Science and technology in the forest sector: widening gaps and narrowing options

Improvements in science and technology are critical to the sustainable management of forests, woodlands and trees, and to their capacity to meet growing demand for the range of goods and services that they provide, including environmental and social benefits. A significant shift in research and development is needed to address multiple-use management, with more attention given to ecosystem processes and their interaction with social and economic systems. Yet the resources invested in forest research are alarmingly inadequate and significant imbalances exist between developed and developing countries, government and industry, and different segments of the forest sector. It is in this context that the present chapter examines issues relating to scientific and technological capacity in the forest sector, focusing on the widening gaps and narrowing options.

CHANGING FOREST SECTOR PRIORITIES

The relative importance of the different functions of forests varies depending on the culture, the state of social and economic development and the specific demands and aspirations of a given society. Investment in research and development reflects the changing priorities, although the improvement of wood-production and wood-processing technologies has traditionally attracted the most public and private resources, while research related to other ecosystem functions and social dimensions, such as poverty alleviation, has largely been neglected. However, pressure from local communities, environmental groups, the private sector and civil society, coupled with international efforts that began with the United Nations Conference on Environment and Development (UNCED), has led to better recognition of the broader values of forests, with implications for forest research and development as noted in the following.

Environmental concerns

Environmental concerns are receiving greater attention as many former assumptions are coming into question. For example, a substantial body of knowledge has accumulated on the conservation of biological diversity, climate change, hydrological cycles and land degradation, all of which have a bearing on land use, particularly forests.

Biological diversity. Concern over the conservation of the totality of life, including the entire system of natural processes, has significant implications for forestry, forest management practices and forest research (see the preceding chapter). Replacing commercially less valuable vegetation with monoculture plantations has become less acceptable and now requires consideration of biological diversity issues. Improved methods of assessing current and changing values of biological diversity will therefore help to fine-tune required interventions.

Climate change. Concern about the impact of human activity on climate change has drawn attention to the role of forests in storing and

sequestering carbon, given that they account for an estimated 80 percent of annual exchanges of carbon between terrestrial ecosystems and the atmosphere (see p. 25). This calls for substantial work on carbon budgets, the costs and benefits of various interventions, and the use of market and non-market mechanisms to mitigate climate change.

Forests and water. Access to freshwater has already become a critical limiting factor in the economic development of several countries and a cause of conflict in many parts of the world. However, considerable uncertainty exists regarding the link between forests and water (see chapter on freshwater resources, p. 74). Additional multidisciplinary research is required in order to reach a better understanding of the consequences of various land uses, including forestry, for water yield, and to develop systems for equitably sharing the costs and benefits of protecting watersheds.

Socio-economic issues: alleviating poverty and enhancing food security

Despite unprecedented economic progress, the gap in wealth and income is widening, and poverty and deprivation are persisting. An estimated 815 million people suffer from malnourishment (FAO, 2002), and progress towards the United Nations' Millennium Development Goals is too slow (UNDP and UNICEF, 2002). Approximately half the world's population of 6 billion survives on less than US$2 per day. Although most live in rural areas and depend on natural resources, the lack of skills, of access to appropriate technology and of secure tenure, as well as a host of other problems, means that they are unable to manage and use resources sustainably. The fact that developments in science and technology have bypassed large segments of society also contributes to the unsustainable use of resources and environmental degradation. It also aggravates poverty, and not only in developing countries, for there are pockets of deprivation everywhere, even in the midst of plenty.

Implications for forest research

In terms of research, both alleviation of poverty and environmental protection will require:

- better understanding of the interaction between ecosystem processes and social and economic systems, and development of tools and techniques based on more comprehensive knowledge;
- an increase in the production of goods and services required by the poor, and enhancement of employment- and income-generating opportunities;
- modification of technology to comply with environmental requirements, especially the protection of biological diversity and the maintenance of key ecosystem processes.

The fundamental question is whether science and technology, as a whole, and forest research, in particular, are moving in that direction, or whether the gaps in knowledge and capacities are widening and long-term options narrowing.

WIDENING GAPS

Precisely when science must focus on social and environmental concerns in the forest sector, it seems that gaps in capacity among countries are widening and that, despite the need to undertake more broad-based research, current shifts in priorities and institutional arrangements

Power and impotence

"A profound paradox of power and impotence, crying out for a solution, now faces concerned people in every society. On the one hand, there is the unmatched power of basic scientific and technological research, reporting one remarkable advance after another at dizzying speed. On the other hand, individuals and whole societies are plagued by ominous problems that yield all-too-slowly, in part because of persistent ignorance at the fundamental level."

Branscomb, Holton and Sonnert, 2001.

could result in reduced attention to public goods research in these areas.

The technology divide

Almost all science and technology efforts and their results point to a wide gap between developed and developing countries. Table 9 classifies 87 countries on the basis of per capita investment in technology efforts and patents. The high-technology group consists entirely of industrialized countries, while all those in the low and negligible groups are developing countries. The moderate group includes some industrialized countries and some in transition.

On a per capita basis, countries in the high-technology group invest about 20 times more than those in the group immediately below. This is consistent with other parameters, such as the number of patents per 1 000 inhabitants and the average number of patents per country group in 1997–1998. As can be seen, the bulk of the world's population lives in countries with low and negligible investment in research and development. This disparity is manifest in the level of output.

The involvement of developing regions in science and technology efforts is clearly very low. Although not a perfect indicator, the differences

CANADIAN FOREST SERVICE/K. KLIMASZEWSKA

Technology divide, narrowing options: white spruce **(Picea glauca)** *seedlings developed through somatic embryogenesis – a sophisticated but expensive biotechnology for large-scale production of trees*

TABLE 9

Average technology effort per country divided into technology groups, 1997–1998

Technology group	Number of countries	Total population *(millions)*	Research and development per capita *(US$)*	Patents per 1 000 inhabitants	Number of patents per country
High	23	855.1	293.25	0.99	6 803
Moderate	20	756.0	14.01	0.02	50
Low	23	2 536.4	0.24	0.00	11
Negligible	21	655.6	0.00	0.00	0

Source: Based on Lall, 2001.

in the number of scientific articles published by region hint at disproportionate efforts and the marginalization of developing countries in knowledge advances. In 1999, North America and Western Europe accounted for about 70 percent of scientific articles published, while sub-Saharan Africa accounted for about 0.6 percent (Table 10). Furthermore, the broad groupings conceal disparities within regions. For example, Australia, China, India and Japan accounted for 94 percent of the publications in the Asia and the Pacific region. In sub-Saharan Africa, 56 percent of scientific articles were published in South Africa. What is more disturbing, however, is the significant decline in sub-Saharan African output between 1986 and 1999.

Although data comparing research and development efforts in the forest sector in different countries are limited, they appear to mirror the overall situation described in the previous paragraphs. For example, almost 70 percent of the member institutions of the

TABLE 10
Number of scientific articles published in different regions

Region	Number of publications in 1986	Number of publications in 1999
North America	199 138	183 211
Western Europe	143 496	188 548
Asia and the Pacific	59 931	101 369
Eastern Europe and Central Asia	42 299	30 763
Near East and North Africa	7 659	9 086
Latin America	5 583	12 034
Sub-Saharan Africa	4 639	3 632
World	**462 745**	**528 643**

Source: NSF, 2002.

An overview of science and technology investment

- Research and development investment in the 28 OECD countries in 1998 was estimated at US$502 billion; seven countries accounted for 85 percent, and the United States alone accounted for 44 percent of the total (NSF, 2002).
- In 1997–1998, the United States registered an average of 3.3 patents per 1 000 people. South Africa, industrially the most developed country in sub-Saharan Africa, had only 0.03 patents per 1 000 people, while India had just 0.001 (Lall, 2001).
- Per capita productive enterprise research and development for Japan in 1997–1998 was US$858.4, while for Brazil, South Africa and China it was US$13.7, $12.8 and $0.9, respectively (Lall, 2001).
- United States Federal Government support for academic agricultural research and development in 2000 was US$16 345 million (NSF, 2002), while the total budget of the 16 CGIAR centres in that year was US$331 million (CGIAR, 2000).
- Government research and development support for agriculture, forestry and fisheries in the United States in 1999 was estimated at US$15 528 million (NSF, 2002), while government investment in agricultural research in India, a country with a relatively well-developed national research system, was US$348 million in 1995 (Pray and Fuglie, 2001).
- An increasing proportion of research investment in OECD countries comes from the private sector. In 1981, industry accounted for 51 percent of the total OECD research and development outlay of US$251 billion. By 1998, this had increased to 62.5 percent, while the total outlay had almost doubled (Pray and Fuglie, 2001).

Marginalization of developing country research

"The gap between developed and developing countries in forestry research capacity and the delivery of usable results remains unacceptably wide. Developing countries, with 80 percent of the world's population, account for only 2 percent of the global expenditures on scientific research and for an even smaller share of the research output, which is the quantity of direct importance. They continue to face difficulties participating in the globalization process and many risk being marginalized and effectively excluded from global dialogue."

Szaro *et al.*, 1999.

International Union of Forestry Research Organizations (IUFRO) come from the 30 countries of the Organisation for Economic Co-operation and Development (OECD). IUFRO has launched a special programme to address the low level of involvement of developing countries in its networks (IUFRO, 2002).

Despite efforts in recent years, there are no indications that developing country research is increasing or that gaps in science and technology are narrowing, except in a small number of countries in Asia and Latin America. In many countries, especially those in sub-Saharan Africa, where forests could play a critical part in sustainable development and the enhancement of livelihoods, there is little research capacity in terms of institutions and human resources. The few institutions that do exist are underfunded and often lack adequate systems to make effective use of the limited resources that are available. Moreover, they are unable to plan and implement research or to encourage the adoption of appropriate technology.

Declining international support

Until the early 1990s, there were many programmes and projects to build research capacity, and the forest sector also benefited from such initiatives. However, with the decline in development assistance, support for research and development also shrank. This has particularly affected sub-Saharan Africa, where donor funding has been critical in sustaining efforts in several national research institutions. The declining trend in agricultural research and development most probably applies to the forest sector as well.

Private sector involvement

In many countries, structural adjustment programmes have led to public-sector downsizing and significant reductions in research capacity. Economic liberalization policies were thought to provide incentives for growth in the private sector and to more than compensate for the drop in public-sector investment, including research investment. It was also claimed that privatization of forest research would strengthen the links between research and its application, increasing its efficiency by focusing on outputs and products. Proponents of neo-liberal economic policies maintain that increased domestic private sector investment will replace public sector investment and that increased foreign direct investment will fill the gaps left as a result of declining development assistance. These assumptions seem unrealistic, especially in many developing countries where the private sector is weak and has neither the interest nor the capacity to invest in research. The few private initiatives that do exist are limited to adaptive research in areas that provide immediate competitive advantages, such as enhancing the productivity of plantations and wood processing. Even in Europe, where the private sector has a major role in growing and processing wood, the wisdom of privatizing and commercializing forest research is being questioned (Hellström, Palo and Solberg, 1998). This is also the case in New Zealand, where forest research was drastically restructured a decade ago (Richardson, 2002).

Increased flows of foreign direct investment have not been sufficient to compensate for declining development assistance, especially in

Forest research in New Zealand

"At first glance, everything seems rosy in research labs. After nearly ten years of operating under a boldly experimental commercial model, scientists are focusing on industry needs like never before and success stories abound. Last year Crown Research Institutes, including Forest Research, boasted record profits. But look behind the upbeat annual reports and you'll see a different picture."

Richardson, 2002.

Some trends in international development assistance for agriculture and agricultural research and development

- Although the European Community has increased overall development assistance, agriculture's share and support to agricultural research and development have declined. In the 1980s, agriculture accounted for 12 percent of European Community support, but this figure declined to 4 percent between 1996 and 1998.
- World Bank support for the rural sector has been erratic during the past two decades. However, after adjustment for inflation, the trend has been downward. The share of agriculture in total lending has declined from an average of 26 percent in the first half of the 1980s to 10 percent in 2000.
- The amount of funding that the United States Agency for International Development (USAID) directed towards agricultural research in the least-developed countries declined by 75 percent between the mid-1980s and 1996.

Source: Pardey and Beintema, 2001.

forest research. Foreign investment is concentrated in relatively well-off developing countries and newly industrialized countries. In addition, most of it flows to activities that have short pay-back periods and high returns. Although foreign investment results in some technology transfer in forestry, this is mostly related to logging, forest plantations and wood processing. Seldom does it increase indigenous capacity in science and technology, particularly in areas relevant to the needs of local communities.

NARROWING OPTIONS

Imbalances in ongoing research lessen options, thus increasing vulnerability to economic and environmental change. Low investment, coupled with changes in institutional arrangements, is bringing about a significant shift in research priorities, at a time when a broader framework is required to address the complexities of sustainable forest management.

Integrating approaches to science and technology

While the importance of integrated research is recognized, it is seldom reflected in the

Privatization of forest research in Europe: some findings

"Both economic theory and our empirical findings give strong support for the continuing dominating role of public funding in most forestry research. We have not found support from theory or practice that decreased public funding of most forestry research would be compensated by increased private funding in the respective fields of research. In addition, if public funding of forestry research is cut, it means that research orientation is to an increasing degree controlled by the markets, which for forestry research are very narrow. Inevitably such privatization would shift research priorities towards the interests of the private bodies capable of funding forestry research."

Hellström, Palo and Solberg, 1998.

International Union of Forestry Research Organizations: the leading international forest research network

IUFRO is 110 years old and has grown into the largest international non-governmental forest research network, encompassing virtually all aspects of forest research. Membership consists of 15 000 scientists from 700 institutions in 112 countries. Much of IUFRO's work is carried out by divisions and working groups that are organized according to the various disciplines. However, task forces are also established to examine such cross-disciplinary issues as:

- environmental change;
- forests in sustainable mountain development;
- management and conservation of forest genetic resources;
- water and forests;
- global forest information services;
- the science–policy interface;
- public relations in forest science;
- the role of forests in carbon cycles, sequestration and storage;
- information technology and the forest sector.

Research needs to be selective

"Research will need to avoid the perennial temptation to glorify all small-scale enterprises. In fact, many such activities are mere disguises for open unemployment; refuges for the desperate deprived of options; are poverty traps with no potential to bring real well-being in the long term; or offer little room for helping those dependent upon them to achieve technological and institutional upgrading. It will be essential to be selective and to favour activities with some improvement potential."

Kowero, Spilsbury and Chipeta, 2002.

formulation and implementation of science policy. Many developing countries have established science and technology departments, and their policies acknowledge the need to increase research capacity. However, substantial efforts are still required to integrate forest research so that it is not undertaken as an isolated activity with limited links to research in other sectors. Moreover, within wider policies concerning economic and social development, most countries, especially developing ones, have yet to link priorities and strategies for forest research to outcomes and impacts on society and the environment.

Continued focus on traditional areas

A major thrust of forest research has been the improvement of timber production, largely in plantations through enhanced technology. Neither research institutions nor those concerned with science policy formulation have been able to adapt adequately to the need for more comprehensive approaches to address the basic purpose of research. Many are finding it hard to make changes in their portfolios and are therefore making only cosmetic changes. Most projects and programmes still focus on products or disciplines. Only recently has IUFRO, for example, started paying more attention to cross-disciplinary issues.

Emergence of large corporate players

In the context of globalization, forest industries are restructuring through mergers, acquisitions and diversification (ILO, 2001). Some of the larger players are investing in developing countries and positioning themselves to take advantage of low labour costs and economies of scale, especially in technology development. Producing for a global market means standardizing products and processes, which to some extent limits the pursuit of a diversified and broad-based research agenda. Experience in most sectors, including agriculture,

demonstrates that the corporate research agenda is narrowly focused on technology that increases productivity, especially breeding, pest management and processing. Even large concession holders operating in tropical forests for decades have not invested sufficiently in research on sustainable forest management, and the situation is compounded by the preoccupation of many companies with short-term profits.

Neglect of the informal sector

In many developing countries, the forest sector is characterized by small-scale enterprises, of which a significant proportion operates in informal markets. A study by the International Labour Organization (ILO) indicated that 63 percent of total global employment in the forest and wood industries is in the "invisible forest sector", comprising informal sector small enterprises (34 percent) and fuelwood collection (29 percent) (ILO, 2001). Despite a number of deficiencies, rural enterprises based on the collection, processing and trade of forest products are a major source of employment and cash income in some places (Kowero, Spilsbury and Chipeta, 2002). Many of these enterprises are small, consisting of little more than one family working on a part-time basis. Investment is low, most technology is simple, and the failure rate is high. Notwithstanding the importance of the informal sector, few efforts have been made to improve its technological capacity, and there is a real need to gain a clear understanding of its potential and to develop technology that is relevant to small-scale producers.

Although attention is now paid to indigenous technology and local technical knowledge, efforts to improve these through modern science have been limited. Two trends seem to be emerging: total acceptance of traditional or local knowledge, based on the assumption that it is the best available; or its outright rejection as unscientific and inappropriate. Neither stance has helped to improve capacity at the community level. While there is an urgent need to give greater consideration to traditional knowledge, out-of-hand replacement of what is considered "modern" often results in systemic rejection and unsustainability.

Impact of developments in science and technology in other sectors

A substantial proportion of developments in science and technology is generic, and has been adapted to forestry as appropriate. For example, advances in the following areas have had impacts in the forest sector:

- molecular biology and biotechnology;
- chemical and process engineering, including new materials technology;
- transport technology;
- space technology, including remote sensing techniques;
- information and communications technology.

Transport technology, for instance, has revolutionized forestry, permitting greater access to distant markets and increased flexibility to shift the production site. Techniques such as helicopter logging have opened up areas previously considered inaccessible, while tree improvement techniques have led to substantial increases in the productivity of plantations, and more precise remote sensing could make it possible to assess and monitor resources on a real-time basis. However, the inadequacy of technological capacities poses certain constraints and raises two key issues: access to generic technology and the adaptation of such technology to the specific needs of a place or sector.

Patent regimes are increasingly acting as barriers, because some countries are not in a position to pay royalties for access to knowledge. Where the potential exists for technology transfer, large enterprises with well-developed research and development capacity capture a significant proportion of benefits. Countries that fail to develop indigenous science and technology capacity thus become markets for capital and consumer goods or, at best, producers of goods for global markets largely using cheap labour and natural resources. In most cases, even the capacity to assess the appropriateness of technology in the global marketplace is lacking.

Effectiveness of partnerships

Partnerships between the private and public sectors. Partnerships between the private and public sectors can strengthen research efforts by making them more demand-driven, with a focus on well-defined outputs. They are also a way of generating funds in times of declining resources. However, pitfalls do exist. Public institutions, under pressure to mobilize resources, are often compelled to enter into partnerships with the private sector on terms that compromise the purpose of their research. Most partnerships of this type increase the competitive advantage of the private sector, and a substantial proportion of research tends to be product- and productivity-focused. Other limitations include:

- a decrease in resources for more fundamental public goods research, which in due course negatively affects applied and adaptive research;
- increased vulnerability to unforeseen problems, such as pest infestation and disease resulting from a narrow focus on a limited number of species and clones;
- restricted access to outputs, limiting the generation and wider application of knowledge.

Public sector partnerships with communities and non-governmental organizations (NGOs). Traditionally, most public sector forest research has responded to the needs of government forest agencies and has been related to large-scale forestry, especially plantations. The narrow technical specialization this entails has limited the ability to build up strong links between public sector institutions and local communities. Although the recent focus on agroforestry by the World Agroforestry Centre (ICRAF) and some NGOs, for example, has helped to improve the scientific basis of traditional practices, there are nevertheless serious gaps. The fragmented nature of conventional research, coupled with limited capacity in social science research, often undermines the potential for a strong partnership between the public sector and local communities.

Partnerships between the private sector and the community. In several countries, private industries are increasing support to local communities and farmers for tree growing. Industries provide seeds, seedlings and technical expertise, and invest substantially in efforts to identify appropriate species and

Center for International Forestry Research: adaptive responses to emerging concerns

CIFOR, established a decade ago to strengthen forest policy research at the global level, is helping to redefine the focus of such research. Through four research programmes and one programme for research support, CIFOR is responding to evolving demand and emerging issues, for example in the following areas:

- the underlying causes of deforestation, forest degradation and poverty in forest margins;
- forest ecosystem management;
- multiple resource management of natural forests;
- assessing the sustainability of forest management – testing criteria and indicators;
- plantation forestry on degraded or low-potential sites;
- conservation of biological diversity and genetic resources;
- livelihoods, community forests and devolution;
- sustainable use and development of non-wood forest products (NWFPs);
- research impact, information and capacity building;
- policies, technologies and global change.

provenances and standardize management practices. They also provide market access. Such partnerships concentrate mainly on the production of industrial roundwood, often from fast-growing species, and industry undertakes most of the applied and adaptive research. With other aspects receiving little attention, these partnerships can be vulnerable to economic and environmental changes.

International initiatives

Collaboration through networking is an important mechanism to add value to ongoing science and technology efforts, and there are some excellent examples. IUFRO has been operating for more than a century and is seen as a pioneer. Recently established regional networks of forest research institutions, such as the Asia-Pacific Association of Forestry Research Institutions (APAFRI) and the Forestry Research Network for Sub-Saharan Africa (FORNESSA), are attempting to improve the prioritizing of research and the exchange of methodologies, experience and results. With limited numbers of researchers in many countries, building up strong collaborative networks at the subregional, regional and global levels becomes imperative. During the past decade, the Consultative Group on International Agricultural Research (CGIAR) has established the Center for International Forestry Research (CIFOR) and incorporated ICRAF into its system. In the context of evolving priorities, these institutions have adapted and reoriented their research agendas to tackle issues related to environmental services, sustainable livelihoods and governance.

While international research institutions provide frameworks and concepts that can be applied more widely, such application largely depends on capacity at the country level. As previously noted, most traditional forest research institutions lack the resources, capacity and orientation to design and implement the new agenda required for sustainable forest management, and alternatives are yet to emerge. Meanwhile, research remains narrowly focused,

Global Forum on Agricultural Research

GFAR was founded in 1996 by representatives of national agricultural research systems in developing countries, advanced research institutions, regional and subregional organizations, universities, NGOs, farmers' organizations, the private sector, international research centres and the donor community. It became fully operational in 1998. Its mission is to mobilize the scientific community and all those with a stake in agricultural research for development, to alleviate poverty, increase food security and promote the sustainable use of natural resources.

The objectives of GFAR are to:

- facilitate the exchange of information and knowledge in crop and animal production, fisheries, forestry and natural resource management;
- promote the integration of national agricultural research systems and increase their capacity to produce and transfer technology in response to users' needs;
- foster cost-effective partnerships among those with a stake in agricultural research and sustainable development;
- facilitate the participation of all stakeholders in formulating a global framework for development-oriented agricultural research;
- increase awareness among policy-makers and donors of the need for long-term commitment to, and investment in, agricultural research.

Natural resource management and agro-ecology is one of the five priority areas of GFAR. It will therefore need to develop a forestry dimension in its work at the national, regional and global levels.

largely driven by the short-term priorities of an imperfect market. The Global Forum on Agricultural Research (GFAR), established in 1996, has the potential to fill the gaps, although its effectiveness remains to be seen.

CONCLUDING OBSERVATIONS

If current weaknesses in forest science and technology efforts persist, the following circumstances could prevail in coming years.

- The technology gap between advanced countries and those at the lower end of the ladder may widen, with many countries remaining excluded from the generation and application of knowledge.
- It will be hard to adopt sustainable forest management on a wider scale and to address the growing number of social and environmental issues in forest resource use.
- Limited application of scientific advances to a few élite segments of the forest sector will contrast sharply with the lag in the rest of the sector resulting from insufficient research and development efforts, especially in the management of indigenous forests and those catering to local needs.
- The narrow pursuit of commercial profits could increase society's vulnerability to unforeseen environmental and economic changes, and declining public sector investment will impair its capacity to address such situations.

There is therefore an urgent need to strengthen scientific capacity, especially in countries where it remains poor. Innovative approaches are required to ensure that limited resources are effectively utilized and that results have wider relevance and application. ◆

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