Cells harbouring the introduced DNA are then selected and/or by selection or identification of the incorporation of a marker gene that acts as a surrogate to identify successful transformation (*i.e.* GFP, GUS and/or antibiotic resistances genes) and finally cultured to replicate the entire genome including the inserted gene(s) and clonally propagated. For example, the method has been used for inserting pesticide- or herbicide-resistant genes into plant cells. Limitations include: inconsistent delivery of DNA in a systematic fashion to the target cells, frequent cell damage (known as the “pit effect”), random insertion points, uncontrolled/unknown number of insertions (usually multiples), silencing of other functional genes, and most importantly it is totally dependent on a successful tissue culture protocol that is capable of regenerating transformed cells.

A modification of the traditional gene gun technology was introduced by Pui and Chen (1997) to overcome some of the technical limitation of the conventional method. The improved gun delivers a continuous supply of desired DNA genes and is capable of inserting the target genetic material into the living cells of plant and animal as well as a cell's organelles using nanotechnology. The modification relies on the application of an additional high electric field which forces a liquid stream to disperse the gene particles with high velocity permitting penetration of the cell membrane and the release of the genetic material into the cell. The main advantage of this new technology is the lack of pit damage (electrically charged particles repel each other), as inert carrier particles are not essential. This in turn reduces the cost, and facilitates the creation of a continuous stream of DNA, eliminating the need for reloading the system. Furthermore, the spray from the electronanospray is ultra small, highly uniform and does not contain any foreign contaminant. The use of electronanospray technology in forestry is expected to overcome some of the known limitation of the conventional gun.

Agrobacterium-mediated transformation

Agrobacterium tumefaciens, is a well-known natural plant pathogen that has been employed to deliver target DNA to the host genome with great efficiency (Hooykaas and Schilperoort 1992). Genetic transformation generally occurs when plant tissues are exposed to *Agrobacterium* stains harbouring T_i plasmid vectors with desired DNA segment engineered into them (often with marker genes needed to confirm successful transformation). Following co-cultivation with plant tissue, the vector (bacterium) expresses virulence proteins (often in response to exposure to phenolic compounds produced from wounded plant tissues), which then permit the integration of the foreign DNA into the host tissue. This is accomplished by an intricate network of virulence proteins that effectively ensure the excision, transfer and insertion of the desired segment of DNA into the target plant genome. Similar to the gene gun technology, specific gene markers are used to confirm successful transformations. Marker genes confer selective advantage to the transformed cells over non-transformed, hence allowing cell multiplication to be restricted to those with the desired DNA segments. The *Agrobacterium*-mediated transformation technique is also dependent on competent tissue culture systems that facilitate the generation of transformed cells into plants. The method's major limitation is generally related to tissue culture restrictions, such as the inability to generate advantageous shoots and thus propagation of transgenic trees (*i.e.* Salix).

Where are genetically modified trees research and application taking place?

The Food and Agriculture Organization (FAO) of the United Nation's preliminary review of biotechnology in forestry represents the most comprehensive summary on the global scope of research and development on genetically modified trees to date (FAO 2003;

Walter and Killerby 2003). While the FAO report is based on the responses obtained from a global questionnaire, the summary provides valuable information and insight on the magnitude and status of research on engineered trees. In short, research and development in the area is being conducted on virtually every continent (Figure 1), and is common to research institutions, universities, private commercial companies, as well as non-profit organizations (Walter and Killerby 2003). The result of both laboratory- and field-based experiments is the extensive overlap of traits (Table 1). The vast majority of activities are restricted to basic fundamental research attempting to elucidate the complex biosynthetic pathways signalling cascades, and few are commercially driven. However, it is possible that some of the basic research findings could spawn commercial applications. Although the majority of work is being concentrated in *Populus*, *Pinus*, *Liquidambar*, and *Eucalyptus* (Wheeler 2003), a wide array of species are being studied (see Mullin and Bertrand 1998 and van Frankenhuyzen and Beardmore 2004, for a comprehensive list).

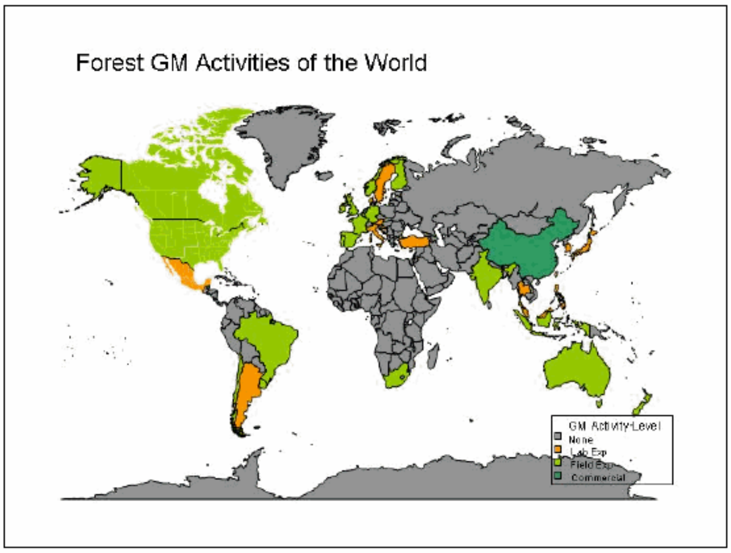

Figure 1. Countries where research investigations focused on genetically engineering trees are taking place (after Wheeler 2003).

The number of genetically modified tree field trials is dynamic and therefore difficult to determine, as a result of continuous establishment of new and the removal of existing trials before reaching sexual maturity. Similarly, the size of trials (range: 0.01 - 80 ha) and number of plants/trial (range: 90 – 2900) varies substantially (Walter and Killerby 2003).

Following several research initiatives, the introduction of *Bacillius thuringinensis Bt* toxin genes into *Populus nigra* resulted in a 1-ha pilot test trial (Tian et al. 1993) in China, and consequently the first environmental release of transformed trees was approved in 1998, with 80 ha of pilot plantations of *P. nigra* being established over eight sites. This introduction was followed by the additional approval of 1 million genetically modified *P. nigra* trees in 2002 covering 300 ha of commercial plantations (Su et al. 2003). Therefore, at present, China is the only country where genetically modified trees have been released commercially, following regulatory biosafety approval (Wang 2003).

Further to the *Bt*-poplar, several engineered trees displaying a range of desired traits have been released, including, drought and salt tolerance, and reductions in lignin content, and have been targeted for environmental rehabilitation, soil and water restoration, and increased paper industry efficiency, respectively. The process of releasing genetically modified trees for commercial purposes in China followed four strict and systematic phases starting with: 1) the creation of transformed plants in the laboratory (phase I), 2) their propagation and multiplication in nurseries (phase II), 3) field testing (phase III), and 4) deployment of selected clones (phase IV) (Wang 2003). Phases III and IV are classified as "environmental" releases as they are planted in the field and, consequently biological, biosafety, and silvicultural assessments are conducted prior to release for commercial applications.

Table 1. Summary and number of laboratory- and field-based experiments evaluating genetic engineering of trees for desired phenotype, classified according to the trait under investigation (based on statistics provided by Walter and Killerby 2003).

Trait/gene investigated	Experiments type	
	Laboratory	**Field**
Markers/reporters/antibiotic resistance	26	9
Reproductive development	19	2
Herbicide resistance	11	6
Wood properties	8	1
Insect resistance	7	3
Lignin biosynthesis	6	5
Defence traits	3	
Nitrogen metabolism	3	
Pest and disease resistance	2	
Phenotype	2	
Somatic embryogenesis	2	
Cellulose biosynthesis	2	
Hormones	2	
Growth characteristics	1	
Metabolism	1	2
Detoxification of pollutants	1	1
Bud development	1	
Sterility		1
Transgene stability		1
Activation tagging		1

The fundamental power of genetic engineering in trees

Like all plants, trees possess mechanisms that integrate and interpret the information provided by internal and environmental signals. Ultimately, these phenomena are controlled at the level of gene expression that is manifested in the synthesis of a variety of compounds that culminate in the formation of specific cell types, form soluble signals which participate is cell function and development, and/or develop into stress of defence compounds, to mention only a few. Trees are relatively “plastic” in their ability to develop and respond to biotic and abiotic signals, and as such their adaptive flexibility has permitted them the capacity to (i) match resource allocation with resource acquisition, (ii) acquire new resources more effectively, and/or (iii) avoid adverse conditions. This inherent plasticity has a profound effect not only on the development and physiology of trees, but also on the industrial harvesting and utilization of the terminal resource. Genetic engineering of trees with targeted use has for the most part aimed at improving the latter fact, and driven much of the commercial applications and field testing. This has also simultaneously created much of the negative public concern. However, the true power of genetic engineering lies in the ability to discern the true function of a given gene(s), and its consequential effect on the complex networks to which it contributes, in a specific, targeted, systematic fashion. Elucidating the role(s) of each gene in essential pathways, their regulation, and their spatial and temporal expression, should ultimately unlock some of the age-old mysteries of plant growth, development and response to biotic and abiotic cues.

Integration with existing tree breeding programs

At present, the strategies for, and linkage between existing tree breeding programmes and genetically modified “experiments”, and ultimately their respective production populations (seed orchards and/or vegetative propagation methods) are not well established. Burdon and Libby (2006) pointed out the importance for such an interface, and emphasize the need for a thorough understanding of both disciplines and their appropriate roles before successful integration of conventional breeding and the evolving “high-tech” tree improvement (genetic engineering, molecular markers, etc…) can be established. However, over time, classical breeding has been very successful in improving traits under polygenic variation, while in contrast targeted genetic engineering aims to augment major genes (those with large phenotypic effects). The diverse nature between these two genetic models supports the notion that genetic engineering should be viewed as a supplement to and not a substitute to classical breeding, and the combined, integrated approach could substantially alter the growth, development, yield and properties of commercial tree breeding programmes.

The relatively recent successful integration of genetic engineering into annual crop plants, with their seasonal field duration, should not be viewed as the roadmap for forestry. The substantive differences in the two systems' genetic backgrounds, deployment strategies, and rotation ages create distinctly different environments. Unlike the agriculture model where inbred lines, single and/or double crosses, or individual varieties are commonly deployed with their maximum genetic homogeneity (similarity among deployed plants) and genetic heterozygosity (variation on the gene level), forest tree species deployment strategies aim at maximizing both genetic heterogeneity and heterozygosity and, in some cases, at the expense of genetic gain. Thus, it is reasonable to assume, for the time being, that the application of genetic engineering in forestry, if successful, will be restricted to the production and deployment of populations through the use of vegetative propagation of "superior" lines. Methods for multiplying transformed genotypes and incorporating transgenics into breeding populations should be considered only as a distant future possibility, and only after successfully strategies for controlling gene flow have been witnessed. However, the long time required for trees (including transformed genotypes) to reach sexual maturity coupled with the appropriate cautious and revered approach of tree breeders to their breeding populations represent, among other factors, reasons for delayed integration into the more traditional breeding programs.

Successful large-scale vegetative propagation systems, such as somatic embryogenesis (Sutton et al. 2004), are expected to be the gateways to the possible integration of desired genes into selected genotypes and ultimately the deployment of genetically modified trees (i.e., enabling technology). However, the rudimentary nature of the transformation methods is expected to add additional burden to any successful large-scale deployment strategy. Currently, the transformation technologies commonly employed do not control for either the number or the positions of integration of the desired transgene segment into the selected genotype(s)' genome, and therefore every transformation event will result in a different, and unknown number and positions of the desired DNA segment (i.e., similar in genetic background but different in the transformed gene(s)). As such, these arbitrary events will exponentially increase the scale of testing of the transformed genotypes, as multiple clonally propagated individuals, from each transformation event, in several genetic backgrounds presents an additional, extensive screening event for each selected genotype. Additionally, the successful generation of plants from each "genetic integration" does not guarantee their clonal propensity for large-scale production and deployment. Furthermore, in cases where all the hurdles of molecular biology, tissue culture and tree propagation are overcome, the genetic diversity of the deployed material will continue to be a major concern, thus the programme scale should be considered to permit the production of an acceptable number of transformed genotypes (see El-Kassaby and Askew 2004, for issues related to genetic diversity in clonal forestry).

The integration of genetic engineering technologies into gymnosperm programmes is associated with greater difficulties compared to their seemingly simpler angiosperm counterparts. To date, successful large-scale tissue culture propagation methods such as somatic embryogenesis and/or organogenesis are dependent on sexual reproduction modes (i.e., successful induction and generation of clonal lines for testing and selection are based on coaxing immature and/or mature embryos), and therefore the immediate integration of a desired transgene(s) into selected, pre-screened elite genotypes would be contingent on their availability. Transforming mature, proven genotypes is not possible in the foreseeable future. Any attempt to concurrently integrate transformation with clonal development and selection is very inefficient and not recommended. A similar scenario is not as prevalent in angiosperms, which generally display faster growth rates (evaluation of traits of interest can be undertaken sooner), and mature tissue can be clonally (in many cases) propagated in tissue culture and consequently re-introduced into trials where a known "superior" genotype can also express the transgene of choice.

Regulation of genetically modified trees

The regulatory protocols for controlling the development and release of genetically modified plants vary among countries, and ranges from the very simple (China) to very complex (European Union countries). The Chinese regulatory system adopted a scale with varying risk levels (no, low, medium, and high) and every newly-developed genetically modified plant is permitted a preliminary assessment, and is classified to one of these categories of risk. Plants within the first two risk classes (i.e., no and/or low risk) are granted automatic release without any further appraisal. However, those in the higher risk classes (i.e., medium, and high) are subject to a more extensive assessment protocol before release is granted. The European Union regulatory system, with its zero risk tolerance policy, requires formal assessment for all genetically modified plants before any release is considered. Countries like Canada and the United States accept some level of risk, and fall somewhere between these two extremes (Sedjo, R., Resources for the Future, Washington, D.C., unpublished contribution to the IUFRO Biotechnology Task Force Report). In summary, to date, no consensuses has been reached on the development of a universal regulatory system for controlling the development and release of genetically modified plants (Pachico 2003), and such efforts are warranted and timely.

Benefits and risks of genetically modified trees

Benefits

The use of genetically modified trees is commonly justified by their ability to increase wood supply, specifically in high-yield plantations, and the possible elimination of the perceived inefficiencies of traditional tree breeding programs that are constrained by long generation times (i.e., acceleration), or their "limited" genetic background through the introduction of alien DNA segments (i.e., elevating species' biological ceilings) (Sedjo 2004; Mullin and Bertrand 1998; van Frankenhuyzenand and Beardmore 2004). Generally, the benefits of genetically engineered trees are classified under some broad categories, each with several possibilities. For example, Mullin and Bertrand (1998) classified the benefits under four main categories; namely, 1) *increasing ecological competence* (such as the use of *Bt* genes coding for endotoxins for insect resistance and the production of glyphosate [Round-up ready®] plants) for weed control and production of plants that are resistant to microbial pathogens (citing the papaya's ring-spot virus success), 2) *increasing production* (through the improvement of trees' adaptation, by altering the allocation of photosynthate towards growth and yield attributes or their reallocation from reproduction to stem growth), 3) *increased product quality* (such as changes to lignin composition for increased pulping efficiency), and/or 4) *increased product diversity* (the development of trees tolerant to heavy metals for phytoremediation of polluted soils or the production of pharmaceuticals such as taxol). Others have employed different classification categories, but emphasized the value of herbicide tolerance, insect and disease resistance, abiotic stress, wood quality and quantity, and reproductive development etc., and as such are more quantitative (Walter and Killerby 2003; van Frankenhuyzen and Beardmore 2004; Sedjo 2004).

Risks

van Frankenhuyzen and Beardmore (2004) summarized and classified risks into three ecologically interrelated components, including: 1) uncontrolled spread of genetically engineered trees (i.e., irreversible release and spread of transgenes through increased invasiveness, “vertical gene flow” as defined by the transfer of alien genes to wild relatives through sexual hybridization and/or “horizontal gene flow” to unrelated species through nonsexual means), 2) unexpected perturbations to non-target organisms or ecosystem processes caused by the introduction of the new traits, and 3) the imprecise nature of genetic transformation technology could potentially result in the appearance of delayed instability in transgene expression and possible unforeseen negative effects on tree fitness (“pleiotropic effects”).

It is fair to conclude, however, that the actual assessment of any risk(s) associated with genetically engineered trees is difficult or currently impossible to determine. In most cases, examples of potential adverse effects in transgenic trees are a result of extrapolations from studies evaluating annual crops, implying parallel scenarios. Generating credible, tangible data from genetically transformed trees with inherent long-lived generation times requires experimental work at an unprecedented scale that spans multiple generations and multiple sites, and most of all, needs securing regulatory permits and public acceptance. These experiments are not feasible due to several technical factors, including the enforced termination of all genetically modified tree experiments before reaching sexual maturity, the long times required for valid assessment, the unpredictable nature of the transformation technology, and the unknown long-term stability of transgenes. Additionally, societal and market place pressures present a formidable barrier to the development and deployment of genetically engineered trees, thus creating a “catch 22” situation where technical innovations are overwhelmed by non-scientific considerations, as expressed by Brunner et al. (2007). These factors collectively create an intangible situation where obstacles to experimentation become barriers to addressing legitimate questions.

Genetic containment

The potential irreversible escape and dispersal of transgenes into the environment from genetically modified trees is not only a major scientific apprehension, but a concern that covers a multitude of other tangible and intangible policy, market, trade and societal issues that requires workable and meaningful genetic containment strategies. Brunner et al. (2007) listed five major approaches to containment, including: 1) *mitigation* (fitness advantages of transformed trees within plantations are effectively cancelled by their tight linkage to a deleterious gene that is expressed when planted elsewhere), 2) *ablation* (floral tissues are effectively destroyed or made non-functional by cytotoxins, 3) *excision* (a technology known as "GM-gene-deletor" in which all functional transgenes are removed from pollen, seed or both (Luo et al. 2007), 4) *gene suppression* (activity impairment of one or more genes essential to reproduction at the DNA, RNA, or protein levels), and 5) *repression* (postponement of flowering onset or repressing the transition to reproductive growth). The effectiveness of any one of these potential methods varies, and the attainment of total prevention to sexual reproduction might be difficult. However, Luo et al. (2007) suggest that the GM-gene-deletor technology proved 100% effective in tobacco.

Whatever method or combination thereof is used to control containment, two factors must be considered. First, the stability of transgenes expression over the tree's lifetime needs to be determined, and secondly, the specific nature of the given transgenic tree's life cycle needs to be known. The life-cycle of plants is characterized by the presence of two distinct phases: the haploid gametophyte which produces gametes, and the diploid sporophyte, which contains cells capable of undergoing meiosis. Shoot apical meristems produce vegetative tissue until an external signal triggers a switch to floral development. Thus, floral structures are derived from a set of cells that are part of the plants' vegetative body. Annuals convert most of their apices to floral structures, while in perennials only a fractional (species-specific) subset of the apices is converted from vegetative to floral development, leaving some to form vegetative buds that will continue to support the following year's growth. In trees, where floral structures are produced from vegetative parts, the availability of numerous branches provides a mechanism by which somatic mutations could occur (Antolin and Strobeck 1985). Should any of these mutations affect the transgenes expression and/or the occurrence of an independent transgenes malfunction take place, this will result in the creation of "islands" within the tree where the containment system could be compromised.

Conclusions

The successful introduction and deployment of transgenics in agriculture is commonly viewed as the road map for forestry despite the vast differences between the two systems. The feasibility of deploying genetically modified trees on a commercial, large-scale level has raised many questions and concerns regarding their possible benefits and risks. However, due to the paucity of reliable information it is not yet possible to reach a firm conclusion(s) about the potential impacts, positive or negative. Technological developments in method refinement and genetic containment are rapidly advancing worldwide, and as such offer much promise for a timely integration into common practice. Furthermore, current trends suggest that their anticipated introduction would mainly target high-yield commercial plantations, isolated from native forests. While the debate continues to rage regarding the pros and cons of genetic engineering in trees, the technology cannot be overlooked as an indispensable research tool to understanding basic fundamental systems biology. Irreversible gene escape was identified as the most serious issue associated with their use, and research on genetic containment is advancing with promising breakthroughs such as "GM-gene-deletor." Finally, the development of a global regulatory framework governing research and applications of genetically modified trees is recommended and deemed essential.

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Forest and water interactions, and the energy-water nexus

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Summary

This paper outlines the work of the Task Force on forest and water interactions and its efforts to provide guidance to policy makers so that the multitude of benefits that forests provide can be secured whilst minimizing any water resource costs. New policy drivers relating to bio-energy production and payments for environmental services are underpinning forestry schemes in many parts of the world and it is becoming increasingly important to be able to assess any potential adverse water resource and associated impacts. Efforts by Task Force scientists to develop policy briefs and impact assessment frameworks are described.

Introduction

New policy drivers are underpinning forestry schemes in many regions of the world. Fluctuations, though recently predominantly rises, in the price of fossil fuels have led to a renewed interest in forests as alternative sources of possibly lower cost bio-energy (UN-Energy report, 2007). 'Payments for Environmental Services' (PES) schemes increasingly focus on forests as the supplier of these and other services; but what are the water resource implications of these schemes? How much water will be consumed in the growing of these forest crops and what might the costs and/or benefits be in relation to other societal and environmental factors; including water quality, biodiversity and carbon sequestration?

The role of forests in relation to the sustainable management of water resources remains a contentious issue. This is despite a significant advance in scientific understanding of forest and water interactions based on almost a century of research in forest hydrology. Uncertainty, and in some cases confusion, persist because of difficulties sometimes in translating research findings between countries and regions, between different catchment scales, between different forest types and species, and between different forest management regimes.

Never before has the need to bridge the gap between science and policy, and to clarify and communicate to policy makers the actual impacts of forestry schemes on the quantity and quality of water resources, been so great. The development of assessment frameworks for evaluating forest impacts together with the production of policy briefs are ways in which these needs can be addressed.

The role of the Task Force on Forest and Water Interactions

Task Force scientists are working on ways both to improve our understanding of forest and water interactions and to convey this information to policy makers. The challenge of maximizing benefits from the world's natural and planted forests whilst taking into account and minimizing possible negative water impacts have been addressed at two major international conferences co-sponsored by IUFRO.

The 'Forest and Water in a Changing Environment' symposium held in Beijing in August 2006 addressed the issue of watershed degradation and its implications for water resources and ecosystem sustainability. The goal of the symposium was to provide a forum for experts on eco-hydrology, restoration ecology, forest ecology, watershed management and global change sciences from around the world to share knowledge and research experiences and develop long-term international collaborations on watershed research. This goal was very successfully achieved and the symposium also led to agreement on the objectives of the new IUFRO Task Force on Forest and Water Interactions (http://www.iufro.org/science/task-forces/water/).

The 'Ecosystem Goods and Services from Planted Forests' conference in Bilbao considered how far plantations can substitute or augment ecosystem goods and services from native forest, and also how plantations can be managed to optimise the provision of ecosystem goods and services such as: habitat, clean water and non-timber forest products. As a follow up to this conference IUFRO scientists will be contributing to a book on 'Ecosystem goods and services from plantations' based on the conference presentations.

IUFRO scientists are also contributing to the Ministerial Conference on the Protection of Forests in Europe (MCPFE). Following a technical consultation meeting on forest and water interactions held by the friends of the MCPFE in Cyprus in January 2007, a draft resolution was prepared for submission to the Ministerial Conference to be held in Warsaw in November 2007.

The new Task Force on Forest and Water Interactions has raised awareness of its activities and goals through presentations at other meetings and conferences including: the WWF hosted 'Science for Nature Symposium' in Washington, DC, which focused on ecosystem services and how to harness their value to conserve biodiversity and enhance human well-being; the 12th session of the Conference of the Parties to the Climate Change Convention (COP12), held in Nairobi, November 2006; and the Royal

Meteorological Society meeting on the 'Interaction of Forests and the Atmosphere' in London in February, 2007.

Regulatory and impact assessment frameworks

The development of a framework for assessing the costs/benefits of forestry schemes in relation to timber production, biodiversity, societal, environmental and water resource factors remains an important challenge for IUFRO scientists and one which will be addressed through linkage with a number of ongoing projects on these issues. One project of particular relevance is the recently started EU AIDCO funded Rural Energy (RE)-Impact project. RE-Impact aims to develop an improved forest impact assessment framework to assist policy makers and planners in making evidence based decisions on forest and bio-fuel land-use policy.

The need for such a framework to avoid perverse policy outcomes is evident. On the wood-fuel supply side existing forest resources are often poorly managed and highly degraded with unsustainable extraction rates. As a consequence, in Asia, countries like India and China have imposed logging bans in natural forests but are supporting the development of woodlots and bioenergy plantations on a large scale. In Africa similar trends are recognised for Eastern Africa and South Africa. But where large changes in land use involving afforestation and reforestation programmes for wood fuel or biodiesel are planned it will be important to ensure that existing societal, food production, biodiversity and water resource benefits are properly taken into account in the planning process.

Where water resources are already scarce the availability of water for downstream users and the environment can be a critical issue. Even more problematic are the situations, now common in Southern India and many other parts of the world, where multi-sector driven land-use changes involving combinations of irrigation, afforestation and soil water conservation programmes are leading to rivers drying out and the increasing occurrence of catchment closure (where there is no flow out of a catchment except in high rainfall years).

The widespread promotion of short-rotation coppice and short-rotation forestry and biodiesel crops raises serious questions concerning water use, especially with the understanding that the areas of land under consideration are not trivial. To achieve the Government of India's target of 20% use of biodiesel by 2011 would require 13.4 million tonnes of biodiesel to be produced from 13 million hectares of plantations (Mehendale and Goswami, 2005). It has been suggested that the virtual water use, i.e. the water evaporated in the production of sugar based bio-fuels, is as much as 20,000 litres of water for each litre of fuel produced. For biodiesel from the tree crop *Jatropha curcus* (Jatropha), the efficiency is likely to be better at 5,000 to 10,000 litres per litre of biodiesel, but will still raise questions about the value of the energy produced in relation to the value of the water consumed, the energy-water nexus.

But perhaps even more important than questions of water and energy efficiency is the question as to whether there are site and species combinations which can provide reasonable yields of biofuels whilst evaporating similar or lesser amounts of water than indigenous vegetation types. A land use of this type would have the win-win value of providing an energy crop whilst going some way to reversing trends of catchment closure.

These questions will be addressed within the framework that will be developed to identify and assess appropriate land areas for integrated bioenergy project land-use systems. The framework will consider sustainable (renewable production), pro-poor, water allocation equity and biodiversity issues and will be developed from consideration of case studies in selected target countries: China, India, Uganda and South Africa. The project will aim to provide planning and implementation guidance for policy makers, NGOs and the bioenergy business community.

Policy briefs

Task Force scientists are working towards ways in which a consensus can be drawn on many of the presently controversial issues in which forests relate to the water environment. The preface paper of the special issue of the journal *Forest Ecology and Management* (Van Dijk and Keenan, 2007) prepared mostly on papers presented at the IUFRO Brisbane World Congress in 2005, provides a concise description of the current scientific understanding of many of these issues. Based on this material an outline policy brief has been prepared (Appendix 1) which will be discussed and developed by Task Force members at this symposium and will be continually reviewed and developed during the time span of the Task Force.

Conclusions

The question of how to realise the multitude of benefits that forests provide whilst minimizing any water resource cost is of great importance under the present world climate. As climates change and water resources are in many countries expected to become increasingly scarce the question will become of even greater prominence. These are challenges that the Task Force will need to address and is well qualified to do so.

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The potential role of forests in aiding global attempts to reduce atmospheric CO_2 concentrations

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Summary

Forests store large amounts of carbon in biomass, dead organic matter and soil pools. Forest management and land-use change decisions affect the quantity and dynamics of carbon stored in the forest, and the amounts of carbon transferred to meet society's needs for harvested wood products and energy. Activities aimed at protecting and expanding forest area, increasing carbon density in forests, and using biomass for wood products and energy all affect the carbon (and non-CO_2 greenhouse gas) balance. The management of forests and wood products can therefore contribute to mitigation portfolios aimed at reducing atmospheric CO_2 concentrations. The design of mitigation portfolios requires an understanding of the processes that contribute to regional carbon balances and of the costs and benefits of alternative actions: slowing deforestation rates brings a large and immediate reduction of emissions while increasing forest area through afforestation contributes long-term CO_2 uptake, albeit at slower rates per hectare. Ideally, mitigation portfolios should be designed with an understanding of land-use change and forestry impacts on the climate system and the energy balance as affected by albedo and hydrological contributions of land surfaces. Climate change is expected to reduce the mitigation potential of forests in many regions.

Introduction

Forests cover about 4 billon hectares globally (FAO 2007, Sabine et al. 2004) and store an estimated 536 billion tons carbon (Gt C) in biomass, 1104 Gt C in soils (to a depth of three metres) (Saugier et al. 2001, Jobbagy and Jackson 2000, Sabine et al. 2004), and additional amounts in dead organic matter pools, including fine and coarse woody debris.

Global emissions from burning of fossil fuels were 7.2 ± 0.3 Gt C yr^{-1} in the period 2000 to 2005 (IPCC 2007). To put these emissions in perspective, the total amount of carbon stored in the tree biomass of China is about 6.1 Gt C (FAO 2007). Forests and forest management cannot completely off-set the global emissions from the burning of fossil fuels, but they can contribute to a mitigation portfolio aimed at reducing atmospheric greenhouse gas concentrations.

Land-use change involving the conversion of forest to non-forest land cover results in large emissions of carbon into the atmosphere. The annual emissions resulting from deforestation are estimated at 1.6 Gt C yr^{-1} for the period 1990 to 2000 (IPCC 2007), more than the annual emissions from the global transportation sector. The FAO's State of the World's Forests 2007 report estimates the global deforestation rate at 13 Mha per year for the period 2000 to 2005. This is partly off-set by increases in forest area in other regions of the world, with net area losses amounting to 7.3 Mha per year (FAO 2007).

Forest management and land-use change decisions affect the quantity and dynamics of carbon stored in the forest, and the amounts of carbon transferred to meet society's needs for harvested wood products and energy. With growing awareness about the need to stabilize greenhouse gas concentrations in the global atmosphere, forest managers are increasingly expected to quantify the impacts of their management actions on the forests' net greenhouse gas balance and to find ways to enhance forest C stocks. This paper provides a brief overview of the potential contribution of forests, forest management and forest product use in the efforts to mitigate increases of atmospheric greenhouse gas concentrations.

Mitigation options involving forest management

Forest managers have to consider both the amount of carbon stored in the forest and the annual rate of harvest to meet society's needs. This is comparable to the role of the manager of a water reservoir, who needs to balance water storage and water flow to meet management objectives. Land-use change and forest management activities affect both the amount of carbon stored in forest landscapes and the future availability of harvestable biomass (Figure 1). Deforestation, i.e. the human-induced conversion of forest to non-forest land reduces both carbon stocks and future harvest rates, while afforestation has the opposite effect, albeit with very different rates of carbon stock changes per hectare. Other forest management activities, such as changes in rotation lengths, forest degradation, and intensification of silviculture all affect both the landscape-level carbon stocks and the future sustainable harvest rates.

Forest management can maintain or increase forest area, or increase the stand and landscape-level carbon density (Nabuurs et al., in press). The impacts of stand and landscape-level management on carbon stocks and future carbon dynamics can be quantified (e.g., Colombo et al. 2005). Silvicultural activities such as planting to reduce regeneration delays, tree species selection, and vegetation control to reduce competition increase stand-level carbon density. At the landscape-level, managing for longer rotations between harvests, maintaining continuous forest cover, and reduction of natural disturbances can increase carbon storage (Nabuurs et al., in press). There is ample evidence about the effects of management on the amount of carbon in the organic layers of the forest floor, but much less information about measurable effects of management on stable carbon pools in the mineral soil (Jandl et al. 2007). Using computer simulation models, forest planners can determine the carbon implications of alternative management scenarios and integrate carbon into the forest management planning process (Kurz et al. 2002, Neilson et al. 2006)

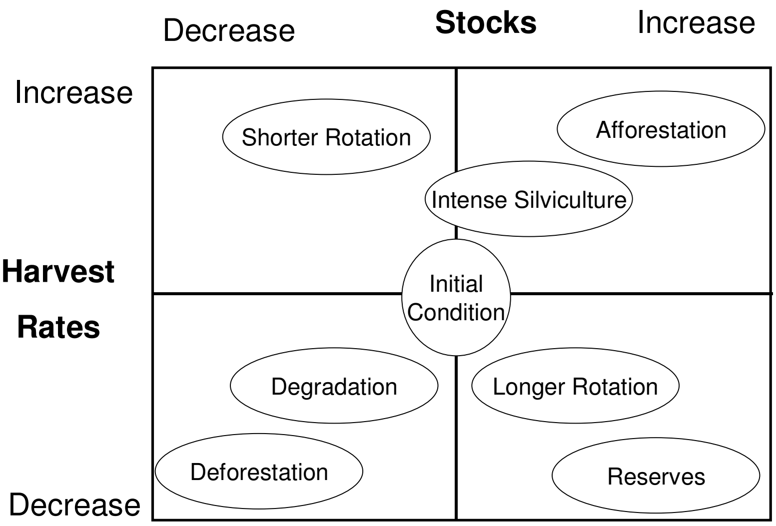

Figure 1: Land-use change and forest management actions affect both the landscape-level carbon stocks and the future sustainable harvest levels. For example, relative to the initial condition, deforestation reduces both the amount of carbon stored in the landscape and the future sustainable harvest rates, while afforestation has the opposite effect.

Fossil fuel use in the management of forests typically amounts to a small fraction of the carbon sequestered by these forests. In intensively managed Douglas-fir plantations in the Northwestern United States, fossil fuel emissions from management averaged 1.6 Mg CO_2 eq per 100 m^3 of harvest, or ~2% of the carbon stored in the harvested biomass (Sonne 2006). Additional emissions are associated with the transport of the harvested material. Although small compared to other options, opportunities for emission reductions in the fossil fuel use and emissions of non- CO_2 greenhouse gases during forest management activities do exist (Sonne 2006).

Mitigation options in the forest products sector

In the forest products sector, product usage and disposal both determine the duration of carbon retention in wood products. The carbon benefit of wood products is also affected by fossil fuel substitution, (1) where wood products are used instead of other products that are more fossil fuel intensive (i.e., more fossil fuels are emitted in production, maintenance and disposal of such products), and (2) where woody biomass is used for energy instead of fossil fuels. The duration of carbon storage in wood products ranges from days (biofuels) to centuries (houses and landfills) and mitigation options include prolonging the carbon retention through better construction methods, re-use and recycling of harvested wood products, and decisions about the final disposal of wood products. Large accumulations of wood products have occurred in landfills because anaerobic conditions slow down or stop decay (Micales and Skog 1997, Apps et al. 1999). One mitigation option is to extract energy from wood products instead of discarding them in landfills, and to use this energy instead of fossil fuels.

Significant reductions in emissions can also be achieved where wood products displace more fossil-fuel-intensive construction materials such as concrete, steel, aluminum and plastics (Perez-Garcia et al. 2005, Petersen and Solberg 2005). Constructing apartment buildings in Scandinavia with wood instead of concrete frames reduces their lifecycle net carbon emissions by 110 to 470 kg CO_2 m^{-2} of floor area (Gustavsson et al., 2006, Gustavsson and Sathre, 2006). When buildings are demolished, wood products can be retrieved and either recycled or used as biofuels.

Designing a mitigation portfolio

Studies on the costs of forest and land-use based mitigation portfolios typically demonstrate that there is a substantial potential for increased carbon sequestration (or reduced emissions) through forest and land management activities, and that these costs are well within the range of other large-scale emission reduction programs (Stavins and Richards 2005, Nabuurs et al., in press). There is a need, however, to develop regionally appropriate portfolios based on a detailed quantification of the economic costs and the carbon benefits of each specific activity in that region.

The design of a mitigation portfolio involving forest management options requires an understanding of the trade-offs between increased storage of forest carbon and reduced rates of harvest. To assess the net benefit on the climate system, the amount of fossil carbon substitution per unit of biomass carbon extracted from the forest must be quantified. For example, using woody biomass to generate electricity alone has a lower substitution rate than using it in combined heat and power systems.

The current IPCC reporting convention that all harvested biomass carbon removed from forest ecosystems is emitted in the year of harvest reduces the incentives to consider the fate of harvested biomass in mitigation options. The outcome of ongoing international negotiations on the accounting of harvested wood products will affect the relative contribution of mitigation options in the forest product sector.

The design of mitigation portfolios requires an understanding of the processes that determine regional carbon balances, of the costs and benefits of alternative actions, and of the projected future carbon dynamics of the forest landscape. Mitigation options can be evaluated relative to the anticipated future, using a dynamic baseline. For example, reductions of emissions from deforestation and degradation are quantified relative to the baseline of expected future losses: a forest region subject to deforestation may be a net carbon source, and the mitigation benefits are derived from the reduction of the rate of emissions relative to the expected losses. Other mitigation activities will result in net increases in forest carbon stocks. Depending on the accounting framework used, these stock changes can be accounted in absolute terms or relative to a baseline.

Regional differences in forest age-class structures, growth rates, natural disturbance regimes, management intensity, land and labour costs, and distance to markets all affect the design of mitigation portfolios involving forests and the ranking of available options. Mitigation portfolio design is also affected by existing land tenure and forest legislation, which can place significant barriers to change or innovation.

Ideally, mitigation portfolios should be designed with an understanding of land-use change and forestry impacts on not only the greenhouse gas balance, but also the climate system. Changes in the composition and extent of land cover have impacts on the global climate system through albedo and hydrological cycles (Betts 2000, Gibbard et al. 2005, Bala et al. 2007). Systems to reliably quantify these impacts and to translate them into comparable units for trade-off analysis, such as CO_2 equivalents or radiative forcing (watts m^{-2}) are not yet available (Marland et al. 2003). Moreover, forest management activities that change the stocking and carbon density of forests are likely to have smaller impacts on albedo and hydrological cycles than the impacts of conversion of forest to non-forest and vice versa.

Conclusions

With increasing recognition that global climate change is real and caused by human interference with the global climate system (IPCC 2007), humanity will increasingly demand that all human activities, including forest management, be assessed in terms of their impacts on the global climate system. Forests, forest management and land-use change involving forests cannot solve the problem of increasing atmospheric CO_2 concentrations from fossil fuel emissions, but they have the potential to make a substantial contribution in mitigation portfolios. The forest management community is largely responsible for the management of the largest terrestrial biomass carbon stocks, and will therefore come under increasing pressure to contribute to the design, assessment and implementation of mitigation portfolios that include forest sector activities. The technology for mitigation options in the forest sector exists today, but to make globally significant contributions, the scale of implementation would have to be increased substantially (Pacala and Sokolow 2004). Reducing rates of deforestation and degradation could significantly reduce emissions in the short term. Afforestation, where ecologically appropriate and cost effective, can contribute long-term carbon uptake from the atmosphere. Conservation and forest management options are available and require an assessment of the trade-offs between increased forest carbon storage and reduced harvest rates. Reductions of net carbon emissions can also be achieved through product substitution and the use of biofuels to displace fossil fuels. Sustainable forest management can maintain forest carbon stocks while providing an annual supply of wood biomass to meet society's needs. The impacts of climate change are likely to reduce the mitigation potential in the forest sector.

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Traditional forest knowledge and its relevance for local and indigenous communities, forest scientists and policy-makers

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Summary

There is growing recognition within the international forest science and policy communities of the importance of local and indigenous ecological knowledge, and the need to consider this knowledge in the development of policies and practices that support sustainable management of forest resources. The IUFRO Task Force on Traditional Forest Knowledge seeks to promote a much needed, and broader, understanding of traditional forest knowledge within the forest science community, and to foster a clearer vision of the opportunities and limitations for enhanced collaboration between these two broad communities and with decision-makers. It works closely with partner organizations that support the conservation of traditional knowledge to convene regional conferences to discuss and share of experiences among and between forest scientists and holders and users of traditional forest knowledge. The first of these was held in Italy in June 2006, and the North American regional conference will be held in June 2007; future regional conferences are planned in Asia, Africa, Australia, and Latin America. The Task Force is also developing a global state-of-knowledge report and other information products for use by scientists, local and indigenous communities, and policy-makers that will cover key issues relevant to the objectives of the Task Force.

Introduction

Forests affect the lives of people everywhere, especially those who are poor and dependent, or semi-subsistent, on forests for food, wood and non-wood forest products, and the ecological services that they provide. Large forest areas worldwide are the traditional homes of hundreds of millions of people in local and indigenous communities, who have managed their forests for generations, drawing on the knowledge and wisdom passed down from their ancestors, to meet their food, shelter, medicine and other daily needs, as well as for their cultural and spiritual development. This knowledge is often based on long historical experience and deep insight into the dynamics of forest ecosystems, and the behaviour and characteristics of animal and plant species that are of special economic, social, cultural and spiritual significance to these communities. This collective knowledge, with its strong links to the past, is critical to the survival and future well-being of local communities worldwide and, particularly, indigenous peoples in their efforts to maintain their distinctive cultural identities and livelihoods, and the integrity and health of the forest ecosystems on which they depend. That indigenous peoples in particular have historically been wise stewards of forests should come as no surprise – most of the world's "primary forests" and biodiversity "hotspots" are located in regions with the highest diversity of indigenous cultures and their associated traditional knowledge and wisdom.

Traditional forest-related knowledge, as used by the IUFRO Task Force on this topic, can be defined as: "a cumulative body of knowledge, practice and belief, handed down through generations by cultural transmission and evolving by adaptive processes, about the relationship between living beings (including humans) with one another and with their forest environment" (United Nations Forum on Forests 2004; adapted from Berkes et al. 2000). As this definition implies, traditional forest knowledge is usually strongly rooted in cultural, philosophical, and spiritual traditions and perspectives on the world and human beings' place in it ("cosmovisions") that are generally quite distinct from those which underlie Western scientific thought in general, and forest science in particular. Nonetheless, there are very definite links, or common visions, between this body of knowledge and the relatively recent field of ecology, a field whose development over the past 50 years in particular owes more to the wisdom and knowledge of indigenous peoples than is generally appreciated.

The relevance of Traditional Forest Knowledge

In recent years, the importance of traditional forest knowledge has been increasingly recognized and emphasized by intergovernmental organizations and policy forums, non-governmental organizations, national governments, scientific societies, and others. A few notable examples at the international level include the work of such disparate organizations as the International Alliance of Indigenous and Tribal Peoples of Tropical Forests (c.f. IAITPTF 2005; http://www.international-alliance.org), the Forest Peoples Program (http://forestpeoples.org), the Global Caucus on Community Based Forest Management (http://gccbfm.org/), UNESCO's Local and Indigenous Knowledge Systems (LINKS) project (http://portal.unesco.org/sc_nat), the Society for Ecological Restoration International's Indigenous Peoples' Restoration Network (http://www.ser.org/iprn/), the International Council for Science (ICSU 2002; http://www.icsu.org/), and various activities within the U.N. Convention on Biological Diversity (http://www.biodiv.org/programmes/socio-eco/traditional/default.shtml) and the U.N. Convention to Combat Desertification (UNCCD 2005; http://www.unccd.int).

There are a number of reasons for this growing interest. The holders and users of traditional knowledge in many parts of the world, faced with continuing encroachment and/or expropriation of their lands, degradation of their forests, and the erosion of their cultures, values, and traditional lifestyles, are making concerted efforts to preserve this knowledge and the links to the land and to past and future generations that it represents. Further, issues connected to actual or potential expropriation of traditional knowledge by scientists and commercial interests, such as the patenting of plant and other natural products from forests long used for medicinal purposes by indigenous and local communities, have both raised public consciousness about the importance and relevance of traditional knowledge, and sparked contentious debates over prior informed consent in the use of traditional knowledge and the equitable sharing of benefits derived from the commercial use of forest biodiversity. The protection and preservation of traditional forest knowledge is an uphill battle for most societies, particularly in the face of rising exploitation pressures on indigenous forest resources, imbalanced power relations that usually put local and indigenous communities at a distinct disadvantage, global cultural homogenization, and many other challenges.

There are, however, other developments in mainstream society, forest science, and forest-related policy that offer both hope and clear opportunities for both protecting and preserving traditional forest knowledge and applying this knowledge to resolve critical forest conservation and management challenges. Over the past decade, the number of initiatives by indigenous peoples' organizations, NGOs, intergovernmental organizations and others related to traditional knowledge, and specifically to traditional forest knowledge, has increased markedly. These activities have sought to better define and defend the rights of local and indigenous communities to manage their traditional, often ancient, territories and homes, to recover and preserve rapidly vanishing traditional knowledge and practices, and to develop innovative strategies for combining these with formal "mainstream" science to manage forests for multiple economic, social, and environmental goods and services in a changing world.

Another trend that has led to the growing awareness and interest in traditional forest knowledge has been the increasing public support, commitment of local and national governments, and the international forest policy community, to the principles of sustainable forest management, based on defined criteria and indicators for ecological, social, cultural, spiritual, and economic sustainability. The definition of forest management objectives and forest management practices that meet diverse criteria for sustainability requires collaboration among relevant stakeholders. Further, there is a clear need for decision-makers and forest managers to consider all relevant knowledge about forest ecosystems and the impacts of forest management options in the development of forest policies and operational practices.

Traditional forest knowledge in international policy processes

Traditional forest-related knowledge (TFRK) is recognized and respected in many countries and by the international community as a whole. Indigenous and local communities in many parts of the world have continued their historical and cultural management of forests, and these practices are widely recognized as a form of sustainable forest management in the international arena.

For example, Article 10[c] of the Convention on Biological Diversity (CBD: http://www.biodiv.org/convention/) encourages Parties to "Protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements". Likewise, CBD Article 8[j] emphasizes the need to respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles for the conservation and sustainable use of biological diversity and promotion of their wider application with the approval and involvement of the holders of such knowledge, and encourages the equitable sharing of the benefits arising from the use of this knowledge. TFRK also is also explicitly considered in the CBD's expanded programme of work on forest biological diversity.

Similarly, the Article 18[a] of the UN Convention to Combat Desertification requires parties to: "…protect, integrate, enhance and validate traditional and local knowledge, know-how and practices" and that "…owners of that knowledge will directly benefit on an equitable basis and on mutually agreed terms" (CCD, Article 18[a]; http://www.unccd.int).

The Intergovernmental Panel on Forests/ Intergovernmental Forum on Forests (IPF/IFF) proposals for action include numerous references to Traditional Forest-Related Knowledge related to: the use of TFRK for sustainable forest management; development of intellectual property rights for TFRK and promotion of equitable benefit-sharing; technology transfer and capacity-building; and promotion of participation of people who possess TFRK in the planning, development and implementation of national forest policies and programs. These proposals were taken up during the 4th session of the UNFF in May 2004, although no resolutions were reached on this issue.

The TFRK issue is also an important element of discussions within the World Intellectual Property Organization (WIPO) Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore, the UN Working Group on Indigenous Populations, and the International Covenant on Economic, Social and Cultural Rights.

Objectives of the IUFRO Task Force on Traditional Forest Knowledge

In establishing this Task Force in 2005, IUFRO has sought to address the need for a systematic, global, effort to explore and strengthen the linkages between traditional and formal/scientific forest knowledge systems, and to foster effective synergies in forest management applications. It is the product of IUFRO's increasing involvement in international forest-related processes and conventions, particularly the UNFF and the CBD, and reflects IUFRO's commitment to become more actively engaged in the issues that are most important to forest-dependent communities, forest managers and decision-makers, and the general public. It recognize the importance of facets of this topic that relate to issues such as intellectual and cultural property rights and interests, land and access rights, and benefit-sharing. Through its activities the Task Force strives to clarify and increase understanding of the importance and relevance of these issues and carries out its work in a way that respects these concerns and principles.

The Task Force's primary objective is to increase understanding of the inter-relationships between traditional and formal (scientific) forest-related knowledge and promote appropriate opportunities for its application to sustainable forest management. Its principal activities include: (1) review and synthesize information and experiences on how these two different knowledge communities work at various geographic and temporal scales, (2) identification of significant knowledge gaps for further work by IUFRO, and (3) promotion of research and collaboration between forest scientists and the holders and users of traditional forest knowledge based on trust and mutual respect to address these gaps.

Beginning with a European regional conference held in Florence, Italy in June 2006 (Parrotta et al. 2006; Parrotta and Agnoletti 2007) and the upcoming "Sharing Indigenous Wisdom" conference to be held in Green Bay, Wisconsin (USA) in June 2007, the Task Force is convening a series of regional events that serve as platforms for dialogue between the forest science community and the holders and users of traditional forest-related knowledge. These conferences are being organized in collaboration with appropriate partners such as intergovernmental, governmental, and non-governmental organizations representing the interests of local communities and indigenous peoples, forest research institutes, universities, international policy forums, and others. The specific issues covered in each regional meeting will vary depending on the regional priorities and needs, but most will include the following topics:

- Context and history of the relationship between formal scientific forest knowledge and TFK with respect to forest management;
- Application of traditional forest-related knowledge to forest ecosystem assessments and management;
- Local and indigenous community priorities for scientific study (research) in relation to forest resource management;
- Analysis of case studies on successful integration of traditional and (formal) scientific knowledge in forest management activities;
- Experiences and lessons learned related to resolution of conflicts regarding TFK in relation to forest science and forest management;
- Development of good practices for including both traditional knowledge and western science in forestry education, research and forest management activities;

The outcomes of these regional meetings will be used, along with a variety of other sources of information, to prepare a major State-of-Knowledge report as well as other publications and products from our regional conferences. The State-of-Knowledge report, which we expect to publish prior to the next IUFRO World Congress in Korea in 2010, will provide a broad overview and synthesis of current knowledge and experience on the topics covered in the regional meetings.

Conclusions

Traditional wisdom and its associated forest knowledge, the heritage of the diverse cultures and peoples who have lived in close association with forests, and who continue to depend on forests to sustain their communities and their links to past and future generations, is eroding rapidly in most parts of the world. This collective wisdom, long ignored, disrespected, undervalued, and/or exploited by dominant "modern" society and by the scientific community, appears to be enjoying a renaissance in recent years, and is finding a prominent place in an increasing range forest policy and management discussions at local, regional, and international levels. Through its work with various organizations promoting the conservation and revitalization of this vanishing heritage and its application for sustainable forest management, the IUFRO Task Force on Traditional Forest Knowledge is working to build mutual understanding and trust between the forest science community and the holders and users of traditional forest knowledge, and to foster closer cooperation among scientists, local and indigenous communities (and their supporters), and the international forest policy community. By the end of its 5-year life span in 2010, we hope to have made significant steps in this direction.

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Research issues of relevance to the international debate on illegal logging and ongoing FLEG(T) (Forest Law Enforcement, Governance (and Trade)) process. Results from the IUFRO Task Force "Illegal Logging and FLEGT"

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Summary

The prominence of illegal logging on international and national forest policy agendas has been steadily increasing over the past ten years. The IUFRO Task Force "Illegal Logging and FLEG(T)-processes" has been set up to analyse the potential of scientific information to contribute to these processes and to raise awareness to this contribution. The Task Force activities over the past couple of years highlight the difficulties that science faces in this debate, in which information is produced and used strategically by all stakeholders. This paper introduces research topics identified by the Task Force from the analysis of major national and international processes. Types and causes of illegal activities, development of methods to identify quantities of illegal logging and trade, consequences of illegal logging and countermeasures and improvements for forest sector practices and policies are identified as broad research categories. For each of these, a few examples of research results are referenced, aimed at illustrating the broad scope of relevant research disciplines that are considered to be of interest for contributions to the international illegal logging debate and ongoing FLEG(T)-processes.

Introduction

IUFRO Task Force "Illegal Logging and FLEGT".

Over the past ten years the issue of illegal logging has risen to the top of international debates on forest sector issues. Specific attention is also being paid to the various actions taken by national and international public actors, non-governmental organizations (NGOs) and the private sector to counter this problem. Examples of this can be seen in the various FLEG(T) (Forest Law Enforcement, Governance (and Trade)) processes, the renewed attention given to certification initiatives, public procurement policies and the tracing and verification schemes set up by the private sector. The Task Force has been established to improve scientific networking within IUFRO in relation to issues surrounding illegal logging, to compile the current state of the art in scientific analysis of factors and issues in the illegal logging debate, to raise awareness about the possible contributions of science to ongoing national and international processes and to promote the publication of scientific information in these debates to wider audiences. A full overview of the Task Force's work-program and activities can be found at: http://www.iufro.org/science/task-forces/flegt. Here, due to limited space, only a few references to relevant research activities have been given. These are meant as examples, rather than as an exhaustive representation of all relevant activities.

Research issues related to "Illegal logging and FLEG(T)-processes"

Based on an analysis of international processes and personal experiences from research projects, the Task Force has identified a number of central issues of relevance to the illegal logging debate. Further meetings and communication during 2006 contributed to the identification of relevant research issues, which can be divided into several categories.

Research into types and causes of illegal activities

This group of research issues includes the categorization of illegal activities throughout the forestry wood chain. While definitions themselves are the result of political processes and deliberations, science can contribute to analyzing whether specific practices and observed facts might be considered to fall under a specific legal category. Some analysis in this field is also aimed at identifying ways to allow for the prosecution of illegal activities in one country (typically the producer country) using legislation in another one (the consumer country). An interesting case here is the use of money laundering legislation – initially designed to curb problems within the financial sector – in the fight against illegal logging (Brack, 2005). The analysis of the different forms of illegal logging (e.g., industrial scale logging vs. small scale subsistence use for needs of local and indigenous populations) will also contribute to a more objective view of the situation in different national or regional contexts. The latter will lead directly to the wide field of research into causes of illegal logging, which differ depending on the specific form of activity being discussed. While transgressions by local, rural populations are more often attributed to inadequate legislation, designed in favour of large concession holders or for the benefit of state forest enterprises, illegalities linked to industrial scale activities are seen to be linked to implementation problems, corruption, the strive for financial profits and an ever-increasing demand for forest products in the developed as well as the developing world.

The two major groups of illegal logging activities (subsistence and industrial scale) are joined by their link to rural development and poverty alleviation issues. On one hand, legal and sustainable forest management with adequate consideration of local social and economic interests, is considered to be a possible safeguard, if not precondition, against land-use change in favour of agriculture and development interests, which are considered to be a major factor contributing to deforestation and related illegal logging activities. On the other hand, subsistence-related forms of illegal logging are considered essential for the economic viability, if not the physical survival, of rural populations in many parts of the world. This is not only true for developing countries (Kaimowitz, 2007), but even for rural areas in regions such as North America (Pendleton, 1998) or Europe (Bouriaud, 2005).

A common element of most observed forms of illegal logging is their link to corruption at various levels within the administration. Research into different forms and causes of corruption are thus considered to be essential, even though it is recognized that the problem as such is usually linked to wider deficiencies in society and an analysis restricted to the forest sector will be insufficient (Contreras-Hermosilla et al. 2007).

Development and evaluation of methods to identify the extent of illegal activities

The quantification of illegal logging activities is of central interest in the ongoing international debate. After all, any concern for the topic might only be considered worth the resources put into these efforts. However, some of the most widely referenced sources aimed at the quantification of the problem (e.g., Seneca-Creek 2004) have not been subject to independent peer-review before publication and are themselves based on figures reported by NGOs (e.g., Brukhanov et al. 2003). This reflects to some degree the problem that the scientific community is facing in engaging in quantifying the problem. While the theory of methods such as production-consumption comparisons or monitoring systems using remote sensing information and geo-referenced data on logging-concessions is sound and based on straightforward approaches, it is often difficult to obtain reliable data.

An example of applying the “production-consumption-method” to EU-member states (results for 2003, taken from a 5-year time-series analysis) show that relating conclusions drawn from these results to suspicions of illegal forestry practices might prove problematic (Table 1).

Some of the figures used in the illegal logging debate have highlighted more fundamental problems in national and international statistics on forests and forest products, which, while probably known to relevant actors within the forest sector for some time, have only become evident when used “at face value” in a more critical context. This new focus on the political role of “dry statistics” may perhaps contribute to renewed efforts for their improvement. Likewise some of the problems identified in the use of remote-sensing data in combination with geo-referenced logging-data have highlighted issues such as the need for new ground-receiving stations in remote, but resource-rich, regions, problems with the availability of concession data due to communication problems within forest administrations or forms of illegal activities unlikely to be “visible” in even the most accurate resource statistics (Ottitsch et al., 2005). Problems related to data-availability, especially those related to national and international statistics, will have to be taken up by the relevant institutions that are already in close contact with the forest research community. In addition new methods, more suitable for incomplete or “grey” data, may be needed. Experiences from other sectors of crime, such as the analysis of “street prices” as an indicator for the level of supply with illegal drugs or the development of relationships between observed / detected and committed crimes (i.e., detection rates) may be another useful approach.

Research into the consequences of illegal logging

All of the sources cited here also report on the consequences of illegal logging. Usually, these are reported under the "sustainability" categories of social, economic and ecological effects. As with other issues related to the illegal logging debate, there has been considerable progress towards the conceptualization of possible effects for any of these three categories. Quantification, however, has proven more difficult. Even most published data on economic effects (e.g., Seneca-Creek, 2004, Ottitsch et al. 2005) remain closely focused on the impacts of illegal logging on timber prices (in the two referenced texts modelled as an artificial increase in supply, leading to lower prices). Yet even here the interpretation of results as "good" or "bad" is very subjective. While higher timber prices are positive for forest owners and those employed in the supply-chain "up to the mill gate", they can be seen as advantageous for the processing sector, which is usually considered to have a more important role for income and wealth generation than forest management and harvesting.

Research into countermeasures and improvements

The fight against illegal logging is essentially the focus of all ongoing international and national FLEG(T) (Forest Law Enforcement, Government (and Trade) processes, NGO-campaigns, verification and certification schemes, forest industry initiatives (e.g., tracking-systems) and national initiatives (e.g., monitoring schemes, legal and law enforcement reform in producer countries, governmental public procurement schemes in consumer countries). Research issues in this context can broadly be divided into research aimed at providing adequate technology and processes (e.g., remote sensing (Asner et al. 2001, supply chain management, tracing and systems (TFT, 2006), including DNA-based identification of timber origin (Carr 2007, Deguilloux et al. 2006) and research into institutional reform for both public and private sector institutions (e.g., reform of forest administration (Mac Allister et al., 2007), adequate forest use and property schemes (Clark et al., 1993), corporate social responsibility (Elad 2001) and policy evaluation research. In relation to the last area, there has been a range of papers published with an ex-ante perspective aimed at supporting ongoing processes such as the EU-FLEGT-Action Programme (e.g., Brack 2006, Brack 2007); as with many studies in this field, these have not been subject to formal peer-review. For ex-post evaluation studies, there has been research into processes in developing countries (Casson A. 2002, Smith et al. 2006).

Conclusions

As this short contribution has shown, the forest research community has valuable contributions to offer in the international debate on illegal logging and the related intergovernmental processes. Results have contributed to highlighting underlying causalities and identifying the multi-facetted nature of the problem. For the major question of quantification of the problem, there has been a scarcity of peer-reviewed work, contrasted by an abundance of information published in other media. This is considered to be less a problem of available methods. Rather it is of concern for the quality of data required as input. This is a problem not only for countries struggling with governance issues and lacking adequate forest sector institutions, but even for countries that are not normally considered as problematic in this context. In relation to technological solutions, research has offered interesting and novel approaches. In this context the importance of interdisciplinary co-operation and cross-links between forestry research and other disciplines, both from applied as well as fundamental sciences, have become evident. The latter is also of importance for the future planning of the Task Force's activities. However, as illegal logging is ultimately linked to social and economic issues and problems, there is a need for further research grounded in social sciences for both a more thorough analysis as well as the development of policies aimed at combating the issue. All of this must be undertaken bearing in mind that illegal logging is ultimately also an indicator of deeper problems in society and as such cannot be tackled from "within" the forest sector alone. As a consequence the need for inter-sectoral co-ordination, one central element of scientific as well as policy discussions such as the latest UNFF 7, has become evident once again.

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		2003				2003 TRADE FROM DATABASE EFI			
		TOTAL RESOURCE	TOTAL WOOD USED	DIFFERENCE	DIFFERENCE/ TOTAL USED (%)	TOTAL RESOURCE	TOTAL WOOD USED	DIFFERENCE	DIFFERENCE/ TOTAL USED (%)
EU 25 MEMBERS	Austria	23,874,000	32,588,724	-8,714,724	-26.74	27,084,966	32,588,724	-5,503,758	-16.89
	Belgium	7,373,628	8,582,100	-1,208,472	-14.08	6,348,247	8,582,100	-2,233,853	-26.03
	Cyprus	15,136	18,310	-3,174	-17.33	15,680	18,310	-2,630	-14.36
	Czech Rep	13,120,000	12,529,000	591,000	4.72	12,306,508	12,529,000	-222,492	-1.78
	Denmark	1,591,544	1,123,000	468,544	41.72	1,774,295	1,123,000	651,295	58.00
	Estonia	6,276,112	4,929,400	1,346,712	27.32	7,179,558	4,929,400	2,250,158	45.65
	Finland	79,763,061	77,409,300	2,353,761	3.04	83,311,582	77,409,300	5,902,282	7.62
	France	42,419,118	37,540,900	4,878,218	12.99	42,582,500	37,540,900	5,041,600	13.43
	Germany	46,485,000	60,757,434	-14,272,434	-23.49	48,524,810	60,757,434	-12,232,624	-20.13
	Greece	994,353	1,564,573	-570,220	-36.45	830,292	1,564,573	-734,281	-46.93
	Hungary	1,412,000	1,677,500	-265,500	-15.83	1,989,763	1,677,500	312,263	18.61
	Ireland	3,562,740	3,475,392	87,348	2.51	3,619,934	3,475,392	144,542	4.16
	Italy	10,382,096	14,352,954	-3,970,858	-27.67	10,286,466	14,352,954	-4,066,488	-28.33
	Latvia	9,500,966	8,750,500	750,466	8.58	8,503,279	8,750,500	-247,221	-2.83
	Lithuania	5,044,741	3,487,100	1,557,641	44.67	5,002,520	3,487,100	1,515,420	43.46
	Luxembourg	3,634,773	514,300	3,120,473	606.74	3,331,909	514,300	2,817,609	547.85
	Malta	5,144	0	5,144		1,618	0	1,618	#DIV/0!
	Netherlands	2,194,300	887,800	1,306,500	147.16	2,114,638	887,800	1,226,838	138.19
	Poland	26,399,700	20,452,650	5,947,050	29.08	26,367,271	20,452,650	5,914,621	28.92
	Portugal	9,854,000	11,003,000	-1,149,000	-10.44	9,231,201	11,003,000	-1,771,799	-16.10
	Slovakia	5,584,205	6,060,600	-476,395	-7.86	5,972,334	6,060,600	-88,266	-1.46
	Slovenia	2,348,174	2,245,961	102,213	4.55	2,352,236	2,245,961	106,275	4.73
	Spain	21,258,000	21,126,200	131,800	0.62	21,157,770	21,126,200	31,570	0.15
	Sweden	86,415,320	83,386,560	3,028,760	3.63	88,637,160	83,386,560	5,250,600	6.30
	UK	9,946,261	11,617,300	-1,671,039	-14.38	9,854,400	11,617,300	-1,762,900	-15.17
			426,080,559	-6,626,187			426,080,559	2,300,378	
		TOTAL (%)	-1.555			TOTAL(%)	0.540		

Table 1: Results of a production-consumption analysis using FAOSTAT Forest Resource Data for EU-member countries (reference year: 2003). To illustrate the impact of trade data a comparison of FAOSTAT trade data and trade data stored in the European Forest Institute's "Trade Flow Database" is also made. The figure shows surprisingly high discrepancies for countries with well developed statistics and forest sectors (e.g. Austria: -26.7%, Germany: -23.49%, France + 12.99%). However, when aggregated for the members of the EU25 (i.e. 2004 – 2007), the total discrepancy is reduced to -1.599% or 0.54% when using EFI-TradeFlow Database data as a basis for trade. Source: (Ottitsch A., Moiseyev A. 2007. Production Consumption Comparison – A critical analysis of a widely used method. unpublished draft – draft version available from Taskforce-Website)

Endangered species and nature conservation: issues and challenges

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Summary

The key issues to be addressed by activities of the International Union of Forest Research Organization's (IUFRO) Task Force on endangered species and nature conservation include such issues as (1) preventing species from being listed, (2) recovering threatened and endangered species, (3) developing management practices and strategies, (4) balancing actions affecting suites of threatened or endangered species, (5) developing conservation strategies for species without definitive taxonomic treatments, (6) dealing with global change, and (7) dealing with invasive species.

Introduction

A total of 15,589 species (7,654 found specifically in forests) face extinction, according to the 2004 IUCN Red List of Threatened Species (World Conservation Union 2004). One in three amphibians and almost half of all freshwater turtles are threatened, on top of the one in eight birds and one in four mammals known to be in jeopardy. There is some good news. Conservation measures are already making a difference – a quarter of the world's threatened birds have benefited from such measures. What is needed is more of them, and to focus them better using the constantly improving information at our disposal.

The Olympic Natural Resources Center (2002) described the issue of threatened and endangered species as "No issue has caused more anxiety for conservationists and commercial forestland managers than the controversy surrounding the efforts to protect threatened and endangered species on forest lands. No other issue has created more public demand for sensible pragmatic solutions. Unfortunately, strategies to protect species can be confoundingly difficult: individual animals must be protected in the short run and entire populations in the long run. In the short term, individual animals need to be protected from injury or harm. Survival of a species over time entails the provision of food, adequate habitat and sufficient breeding populations. Resource managers often are faced with the need to secure species survival without full knowledge of basic ecological and habitat requirements. Imprecise and often ineffective conservation of species is a result."

Issues and challenges

Much needs to be learned about conserving endangered species and nature conservation in general and for particular issues and challenges. Many of these needs are discussed in this paper as a starting point for action by the IUFRO Task Force *Endangered Species and Nature Conservation*. This paper will examine the context and opportunities for addressing endangered species and nature conservation with respect to management, conservation, and restoration. Areas of particular interest include: (1) preventing species from being listed, (2) recovering threatened and endangered species, (3) developing management practices and strategies, (4) balancing actions affecting suites of threatened or endangered species, (5) developing conservation strategies for species without definitive taxonomic treatments, (6) dealing with global change, and (7) dealing with invasive species.

Preventing species from being listed

One of the most effective ways of dealing with threatened and endangered species is to prevent them from being listed in the first place. As an ever-expanding list of listed species draws increasing focus and resources to these critically threatened individual species, we must at least partially shift to a strategy of preventing systems and their species from becoming threatened. How can conservation planners optimally and effectively allocate limited resources between imminently threatened and presently secure areas? Such choices must be made at multiple spatial scales involving a variety of conservation targets (Spring et al. 2007).

Recovering threatened and endangered species

As human effects on the earth's ecosystems increase, nature conservation must increasingly focus not only on maintaining the current distribution of biodiversity but also on restoring species to areas from which they have been extirpated (Breitenmoser et al. 2001; Carroll et. al. 2006). Recovery goals are often specified in terms of increasing the abundance of a species above some threshold with this threshold often viewed as a specific level rather then being viewed as a point along a continuum of varying levels of population and human intervention (Figure 1, Scott et al. 2005).

Where little is known about a particular species and even basic knowledge may be scant (as is often the case for species that are either naturally rare or have become rare as a result of human impacts in the past), it is vital that the biology and habitat preferences of the species concerned become a subject of study. Only if such information is available can effective conservation measures be implemented (Matern et al. 2007).

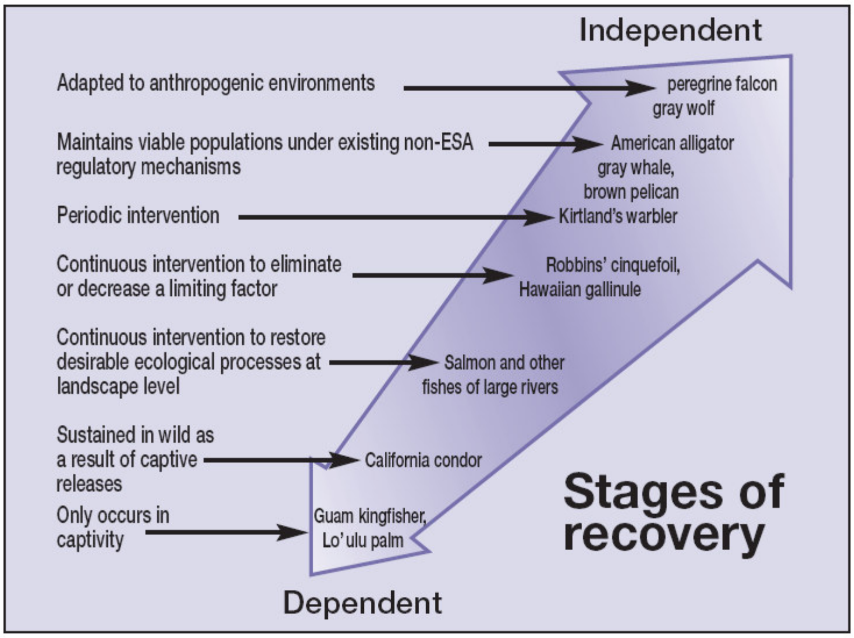

Figure 1. The Recovery Continuum (From Scott et al. 2005).

Developing management practices and strategies

Most forestry-related activities do not negatively affect threatened or endangered species as long as ecosystem-based sustainable forestry practices are used (Kopitzke and Sweeney 2000). Yet, ignoring the need for an array of different strategies can lead to compounding or cumulative negative impacts for biodiversity (Lindenmayer et al. 2006). For example, the loss of structural complexity within stands can accumulate over many cutover sites and result in homogenised landscapes that are much more susceptible to fires, insects, and pathogens. Conversely, an advantage of multiple management strategies is that a given approach may generate positive benefits for another strategy implemented at a different spatial scale (Franklin et al. 1997).

Management practices and strategies need to recognize that much of the world's biodiversity occurs outside protected areas. Programs involving stakeholders in these areas whose primary functions are not protection require a higher level of collaboration and interdisciplinarity to resolve challenges. It is also in these areas where multiple resources, multiple uses, and multiple users can be accommodated. Conservation issues can best be resolved through natural resource community-based planning approaches that are embedded in a strong component of social participation, especially in light of widespread rural poverty throughout much of the world (Valdez et al., 2006).

Balancing actions affecting suites of threatened or endangered species

Situations arise where there are conflicts between land management practices (such as forestry) and the protection of species. In most of these cases, there are workable solutions. Solutions that not only protect the species in question but also allow the land to be used for other legitimate purposes should be the goal of everyone (Kopitzke and Sweeney 2000). The numbers of species at risk of extinction in a single region often go beyond populations of a single species (Barrows et al. 2005). For example, in a six-county area of southern California there are 102 state or federally listed threatened and endangered species. Conservation practitioners frequently extrapolate data from single-species or surrogate investigations when managing critically endangered populations. However, few researchers initiate work with the intent of making findings useful to conservation efforts for a range of similar species (Kesler and Haig 2007). Future research aimed at suites of species should not only be able to be more broadly applicable but also hold the benefit of increasing our understanding of the interactions between species.

Developing conservation strategies for species without definitive taxonomic treatments

The increasing loss of biodiversity presents a daunting challenge to taxonomists and requires the discovery and analysis of biodiversity at a greatly accelerated pace (Smith et al. 2005). Conservation priorities are difficult to set when species identification is lacking. New techniques such as DNA barcoding have proved an effective surrogate for morphospecies diversity patterns across localities in northern Madagascar (Smith et al. 2005). This study demonstrates how inventories of hyperdiverse taxa such as ants can provide rapid analysis of diversity for conservation assessment. The combination of DNA sequencing data coupled with inventory and traditional taxonomy is a model that can be applied across disciplines and will allow analytical needs to scale to the enormity of the biodiversity crisis (DeSalle and Amato 2004). It will help in the identification and conservation of the evolutionary processes that generate and preserve biodiversity. Application of DNA barcoding to sequences of CITES listed cycads (Cycadopsida) provides an example of the potential application of DNA barcoding to enforcement of conservation laws (Little and Stevenson 2007). Currently, there is an effort underway to make species identification more readily available across a broad range of taxa through the sequencing of a standard gene (Richardson et al. 2007).

Dealing with global change

Species, natural communities, and ecological systems have evolved over time in response to changing and dynamic environments. The natural variation of the physical environment and biotic interactions within that environment create a dynamic template that shapes how species evolve and what species may (or may not) be able to persist in any given area (Parish et al. 2003). Rapidly changing climate has potentially profound implications for nature conservation and threatened and endangered species management.

For example, a study of six biodiversity-rich regions around the world representing 20% of the planet's land area found that 15 to 37% of all species in the regions considered could be driven extinct by the climate change that is likely to occur between now and 2050 (i.e., for mid-range climate warming scenarios) (Thomas et al. 2004). Similarly, Wormworth and Mallon (2006) found that future climate change will put large numbers bird species at risk of extinction, with estimates of extinction rates varying from 2 to 72 per cent, depending on the region, climate scenario and potential for birds to shift to new habitats.

Combined with such widespread extinction predictions as a consequence of global warming, extinction risk has been found to increase with decreasing distribution size (Schwartz et al. 2006). The general pattern that emerges is that species with small ranges have high predicted climate change vulnerabilities. Conservation management has already shifted its emphasis away from narrowly endemic small populations (Schwartz 1999) based, in part, on ecological theory suggesting that these species may be unsustainable. If one asserts that narrowly endemic species are doomed to extinction by climate change, then logic dictates that we either begin programmes of assisted migration or divert conservation resources away from such species (Schwartz et al. 2006). The rate of future climate change is likely to exceed the migration rates of most plant species (Nielson et al. 2005). The replacement of dominant species by locally rare species may require decades, and extinctions may occur when plant species cannot shift distributions fast enough to escape the consequences of rapidly changing climate.

Dealing with invasive species

Invasive species are a leading cause of species extinctions (Drake 2005). Invasive species complicate the prediction of future ecosystem dynamics, including the capacity of native species to migrate successfully, since many invasive species tend to be well adapted to disturbed conditions such as may accompany rapid climate change (Nielson et al. 2005). Introduced species have been cited as a the leading cause of animal extinctions worldwide (Clavero and Garcia-Berthou 2005) including for many amphibians and reptiles (Gibbons et al. 2000) and pose the principal threat to the terrestrial ecosystems of island systems such as the Galapagos Islands (Causton et al. 2006). Invasive alien species are recognized as contributing to the decline of nearly half of the imperilled species in the United States for which threat information is available (Delach 2006).

Conclusions

The issues and challenges facing us in ensuring the survival of as many species and ecosystems as possible calls for a renewed research focus to address the issues needed to improve management strategies and policy-making. The greatest challenge is to prepare for the environmental changes that loom in the future. Many of these changes will result from human activities: global climate change, human population growth, deforestation, and toxic waste. We need to understand how populations and ecosystems will respond to these activities. Without a determined effort to understand these relationships and possible future scenarios we will be unable to manage and sustain this foundation.

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Working at the science-policy interface

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Summary

The IUFRO Task Force on the Forest Science-Policy Interface gathered more than 60 case studies describing situations where forest science influenced forest policy. An interdisciplinary group of researchers and forest policy experts analyzed the case studies and identified common themes that occurred repeatedly. From those common themes, a set of thirty guidelines were developed for working effectively at the interface of forest science and forest policy. Some of the guidelines pertain to individual researchers and some pertain to the research institutions that employ them. This paper presents an overview of the Task Force's guidelines and findings.

Introduction

An interface is the boundary between two systems that are often quite different. The nature of the boundary between the systems can have several different characteristics. For example, boundaries are sometimes clearly visible with distinct edges. Other times, boundaries are zones whose edges are blurred or indistinct. Some boundaries are quite permeable, allowing information to flow quickly and easily between the two systems. Other boundaries are relatively impermeable, constricted or restricted, resulting in only a slow trickle of information flowing between the two systems. Where the interface between two information-based systems is relatively impermeable, the information from one system may need to be transformed, translated, interpreted or provided some other form of assistance to help it flow across the interface.

The boundary zones at the science-policy interface are typically unclear and indistinct, and often somewhat impermeable to information flows. Within the policy system, policy makers often do not have all the scientific information they need to estimate what the expected outcomes or natural resource management policies may be or what their associated risks and uncertainties are. Further, policy makers may see individuals in the science system as unwilling or unable to respond in a timely fashion with data that would strengthen the foundation of the policy-making process.

Within the science system, information relevant to the policy issue may be available, but barriers in the science-policy interface or misunderstandings about the policy-making process may hinder the flow of scientific information to policy makers. Sometimes, it is necessary to transform or interpret the scientific information for policy makers so they can better understand and use it.

Within the policy-making system, information needs may not be clearly defined. Scientific information may only be one aspect of the decision. Further, in contrast to the scientific method which is a rational process, the policy-making process may seem quite irrational to outsiders. These facts are often not clear to scientists because the feedback loop may also be constrained, hindering the flow of information about policy making back to the science community.

These difficulties in getting information to flow back and forth across the science-policy interface can lead to mistaken conclusions. Scientists and their science may be seen as insensitive or irrelevant by policy makers. Although some researchers may wonder why their results apparently have little influence on policy, they may never fully comprehend the reasons. Lacking understanding, scientists may have little motivation to change.

When these situations occur at the interface between forest science and forest policy, frustration often erupts on both sides of the interface. Better ways are needed of sharing information across the forest science-forest policy interface. Often, neither researchers nor policy makers have the full suite of skills or all the knowledge needed to operate effectively or communicate clearly on both sides of the science-policy interface. Few people exist who can span the boundary between the science and policy systems; people who speak the special languages of both systems; people who understand the rules of the game of both systems.

IUFRO's response

In 1998, the International Union of Forest Research Organizations (IUFRO) established a Task Force on the Forest Science-Policy Interface. The goal of the Task Force is to identify strategies and mechanisms for improving communication between forest scientists and policy-makers to ensure that sound science is considered in the formulation of forest policies and on-the-ground forest management practices. The Task Force has worked towards the goal in a two-step process.

- Three regional workshops were held to gather case studies describing instances where new knowledge and technologies from research influenced policy deliberations. The workshop in 2001 in Costa Rica s focused on the Americas. The workshop in India in 2002 focused on the Asia-Pacific region. The 2003 workshop in Denmark focused on Europe, Africa, and Middle East regions.

Results have been published in three special issues of international journals and are available on the IUFRO website.1

- A final workshop was held in June 2004 in Switzerland that brought together leading researchers and forest policy experts to synthesize findings from the case studies and identify recurring themes. The recurring themes were refined into guidelines for scientists, research teams, and leaders of research organizations. The full report from this workshop is also available on the IUFRO website.

Throughout these workshops, I was ably assisted by Eeva Hellström from Finland, the Task Force Deputy Coordinator, and John Parrotta, a colleague from my office.

Purpose of the guidelines

Society is the ultimate beneficiary of forestry research. But to generate value for society, research results must be used by someone—policy-makers, forestry practitioners, landowners, educators, other researchers. The science-policy interface is all about more effectively utilizing scientific knowledge and receiving feedback from the policy realm. The purpose of the 30 guidelines developed by the Task Force is to provide advice to researchers and research leaders on how to plan, organize, and conduct research activities so that results can be more quickly and easily transformed into usable information for problem-solving and policy-making[2]. I believe that the guidelines developed by the Task Force can increase the impact of research on forest policy and improve the practice of forestry, thereby creating more value from research more quickly for society.

The 30 guidelines developed by the Task Force fall into four categories:

- Focusing research on questions that are relevant to policy issues
- Conducting research in a communicative and collaborative manner
- Understanding, serving, and engaging in policy processes
- Creating organizational capacity and culture that enables and encourages work at the science-policy interface.

For more detailed information about the guidelines, see IUFRO Occasional Paper No. 17.

Focus research on questions relevant to policy issues

Many of the problems of most interest to policy makers are complex, embracing broad environmental issues that have important social and economic dimensions. Complex

[1] *Revista Forestal Centroamericana* No. 37, 2002; *Forest Policy and Economics*, Vol. 5, Issue 4, December 2003; and the *Scandinavian Journal of Forest Research* Vol. 19, Supplement No. 4, August 2004. http://www.iufro.org/science/task-forces/sciencepolicy-interface/

[2] Guldin, R.W., Parrotta, J.P., and Hellström, E. 2005. Working effectively at the interface of forest science and forest policy. IUFRO Occasional Paper No. 17. Vienna, Austria: IUFRO. 29 p. http://www.iufro.org/publications/series/occasional-papers

issues are best attacked through interdisciplinary and cross-sector research. If scientists want to have an impact on policy, they must carefully assess what research is relevant. As an example, if rural poverty reduction is a critical policy issue, then what may be needed is additional understanding of the role of forests and how they might be managed to increase their socio-economic contribution to rural communities. This will require a blend of biological, social and economic research skills. Picking research questions that are relevant to the most pressing policy issues helps build interest and support for research.

When designing experiments and analyzing results, researchers should focus on the many different values that people place on forests. Researchers who invest effort to become culturally aware and sensitive to alternative value systems and who understand the depth of feeling that people have for forests have been more successful in seeing their results influence policy and be implemented on the ground.

One of the foremost concerns of policy makers is being surprised by an unexpected natural resource issue or problem. What often causes the most consternation is the element of being surprised by the unexpected. This is especially true when policy makers are politicians or political appointees. An excellent technique for avoiding unexpected surprises regarding natural resource issues as a type of policy research called “futuring” or “foresighting.” The process of futuring provides research institutions and policy makers with a way to work together to identify potential or emerging issues before they unfold unexpectedly. Futuring together with policy-makers is an excellent way to build political awareness among researchers. Leaders of research institutions and researchers who use the results of futuring exercises to refocus their research agenda will be better able to respond more quickly if the issue emerges, and as a result, will be seen as more relevant to policy makers.

Conduct research in a communicative and collaborative manner

Each researcher and leader of a research institution should be prepared to convince a sceptical world that their results have contributed to creating a better society. That takes solid information and solid communications skills. Researchers are information and knowledge brokers, communicating both inside and outside their institutions. Research institutions are information and knowledge managers, creating and disseminating corporate messages based on the sum of their researchers’ findings. Networks and partnerships—both of institutions and of individuals—can enhance effective communication across the science-policy interface. To communicate effectively, scientists and research organizations need to consider several strategic and tactical questions and be clear about their relative roles as individual and institutional communicators.

Effective communication is always two-way communication. Researchers and leaders of research institutions should recognize that each opportunity to share information with policy makers is also an opportunity to receive feedback from clients about the usefulness and importance of research results. Feedback is not always verbal. Good communicators can read non-verbal signals in the body language of their audience. Good communicators are good listeners.

Understand, serve, and engage in policy processes

Key interactions between policy makers, stakeholders[3], and constituents often take place in the context of a political process. Researchers should pay attention to how the political process influences policy making and how science and contribute to the political process. Researchers should keep in mind that science is only one source of information used by politicians, policy makers and stakeholders to make decisions.

To be successful at moving science information across the interface to policy makers, researchers must become proficient in both the scientific process *and* the policy process. Most researchers are well-trained in the scientific method. Just as the scientific method has some key tenets, or “rules of the game” that help to bring credibility to the research results, the policy-making process also has some key tenets that help assure that policies are sound, efficient, and don’t impose unintended burdens on constituents. Another important role for researchers and research organizations is helping to evaluate ongoing policy processes and advising policy makers on how to improve the policy process. By developing a better understanding of the policy process, researchers are better able to contribute information to improve policy making and also to interpret better the feedback received from policy makers.

A word of caution is appropriate here. Scientists are sometimes drawn into the debate that inevitably surrounds policy issues. A key challenge for researchers is to engage in a way that simultaneously retains the scientist’s credibility and reputation in the scientific community as well as makes a positive contribution to the policy process. A scientist’s credibility is based largely on the ability to present research results in a way that is unbiased and not perceived as advocating for a particular policy option. If a scientist becomes an advocate or apologist for a particular policy, their personal credibility and the credibility and independence of their institution can be harmed.

Create organizational capacity and culture that enables and encourages work at the science–policy interface

Science organizations that want to ensure that sound science is considered in the formulation of forest policies should include this objective in their mission statement and foster it in their organizational culture. These institutions should develop the necessary structure to achieve their mission, strive to improve the policy relevancy of their research

[3] People and groups with an interest in a decision or policy are sometimes called “stakeholders.” Their interest arises from the fact that the policy decision may affect values or needs important to them—both as gains or losses.

programs and their ability to learn from success and failures, and to anticipate and adapt to changing societal needs while maintaining their long-term vision, independence, and neutrality. In many, if not most, research institutions, this will require special investments and efforts to improve the capacity of scientists and other staff to engage effectively at the science–policy interface.

Research institutions may need to develop strategies and incentives to encourage scientists—both individually and as members of teams—to work across the science–policy interface. This may require changes in personnel management practices, such as adjusting assignments, and offering incentives, such as promotions, perquisites or bonuses for successful support of policy making.

Closing commentary

In recent years, the forest science community has begun to engage more effectively across the forest science–policy interface. The need to strengthen capacities of forest scientists and forest research institutions to work effectively at the forest science–policy interface is a great challenge—now and for the future.

IUFRO has more than a century of experience in building networks of researchers stretching across country borders and across scientific disciplines. Through IUFRO, we can share success stories of working across cultures—not only organizational cultures within a country but also organizational and social cultures among many countries. More recently, IUFRO has provided leadership within the forest community by using Task Forces and special programmes to provide more focus on complex issues. Through the Task Force on the Forest Science-Policy Interface, IUFRO has focused attention on assuring that sound science is considered in the development of forest policies and that policies are implemented more effectively on the ground.

To paraphrase Henry David Thoreau, an American essayist, poet and philosopher who lived 175 years ago, forest science must not only be good, it must be good for something. By encouraging us to learn how to work more effectively across the boundaries between the scientific and policy communities, IUFRO encourages each of us not only to do good science, but also to push our science across the interface to policy makers. That is one way to make our science good for something.

International forest policy priorities: The perspective of IUFRO

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Summary

The IUFRO Strategy 2006–2010 calls for strengthening links and interaction, *inter alia,* with policy and decision makers at the international level. This interaction builds on the research priorities and results of the IUFRO Divisions, Task Forces, Special Programmes and Projects.

Currently, IUFRO is actively involved in forest-related international conventions and processes such as the United Nations Forum on Forests (UNFF), the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC) in order to make its scientific work known at the international level. In this context it is important to be aware of the complex and dynamic process which makes scientific knowledge relevant for political decision makers.

The most recent example of active involvement in the international forest policy context is IUFRO's leadership role in a Joint Initiative on Science and Technology. This initiative of the Collaborative Partnership on Forests aims at contributing scientific knowledge to the UNFF and other international forest related processes.

Background

In its Strategy 2006–2010 IUFRO acknowledges that there is a considerable need and potential to enhance its role in providing objective and independent contributions to policy and decision makers on the basis of the best available scientific knowledge generated by the individual IUFRO Units and Special Projects. This includes both informing policy discussions and assessing the likely implications of policy options on forest resources and their management. To make the scientific activities and output of its global network of science collaboration more visible and relevant, IUFRO is strengthening its activities at the science–policy interface (IUFRO 2006a).

However, it is important to understand the context in which IUFRO as a global research network operates: About 1.6 billion people of the world population – out of a total of 6.4 billion – depend on forests to a varying extent for their livelihoods. Some 60 million people are employed in forestry and wood industries. While the forest area amounts to about 4 billion hectares – or one third of the total land area – about 13 million hectares are lost due to deforestation every year (FAO 2005).

Moreover, global developments, such as population growth, urbanization, climate change and advances in technology are factors that have further influenced the ways in which forests are perceived, managed, conserved and used (Mery et al. 2005) and therefore also influence the priorities of global forest research.

Consequently, this evolving context for forest science presents challenges for IUFRO – and its member organizations – who aim at strengthening research for the benefit of forests and people by addressing in an effective manner the varying research needs and priorities related to forests and trees at all levels (IUFRO 2006a). One means to meet this challenge is to enhance the interaction of the scientific community with potential users of scientific knowledge, most notably policy makers at the international level.

Making forest research relevant for policy makers

In order for forest science to retain its relevance, it is increasingly important to be responsive to the needs of the various users of scientific knowledge when setting research priorities. Those who have an interest in research findings include policy and decision makers at all levels.

More than ever, scientists are also being called upon to explain their research publicly. In addition, there are growing demands from those who are interested in scientific information to be involved in the development of research agendas. Therefore, communication between the scientific community and the potential users of scientific knowledge is essential. Continuous interaction and networking can help both the scientific community and its actual and potential beneficiaries (such as policy makers) to better understand their respective roles and enhance relevance (IUFRO 2006a).

Based on practical models of success, the IUFRO Task Force on the Forest Science-Policy Interface identified guidelines for scientists and research organizations to strengthen science-policy interaction (Guldin et al. 2005). In this context it is important to note that the linear conceptualization of science–policy interactions between a place of knowledge production and a place of knowledge use without further interaction is very limited when creating relevance for policy makers. While this model still dominates perceptions and expectations of scientists and policy makers alike, recent studies on the interaction between science and policy suggest that this transfer has to be seen as a dynamic, long term and most of all social process. This also suggests that research often has no immediate influence on policies but introduces new concepts that incrementally alter the language used in policy circles (Pregernig 2007).

IUFRO is actively pursuing close involvement and interaction especially in the international policy sphere in order to increase the relevance of science available through the IUFRO network for international policy processes.

IUFRO research priorities

IUFRO has identified three strategic goals and related objectives for its work in the period 2006-2010 in its Strategy (IUFRO 2006a):

- Goal 1: To strengthen research for the benefit of forests and people
- Goal 2: To expand strategic partnerships and cooperation
- Goal 3: To strengthen communication and links within the scientific community and with students as well as with policy makers and society at large

While the IUFRO Strategy provides the broader framework for all IUFRO operations, the more detailed research priorities of IUFRO are reflected in the planned and implemented activities of the various IUFRO research entities.

The eight IUFRO Divisions have identified their research agendas individually according to their focus. Nevertheless, a number of recurrent themes can be identified in Divisional work plans (IUFRO 2006b), such as:

- climate change and its various consequences on trees and the forest ecosystem
- the impact of natural disasters on forests
- the threat of alien invasive pests
- the increased demand for wood and non-wood goods and ecosystem services
- the need for a better understanding of plantations and genetically modified trees
- the increased demand for biodiversity conservation
- the need for research into social and behavioural processes
- the increased interrelation with users, stakeholders, policy makers and other sectors

Furthermore, the interdisciplinary IUFRO Task Forces address a series of policy-relevant themes such as Forests and Carbon Sequestration, Forests and Genetically Modified Trees, Forests and Human Well-Being, Forests and Water Interactions, Illegal Logging and Forest Law Enforcement, Governance and Trade (FLEGT) and Traditional Forest Knowledge.

Finally, the IUFRO Special Programme for Developing Countries, the SilvaVoc Terminology Project, the IUFRO Special Project "World Forests, Society and Environment", and the Global Forest Information Service (GFIS), an IUFRO-led joint Initiative of the Collaborative Partnership on Forests (CPF), complement the IUFRO research priorities.

All of the above reflect the increased interest of IUFRO units in working on issues of political relevance, but also confirm a trend that became evident in an IUFRO member survey conducted at the occasion of the XXII IUFRO World Congress in Brisbane, Australia, 2005. According to that survey, forest research priorities in the past have shifted from more technical to environmental issues and are now more and more focusing on social issues in the research agendas of IUFRO's research units (Mayer 2005).

Altogether the ongoing research and the results of the various IUFRO research activities provide the basis for the interaction with policy makers, *inter alia*, at the international level.

IUFRO's strategy for interaction with international policy

IUFRO has gradually increased its participation in international forest policy processes and contributed its scientific and technical expertise to the development of forest policies aimed at advancing sustainable forest management at the international level. For example, it has provided thematic contributions to the United Nations Forum on Forests (UNFF) and the Convention on Biological Diversity (CBD). Also IUFRO's long-standing cooperation with the Food and Agriculture Organization of the United Nations (FAO) has significantly facilitated the provision of scientific information and advice to international policy making and on-the-ground applications. Thematic contributions to key publications of intergovernmental organizations, such as the FAO State of the World's Forests report, have been important means for the active dissemination of forest-related scientific information.

In recent years IUFRO, as a representative of forest science, has succeeded in systematically strengthening its participation in the Collaborative Partnership on Forests (CPF), where IUFRO cooperates with major forest-related international organizations, institutions and convention secretariats. The most recent example of interaction with international policy makers is the launch of the IUFRO-led Joint CPF Initiative on Science and Technology. The mission of the Joint Initiative is to support UNFF and other forest-related intergovernmental processes by assessing available scientific information in a comprehensive, interdisciplinary, objective, open and transparent way and by producing reports on forest-related issues of high concern, including emerging issues (IUFRO 2007).

The Initiative aims at producing reports that reflect the state-of-the-art understanding of the subject matter and are written so that they are comprehensible to policy makers and stakeholders. The number and frequency of reports will be determined by the information needs and requests coming from the intergovernmental processes. Different types of publications may be prepared for diverse target groups and with different time horizons. The aim is to widely distribute the outcomes of the initiative through information means accessible to all relevant audiences. The most important topics currently discussed are centred around the issues of adaptation of forests to climate change, genetically modified (GM) trees, social and economic driving forces behind deforestation, and economics of forest plantations. If successful, the Joint Initiative will provide an effective link between the scientific community and international policy makers.

Conclusions

Scientific knowledge is needed to fully understand emerging problems and developments. Through its global research network IUFRO is well positioned to interact with and inform not only policy makers but also practitioners and stakeholders in order to provide a scientific basis for their decisions. Nevertheless, it is important to be aware of the complexity of information transfer and uptake of scientific knowledge by decision makers.

IUFRO's involvement in international forest-related processes aims at increasing the visibility and relevance of forest-related science in order to contribute to the improved conservation and sustainable management of forests. Moreover, the wide array of research results produced in the global IUFRO network also aims at helping to further the achievement of broader sustainability goals such as the United Nations' Millennium Development Goals, notably Goal 2 "reducing extreme poverty and hunger" and Goal 7 "ensuring environmental sustainability".

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International forest policy priorities: the perspective of FAO

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Summary

While forests provide multiple benefits to people and the environment, many decisions that affect their management are made outside the forestry sector. In many countries the sector is now considered less of a priority while at the same time it is increasingly interlinked to other sectors. The loss of forests at a rate of 13 million hectares per year remains alarming. However, there is also progress towards sustainable forest management, as demonstrated for example by the positive trends in designating forests for the conservation of biological diversity, increasing private ownership and in the formulation and implementation of national forest programmes.

Many countries continue to face serious problems, lacking adequate institutional capacity, financial resources and coordination mechanisms to realize the full benefits of forests. It is thus essential that the international policy dialogue fully reflect national priorities. In the FAO Committee on Forestry (COFO), governments have recently emphasized the role of forests in poverty alleviation, energy supply and climate change. Participatory forestry, tenure arrangements, forest law enforcement and forest protection, including from pest outbreaks and fire, are also in the list of COFO priority issues that originate at national level. FAO's response continues to focus on the implementation of sustainable forest management – in partnership with countries and organizations.

Introduction

The world is changing rapidly due to globalization, freer trade and new technologies for communication. People's perception of forests has also changed over the generations, from a resource base to the provision of a wide range of goods, benefits and services. To what extent have the forestry sector and forestry professionals adapted to these changes?

Certainly, these changes pose new challenges and opportunities for interaction between the scientific community and policy-makers, both at the national and international levels. There is a need to improve understanding between these two parties, in order to capitalize on modern technologies, scientific knowledge and research results, not only as a solid basis for forest-related decision-making, but also to support the implementation of policy decisions on the ground.

Forestry in a changing world

While forests provide a rich array of economic, environmental, social and cultural benefits, many decisions that affect their management and use are made outside the sector as a result, for example, of pressures from agriculture, energy, transportation and population growth.

During the past decade, the importance assigned to the forestry sector has declined in many countries, with government agencies responsible for forests, research institutions and universities experiencing a reduction in their budgets. Also, in many countries responsibility for forest issues has shifted to the ministries of natural resources or environment and in some cases forestry has even been split among many different ministries, calling for increased and new forms of cooperation. Forestry is perceived as being increasingly interlinked to other sectors and contributing to their development. Moreover, today the political focus is more on the social agenda – on people – rather than natural resources management per se. This shift is already a reality in international policy dialogues. On the one hand, forestry is a component of negotiations on biological diversity, climate change, desertification and trade, and on the other, the global forestry fora, notably the Committee on Forestry (COFO), increasingly address the linkages between forests and water, forests and energy, forests and food security and the role of sustainable forest management in the achievement of internationally agreed broad development objectives such as the Millennium Development Goals. The shift from sectoral to inter-sectoral approaches will also require changes in the way forestry professionals and decision-makers collaborate with other sectors to enhance the visibility of forestry in national decision-making and to accord forestry high priority in national budgets and development strategies.

The following facts and figures will help to provide a context for the international forest policy priorities.

- The FAO Global Forest Resources Assessment (FRA 2005) estimates that forests cover about 4 billion hectares (3 952 million hectares); that is 30 percent of the total land area.

- Each year about 13 million hectares of the world's forests are lost due to deforestation, but the rate of net forest loss is slowing down, due to new planting and natural expansion of existing forests. From 1990 to 2000, the net forest loss was 8.9 million hectares per year. From 2000 to 2005, the net forest loss was 7.3 million hectares per year – an area the size of Panama.

- Plantation forests are being established at a rate of 2.8 million hectares per year.

- The world's forests store 283 gigatonnes (Gt) of carbon in their biomass. The carbon stored in forest biomass, dead wood, litter and soil together is more than the amount of carbon in the atmosphere.

- 84 percent of the world's forests are publicly owned – but private ownership is increasing.

- 11 percent of the world's forests are designated for the conservation of biological diversity, and this proportion is increasing.

- Less than four percent of the world's forests are managed primarily for social services such as recreation, education and tourism.

- International trade in forest products is currently valued at US$150–200 billion per year and has increased four times in real terms over the past three decades. A small number of industrialized countries account for most exports (FAO, 2004).

- Approximately seven percent of the world's forest area is certified. This represents nearly a five-fold increase since 2000 (UNECE/FAO, 2006). However certification is mainly concentrated in the industrialized countries that account for 87 percent of all certified area. Thus, the original goal to prevent deforestation and enhance forestry in developing countries by introducing large-scale certification has not been achieved.

- An estimated 12.9 million people are employed in the sector (FAO, 2004).

- According to the World Bank, governments lose an estimated US$5 billion annually to illegal logging and economies of timber-producing countries lose a further US$10 billion (Contreras, 2002).

- An estimated 1.6 billion people rely on forest resources for subsistence or income generation and 1.2 billion people in developing countries use trees on farms to generate food and cash (World Bank, 2004).

National priorities determine international policy

It is important to emphasize that the international policy dialogue should not be a top-down process, but should fully reflect national concerns and priorities. In developing the agenda for the global FAO Committee on Forestry (COFO) that meets every two years, FAO consults with countries on the priority topics they would want COFO to address. The COFO agenda also builds on the outcomes of the six FAO Regional Forestry Commissions. In 2005, COFO emphasized the role of forests in a broader development context and poverty alleviation, including the achievement of the Millennium

Development Goals. In 2007, the priorities were summarized as forests and energy, putting forestry to work at the local level, forest protection, and progressing towards sustainable forest management. These are all key issues of international concern, but emanate at the national level.

Among many other issues COFO emphasized the need to promote the efficient use of biomass as a source of carbon-neutral energy. It recognized the significant threats to forest ecosystems from wildfire, pests and invasive species and stressed that the focus should be on prevention, preparedness and restoration, and supported the establishment of regional networks for this purpose. COFO also regarded the engagement of local populations and forest tenure reforms as a prerequisite to poverty reduction. In all the above-mentioned areas, COFO requested that FAO assist countries to strengthen their institutional capacity to address these challenges. These and other COFO recommendations guide FAO's work in forestry.

Many other forest-related processes such as the Rio Conventions on biological diversity, climate change and desertification and the United Nations Forum on Forests have years of experience in developing recommendations and proposals for action related to forest management, conservation and use. Much progress has been achieved at the conceptual level. Yet many of these processes lack consensus on the provision of the means of implementation, especially financing, of the agreed actions.

Focus of FAO: implementation of sustainable forest management – in partnership

FAO's mandate and its Programme of Work in Forestry enable it to provide broad support to countries in their work towards sustainable forest management, including all its elements and linkages to many other sectors. An example of this inter-sectoral approach is the development and implementation of national forest programmes. Today, these processes are country driven, increasingly participatory and constitute cross-sectoral processes for the development of the country's forest sector and for achieving sustainable forest management (The National Forest Programme Facility and FAO, 2006).

Through its field programme, voluntary guidelines and global forest information, the Global Forest Resources Assessment (FRA), Forest Products Yearbook and the State of the World's Forests report, FAO is helping developing countries to have a more accurate understanding of their forest resources as well to improve their management practices to comply with multiple economic, environmental, social and cultural dimensions and requirements. With these products and services, FAO is well positioned as an "executing agency", given the growing global emphasis to move from dialogue to action – from recommendations to implementation.

Yet, FAO does not work alone but in partnership with its member countries and a wide range of international, regional and national organizations. Probably the oldest, still valid example of FAO's forestry cooperation is in fact with IUFRO, dating back to the late 1940s. Both organizations are today among the most active members of the Collaborative Partnership on Forests (CPF), which is an interagency mechanism that was established to enhance international cooperation and coordination on forest issues.

Role of forest research

Given the changing global situation and new and emerging challenges to forests, the role of forest research in supporting policy-making is more important than ever. There is no doubt that today climate change is the issue that is among those of greatest concern to policy-makers around the world. However, it is not an easy task to integrate climate change mitigation and adaptation measures for example within forest management. While progress has been made on the inclusion of forestry activities in the mitigation of climate change, less attention has been paid to analyzing vulnerability and development of options for adapting forest ecosystems to climate change, focusing specifically on aspects such as forest health, productivity, invasive species, biodiversity, land degradation, rural livelihoods and investment availability for forest resources.

In addition to tackling new research topics, another major challenge is the very limited capacity in many developing countries to participate in international research projects or to capitalize on results, adapt them and apply them for local development. Many developing countries are also highly dependent on imported technologies as this is easier in the short term and often comes as part of an aid package. But such a situation often undermines the development of indigenous science and technology capabilities, which are critical for long-term economic progress. Strengthening national research institutions and their linkages to the international research community as well as policy making is essential. (FAO, 2007). Forestry education and training are also pivotal factors.

Conclusions

Forestry is thus increasingly interlinked with other sectors, with the political focus projecting towards social agenda rather than forestry per se. Consequently both national and international forest policy priorities will need to be determined from different perspectives than in the past. Increasingly the focus is on integrated management approaches and the contribution of forestry to the provision of clean water, affordable energy, food security, conservation of biological diversity, and the role of forests and sustainable forest management in climate change mitigation and adaptation as well as in the achievement of development goals.

At the conceptual level, progress has been made in many of these areas but far less has been achieved in shifting the focus of international negotiations towards transforming recommendations into action. In this context the role of the Collaborative Partnership on

Forests that includes both FAO and IUFRO should be expected to become more important than ever before.

IUFRO has great potential in further promoting understanding between the scientific community and policy makers. A good example is the CPF initiative led by IUFRO on science and technology that aims to link research results to international forest policy dialogue, for more informed decision-making. But the challenge is not only on policy development. Rather it is on finding practical and cost-effective ways to implement sustainable forest management.

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Regional research priorities: South East Asia

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Summary

Eight priority areas and 24 priority issues in forestry research have been identified for South East Asia. The priority areas in descending order of priority are: forest ecosystem management, forest plantations, social or community forestry, forest conservation and environmental protection, non-timber forest products, biomass and wood utilisation, agroforestry, and urban and landscape forestry. Biomass and wood utilisation and agroforestry are considered of medium priority while urban and landscape forestry of low priority. Four issues common to each priority area were also identified, namely, policies and institutions, socio-economics, interdisciplinary linkages, and uptake and impact of research. Substantial strengthening of national forestry research systems is needed in order to meet the long-term capability and research needs of many South East Asian countries. IUFRO can play an important role in the region by facilitating collaboration, supporting capacity building through its Special Programme for Developing Countries, providing access to information networks such as GFIS and SilvaVoc, and highlighting relevant regional forestry research issues in global discussions.

Introduction

South East Asia generally refers to the region made up by the ten countries of Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam, who also make up the members of the Association of South East Asian Nations (ASEAN). Geographically, South East Asia also includes the Andaman and Nicobar Islands, Christmas Island, Cocos (Keeling) Islands and East Timor. For the purpose of this paper, however, the discussion will focus on the ASEAN member countries.

The region mainly has a tropical climate that is generally hot and humid all year round but countries to the north have a more seasonal climate. South East Asia has a total land area of about 4.3 million km^2 of which 48.6% is under forest cover (Table 1). Forest cover, however, is heterogeneous; some countries such as Brunei, Cambodia, Indonesia, Lao P.D.R., Malaysia and Myanmar still have more than 50% forest cover while Thailand and Vietnam have about 30%, the Philippines less than 20% and Singapore hardly any (Table 1).

Table 1: South East Asia – land and forest area in 2000.

Country	Total land area ('000 ha)	Total forest ('000 ha)	% of land area	Forest plantations ('000 ha)	Forest cover change 1990-2000 An. change (%)
Brunei Darussalam	527	442	83.9	3	-0.2
Cambodia	17,652	9,335	52.9	90	-0.6
Indonesia	181,157	104,986	58.0	9,871	-1.2
Lao People's Dem. Rep.	23,080	12,561	54.4	54	-0.4
Malaysia	32,855	19,292	58.7	1,750	-1.2
Myanmar	65,755	34,419	52.3	821	-1.4
Philippines	29,817	5,789	19.4	753	-1.4
Singapore	61	2	3.3	-	n.s.
Thailand	51,089	14,762	28.9	4,920	-0.7
Vietnam	32,550	9,819	30.2	1,711	0.5
Total	434,543	211,407	48.6	19,973	

Source: FAO (2005).

The rain forest of South East Asia, which in the 1980s was considered the second largest rainforest on Earth (Whitmore 1988), is now only the third largest, after that of tropical America and Africa (Primack and Corlett 2005), due largely to extensive logging and large-scale land conversion. In northern parts of South East Asia, the rain forest is replaced by subtropical forests while rain forest is not found in large areas of Thailand and Myanmar because of rain-shadows caused by the long north-south mountain chains. The combination of a growing population, high levels of logging and increased clearance for plantation crops, has resulted in the degradation and elimination of much of the lowland rain forests over a wide area. In Indonesia, the rainforests of Java island have been almost totally cleared to meet the needs of its dense rural population and for cultivation of its fertile volcanic soils, while that of the Philippines were nearly completely destroyed by massive uncontrolled logging and agricultural clearance from the early 1950s until the mid-1970s (Primack and Corlett 2005). Over the last decade, large areas of the rainforests of the Indonesian islands of Sumatra and Kalimantan have been destroyed by fires resulting from land clearing activities, giving rise to the almost annual phenomenon of trans-boundary haze the neighbouring countries of Malaysia, Brunei, Singapore and parts of southern Thailand. The only South East Asian country which has seen a net increase in forest cover over the last decade is Vietnam (Table 1).

Another recent development in South East Asia is the establishment of large-scale industrial forest plantations of fast-growing species such as *Acacia mangium* and *Eucalyptus* spp., for pulp and paper. Extensive industrial plantations can be found in Indonesia, Thailand, Malaysia and Vietnam (Table 1). It has been predicted that when the natural forests of Sumatra and Kalimantan are completely destroyed, in 2015 and 2020 respectively, plantation forests will be the main source of timber for Indonesia (Rimbawanto 2002).

Regional research priorities

Forestry research priorities and the major constraints faced by countries in the region have been the subject of the priority-setting exercises carried out by Asian countries supported by the Asia Pacific Network of Forest Research Institutions (APAFRI) and the Forestry Research Support Programme for Asia and the Pacific (FORSPA) since the late 1990s. A regional seminar on Asia-Pacific Forestry Research – Vision 2010 was held in Kuala Lumpur in March 1999 (see Tan and Kamis 2000) followed by a desk review conducted by FORSPA in August 2001 and a consultative workshop in Kuala Lumpur in September 2001. These exercises culminated in the publication of the report "Forestry Research Priorities for the Asia Region" (FORSPA and APAFRI 2001). The present presentation draws heavily from that document and its precursor, the proceedings of the regional seminar on Asia-Pacific Forestry Research – Vision 2010 (Tan and Kamis 2000). As the identification of these priorities was dependent on documents that were available for the FORSPA desk review, the identified research priorities may not be conclusive for many South East Asian countries and any gaps in the information may reflect a gap in the documentation rather than an absence of priority (FORSPA and APAFRI 2001). In some cases no information on priorities was available and a list of current research activities had to be substituted. The process by which countries determined their priorities was also not clear.

The FORSPA and APAFRI report (FAO and FORSPA 2001) identified eight priority areas and 24 priority issues (Table 2). These priorities, although identified for the larger Asia Pacific region are directly relevant and applicable to South East Asia as all the South East Asian countries, with the exception of Brunei and Singapore which have very small forest areas (Table 1), were involved in the consultative workshop.

Forest ecosystem management

Although natural forest stocks are declining and forest plantations are increasing in area and importance in the region, natural forest ecosystems and their management remains of the highest research priority among South East Asian nations. Growing demands for the utilisation of secondary forests demonstrate a need for further research on their management and sustainable use. Research is needed on the range of economic instruments available for sustainable forest management and their impact on forest ecosystem management. With increasing awareness of the need for certification, many countries also recognise the need for research to develop, test and select suitable criteria and indicators for particular forest types and management systems. Research is also needed on the cross-sectoral linkages, particularly changing policies, institutions and laws between forestry and agriculture, the two dominant land-use activities in South East Asia.

Forest plantations

Forest plantations, mainly of the exotic fast-growing and high yielding *Acacia mangium* and *Eucalyptus* spp., have been established in many South East Asian countries to meet the huge demand of the pulp and paper, particleboard and medium fibreboard industries. In the haste to establish forest plantations, plantations have been established on unproductive, badly degraded, marginal sites or peat swamps, e.g. in Indonesia (Chung 2000) with insufficient research on the physical, ecological and socio-economic factors that determine the optimal choice of species for a given site. Research is needed on genetic improvement to increase growth performance, wood and fibre qualities, and resistance to pests and diseases, especially of plantations established on marginal lands. With the increasing popularity of out-grower schemes and other contract reforestation schemes, research is needed on the optimal legal and policy framework and socio-economic impacts of such schemes.

Table 2: Forestry research priority areas and priority issues for South East Asia.

Forestry research priority area	Priority issues in each area
Forest ecosystem management	• Second-growth forests • Economic instruments • Criteria & Indicators • Interactions between forestry and agriculture
Forest plantations	• Site and species selection • Tree and tree seed improvement • Pest and disease management • Farm forestry
Social or community forestry	• Supportive policies and institutions • Conflict management • Appropriate production systems • Market development for community forest products
Forest conservation and environmental protection	• Ecosystem rehabilitation • Participatory conservation • Markets for environmental services
Non-timber forest products (NTFPs)	• Resource inventory, products and markets • Sustainable management systems • Employment and income generation
Biomass and wood utilisation	• Waste reduction and efficient use • Processing efficiency of small diameter trees • Lesser-known species
Agroforestry	• Adoption constraints, institutional and incentive structures
Urban and landscape forestry	• Management systems for recreation forestry • Management systems for ecotourism

Social or community forestry

Land tenure rights and ownership of forest lands are contentious issues in South East Asia. Research is needed to develop an understanding of the dimensions of the conflicts in natural resource management, the economics of conflicts and indigenous knowledge and practices of conflict management. In some countries local communities and forest user groups are becoming increasingly involved in the local management of forest resources. In such instances, there may be a need to address specific problems encountered by such local communities who may not be in a position to undertake their own research and whose access to commercialized research will be limited (Tan and Kamis 2000). Research is also needed on the organisation and development of small-scale forest products enterprises managed by people with little formal marketing experience, constraints to market access and appropriate measures of support, e.g. improved access to credit, skills, marketing services, etc. (FORSPA and APAFRI 2001).

Forest conservation and environmental protection

Ecosystem rehabilitation is the issue of highest importance as large areas of forest land in South East Asia have been degraded by poor harvesting methods, forest fires, shifting cultivation and other disturbances. The issues of participatory conservation and markets for environmental services have also been identified as important issues in need of research. The latter is particularly pertinent in the search for answers to the question of whether market-based approaches to environmental management can meet social objectives related to poverty reduction while satisfying economic efficiency and environmental aims.

Non-timber forest products (NTFPs)

NTFPs are an important resource for many local people living in and near forests. Unfortunately, until recently, forestry agencies in South East Asia have not paid much attention to the management of NTFPs. There is a need for an inventory of the resource, products and markets, research on appropriate management systems, and an assessment of the contribution of NTFPs to employment and income generation.

Biomass and wood utilisation

This area of research is considered of medium priority in the region as the region continues to have more fibre potentially available than the quantity of wood products consumed, supply-demand balances are not likely to become any more compromised than at present, and most woodfuels continue to be collected and harvested from non-forest resources, largely on a sustainable basis (Durst 2000). Waste reduction, especially during forest logging operations, was identified as the most important issue in view of diminishing supplied of raw materials. There is also a need to explore the usage of alternative raw materials, the potential of lesser-known species, and the most efficient methods of processing, particularly of smaller diameter trees.

Agroforestry

Much research has been conducted on agroforestry systems over the years. Presently this area of medium research priority needs to focus on adoption constraints and institutional and incentive structures such as credit facilities, insurance and price support mechanisms so as to provide a permanent boost to adoption rates.

Urban and landscape forestry

Although this was identified as an area of low priority, it is expected to become more important in the future as urban areas expand and demand for forest recreation areas increases. Management systems for recreation forestry and ecotourism have been identified as issues in need of research.

Common issues

Four common research issues impinge on every priority area to a greater or lesser extent. There is a need to evaluate the impact of policy reforms and new institutional arrangements, including deregulation, smaller governments, the expanding role of the private sector and civil society, privatization and devolution on the forestry sector (FORSPA and APAFRI 2001). Research should be conducted on means of encouraging greater involvement of the private sector in forestry research, as is seen in Indonesia, Malaysia and the Philippines. There is also a need for socio-economic studies in the search for a balance between the different forest functions (or goods and uses) for maximum contributions to the welfare of local communities or the nation. The third over-arching issue is that of interdisciplinary and collaborative linkages which are necessary for communication, technology transfer, effective implementation of some of the priority research areas, and for securing support for forestry research, especially in some of the less well developed countries. Uptake and impact of research is the fourth common issue. Many countries in South East Asia face declines in public sector spending and funding for forestry and forestry related research and activities. Research capacity is particularly weak in countries where the problems are most acute, e.g., Cambodia (Syphan 2000), Myanmar (Win Kyl 2000) and Lao P.D.R. (Manivong 2000). Often researchers in these countries are unable to even take advantage of the knowledge or skills developed elsewhere and adapt them to their specific conditions. The need to demonstrate the effectiveness of public investment in forestry research, and growing demands on forestry development policies to pursue the objectives of poverty alleviation and sustainable development have increased the competitive pressure in obtaining adequate funding for forestry research in South East Asia.

Conclusion

In order for forestry research to remain relevant to the countries in the region, regular assessment, upgrading and revision of these priorities is needed to ensure that research addresses current and emerging issues. In tandem with this there is a need for capacity building and strengthening of national forestry research institutions so that limited resources are efficiently and effectively utilized. Mechanisms for inter-institutional collaboration, information sharing and networking need to be strengthened. IUFRO can play an important role in the region by facilitating such collaboration, supporting capacity building through its Special Program for Developing Countries, providing access to information networks such as GFIS and SilvaVoc, and highlighting relevant regional forestry research issues in global discussions.

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Priorities and goals of forest science and technology development in China

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Summary

The development of forestry in China has experienced a harsh zigzag process, characterized by the damage, rehabilitation and development of forest resources, a declining focus on timber production and an increasing awareness of the status, role and nature of forestry. China's strategic forestry development aims at providing more and better ecological, economic and cultural products for the public, meeting the diversified social demands for forestry, building a sound forest ecological system, a developed forest industry system and a prosperous ecological culture, and promoting sound and rapid forestry development. In order to meet the science and technology needs of forest ecological construction and industrial development, to keep up with the forefront of international forest science development and to attain status as leaders in newly-emerging fields, the planning and layout of research priorities for China's forest science and technology development is allocating resources in seven traditional forestry fields with a focus on scientific research and technological innovation and is providing strong support to the rapid development of forestry. At the same time, research priorities are being allocated to the newly emerging fields focusing on ecosystem rehabilitation and biodiversity conservation, carbon forestry, urban forestry, forest biomass energy and biomass material, and wetlands.

An overview of forestry in China

For the 15 years since the Rio Summit, the Chinese Government has been improving the laws and regulations and policy framework related to sustainable forest development. It encourages all walks of life to get involved in forest ecological improvements. The implementation of the key forest programmes nationwide has given rise to a favourable momentum characterized by the sustained growth of the forest area, a steady increase in stock volume, rising forest quality and a prudent forest structure. According to the 6th national forest resources inventory, China has a forest area of 175 million ha, a volume of 12.456 billion m^3, a forest cover of 18.21%, and 53.2573 million ha of plantations that rank the first in the world. A sharp jump in the development of the forest industry has been achieved and there have been remarkable improvements in the ecological environment, giving rise to an integrated social development system involving afforestation, greening, biodiversity and wetland conservation, the combating of desertification, forest industry, diversified businesses and science, technology and education.

China has made outstanding achievements in the development of forestry. At the same time, it is faced with problems and challenges. First, the gross forest resources are insufficient, and the quality of those resources is poor. The per capita forest area and stock volume is less than one fourth and one sixth, respectively, of the world's average. Secondly, the ecological environment continues to deteriorate. Thirdly, forestry productivity and forest management levels are poor, and science and technology have not contributed much to forestry development. Fourthly, the supply of forest products cannot meet economic and social development needs. There is a great gap between the supply and the demand for timber. In 2005, the net imports of timber were equivalent to 73 million m^3 of logs. Fifthly, since it joined the World Trade Organization, China has significantly reduced tariffs on forest products and eliminated non-tariff measures in a stepwise approach. As a result the domestic wood-based panel and furniture industries are confronting enormous pressures.

History and strategic transformation of China's forestry

Since the founding of P.R. China over five decades ago, the development of forestry has experienced a harsh zigzag process, characterized by the damage, rehabilitation and development of forest resources, a declining focus on timber production and an increasing awareness of the status, role and nature of forestry. The formulation of the forestry development strategy has been closely linked with the dominant social demands for forestry. A review of the history of the development of forestry in China over the past five decades indicates that forestry development has gone through three major phases.

The first phase, focused on timber utilization

From the 1950s to the end of the 1970s, China's forestry development was focused on timber utilization. This phase was dominated by traditional forestry concepts and was characterized by the exploitation of forest resources. In the period right after the founding of P.R. China, full-scale reconstruction was underway and national economic development had to rely on natural resources. In order to meet the needs of this development, the priority task for forestry was timber production. With rigid and inflexible rules, timber production plans had to be achieved and even over-fulfilled. Timber production played a significant role in securing the supply of timber for national development and in rehabilitating and developing the economy. Under these circumstances forests were, to a large extent, simply regarded as economic resources, forestry was seen as a primary industry of the national economy and the forestry sector as an industrial sector.

The second phase, with equal emphasis on timber production and ecological improvement

The period from the end of the 1970s to the late 1990s saw the rapid development of China’s forestry, with the implementation of the Three-north Shelterbelt Development Programme ushering China’s forestry into a phase with equal emphasis on timber production and ecological improvement. This phase almost matched China’s process of reform and opening-up, with profound economic and social changes occurring and the reform and development of forestry being explored and reviewed both in theory and practice. While undertaking timber production, China gradually intensified its efforts in protecting forest resources, conducting a large-scale afforestation and greening campaign, and initiating forestry ecological programmes targeting soil and water erosion control, ecological improvement and the increase of forest resources. The Chinese Government concluded that forestry was both an important primary industry and a social undertaking. It adopted the strategic objective of building both a comparatively complete forestry ecological system and a comparatively developed forest industry system. Significant advances were achieved in forestry development, with certain local ecological environments being remarkably improved, thus contributing significantly to economic and social development. However, China’s forestry had not fundamentally eliminated the influence and constraints of traditional forestry. As a result of the lack of attention given to ecological improvements and the deficiencies in the existing system, the guiding principles of afforestation had to be readjusted.

The third phase, dominated by ecological improvement

From the late 1990s until now, forestry development has been in a new period when forestry development has been guided by the theory of sustainable development, priority is given to ecological benefits, due consideration is given to the three major benefits of forests, and the multiple functions of forests are given full play so as to promote sustainable national economic and social development. During this period, breakthroughs have been made in the reform and opening-up process, the integrated national strength has been remarkably enhanced, and huge improvements have been achieved in peoples’ living standards. China has started its march towards building an affluent society.

The Chinese Government attaches great importance to forestry development. In 2003 it released the Resolution on Accelerating Forestry Development, which defined the national forestry development strategy focused on ecological improvement, and put forward a whole new approach to ecological improvement, ecological security and ecological culture. The ecological awareness of society has been significantly enhanced, the social demands for forestry have experienced fundamental changes, and forestry has become a significant sector giving play to the ecological, economic and social benefits of forests. Implementation of the key forestry programmes, including the Natural Forest Protection Programme, Grain to Green Programme, Shelterbelt Development Programme in the Three-North and the Middle and Lower Reaches of the Yangtze River, Sand Control Programme in the Vicinity of Beijing, Wildlife Conservation and Nature

Reserves Development Programme, and the Forest Industrial Base Development Programme with a Focus on Fast-growing and High-yielding Timber Plantation in Key Regions, have all served to usher forestry in China into a period of rapid development.

In order to better implement its forestry strategy with a focus on ecological improvement, the Chinese Government has initiated the development of a modern forestry oriented towards the future. This was an inevitable choice for China now that it has reached its current stage of development. It is the strategic direction for China's forestry. Modern forestry in China aims at providing more and better ecological, economic and cultural products for the public, meeting the diversified social demands for forestry, building a sound forest ecological system, creating a developed forest industry system and a prosperous ecological culture, promoting sound and rapid forestry development, and ushering China's forestry into a new sustainable development stage in the foreseeable future.

Taking the opportunity of the Six Key Forestry Programmes and the Six Special Science and Technology Programmes implemented by the State Forestry Administration (SFA), the Chinese Academy of Forestry (CAF) has researched and developed a number of patented inventions and technological achievements with a focus on the core technology in research fields of priorities influencing and dominating forestry, and has been making efforts to solve the key technological issues restricting the further development of China's forestry. Working towards the goal of being an internationally leading forestry research institution, the CAF has been working hard on the establishment of more competitive systems of science and technology innovation, disciplines, capacity building and a science and technology industry to meet the requirements of economic and social development and modern forestry. In addition, it has been addressing the core technological issues in modern forestry associated with the ecological, industrial and cultural forestry systems. The CAF aims to be one of the more advanced forest research institutions in the world by the end of the Eleventh Five-Year Plan period (2006-2010) and to be an international leader in forest research by 2020.

Priority research fields

In order to meet the science and technology needs of forest ecological construction and industrial development, to keep up with the forefront of international forest science development and to achieve a leading status in newly-emerging fields, the planning and layout of research priorities for China's forest science and technology is allocating resources in the following seven fields, with a focus on scientific research and technological innovation and the provision of strong support to the rapid development of forestry:

Forest tree breeding and cultivation

The priorities of this field include the functional genomics of the main tree species involved in forestry in China, flora and other plants; 'super' tree species; forest molecular breeding and somatic embryos; space mutation breeding and radiation breeding of forest plants; directed cultivation and efficient utilization of commercial forests; functional genomics of forest secondary vascular systems; genetic analysis of properties of wood formation, tolerance and resistance to pests and diseases; molecular breeding of fast-growing woody plants to attain high quality and high problem-resistance; collection, preservation and scientific utilization of forest germplasm; technology for the quantitative evaluation of forest wood tolerance, early forecasting and selection; integration of biotechnology and conventional breeding technology and innovation; seed selection and breeding of the best tree species for afforestation; somatic embryo propagation techniques; and propagation techniques for new commercial forests and flora of special interests and significance.

Forest ecological theories and construction

The priorities for this field include: the technology of forest ecological network construction; responses of the forest ecological system and its functions to climate change; the technology of the systematic construction and management of soil and water conservation forests, water conservation forests, farm protection forests, coastal protection forests, forests for snail control and schistosomiasis prevention, and ecological landscape forests; vegetation restoration techniques in extremely difficult sites; integrated control technology for desertification; transformation techniques for low-benefit ecological forests; and natural forests restoration and reconstruction technology.

Desertification abatement and control

The priorities for this field include: the formation mechanisms and transport dynamics of sandstorms and desertification; scientific observations of the desert; the principles and techniques of integrated desertification control; the bearing capacity of water resources and techniques for optimized vegetation distribution in desert areas; the technology of structural optimization of ecologically-safe land uses in desert areas; the technology of desertification control engineering of sand sources; real-time monitoring, assessment, forecast and warning of serious sandstorms; research into the health of artificial ecosystems at oases in arid areas; and research into the integrated control and restoration of ecosystems in degraded arid lands and their sustainable development.

Forest disaster control

The priorities for this field include: ecological and biological management of forest disasters; ecological control of serious forest pests and diseases; the mechanisms involved in serious forest disasters; the integrated impacts of multiple stresses on forest health; forest health maintenance and restoration technologies; the sustainable control of serious forest disasters; data management for forest disasters; monitoring and warning of forest fires; and forest fire control and safe fire-fighting techniques.

Efficient utilization of forest resources

The priorities for this field include: value-added wood processing and application technologies; design and fabrication technology of biomass-based composite materials and biodegradable polymer materials; recycling of wood-based waste materials; and forest food and forest health-care function development.

Key technologies for digitized forestry information

The priorities for this field include: sensor networks for forest biological and environmental information, spectroscopic detection and analysis and video surveillance; key technologies for digital forestry; forest growth digital modelling and system simulation; prediction and early warning of forest resources based on growth modelling and 3S technologies; quantitative analysis of forest ecological and environmental quality; virtual forestry and design of the digitization of key forestry programmes; digitized management and information services.

Equipment for advanced forestry technology

The priorities for this area include: equipment for forest resource development; equipment innovation for advanced forestry technologies; environment-friendly machinery for the control of forest diseases, pests and mice; equipment for forest fire prevention and fighting; advanced equipment for the efficient and intelligent processing of wood; equipment for the industrial production of bamboo timber; machinery and equipment for the advanced processing of non-timber forest resources; equipment for biomass energy development and utilization; equipment for the efficient processing of value-added products from special forestry resources; technologies for digitized monitoring and control during the processing of forest products.

Emerging fields and research

The research centres for biomass material engineering, wetlands and urban forestry of the State Forestry Administration will be the major institutions undertaking studies in these emerging fields. The focus of research will be on eight major areas such as ecosystem rehabilitation and biodiversity conservation, wetlands and ecological protection in coastal areas.

Ecosystem rehabilitation and biodiversity conservation

Priorities: Processes of degradation and mechanisms of rehabilitation of forest ecosystems; forest biodiversity conservation and valuation.

Ecological protections for wetlands and coastal areas

Priorities: wetland ecosystem protection and rehabilitation; establishment and management of coastal shelterbelt forest systems.

Carbon fixation forestry and carbon trading

Priorities: Mechanisms for and implementation of the convention to reduce carbon dioxide emissions and increase of carbon sinks in forests.

Forest biomass energy and biomass material

Priorities: Early assessment and prediction of the utilization of biomass material and resources; utilization of the chemical resources associated with biomass materials; biomass chemistry and efficient biological decomposition; high performance new materials from forest biomass; efficient transformation of forest biomass energy; high quality and high yield energy from forest development and the chemical basis of biomass energy; basic studies in wood fibre chemistry and biological transformation.

Urban forestry and rural forestry

Priorities: Strategies for urban forestry development; strategies for ecological protection in rural areas and development of new homesteads for forest dwellers.

Green accounting and regional forestry development strategy

Priorities: Value accounting of forest resources and green GDP; regional forestry development strategies.

Safety, energy saving and environmental protection

Virtual reality and visualized forestry

Goals of science and technology innovation

By 2010, the capacity of science and technology innovation in some disciplines and research fields in the Chinese Academy of Forestry will be consistent with first-class forestry research institutions around the world. Research in forest silviculture, tree breeding and genetic engineering, biomass materials and chemical utilization, abatement of desertification, forest hydrological processes, the biological control of forest diseases and pests, bamboo cultivation and utilization, and resource information technologies will all reach global levels of innovation.

Major basic studies and strategic high technologies will achieve breakthroughs

Genetic engineering in forest trees will achieve breakthrough progress, 4-6 functional genes of forest trees will obtain independent intellectual property rights; somatic embryogenesis and cell engineering technologies will make important breakthroughs, studies in forest and water relations and forest carbon sinks will make critical progress.

A number of superior varieties and clones will be developed

5-10 high quality and strongly resistant transgenic tree varieties will be developed; about 40 superior plant species/varieties will be selected/developed for ecological purposes; and more than 100 superior commercial tree varieties and clones will be developed.

Significantly strengthened capacity of technology transfer and research extension

More than 50% of research achievements will be transferred into practical operations; 50 demonstration areas and centres will be established according to geographic regions and forest types; and the coverage of research extension and demonstration will exceed 60%.

The number of research achievements with independent intellectual property rights and critical technology will steadily increase

The total number of patents and plant variety rights will be doubled, and the protection of intellectual property rights will be further strengthened. The number of research papers included in SCI and EI will be more than doubled.

An innovation system of forestry science and technology will be established

10-15 national forestry science centres will be established, 8-10 regional forestry science and technology centres will be formed, and 20-30 forestry experimental centres will be established; 1-2 national-level key laboratories will be constructed, establishing 5-10 ministerial-level new field-based scientific observation and research stations; 5-10 conservation banks of germplasm resources of forest plants will be established; 5-10 technical committees for specific forestry standards will be set up; 3-5 sub testing centres and 10 testing stations of new plant varieties will be established; 3-5 forestry science data sharing centres, digital libraries and science and technology information networks will be established.

By 2020, the CAF's science and technology innovation capacity will be consistent with the world's research frontier, and some disciplines and research fields will leading the rest of the world. Based on the "11th 5-year plan", the Chinese Academy of Forestry will continue to improve the innovation system of forestry science and technology and its operational mechanisms, will establish 1-2 additional national key laboratories and 3-5 national level field stations. The number of national science and technology progress awards obtained will account for more than 50% of the total number of awards obtained in the forestry sector. The increased rate of invention patents with independent intellectual property rights will be greater than 30%, and the technology transfer rate will be increased by 10% compared to the 11th 5-year period.

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A North American forest research agenda for the 21st century

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Summary

Approximately 100 academics, government researchers and administrators, industry leaders, and non-governmental organization representatives engaged in a summit in January 2006 to develop a research agenda for North American forestry for the 21st century. In addition they dealt with needed reforms in education to develop future research capacity and with ideas for funding models to better support the research and graduate education needed. The research agenda emerging from this summit and how it has been used is the focus of this paper.

Introduction

Developing a national research agenda for forest research in an area as large as North America is always a challenge, given the political and population diversity and the vast geography of such a territory. But there are times when a unified agenda is needed and the past four to five years has been one of those times, especially for Canada and the USA. Sustaining the capacity for forest research has been a challenge and forest research has not been high on the political agenda. Forest research budgets have been fairly stagnant and yet the need for research has grown considerably.

Into this situation stepped the National Association of University Forest Resources Programs (NAUFRP) with three initiatives and the USDA Forest Service with an additional one. NAUFRP developed a vision for the Nation's forests, it led a national summit on forest research and graduate education, and it developed a strategic plan for the US McIntire-Stennis Cooperative Forestry Research Program. The USDA Forest Service initiated a parallel, but linked, Outlook Process focused on science responses to anticipate decision makers' future needs. One outcome of these efforts was an agenda for forest research. That agenda is evolving, but the basic dimensions of it are fairly clear, and in this paper we describe how it emerged from the summit held in January 2006 in addition to illustrating its basic components.

Over the past several years the leadership of NAUFRP sensed several issues that needed to be addressed, both for the future of forestry education programmes and for the future of our forests.

- It became clear that we needed to improve dialogue within the forestry community.
- We needed clarity about who we are, where we are going, and what we need to do to get there.
- We needed to expand our research horizons and place our work in a larger context.
- We could not ignore the question of why there is declining student interest in our field and whether or not we were viewed as relevant.
- We needed to understand our place and role in a rapidly changing landscape.
- We needed greater investment in our field, but we needed to recast the importance of our work and rethink how we allocate and spend the funds that already exist.

With these thoughts as background we decided to step forward and recognize that the *status quo* was not advancing our field, our programmes, our nation, or the global condition of forests. We knew that there needed to be a compelling new agenda for natural resources research that truly matters: a bold agenda built around new ideas, real societal needs, new approaches, and the potential for high impact—an agenda built around new knowledge and science, not simply a rehash of the important issues of the day, that would advance the health and sustainability of forests and engage and enrich humanity.

The first of our initiatives was completed and released—*Forests for a Richer Future* (NAUFRP 2006). It was built upon a foundation of promoting shared values, applying the "best" science, and advancing a new stewardship ethic to create lasting forests. It paints a picture of America's future forests.

The second initiative came to fruition in January 2006 with the summit, *Forest Research for the 21st Century: Defining Strategic Directions and Rebuilding Capacity*, and published as *Redefining the Future of Forest Research* (DeHayes et al. 2006). Results of this effort flowed into the USDA Forest Service Outlook Process and it has formed the basis for our third initiative, the McIntire-Stennis Program Strategic Plan, *Sustaining*

Healthy and Productive Forests: Investment in America's Position in the Global Marketplace (NAUFRP in press), which is currently in publication. It is the result from this summit that we report in this paper.

Our process

To develop a bold new agenda we decided to hold a focused meeting among a set of key forestry and forest research leaders from the USA and Canada. We formulated it as a three-day workshop and invited 100 participants from academia, industry, government agencies, and non-governmental organizations. We also staffed it with professional facilitators and doctoral student recorders. We held the summit at an isolated location, the National Conservation Training Center in West Virginia, to ensure that the participants would not be unduly distracted. We secured the services of creative thinkers to offer keynote talks on each of our objectives—a research agenda, graduate education, and research funding—but spent most of our time in 10 diverse work teams fleshing out the issues and agenda for each topic. These sessions were followed by synthesis sessions of the team leaders and the recorders so that ideas were recorded and synthesized immediately. Immediately after the summit the organizers outlined the reports that were needed and within two months of the close of the summit a draft document was produced so that it could be used in other meetings and as a point of reference. The final report of the summit was published within four months and widely distributed.

The agenda

There are three parts to the agenda: Emerging and Integrative Areas of Knowledge, Crosscutting Issues and Foundation Areas of Knowledge. The exciting part of the agenda is the Emerging and Integrative Areas which are the following:

- *A New Science of Integration*
- *Forest Ecosystem Services*
- *Human Attitudes and Behaviours*
- *Conflict, Uncertainty, and Decision making*
- *Technology Advancements and Applications*

Among the ten workshop teams these five areas of research were unanimous recommendations. That is, all ten groups independently identified them as critical components of the future research agenda. In addition, there were two other areas of knowledge identified by most of the groups:

- *New Applications of Forest Products*
- *Urban Ecosystems*

A new science of integration

The focus of a New Science of Integration is on whole systems analysis, exploration across boundaries, ownerships, and jurisdictions, and the development of models, tools, and theories for the integration of ecological, socioeconomic, and cultural dimensions of natural resources management. This integrative science will deal with the complexities exacerbated by issues of global climate change, natural disturbances, human-initiated disturbances such as the rapid spread of invasive species and urbanization, the interactions of communities and natural resource use, and many other broad and complex topics.

Forest ecosystem services

We determined that we need a comprehensive understanding of Forest Ecosystem Services, including their value and retention, the viability of ecosystem service markets, and the full contributions of forests to the global economy and quality of life. With the many predictions about the effects of rapid and dramatic global warming, the life sustaining value of our forests is recognized as more important than ever before. In addition, these forests ensure a quality of life that is critical to social justice, welfare and prosperity.

Human attitudes and behaviours

Being good at modern forestry involves increasing our understanding of human attitudes and behaviours with regard to management and stewardship of natural resources and the development of effective tools to engage a variety of perspectives in natural resource decision-making. The support of people is critical in forest sustainability and it is necessary for us to understand the needs and desires of our populations and how they use natural resources. The sub-area of natural resource governance has become a critical issue affecting nearly every country in the world and these institutional arrangements are an important part of this area of study.

Conflict, uncertainty, and decision-making

Decision-making in natural resources has been undergoing considerable scrutiny in North American and thus this area of study focuses on the development of natural resource decision-making frameworks in the face of uncertainty with careful consideration and analysis of risk, roles of government structures, disturbance, and adaptive management. Given scarce financial resources and major natural resource effects from climate change involving wildland fire, insect and disease infestation, and extinction and migrations of species, it is even more critical than ever before to asses risk and uncertainty and to develop adaptive strategies for the future of our forests and grasslands. In addition, the competition over resources for a wide variety of products and services means that we are plagued with conflict and the means to resolve conflicts need to be better understood and developed.

Technology advancements and applications

Advancements such as applications of remote sensing and nanotechnology for monitoring and assessing impacts are included in this theme as are applications for sustainability of the earth, including earth system analysis focused on the convergence of ecology and people on a global scale. Major strides are being made from nano to global scales and these technological advancements need to be incorporated into our forest resource management tool kits and into our development of management, preservation, and business applications.

New applications for forests and products

New Applications for Forest Products deal with the development of sustainable forest industry practices and business models and with innovative forest products and applications such as bio-based polymers, alternative wood fibers, renewable energy systems, and bioremediation. The arena of sustainable forest management and the use of wood and other forest-based products demands considerable attention to ensure effective and efficient use of forests and to wisely use resources that are renewable and sustainable.

Urban ecosystems

Urban Ecosystems is about developing our understanding and appreciation of urban centres as functioning ecosystems that include substantial human elements and interacting natural-built environments and to enhance the livability of urban places through developing and sustaining urban forest resources. In particular, understanding the role of urban forest landscapes in quality of life, human health, mitigation of storm water pollution, and air and water quality are of increasingly high priority as are issues of equitable distribution of forest resource benefits across ethnic and socioeconomic communities.

Crosscutting issues

In addition to these major themes, the participants in the Summit recognized many crosscutting issues that are examples of the need for new comprehensive approaches to research. Some prominent environmental issues recognized were global climate change, alternative energy sources, biodiversity, invasive species, and carbon fluxes. These are all issues that include biophysical and social dimensions that need to be addressed through new comprehensive and integrated approaches to research. Furthermore, issues related to climate, water, air, and nature-based recreation and leisure activities can be addressed in the context of the major emergent research themes. Finally, participants recognized the need for increased attention to the development of comprehensive approaches to natural resources and ecological planning at varying scales.

Foundation areas of knowledge

While emphasizing the emerging and integrative areas of knowledge, summit participants recognized that there is a need for on-going research in fundamental and foundation areas of knowledge for success. Research must continue in a wide variety of foundation areas and in the development of models to enable us to synthesize complex systems and make environmentally and socially sound management decisions. Fundamental research on species, soils, hydrology, invasive species, pathogens, and wildfire are still critical to our understanding of forests, watersheds, and global functions. Fundamental research in the social, physical, engineering, and material sciences will also be instrumental in our decision-making processes, the development of new processes, and more effectively utilizing natural resources in environmentally and socially sound ways. Many resource management problems are complex and large scale, demanding a fundamental understanding of the integrative science of ecology, ecosystems, watersheds, social processes, and the connectedness of global forests and watersheds. Yet, it also was recognized that all foundation research must expand with technological advances in areas such as nanotechnology, biotechnology, and remote sensing as we meld our current knowledge with any of the topics noted above so that we can increase our ability to find the interconnectedness of plants and animals that reside in our forests, watersheds, and global communities.

Use of the agenda

An agenda for North American forest research has been unfolded for the first decades of the 21st century, but how is it being used? Following are a few examples (all from the USA).

- Broad discussion among research administrators (universities, federal and state agencies, private sector, and non-governmental organizations)
- Discussions with members of the US Congress and their staff
- Input to the US Forest Service Outlook Process
- Foundation for the Research Agenda for the Federal McIntire-Stennis Cooperative Forestry Research Program
- Input to discussions about graduate education reform
- Input to discussion of undergraduate education reform scheduled for 2008

Conclusion

Over the years we have been engaged in many research agenda exercises. This time, we have made real strides in forging a framework for forestry and natural resources research for the beginning of the 21st century across North America. There will be localized ways that the agenda is carried out across the continent, but the framework and the research it suggests is finding its way into many discussions about the future of forests and other natural resource environments. We are on the cusp of a new era of forest-focused research, but it will take a lot of work to be successful. Those who allocate funds for forest research still need to be convinced that such research is critical and they must be convinced that we are building capacity for sustained enhancements in research, productivity, and competitiveness, while ensuring sustainability of our life giving forests. We also must ensure that we are building the capacity for quality research that will make a difference and we must ensure means of using limited financial resources in the very best ways possible. This takes cooperation among all of us—academics, industry, government agencies, and non-governmental organizations—and this stakeholder driven agenda that many of us now own is an important part of forming this needed cooperation and collaboration.

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