Sustainable Forest Management, Forest Certification, Tree Improvement, and Forest Biotechnology

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INTRODUCTION

Sustainable forestry has become a widely accepted paradigm for forest management and protection since the UNCED conference on sustainable development in 1992. Since then, several international agreements have supported Sustainable Forest Management (SFM) and many forest certification approaches have been developed. This paper reviews the concept of SFM and forest certification as related to tree improvement and forest biotechnology. It covers general principles from the Montreal Process agreement, which the U.S. is a signatory member, and the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) certification systems.

A commonly accepted principle of sustainable forestry is that we must balance the growth and removals of forests over the long run to be sustainable. Furthermore, many people believe forest plantations are crucial in ensuring sustained yield of wood supply, and that forest plantations can help preserve some of the remaining natural forests in the world (i.e., Sedjo and Botkin 1997, World Wildlife Fund 2003).

World forest and plantation data from UN FAO and from our research were analysed in a paper by Siry et al. (2003), which is drawn on here for summary purposes. According to the Forest Resource Assessment (FRA) 2000 (FAO 2001), the world's forest cover amounts to nearly 3.9 billion ha. Forest plantations consist of forests that are artificially created and one or a few species, and often have greater yields than native forests. FAO (2001) estimates that there are 187 million ha (5%) in forest plantations. Drawing on additional surveys and our research, we estimate that there were about 204 million ha of planted forests by 2002.

Fast grown industrial plantations would be comprised of forests with growth rates of greater than 5 cu m/ha/yr and rotations of less than 30 years. This area would comprise 40 million ha, or 1.0% of the world's forests. However, they provide about 25% of the world's industrial fiber supply. In the United States, planted forests comprise about 18 million ha, with 14.4 million ha in the South (Smith et al. 2001). Thus 36% of the world's fast grown forests are in the U.S. South—in fact more than any other region in the world. Almost half of the softwood timber harvests in the South now come from pine plantations.

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The South also contributes about 15% to 20% of the world's industrial wood fiber supply—again the largest share of any region in the world (FAO 2002). At the end of 2002, about 121 million ha of forests were certified worldwide. This area amounts to only 3% of global forest area, but the influence of these systems on setting standards for forest management and affecting tree improvement and forest biotechnology is much greater that the small area covered might suggest.

SUSTAINABLE FOREST MANAGEMENT CRITERIA AND INDICATORS

According to the Brundtland Report in 1987, sustainable development is "…development that meets the needs of the present without compromising the ability of future generations to meet their needs." Sustainable forest management is an extension of the sustainable development and sustained yield principles. It includes sustainable ecosystems, communities, and economies, as well as commodity and noncommodity, market and nonmarket goods and services. It infers that society seeks to provide enhanced forest management and protection for diverse values. It can be implemented through measurement and monitoring of the status of forest and social conditions, improved forestry research and innovation, and application of new technology in adaptive forest management practices. These approaches will help sustain, enhance, and restore forests and their innumerable economic, environmental, and social values.

Montreal Process Criteria and Indicators

World leaders at the United Nations Conference on Environment and Development (UNCED) in 1992—termed the Earth Summit in Rio de Janeiro—developed a non-binding Statement of Forest Principles that consisted of 17 points outlining guidelines and means for protecting the world's forests. Since then, countries throughout the world have developed regional and international criteria and indicators that can measure and monitor success in achieving sustainable forest management (SFM). SFM criteria are large-scale reflections of major public values; indicators are means for measuring forest conditions and tracking subsequent changes. The "C&I", as they are termed, are tools to assess forest conditions and sustainability, not performance standards for certifying management.

Of the nine criteria and indicator initiatives in the world, the Montreal Process (2003) is geographically the largest, encompassing most of the world's temperate and boreal forests, and 60% of all of the world's forests (http://www.mpci.org). The broad Montreal criteria [indicators] encompass: (1) conservation of biological diversity [indicators 1-9]; (2) maintenance of productive capacity of productive ecosystems [10-14]; (3) maintenance of forest ecosystem health and vitality [15-17]; (4) conservation and maintenance of soil and water resources [18-25]; (5) maintenance of forest contribution to carbon cycles [26-28]; (6) maintenance and enhancement of long-term socio-economic benefits to meet the needs of societies [29-47]; and (7) development of legal, institutional, and economic framework for forest conservation and sustainable management [48-67]. The first approximation report for SFM C&I under the Montreal

Process was made in Seoul, South Korea in1997, and the current national plans will be summarized at the IUFRO meeting in Quebec City, Canada in September 2003.

Selected SFM C&I for Tree Improvement and Forest Biotech

Several SFM C&I are particularly relevant for tree improvement and forest biotechnology. A few salient components of the Montreal Process C&I follow. Criterion 1, the conservation of biologic diversity, specifically lists broad categories of ecosystem diversity, species diversity, and genetic diversity. The include indicators (6) number of forest-dependent species; (7) status of species of risk of not maintaining viable breeding populations; (8) number of species that occupy small portion of their former range; and (9) population levels of representative species from diverse habitats monitored across their ranges.

Criterion 2, maintenance of productive capacity, addresses measurement and monitoring of area, growing stock, removals, etc. of native and exotic species, compared to volume determined to be sustainable. These indicators (10-14) are extensions of the classic sustained yield/sustainable forestry principles to include broader timber, nontimber, and nonmarket forest outputs. Criterion 3, maintenance of forest ecosystem health and vitality, includes indicator numbers (15) area and percent of forests affected by pathogens, fire, land clearing, etc., (16) area and percent affected by air pollution, and (17) area with diminished biologic components. Tree improvement and forest biotechnology also can obviously contribute to Criterion 5, maintenance of forest contribution to global carbon cycles.

SFM Criterion 6, socio-economic benefits, includes relevant indicators (29) volume and value of wood products and (38) value of investment…including planted forests. Criterion 7 addresses the legal, institutional, and economic framework that supports SFM, and the capacity to conduct and apply research. Relevant indicators include (63) scientific understanding of ecosystems and (65) new technologies and the capacity to assess the socioeconomic consequences associated with the introduction of new technologies. These both encourage research, and suggest needs to monitor social effects of that research, such as with genetically modified organisms.

FOREST CERTIFICATION

As indicated, forest certification also has many components that are relevant to tree improvement and forest biotechnology programs, in both forestry research and in forest operations. The principles and objectives of forest certification are often quite similar to those of SFM. However, while SFM is aimed at measuring, monitoring, and tracking the status of forest at a national and global level, forest certification is more directly aimed at measuring, monitoring, auditing, and improving forest practices at the forest level. In the United States, the Sustainable Forestry Initiative (SFI), which was initiated by the forest industry, is the dominant certification system. The Forest Stewardship Council (FSC), which was initiated by environmental nongovernment organizations, is less prevalent in the U.S., but remains a benchmark for “green” certification. Relevant components for each program are paraphrased below.

Sustainable Forestry Initiative

The SFI Objectives (Sustainable Forestry Initiative 2002) state that the program participants must: (1) broaden practice of sustainable forestry, such as with written policies, funding for research, recreation and education, and maintenance of sustainable harvest levels; (2) ensure long-term forest productivity and reforestation, protect forests from fire, disease, etc; (3) protect water quality with Best Management Practices (BMPs), exceed state water laws, provide BMP training; (4) manage quality and distribution of wildlife habitat and biological diversity; and (5) manage visual impact of forest operations.

The SFI Objectives also require that program participants must: (6) protect sites with ecologic, historic, geologic significance; (7) minimize waste and utilize wood efficiently; (8) cooperate with forest landowners, wood producers, consulting foresters, logging and forestry associations to use of BMPs; (9) publicly report progress; (10) provide for public participation; and (11) promote continual improvement, monitor, measure, and report progress.

SFI objectives are implemented through specific core indicators that all program participants must follow, and other indicators that participants may elect to use to document their compliance with the sustainable forestry objectives. Program participants must demonstrate their compliance with these objectives and indicators through third person certification audits of their written documentation and field practices.

Selected 2003 SFI Objectives and Indicators relevant for tree improvement and forest biotech include the following (Sustainable Forestry Initiative 2002). Section 4.1.1, Objective 1 states that program participants must broaden the implementation of sustainable forestry, using the best scientific information available. Germane specific core indicators require that: “*Program Participants* shall (individually, through cooperative efforts or through associations) provide funding for...”: (1) “... forest research to improve the health, *productivity*, and management of all forests.” (Performance Measure 4.1.1.1.2, Core Indicator 1); and (2) “...research to improve the science and understanding of wildlife management at *stand* or *landscape* levels, ecosystem functions and the *conservation* of *biological diversity*.” (Performance Measure 4.1.4.1.2, Core Indicator 1). The core indicators for each of these components require “1. Current financial or in-kind support of research to address...” each of the relevant subjects.

Program component 4.1.2 Objective 2 requires participants to ensure long-term forest productivity and conservation of forest resources to promote reforestation, soil conservation, afforestation, and other measures. Core indicator 2 requires designation of all management units for either natural or artificial regeneration. Core indicator 5 of this objective requires that planting of exotic species is minimized, and core indicator 6 requires research documentation is available that exotic tree species planted operationally pose minimal risk. An "other" indicator, number 4.1.2, 7, requires that genetically improved stock is deployed appropriately to achieve reforestation requirements. Core indicator 4.1.2.1.3 states that chemicals must applied using appropriate BMPs, which would of course apply to nurseries and to plantations.

SFI Objective 4 states that participants must manage the quality of wildlife habitats and contribute to conservation of biological diversity by implementing stand- and landscape-level measures. Objective 5 requires management of the visual impact of harvesting and other forest operations. All of these first five SFI objectives relate to sustainable forestry practices in various means; the last six relate more to social, utilization, procurement, and reporting goals.

Forest Stewardship Council

The FSC principles focus more on social issues in the first few components, and then address ecological issues. The individual principles cover (Forest Stewardship Council 2003): (1) compliance with laws & FSC principles, (2) tenure and use rights and responsibilities, (3) indigenous people's rights, (4) community relations and worker's rights, (5) multiple benefits from the forest, (6) environmental impact (biodiversity), (7) management plans, (8) monitoring and assessment, (9) maintenance of high conservation value forests, and (10) plantations.

Selected FSC standards for tree improvement and forest biotech include the following. Standard 5.6 states that the rate of harvest of forest products shall not exceed levels which can be permanently sustained. Standard 6.3.a. covers forest regeneration and succession. Subcomponent 6.3.a.2 requires certified owners to maintain or restore forests to natural conditions to the extent possible. Section 6.3.a.4 mandates that owners retain live trees and native vegetation when they employ even aged management.

FSC addresses tree improvement and forest biotechnology very specifically. Key FSC standards related to tree improvement and forest biotech includes section 6.3.b. genetic, species, and ecosystem diversity. This includes 6.3.b.1, select trees for harvest, retention, and planting to maintain genetic diversity and species diversity of residual stand. Standard 6.3.b.2 requires that diverse native habitats be maintained; and 6.3.b.3 requires use of locally adapted seed of known provenance be used for artificial regeneration.

Standard 6.6 requires development and adoption of environmentally friendly non-chemical methods of pest management. Standard 6.8 requires that use of biological control agents shall be documented, minimized, monitored, and strictly controlled. Furthermore, it states that use of genetically modified organisms shall be prohibited. This includes a statement of: "Applicability Note: Genetically improved mechanisms (e.g., …Mendelian crossed) are not considered to be GMOs and may be used. The prohibition of GMOs applies to all organisms including trees." In addition, standard 6.8.a states that exotic predators used only as part of IPM strategy if other methods ineffective.

The FSC standards for tree improvement and forest biotechnology also limit plantations, especially of exotic species. They state that: 6.9 The use of exotic species shall be carefully controlled and actively monitored to avoid adverse ecological impacts; 6.9.a. that they should be contingent on peer-reviewed scientific evidence that any species in question is non-invasive and does not diminish biodiversity…use must be actively monitored; 6.9.b. owners must use control measures for invasive plants. Furthermore, they mandate that: 6.10 Forest conversion to plantations or non-forest uses shall not occur, except for (a) when it occurs as a limited portion of FMU; (b) does not occur in high conservation value forests; and (c) provides long term conservation benefits.

The U.S. SmartWood (2001)/FSC plantation standards, which we used in certifying our NC State College Forests in North Carolina, state that owners must manage their forest plantations per Principles and Criteria 1 through 9; that plantations must complement management of, and reduce pressures on, and promote restoration and conservation of natural forests; that plantation management objectives be clearly stated; that wildlife corridors, streamside zones, different ages and rotations must be employed; and that there must be a diversity in size, species, and distribution of planted and natural forests. Native species are preferred over exotic and plantations must be managed as part of the forest to restore natural cover. Soils in plantations must maintain their structure and fertility and cannot be degraded. Managers must minimize pests, diseases, fire, and pesticides, and assess on- and off-site ecological and social impacts and local access and use. Plantations converted from natural forests after November 1994 normally shall not qualify for certification, unless the manager/owner is not responsible directly or indirectly for conversion. However, typical southern forests regenerated from old farm fields are not considered “natural”, so this may not be daunting as it appears.

TREE IMPROVEMENT AND FOREST BIOTECHNOLOGY

Tree improvement and forest biotechnology offer related scientific means to increase forest productivity, achieve sustained timber yields, and perhaps enhance forest biodiversity and conservation of multiple values. Tree improvement provides classical approaches to achieve better timber production. It has achieved substantial gains through generations of tree selection and breeding. Li et al. (1999) found that tree improvement in the South has improved yields 7% to 12% in the first generation, and 13% to 21% in he second generation. More than one billion seedlings are produced each year, with about 40% being used on forest industry lands and 60% sold to nonindustrial private forest (NIPF) owners or timber management organizations (McKeand et al. 2003).

Tree improvement seeks to identify and improve several important tree attributes, including growth rates, disease and pest resistance, climate change and adaptability, tree form and wood fiber quality, straightness, branch number and size, and taper. Improved fiber characteristics for processing ease, lignin content, fibril angle, specific gravity, and wood density also are sought. Improved forest genetics and intensive silviculture can help achieve SFM High-yield plantations can produce at least triple the volume of natural stands in the South. Enhanced tree improvement can offer more gains, by site. Tree improvement has been widely accepted by environmental organizations, foresters, and certifiers, if natural forests are actually reserved or remain in low intensity management.

In theory, forest biotechnology can identify and map important genes, manipulate and insert desired traits in cells (transgenes), and create genetically modified organisms (GMOs). Biotechnology is a promising opportunity in plantation forestry. It possesses the same productivity advantages of tree improvement, plus others, but has more substantial drawbacks as well. It could provide higher yields, better wood quality, lower risk associated with pests and pest management, as well as offer engineered genetic diversity at the cell, stand, ecosystem, all much faster than waiting for generations of tree breeding and testing and plantation establishment. However, the research and development costs and risks are much higher, and it thus will have higher seedling costs, at least in the short run. There also are major technical challenges, social issues, environmental risks, and market acceptance questions (Lucier et al. 2002, Lindgren 2003).

CONCLUSIONS

I have covered forests and plantations, Sustainable Forest Management, forest certification, tree improvement, and forest biotechnology. What is impact of first three subjects on last two? What is the interaction among all factors?

Plantations provide about 25% of world industrial wood fiber. Furthermore, plantations provide the basis for and target of most of our tree improvement and forest biotechnology efforts. Genetically improved trees and wood, achieved through traditional tree improvement programs, are generally accepted for industry and NIPF private lands.

Sustainable Forest Management criteria and indicators for temperate and other forests have been developed in various international agreements, including the Montreal Process for U.S. and other non-European temperate forests. SFM mandates national measuring and monitoring of progress toward sustainable forestry for a broad range of environmental, economic, and social goods and services. SFM is informative, but not prescriptive. It is largely the focus of governments and policy experts, and perhaps forestry researchers and a small number of forest practitioners. SFM may encourage research support for sustainable forestry. But it is not a strong tool for advocacy, regulation, or encouraging public or private forestry investment per se.

Forest certification, which mandates and audits standards of forestry practice at the stand or ownership level, has potential for a much larger impact of forest management, tree improvement, and forest biotechnology. The SFI specifically requires that program participants demonstrate that they conduct or support forestry research in health and productivity, water quality, and wildlife and biodiversity. SFI clearly encourages use of plantations, tree improvement, and forest management, and infers that forest biotech would be acceptable. With appropriate safeguards, exotics are legitimate under SFI, although there are not many exotic timber species being planted in the U.S. yet. SFI might offer specific opportunities in tree, stand, or ecosystem biodiversity for applying the science of tree improvement or forest biotechnology.

Forest certification by FSC requires that managers favor natural stands and biodiversity. FSC allows plantations and tree improvement with fairly extensive strictures to protect natural stands and ecosystems. It explicitly proscribes the use of GMOs. FSC has been very flexible in decisions, allowing a large number of forests with exotic plantations to be certified if they have a large natural stand/reserve component as well. It does require refereed science to justify the use exotics and ensure that they do not cause any environmental harm.

Tree improvement is a very practical tool to achieve SFM. It has contributed to large realized gains in forest productivity already, and has more potential. It is largely taken for granted by academic administrators and federal forestry research programs. However, it can achieve continual gains without the use of transgenic GMOs. Forest biotechnology can be used to identify desirable traits, and traditional selection and breeding can be used to implement production of the most desirable families of trees. This probably remains most cost effective strategy, and fits well with forest certification. Surely tree improvement and breeding can use more funding by academia, government, and industry. However, it does have a significant marketing and packaging problem, seeming to be too staid for new research programs and new funding.

Forest biotechnology possesses more promise, more charisma, more financial support, and more problems. The perhaps distant promise of forest biotech is that of designer trees that are perfect for specific wood, paper, or environmental remediation applications, with known genetic diversity at the tree, stand, or ecosystem level. Given that even well supported agriculture applications have been limited to modest herbicide resistance or Bt disease insertions (Lindgren 2003), the promise of complex wood quality or growth improvements seems distant, however. The production economics and costs and returns for forest GMOs are daunting, and the social acceptance may be more challenging. FSC forest certification prohibits the use of GMOs for trees or for IPM, and several wood and paper retailers have or are considering adopting this policy. On the other hand, perhaps some of the outstanding recent medical breakthroughs, such as RNAi, can be duplicated in forestry at a much lower cost using similar technology. Maybe medicine and agriculture will pave the way for much less expensive subsequent forestry applications.

Increased government research in forest biotech is necessary, but costly, and the payoff will be distant. We still need to map the genomes of model tree species, discover molecular controls of key processes, assess ecological issues and opportunities, and understand risk management. We must link our forest biotechnology programs with traditional tree improvement, silviculture, and forest management, and vice versa. One avenue for this could be to use forest biotech to identify desirable characteristics, as described before, and then use vegetative propagation and/or somatic embryogenesis to rapidly ramp up and develop container stock for planting of superior trees. Perhaps this would avoid the clear social and certification antipathy for transgenics and GMOs, and still allow rapid implementation of the best science at reasonable costs.

In conclusion, tree improvement can enhance sustainable forestry by enhancing forest plantations and sustained yield of timber. It does increase timber yields, enhance insect and disease resistance, improve tree form and wood quality, and impart other benefits. Tree improvement requires continuous management attention to strategic breeding decisions and tactical operational implementation. It provides reasonable market returns to private and public investments. Forest biotechnology and GMOs offer more promise for dramatic breakthroughs in timber productivity and biodiversity conservation if successful. For example, biotech in medical applications and in the stock market has seen its most dramatic gains ever in 2002 and 2003. Biotech must be pursued with care in forestry so we do not waste scarce resources on extremely distant payoffs. We should capitalize on advances in medicine and agriculture, apply them well in forestry, answer pressing social and market questions, and integrate biotech with existing tree improvement and forest management research and development programs. With such advances, tree improvement and forest biotechnology can help us achieve the widely accepted paradigm of Sustainable Forest Management that promotes economic, ecological, and social benefits for this and future generations.

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