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Chapter 9. ICT in Forest Management and Conservation

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9.1 Introduction

Forest management is the art and science of managing forest resources. However, the term "managing" carries with it various connotations including, for example, directing and controlling. In the sense of directing, forest management is fundamentally concerned with deciding how to use forests to provide the values, goods, and services desired by society (Davis *et al.*, 2001). In the sense of controlling, forest management is concerned with the application of a diverse array of specific operations to satisfy the goals and objectives established by decision makers. As other chapters in this book address the impacts of ICT at the operational level of forest management, this chapter tends to focus on the impacts of advances in ICT on decision making as a forest management process. We draw liberally on conclusions from other chapters to address the impacts of ICT on forest management in the broader sense.

In the context of decision making, the impacts of ICT can be understood in terms of how they influence the effectiveness and efficiency of decision processes or in terms of how ICT inherently impacts the shaping of such processes. We consider the impacts of ICT on the effectiveness and efficiency of forest management in Section 9.2; but what exactly *are* the impacts of ICT? Technology is simply applied science; and as information and communication sciences underlie ICT, the potential sources of impacts on forest management decision processes include technological advances in the acquisition, representation, storage, processing, and sharing of information. ICT advances in the acquisition of information through remote sensing and in the representation and storage of information in enterprise-scale database management systems are well covered in Chapter 5. We thus cover these topics only slightly in Section 9.2, relying on that prior chapter to provide a more detailed background. Similarly, ICT advances in information sharing through the Internet and other more traditional media are well covered in chapters 2 and 6, and we depend on those chapters to provide a more detailed background for our observations here.

There are both direct and indirect effects of ICT on forest management. There are direct effects of ICT on decision-making processes, as discussed in the previous paragraph, and there are also direct effects at the operational level. Moreover, impacts on the effectiveness and efficiency of forest operations can indirectly influence decision processes by introducing, for example, new alternative operating procedures that need to be considered.

The dramatic changes observed in forest management, caused by advances in ICT over the past 20 years, also offer some useful insights into what we might expect to see in the next 20 years. In Section 9.3, we project into the near future the consequences of what seem to be the more important recent trends in the effects of ICT on forest management. For some of these trends, there are reasonably discernible policy implications, which we discuss in Section 9.4.

The title of this chapter addresses ICT in the context of both forest management and conservation. A few words of explanation are perhaps in order. Conservation can be thought of as a principle but, like forest management, it can also be understood as a process. These two processes are not independent; conservation is simply an instance of forest management in the sense that it can be seen as an application of forest management in which conservation values happen to be emphasized. Why, then, do we make a distinction in the chapter title? In part, we think conservation deserves separate consideration because of the international significance attached to forest ecosystem sustainability since the 1992 Earth Summit in Rio de Janeiro, Brazil (United Nations, 1992). Subsequent major international agreements, such as the Montreal Process and Helsinki Accords, and subsequent major international initiatives in forest and forest-products certification, all point to the growing attention being accorded to conservation as a primary consideration of forest management.

9.2 Current Status

Worldwide, forests are a key resource serving a multitude of functions, such as providing industries with timber and communities with plentiful and clean water, protecting infrastructure in mountain regions against natural hazards, creating and managing habitat for wildlife species, maintaining biodiversity and aesthetic values, sequestering carbon, and others. The growing need to consider so many different kinds of values has posed considerable challenges for modern forest management, which must now additionally consider multiple, and often conflicting, ecological and nontimber objectives over a range of spatial and temporal scales. ICT advances and innovations in the past 20 years have enabled significant changes in the practice of forest management. In the following sections, we first consider the drivers behind ICT adoption and recent ICT innovations, then how the practice of forest management has been impacted by ICT, and finally the consequences of these impacts in terms of issues such as the efficiency and effectiveness of forest management.

9.2.1 Drivers behind ICT adoption and innovation

The adoption of ICT and growth of ICT innovations in forest management have been driven by a combination of forces, including advances in the scientific understanding of forest systems, public pressure for involvement in resource management decisions, and organizational needs for enhanced competitiveness. Approaches to forest management have been undergoing dramatic changes since at least the mid-1970s, when forest ecologists began emphasizing the need to understand and manage forests as ecosystems (Duerr *et al.*, 1979). Related concepts of hierarchy theory (O'Neil *et al.*, 1986), adaptive management (Holling, 1978), and forest ecosystem sustainability (Anonymous, 1995; Maser, 1994) have been instrumental in shaping the evolving practice of forest management in the period since 1980. Managing ecosystems and better addressing organizational business needs in general prompted the deployment of remote-sensing systems and enterprise-scale database management systems (Chapter 5) to acquire and store the vast amounts of complex and diverse information. The need to comprehensively project and analyze the likely future development of ecosystems led to the proliferation of ecosystem modeling, which in turn benefited enormously from technological advances in ICT. The latter trend also drove the development and deployment of sophisticated analytical systems able to address the internal needs of organizations and provide the transparent solutions needed to support the continuing dialog on public policy for forest management.

9.2.2 How forest management is currently practiced

Stimulated by developments in business administration and industry, computer-based decision support systems (DSSs) have been improving the quality and transparency of decision making in natural resource management. DSSs provide support to solve ill-structured decision problems (Leung, 1997; Rauscher, 1999) by integrating database management systems with analytical and operational research models, graphic display, tabular reporting capabilities, and the expert knowledge of scientists, managers, and decision makers to assist in solving specific problems (Fischer *et al.*, 1996).

Because DSSs are based on formalized knowledge, their application in decision making has facilitated decisions that are reproducible and as rational as possible. Further, DSSs have proved most useful for complex, strategic problems, that is, for problems that cannot be completely supported by algorithms and analytical solutions (Turban and Aronson, 2004). Finally, through the use of DSSs, the way the decision maker arrives at a decision is automatically documented; thus, the process of decision making can be evaluated *post hoc*. Over the last two decades, research in decision support has evolved to include several additional concepts and views.

In the period since DSSs came to prominence, there has been a shift from automatic cartography to geographic information systems (GIS). The potential power of GIS goes beyond producing maps by providing mechanisms for the input, storage, analysis, and use of spatial information. GIS has increased the acceptance of DSSs and led to the development and application of spatial decision support systems (SDSSs) (David and Reisinger, 1985; Covington *et al.*, 1988; Fedra and Reitsma, 1990; Densham, 1991; Naesset, 1997; Varma *et al.*, 2000). Spatial data and the analytical capabilities of GIS within an SDSS have been necessary to address new demands in strategic and operational planning for natural resource management. SDSSs offer decision-making capabilities based on integration of alphanumeric information with geographic parameters and allow the modeling of spatial processes and spatial analysis to generate new information.

Multicriteria decision making (MCDM) techniques have been integrated with (S)DSSs to help decision makers model trade-offs between multiple and conflicting objectives in multipurpose management implicitly or explicitly (e.g., Lexer *et al.*, 2005). Spatial multicriteria decision problems may involve a set of geographically defined alternatives (events) from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria. The integration of multiattribute methods in SDSSs offer unique capabilities for managing and analyzing single-user as well as collaborative spatial decision problems with large sets of feasible alternatives and multiple conflicting and incommensurate evaluation criteria (e.g., Vacik and Lexer, 2001; Ascough *et al.*, 2002). Recent ICT development has facilitated the integration of new data and new models to build effective multicriteria SDSSs (Engel *et al.*, 2003).

Artificial intelligence (AI) approaches such as artificial neural networks (ANNs) and expert systems (ESs) have been instrumental in supporting new forest management paradigms and in enhancing forest management processes, both at stand and landscape levels. The characteristics of ANNs (e.g., Zahedi, 1993; Turban and Aronson, 2004) make them particularly useful for addressing problems such as pattern recognition, forecasting, and classification, but ANN application in forest management and conservation has some limitations. The accuracy of an ANN solution is highly dependent on the availability of large data sets for network training and testing purposes. Further, determining an adequate system architecture, information processing, and learning methods is not trivial; thus, ANN design can be complex. Another important limitation is the lack of explanation capabilities, as the knowledge base is often a black box to the user.

The characteristics of ESs (Zahedi, 1993; Mallach, 1994; Turban and Aronson, 2004) make them particularly useful for addressing interpretation, prediction, diagnosis, planning, monitoring, and control problems. Both stand and landscape management and conservation have been supported by ESs. For example, the Ecosystem Management Decision Support (EMDS) system (Reynolds, 2001) has evolved an integrated ES approach to multifunctional forest management. EMDS is currently being used to address ecological as well as economic and social sustainability concerns, namely, as portrayed in the Montreal criteria and indicators (Reynolds, 2001; Reynolds and Hessburg, 2003; and Reynolds *et al.*, 2003). Many forestry problem areas are suited to an approach that models the process used by people to make decisions about a system rather than representing the system itself. Further, ES design is relatively easy, and several commercial development environments are available to support it. Knowledge representation in ESs is explicit, so it is simple to alter a rule or to identify an object and change its attributes (Zahedi, 1993). As ESs also open the process of reasoning through explanatory interfaces, the system is a white box to the user (Zahedi, 1993). The ability to explain its reasoning is inherent in the ES knowledge structure (Mallach, 1994). However, ES application to forest management also has some limitations. Knowledge acquisition and engineering are mostly external and people-driven processes, being dependent on extracting knowledge and expertise from people. Experts and knowledge engineers can be expensive and hard to find. Moreover, as pure ESs are primarily applicable to recurring problems, and strategic problems are seldom recurrent, pure ESs are mostly applicable to operational problems and to fairly structured tasks (Mallach, 1994).

9.2.3 Impacts of ICT adoption and innovation

9.2.3.1 Efficiency and Effectiveness of Forest Management

ICT adoption in the forest sector has impacted both the cost of making decisions and the accuracy and quality of decisions. With respect to forest management in the broad sense, ICT impacts on forest operations have generally been positive, creating increases in efficiency and effectiveness at operational levels. For instance, both logging and logistic processes have been generally benefited by

ICT (Chapter 5). Similarly, advances in remote sensing and enterprise-scale database systems (Chapter 8) have contributed to increasing the efficiency and effectiveness of forest management. Here, we consider the contribution of ICT advances related to decision-making processes and some interactions related to acquisition, management, and communication of information.

Impacts of ICT advances on decision processes have not succeeded in appreciably reducing controversies over issues or objectives in modern public policy debates. Moreover, current planning processes for forest management may well be less efficient with respect to the time and other resources that are now being committed to public participation processes compared to 20 years ago. Nevertheless, important progress has been made in the past 20 years with respect to improving the transparency of decision processes, improving access to information on likely impacts of decision alternatives, and improving the effectiveness of public participation. It is hard to imagine how the current forest ecosystem management paradigm might translate into actual planning without the support of ICT.

Both strategic and operational management planning require information about the state of the forests. A field inventory is expensive, and because of the need for cost-effectiveness, stands not under active management may be omitted, which tends to create information gaps. Some basic inventory information such as species composition and standing stock can potentially be obtained by remote sensing. ANN may be used to interpret remotely sensed data, thus contributing to the efficiency of inventory processes, namely, by the automation of photointerpretation and land classification processes (e.g., Blackard and Dean, 1999; Liu *et al.*, 2003). Improved efficiency of inventory processes is the key to addressing ecosystem management problems with large data requirements and is thus a condition for the effectiveness of forest management. Effectiveness is further improved by more transparent and readily available information about forest resources and its socioeconomic context provided by management information systems.

Spatial information is the key to addressing both operational and environmental concerns in forest management. As the diversity of ecosystem management objectives increases, demand grows for spatial resolution. The use of GIS is thus critical for both the efficiency and effectiveness of decision making. Moreover, increased public involvement in the definition and analysis of questions tied to location and geography is becoming more important. Recent developments in the field of GIS (Web services, interactive dynamic maps) allow the limitations of present GIS technologies in public participation processes to be overcome. Web GIS applications allow an expanded framework of communication and discourse, opening opportunities for public participation across the processes of problem definition and problem resolution.

Addressing extended planning horizons requires projection capabilities that are made possible by automated simulators and prescription writers in a model management system. For example, automated landscape-level disturbance simulators may generate information to address the impacts of fires in forest management. The early warning system regarding forest pests of the U.S. Forest Service (www.fs.fed.us/foresthealth/) help integrate health considerations into forest management. According to Davis *et al.* (2001) developing, evaluating, and applying prescriptions is the central activity of professional forestry. Ecosystem management objectives determine the number and the complexity of prescriptions. Automated simulation of prescriptions is thus the key for forest management effectiveness (Rose *et al.*, 1992; Borges *et al.*, 2003).

A DSS may fully implement the basic decision-making process, which includes problem identification and analysis, identification of alternatives, evaluation, implementation, and monitoring (Mintzberg *et al.*, 1994). For instance, the DSS introduced by Lexer *et al.* (2005) can improve the consultation process between small-woodland owners and local forest authorities. The DSS presented by Borges *et al.* (2003) integrated heuristic methods (e.g., Borges *et al.*, 2002) to address both public and private forest management. A good decision, in the sense of decision science (e.g., Keeney and Raiffa, 1993) builds on objective information as well as the preferences and expertise of stakeholders and decision makers. Without such tools, forest owners usually do not otherwise have access to quantitative information about future stand development and the consequences in terms of resource conditions and economic outcomes. Thus, the DSS approach has the potential to facilitate good decisions. It contributes to the efficiency of forest management by automating data management processes. Yet it puts emphasis on the improvement of the effectiveness of forest management by better representation of decision-making problems. Decision making may take longer, but decisions are better (Turban and Aronson, 2004).

Hybrid systems that combine functionalities of ES, ANN, and DSS may further improve both the efficiency and effectiveness of forest management. For example, symbolic processing by ES may help in the interpretation and assessment of scenario-analysis information provided by DSS. Overall, the impacts of advances in ICT have provided forest managers with better tools to reason more effectively and come to conclusions more quickly and easily, despite the increased complexity of issues and the greatly expanded volume of information being dealt with in contemporary forest management. Forest management may be more effective now, compared to, say, 20 years ago, in the sense that it attempts a much more comprehensive understanding of interdependencies among resource conditions as a basis for more-informed management decisions.

9.2.3.2 Management for Conservation

Modern analytical tools supporting decisions in forest management are better able to accommodate much more complex management questions, including management consequences, to a broad array of resources, as described in Section 9.2.2. So, at least in principle, there is the potential to treat conservation issues more effectively in the broader context of forest management. However, a variety of systems have been developed in recent years to specifically support effective and efficient solutions for conservation. Some attempts have been made to maximize conservation values while minimizing impacts on, for example, timber harvest reduction (Andelman *et al.*, 1999; Anonymous, 2001; Fisher and Church, 2003). Conversely, another class of solutions attempt to maximize economic uses while minimizing impacts on resource values such as reductions or threats to biodiversity. Conservation management has been greatly enhanced by capabilities for improved spatial analysis and simulation brought about by advances in ICT. For instance Netherer and Nopp-Mayr (2005) presented a GIS-based approach to virtual monitoring of the risk of bark beetle infestations in national parks in the Czech Republic.

9.2.3.3 Global Variation in ICT Impacts

A digital divide underlies the global variations in ICT impacts on forest management and conservation. A huge gap in telecommunications infrastructure drives the differential use of ICT across the world. In developed countries, better infrastructures generally support the use of ICT in public and private forest management and conservation. Yet the effectiveness of participation in public forest management in these countries is constrained by the dimensions of the digital divide (e.g., income, education, and ethnicity). In developing or underdeveloped countries, ICT mostly impacts both public and vertically integrated forest management. Castells (2001) points out how dedicated systems, often via satellite transmission connected to sophisticated local networks, support the needs of preferential clients (e.g., financial and high-level governmental institutions) in these countries. The forest sector is no exception. The technological sophistication of the vertically integrated forest industry contrasts with the lack of ICT support for communal and private forest management. Both the telecommunications infrastructure and informational literacy have constrained the use of decision systems in the public domain.

9.3 Future Impacts of ICT

Prognosticating about the future is an uncertain business at best, and past predictions about technological advances and their impacts have at times turned out to be amusingly wrong. For example, the editor in charge of business books for Prentice Hall in 1957 asserted in an interview, “I have traveled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won't last out the year” (from www.famous-quotations.com). Suitably chastened by such examples, we nevertheless believe that recent trends lead to some reasonable expectations about advances in ICT and their impacts on forest management in the next 20 years. In particular, the driving forces behind ICT adoption and innovation in forest management for the past 20 years, discussed in Section 9.2.1, remain substantially unchanged and no less compelling today; and they are likely to remain so for at least the next decade.

To help set the stage for this section, we start with two short vignettes.

9.3.1 Private forest management in 2025: A vignette

In 2004, A.M., a 25-year-old, nonindustrial private forest (NIPF) landowner, attended a meeting in northern Portugal organized in the framework of a project to develop decision support tools for private forest management (Instituto Nacional de Investigação Agrária de Portugal, 2002). Twenty-one years later, M. still had vivid memories of that day in Penafiel, where forestry institutions from most regions on the Iberian Peninsula had discussed issues related to NIPF forest management, and where a Web-based innovative NIPF decision support system—MetaForest (Ribeiro *et al.*, 2004b) was presented. For A.M., that meeting was a landmark for NIPF forest management. Actually, it was a milestone for forest management and conservation on the Iberian Peninsula, because 93% and 68% of forestland in Portugal and Spain, respectively, was privately owned. Over the next two decades, research and outreach aiming at the maintenance and the evolution of systems such as MetaForest had a substantial impact on forest policy processes, on the involvement of civil society and nongovernmental organizations (namely NIPF associations) in national forest programs and regional forest plans and, ultimately, on how A.M managed his own forest land.

These memories come to life as A.M. develops a forest management plan for his holding in 2025. He does not need to invest much in technology or software to use the best available tools to develop his plan. He just uses his Web browser to access the computational capacity of the server that stores and manages all relevant ecosystem data from his holding and from other NIPF holdings in the region. A.M only has permission to access data from his holding, but his NIPF association has conducted integrated inventories for all associates and has permission to access all data.

A.M. recalls the progress made in data acquisition, management modeling, and development of information systems. Rather than focusing solely on intrinsic data quality, accessibility, contextual and representational data quality were also considered (Ribeiro *et al.*, 2004a). Further, better representation of decision processes and problems with new models and more effective decision support by hybrid technologies had allowed MetaForest to address ever-changing challenges in forest management over the last two decades. Explicit recognition of the human component of information systems (e.g., NIPF)—people who anticipated and conceived the management problems—had been critical for this development. The forest resource base is a social construct, and it had evolved over time. It was people who translated information into knowledge. It was people who made the decisions. It was people who coped with the consequences of decisions. Forest organizations are mostly people (Oliveira, 1998). As Davenport (1994) puts it, people are the soul of ICT. And yet for a long time, the ICT design for forest management and conservation had overlooked and underestimated the human dimension of information systems. A.M. recalls the high percentage of former ICT investment failures in the forest sector that had ignored this component.

Today, A.M navigates through the remote-information-system interfaces to check the current situation in his holding and to develop alternative management scenarios. Interfaces hide the complexity of models and technology, are user-friendly, and are continuously updated according to NIPF feedback and needs. In particular, they enable trade-off analysis between forest, livestock, agriculture, and environmental objectives. Over 85% of NIPF in the region develop activities other than forestry in their holdings, and the system integrates forestry objectives within overarching holding-level objectives. Furthermore, the system's interface enables interactive planning by A.M. to generate management scenarios. About 30 minutes after he accesses the system, A.M. has the information needed to develop a management plan.

However, A. M. has also agreed to negotiate regional management objectives with other NIPFs. Forest fires are a major concern as a consequence of global warming, and effective forest fire management requires concerted actions by the NIPF. Thus, A.M. accesses the system to send the NIPF association information about his new management options and to request a negotiating round between all involved NIPFs. Upon receiving the request, the planner at the association immediately accesses the system to generate management scenarios for the whole region, based on the current individual management plans of the NIPF and on the options of A. M. made accessible to him by the system. A few hours later the planner realizes that some landscape-level objectives cannot be met with current individual plans and options.

The planner at the association uses standard system features to communicate to the 1,500 associates the trade-offs between individual holding and landscape-wide objectives in the regional management scenarios. She further calls for electronic meetings to negotiate compromises so that landscape-wide objectives may be met. The system has group decision-support features, and its interfaces facilitate the negotiation. Four weeks after A.M first accessed the system, a compromise has been reached that complies with the objectives of regional forest plans. Both the individual management plans (all 1,500 of them, in fact) and a regional forest plan have been revised and updated in this period.

As A.M. uses the system to implement his new plan, he recalls how the idea of developing human-centered ICT in the last two decades has contributed to strengthening NIPF associations and changing political processes. By providing better services, associations have attracted more associates and revolutionized forest management and conservation processes that had been fragmented or nonexistent in 2004. Further, the strength acquired by the NIPF associations has enabled them to participate more actively and effectively in regional forest planning and in national forest programs in countries with a tradition of centralization and state authoritarianism.

9.3.2 Public forest management in 2025: A vignette

J.B. is a regional forest planner for a country in interior Africa, which is richly endowed with forest resources. On arriving at work six weeks ago, she found an e-mail message from the national forest planning staff, advising that it was time for her region to update its forest plan.

J.B. started by consulting the region's Web site. Village elders, via satellite Internet access, regularly visit the regional site to review and comment on regional plans and express their villages' concerns and interests with the forest environment. J.B. queried the site's content bots who gave her an updated analysis of recent key issues raised by the elders. Concerns for forest sustainability remained the top issue, but concerns about timber poaching had lessened, and there was now increased interest among the villages in promoting forest sector jobs.

Issues had changed enough since the last round of planning for J.B. to decide to visit the online planning resources site of the International Union of Forest Research Organizations (IUFRO). Querying the site's model database, she found a model from five years ago, developed for central Europe, that was actually a pretty close fit to the current issues in her region. The selected model needed some minor modifications, but J.B. had not yet had in-depth training in designing these particular kinds of planning models so she visited the online training area of the site. The self-paced training took her four hours. At the end, the training program administered a short test to check that key concepts of model design had not been missed. The program also checked its own database of knowledge resources and recommended a colleague in Hungary that J.B. might want to consult if she needed advice on model design and application.

Model revisions required two days, and, on review, J.B.'s Hungarian colleague concurred that her modifications seemed appropriate. The regional Web site notified the village elders by e-mail that a new planning model had been proposed. Although these models are technologically very advanced, they also are very intuitive and easy to understand. They were quickly reviewed and validated by the elders.

The planning model defined the data requirements for an initial assessment of current condition. J.B. visited the GlobalForestCommunicator site, and quickly assembled the appropriate GIS layers for her region, all suitably transformed to the projection her government routinely uses. The initial assessment was presented to the national forest planning staff, who suggested three strategic alternatives for further consideration. The regional planning site advised the village elders about this new information. After their review, a fourth strategic alternative was added.

Evaluating the alternatives required running a number of programs, including, for example, a harvest scheduling optimizer, a stand growth simulator, and various expert systems, to project the consequences of the four alternatives into the future. The planning model actually documented this sort of information for its users but only in a general way. J.B. also needed more specific guidance on how to tune parameters for the recommended models, so she visited IUFRO's ForestModelArchive Web site.

Once the projections had been run, initial results were again reported to the national planning staff, who recommended choosing their original alternative C. All of the map products, analyses, and recommendations from the planning process were organized with the region's e-plan application and posted to the regional Web site, where they were now reviewed by the villagers. The village elders encouraged everyone to review and comment, so there were actually several thousand comments received. However, the e-plan application's automated processing of comment content made it easy to track public response and document the adequacy of comment handling by the agency.

J.B. reviewed the content analysis and presented her findings to the national planning staff. While the national planning staff had originally recommended alternative C, the villagers were almost overwhelmingly in favor of alternative D, and using map products and documents from the e-plan Web site, they made a rather compelling case. On further review and discussion with the village elders, a compromise alternative, capturing important elements of both C and D, was mutually agreed to by the national and regional planning staffs and the village elders.

With a strategic alternative now agreed to by all parties, J.B. ran additional components of the planning application to develop specific, tactical plans for what sorts of management activities to perform in what areas of the planning region. These plans launched the initial phase of plan implementation. Interestingly, the basic evaluation system used to perform the initial assessment of current condition and the assessment of alternatives would now be used in the plan implementation to track and report progress.

J.B. leaned back in her chair, and paused to reflect at the end of the process. She recalled those horror stories from graduate school of how forest planning processes in North America and Europe could take eight to ten years back in the 1980s and 1990s. Why, even in the 2010s, it was not unusual for a planning process to run 30 to 36 months. She had to smile, realizing that six weeks really wasn't long at all.

9.3.3 How forest management might be practiced

Current technologies supporting strategic and operational forest management (Section 9.2.2) are foundational in the sense that they provide core competencies for forest management; forest research can continue to build on these so that it can respond more adequately to the drivers of Section 9.2.1 (scientific understanding of forest systems, public pressure for involvement in resource management decisions, and organizational needs for enhanced competitiveness). In each of the following subsections, we begin by summarizing the current state of a contemporary forest management topic; we then consider the likelihood of advances in ICT and obstacles to advancement.

9.3.3.1 Supporting Public Participation

The number of stakeholders and interest groups involved in the management of natural resources has substantially increased over the past few decades. Meanwhile, widely disparate laws, information resources, and the environmental concerns of affected communities have continued to accumulate, further complicating planning processes. While there has been great progress in the ability to develop and apply ecosystem models in policymaking and planning for the management of forest resources, social interdependencies in natural resource management have received much less attention

(Kakoyannis *et al.*, 2001). Decision making in contemporary natural resource management is usually about making a compromise between conflicting objectives. To reach solutions acceptable to affected stakeholder groups requires acknowledging the need to include stakeholders in the decision-making process, not just as sources of information but as active participants in the decision process (Mendoza and Prabhu, 2003). The forestry community as a whole has yet to take full advantage of developments in the area of collaboration technologies. The increasing number of stakeholders involved in the management of natural resources and the concomitant need to consider multiple interests and preferences in the decision-making process further suggest the usefulness of those technologies.

ICT has the potential to play an important role in facilitating participatory planning processes. New capabilities, provided by ICT, help to bridge the gap between the general public, whose input must now be more effectively accommodated in the decision-making processes, and scientists, researchers, and politicians, who make decisions on behalf of the general public every day. However, the design of participatory planning processes also poses a major dilemma. On the one hand, there is increasing demand for more rigorous and formalized decision-making approaches to reduce the perception of subjectivity and increase effective communication among participating stakeholders. On the other hand, the use of methods and tools that are too sophisticated often poses the risk that people will be more likely to acquiesce to an unsolved problem than accept a solution that they do not understand. Thus, it needs to be acknowledged that, for land-use planning and resource-sharing projects involving cooperative development, the ICT support potentially available can sometimes be technological overkill. In such an environment, the search for optimum solutions in natural resource management should not be driven by technology but rather by social acceptance of tools and methods by the involved stakeholders (Kakoyannis *et al.*, 2001). There is reason to believe that this argument holds good for many participatory planning situations in industrialized regions of the world.

There will continue to be strong demand for research into the development of ICT solutions that, on the one hand, allow participatory planning processes to be transparent and, on the other, utilize available technology. Types of engagement include either individual discussion (in the form of an online interview) or group-based discussion (participative forums such as citizens' juries, round tables, study circles, and collaborative management groups). ICT is already capable of providing interactive maps based on GIS-server technology or discussion forums handling bulletin boards, polls, FAQs, and notes (Tress and Tress, 2003). In fact, significant progress has recently been made in this area. For example, the GeoCommunicator Internet portal (www.geocommunicator.gov) of the Bureau of Land Management (U.S. Department of Interior) and the Forest Service (U.S. Department of Agriculture) is already offering unprecedented public access to spatially referenced government data on a wide range of natural resources. The e-planning initiative of these two U.S. federal agencies goes further and is beginning to deliver sophisticated, highly interactive, Internet-based planning documents with equally sophisticated backend capabilities for processing public comments (see, for example, www.eplanning.blm.gov/).

Globalization, as well as increasing public awareness of natural resource management issues, will lead to increasingly tough planning problems for many organizations. This suggests the need for further development of group-decision support systems (GDSSs) that are explicitly designed to provide brainstorming, idea evaluation, and communication facilities to support team problem solving (Courtney, 2001). Further development of collaborative technologies such as GDSSs will help avoid the consequences of knowledge fragmentation and will extend support to decision-making processes involving several individuals (Jessup and Valacich, 1993; Palma dos Reis, 1999; Turban and Aronson, 2004).

Implementation of teledemocracy is another feasible way of improving citizen access to participatory decision-making processes. Developments in this area could reduce problems resulting from geographical insularity and long distances, for instance, in participatory planning and decision making, and facilitate rapid registering of large numbers of opinions directly to computer memory

(Kangas and Store, 2003). However, considering contemporary experiences with ICT, teledemocracy is not likely to entirely replace other channels of public participation for the foreseeable future.

9.3.3.2 Managing Across Spatial Scales

Ever since the introduction of ecosystem hierarchy theory (O´Neill *et al.*, 1986) and associated principles of ecosystem management (Holling, 1978), it has been widely accepted within the forest management community that comprehensive planning requires the consideration of a range of spatial scales and that the basic levels of strategic and operational planning need to be at least closely coordinated, if not actually integrated, in order to support a coherent and efficient process over a range of scales. The distinction between coordinated and integrated planning involves both a matter of degree and qualitative differences. In an integrated approach, the outcome of a strategic plan tightly constrains the formulation and selection of options within the tactical planning level, whereas, in a coordinated approach, tactical planning is more loosely constrained by the strategic outcome. The qualitative distinction relates to the ontology of information that is used at different planning scales. In an integrated approach, data used at the strategic scale is derived, when possible, from the synthesis of fine-scale information from operational levels. In a coordinated approach, on the other hand, there may be no such constraint on the derivation of information. Given these distinctions between coordinated and integrated approaches to multiscale planning, the latter is preferable insofar as it assures a higher degree of consistency across scales of planning.

A few DSSs for forest management have an intrinsic capability of explicitly implementing a hierarchical approach to planning (e.g., Martell *et al.*, 1998), but there are only a few definitive examples of integrated, multiscale forest-resource planning that have been described (for example, Rose *et al.*, 1992; Reynolds and Peets, 2001). More importantly, we are not aware of any currently available ICT system that provides both full and explicit support for such an approach to planning. Rapid technological advancement in this area is highly likely in the next few years. Indeed, principles for implementation are well understood, and there are no obvious technological obstacles. The previous paragraph offers some hints as to the nature of an appropriate information theory needed to support the design of such an ICT system, but more research is needed to formulate a useful theory that could guide design of such a system *de novo* or suggest how existing ICT systems might be adapted. The formal articulation of such a theory also has important implications for how information is organized within information management (IM) systems that provide the raw material for planning.

9.3.3.3 Managing Across Ownerships

Lack of standards for data acquisition and representation across ownerships has been a barrier to the development of DSSs that can effectively address problems in forest management involving multiple ownership. A number of complicating factors pertaining to the design of appropriate systems for collections of individual landowners are readily apparent, including 1) diverse sets of values and objectives, 2) issues around property rights, 3) disclosure of private data and business plans, and 4) incentives for voluntary participation. We could probably enumerate many more such issues, and we have not even considered the more technical questions of how such a system might actually operate to support a collective planning process.

Integration across ownerships has been at least partially addressed by some systems. For example, in the framework of the Minnesota Generic Environmental Impact Statement of statewide forestry programs (Rose *et al.*, 1992) the DTRAN SDSS addressed both statewide and national forest management objectives. The Monsu MC-SDSS system (e.g., Pukkala, 1998) has been used to test and demonstrate alternative approaches (e.g., up-down, bottom-up, and integrated) to develop landscape-level forest plans for areas involving multiple ownership (e.g., Pykalainen *et al.*, 2001). The project of the Instituto Nacional de Investigação Agrária de Portugal (INIAP) (INIAP, 2002), which started in 2002, has been evolving a Web-based MC-SDSS for addressing the management objectives of both regional planning and individual holdings.

However, most current IM or ICT systems that provide explicit support for forest resource management in the context of multiple ownerships typically do so only in the most trivial sense that a natural resource agency may be tracking resource status across multiple ownerships and offering forestry consulting services to small landowners. The present lack of IM and ICT systems for integrated management across ownerships is not surprising. Most research and development has been funded by government agencies and large corporate landowners whose primary concern has usually been management of their own resources. A few systems, such as NED (Twery *et al.*, 2000) and DSD (Lexer *et al.*, 2005), have been developed specifically for small landowners, but these systems focus on the individual owner and provide only very limited or no support for active collective management.

The potential benefits to be derived from focusing research and development on this topic are compelling, considering that, in many countries, a sizable proportion of the forest land base is privately held and that, in a significant proportion, private holdings represent the majority of the forest land base. Unfortunately, rapid ICT advances in this area in the next 10 years or so do not seem likely. Apart from the conceptual problems, already noted, when dealing with multiple ownerships, significant progress in this area will also depend on the integration of other emerging technologies such as GDSSs and planning systems (Section 9.3.3.1) and perhaps support for multiple spatial scales (Section 9.3.3.2). Furthermore, availability of data on small woodlands tends to be very limited, even in most developed countries; thus, feasible solutions may also depend on advanced technologies such as remote sensing.

9.3.3.4 Managing for Sustainability

The concept of sustainability, in particular, sustainability of timber production, has a long tradition in forestry. Since the 1990s sustainable forest management (SFM) has become a highly relevant topic both in forest and environmental policy. In the wake of the United Nations Conference on Environment and Development in 1992 (United Nations, 1992), the concept of sustainability has become of significant public interest. In Europe, this trend culminated in the Second Ministerial Conference on the Protection of Forests in Europe (MCPFE) in Helsinki in 1993, when SFM was defined and adopted at a politically binding level (Resolutions H1 and H2). A very similar effort, specific to boreal and temperate forests, is represented by the Montreal Process (WGCICSMTBF, 1995). By the early 1990s the traditional perception of sustainability, primarily focusing on sustained yield, was radically expanded. It is now more broadly defined as "stewardship and use of forests and forest land in a way, and at a rate, that maintains their biodiversity, productivity, generation capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national and global levels" (MCPFE, 1998). Within SFM, the use of criteria and indicators is a widely accepted approach because these appear highly capable of measuring aspects of SFM at national, regional, and forest-management-unit level. In the subsequent process of the MCPFE, pan-European, national-level criteria and indicators were adopted as a policy instrument for evaluating and reporting progress toward sustainable forest management in individual European countries and in Europe as a whole. From the criteria and indicators of the MCPFE and the Montreal Process, it is evident that SFM is not just an ecological issue but a network of ecological, economic, and socioeconomic issues that increase problem complexity and force decision makers to balance multiple, and often conflicting, objectives in natural resource management.

Significant practical advances in SFM are highly likely in the next few years. Analytical systems for SFM are already available, at least in prototype form (Reynolds *et al.*, 2003b) and could be brought to full implementation fairly easily. Lack of suitable data to support such systems is a far more significant problem, but this has more to do with logistical issues than ICT.

Various organizations, most notably the Center for International Forestry Research (CIFOR), have been working on design of SFM assessments for more local scales (Colfer *et al.*, 1996; CIFOR, 1999). Development of integrated, multiscale implementations, linking national, regional, and operational scales, are highly feasible but will not happen without concerted effort (Section 9.3.3.2). Developments thus far have been progressing more or less independently of other scales, although there are obvious parallels across the scales for which SFM assessment is currently being implemented. Development efforts at the various scales are likely to continue along independent lines for the next few years simply because all these initiatives are still relatively new and basic approaches to practical implementation are still being worked out. As assessment programs mature, however, a second round of iterative adjustments, probably requiring several more years, will be needed to reconcile how information is represented at the different scales and to devise effective information structures for efficient communication between scales.

Different approaches used for the assessment of forest conditions or certification issues are described in the scientific literature (e.g., Brang *et al.*, 2002; Mendoza and Prabhu, 2000; Duinker, 2001; Wolfslehner *et al.*, 2004). Many see great promise in forest certification because it strikes a balance between economic needs and conservation objectives, offering a market-based rather than regulatory solution for improving forest practices. Voluntary environmental management systems such as ISO 14001/EMAS (Eco-Management and Audit Scheme) and forest certification (e.g., PEFC, FSC) are already a standard in the forest industry. In addition, forest organizations, industrial plants, and traders must have chain of custody certifications to prove the origin of products. These instruments pose new demands for management information systems in the organizations of the forest sector to provide verifiable evidence of compliance with the certification criteria. This will emphasize the link between quality and environmental management systems and foster the integrated use of information for purposes such as forest certification. GIS systems and forest management plans will have to meet defined requirements to comply with sustainability criteria (Lounasvuori *et al.*, 2002).

New technologies are needed to monitor and control supply chains to meet the requirements of chain of custody verification (e.g., log tracking in the tropics of high-value species based on bar coders). In general, to further support certification programs, forest owners need assistance with implementing sustainable forest management through Web-based systems, for example, for evaluating current management practices and recommending best management practices. Virtually all the underlying technologies needed to support these processes already exist in well-developed forms and require only relatively modest research investment to support adaptation to these new areas of application.

Illegal logging is causing enormous damage to forests, to forest peoples, and to the economies of producer countries. Some estimates suggest that the illegal timber trade may comprise over one-tenth of the total global timber trade, worth more than US$15 billion a year (World Bank, 2004). It seems likely that at least half of all logging activities in particularly vulnerable regions—the Amazon Basin, Central Africa, Southeast Asia, and the Russian Federation—is illegal. The European Commission's Action Plan on Forest Law Enforcement Governance and Trade (FLEGT) recognizes the potential role of trade instruments in preventing cross-border trade in timber products originating from illegal harvests.

Among possible solutions to illegal logging, the use of Voluntary Partnership Agreements (VPAs) has been promoted between the European Union (EU) and those producer countries that see value in a trade instrument as a tool to help control illegal logging in their territory. An important element of VPAs is the introduction of instruments (e.g., a licensing scheme) that would allow EU customs agencies to distinguish between legal and illegal imports from partner countries and allow entry only to legal imports. In addition to activities in building country capacity to establish and strengthen legal regimes, it will be necessary to develop integrated monitoring systems to monitor forest activity, changes in forest conditions, and compliance with laws, including remote-sensing and ground-based technologies (Boehm and Siegert, 2001; Bhandari and Hussin, 2003). Similar to the situation regarding support for certification systems, virtually all the underlying technologies needed to support VPAs already exist in well-developed forms and similarly require only relatively modest research investment to support adaptation to this new area of application.

9.3.3.5 Managing Knowledge

Information management in support of forest management and conservation and the technologies that support such applications of IM have been the central focus of this chapter. However, with the emphasis in Section 9.3 being future research priorities in ICT, it seems appropriate to go a step further and consider research possibilities in the relatively new field of knowledge management (KM).

As a discipline, KM is concerned with the efficient organization and sharing of knowledge, and especially with the efficient generation of new knowledge. IM and ICT are essential foundations of KM, but because the generation of knowledge is a uniquely human enterprise, KM systems can be seen as an evolutionary step beyond IM systems, in which the human actor is an essential component of the system.

KM systems have been rapidly adopted in the commercial world over the past several years. Some indications of the measure of their success can be gleaned from the profusion of KM companies and Web sites that have appeared on the Internet in the past five years and from the number of Fortune 500 companies on the client lists of companies offering KM products and services. Rapid diffusion of KM technology within the commercial sector can be understood in terms of the old adage, "knowledge is power." In a commercial context, this translates to "knowledge is competitive advantage."

Agencies and organizations within the forest sector, and especially those whose primary mission is the management of natural resources, have been relatively slow to adopt KM technologies, but this is quite understandable. Knowledge about commercial business practices tends to be organized within relatively narrow and well-defined domains. In contrast, knowledge about management practices relevant to forest ecosystems represents a vastly larger domain, and even if that knowledge can be efficiently parsed among the myriad disciplines that participate in a large organization, there is still the very formidable problem of organizing the components of a KM system to optimize the exchange and creation of knowledge within the larger domain of resource management. This would therefore seem to be an area of research closely related to ICT and ripe for attention.

In the process of decision making, decision makers combine different types of data (e.g., documents, figures, models) and knowledge (both tacit and explicit), available in various forms. The decision-making process itself results in improved understanding of the problem and the process and generates new knowledge. When solutions are evaluated and found effective, the acquired knowledge can be externalized, for example, in the form of best practices. Although decision making and processes for knowledge creation are interdependent, research has not adequately considered the integration of decision-support and knowledge-management systems (Bolloju *et al.*, 2002). Knowledge management practices might be categorized according to their contribution to problem solving and problem recognition in the decision-making process. The fact that many problems require both the generation of some new knowledge and the application of some preexisting knowledge leads to the classification of practices that support the identification and resolution of new or unique problems and those that deal with previously solved problems (*Figure 9.1*) (Gray, 2001).

The knowledge management framework allows the identification of practices and tools that support decision making and knowledge management with practices and tools that:

(1) Encourage decision makers to discover new problems and opportunities by exposing themselves to new information, situations, issues, and ideas. It might happen to make valuable unexpected discoveries (e.g., discussion forums, virtual communities, workshops, and conferences).

(2) Allow decision makers to actively create new knowledge if they are aware of a new problem and they are developing novel solutions (e.g., developing and applying expert systems, models, etc.).

(3) Capture and retain knowledge, making it available to decision makers who are seeking solutions to previously solved problems (e.g., using expert systems, search engines, hypertext systems).

(4) Could help decision makers recognize upcoming problems for which solutions have been developed previously.

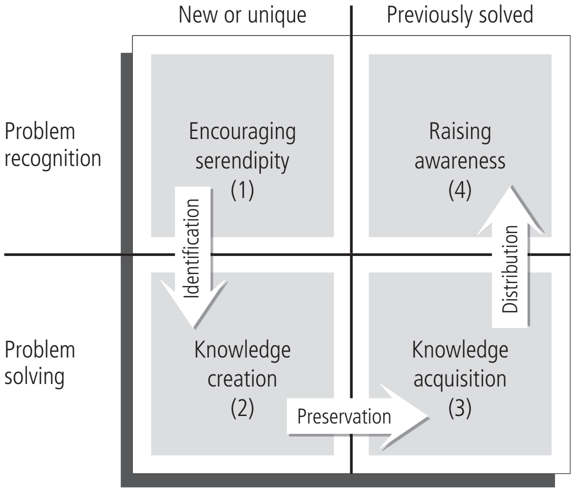

Figure 9.1. Framework for knowledge management practices (Gray, 2001).

Knowledge gains economic value when it is used to solve problems, explore opportunities, and make decisions that improve performance. As the problem-solving process is the vehicle for connecting knowledge and performance, future developments of DSSs will have to address practices for enhancing and promoting knowledge management in organizations (Girad and Hubert, 1999). Historically, the focus of research in the field of DSS has been on model specification and model solution. In the future, the analysis of solutions will be the more important aspect of modeling, along with providing the decision maker with an understanding of the analysis results. This expanded purpose of DSS as knowledge enhancement also suggests that the effectiveness of each DSS will, in the future, be measured based on how well it promotes and enhances knowledge, how well it improves the mental model(s) and understanding of the decision makers, and thus how well it improves decision making (Nemati *et al.*, 2002).

9.3.4 Effectiveness and efficiency of forest management

Likely advances in ICT, discussed in the previous section, bring with them significant potential for improving on the effectiveness and efficiency of contemporary forest management.

Improved support for public participation in forest management decision processes could yield substantial dividends. In this context, effectiveness and efficiency may be very closely linked. As decisions systems become more effective at representing the complexity of management issues and clearly explaining the bases for reasoning about options and solutions, both public understanding of, and confidence in, decision processes are likely to increase. Systems that also effectively engage the public in terms of access to, and input into, processes about which they may have strong concerns, can promote a higher sense of satisfaction with participation in the processes. A significant body of social science research suggests that public satisfaction with decision processes is a much more significant factor than agreement with outcomes (Kakoyannis *et al.*, 2001). To the extent that future forest management can succeed in ameliorating some of the current sources of conflict surrounding forest management issues, dividends are likely to come in terms of issues being settled around the table, as it were, as opposed to by litigation, which is both time-consuming and costly.

Databases are an essential part of the infrastructure of contemporary forest management. However, optimization of their organizational structure to support integrated, multiscale evaluation has not received adequate attention. Research attention in this area could quickly achieve significant efficiencies by minimizing or even eliminating redundant data collection over multiple spatial scales. Effectiveness of decision-making processes in the multiscale context is also likely to be enhanced because synthesizing information from finer scales, when possible, increases the likelihood of this synthesized information, helping direct decisions at coarser scales in ways that assure consistency with decision processes operating at finer scales. It would be a mistake, however, to construe the primary research effort as an exercise in database design. Instead, the initial phase of research needs to be concerned with questions such as: what are the problems that need to be evaluated at each scale, what are the data requirements for the problems at each scale, and how do problems at different scales relate to one another? In other words, at least the initial phase of research in this area is more of an exercise in knowledge engineering.

Evaluating the cumulative impacts of perhaps numerous independent management actions on a forest landscape is not difficult after the fact; at any particular point in time, there is, in principle, a historical record available for interpretation. Projecting cumulative impacts for the purposes of directing forest management in the same context, however, is far more problematic. Decision systems capable of handling diverse ownerships could greatly increase the effectiveness of management activities with respect to adequately accounting for their cumulative effects. Some efficiencies are also possible in terms of targeting intensive research and development on a well-defined but diverse client base. On the other hand, it is not at clear what, if any, efficiencies might accrue to forest management (Lundquist, 2003).

Managing forests to assure SFM on a global scale is perhaps one of the most pressing issues for forest management in the next few decades. Major international initiatives have established broad agreement on the criteria and indicators of SFM that require monitoring (WGCICSMTBF, 1995; MCPFE, 1998), but interpretation of such complex information as a basis for guiding national and international policies remains one of the most important outstanding issues requiring attention before successful implementation of SFM can be fully realized (Raison *et al.*, 2001). Furthermore, initial assessments (e.g., Anonymous, 2004) clearly demonstrate that most data needed for indicator measurement are currently not available, suggesting the need for dramatically expanded monitoring programs in most participating countries. Initial attempts at developing formal frameworks for interpretation of the criteria and indicators of SFM (for example, Reynolds, 2001; Reynolds *et al.*, 2003b) are encouraging, insofar as they suggest the feasibility of implementing effective programs for SFM in the next 20 years. Satisfying the increased monitoring requirements for effective implementation of SFM will impose a heavy burden on virtually all countries. Fortunately, formal frameworks such as those suggested by Reynolds (2001) can also help assure that data gaps are filled as efficiently as possible.

Knowledge is increasingly recognized by organizations as a critical corporate asset that, when properly managed, enhances organizational competitiveness by delivering better solutions faster to management problems. The paradigm emphasizes both conservation and creation of knowledge and is designed to specifically promote efficiency and effectiveness. Compelling success stories from private industry over the past 10 years suggest that application in the forest sector could be very successful.

Given the discussion in this section up to this point, what, if anything, can be concluded about the impact of all these expected impacts of ICT on the future price of wood? There is no way of answering this question with quantitative rigor, but we will attempt a qualitative answer. First, however, other effects on future wood prices due to forest management are covered in chapters 5 to 7 (forest inventory and monitoring and remote sensing, and forest operations such as logging, hauling, wood processing, and distribution). Thus, we need to emphasize that our conclusions are limited to the incremental contributions of expected ICT impacts on decision processes in forest management in particular. As discussed above, most such impacts of ICT are expected to produce efficiencies in management, creating opportunities for cost savings that could be passed along to consumers in the form of lower prices. Perhaps the most significant factor among those discussed is the potential for cost savings as a result of reduced litigation. On the other hand, increased effectiveness often comes at a price. That is, new, more-effective solutions may be less efficient than those they replace. However, in the specific context of ICT impacts on decision processes in forest management, we have generally argued that increasing effectiveness also promotes efficiencies, although in some cases actual increases in efficiency may be questionable. Relative to all other influences from ICT impacts on forest management, those impacts on decision processes probably account for a modest to moderate influence in terms of helping keep wood prices down.

9.3.5 Management for conservation

In Section 9.2.3.2 we discussed a few specific ways in which ICT has contributed to enhanced capabilities for managing forest land from a conservation perspective. More generally, however, it seems likely that conservation considerations will increasingly be seen as integral components of mainstream forest management. For example, indicators to assess the chemical and physical properties of water bodies and soils feature prominently in the major international initiatives on SFM. Whereas conservation measures have historically tended to be implemented at local or, at most, at regional scales, the incorporation of conservation-related indicators in national-scale SFM programs effectively elevates management for conservation to the national and international levels.

The impacts of ICT have a potentially important role to play in enhancing conservation, given the above scenario. First, there are currently major data gaps for many of the indicators related to conservation. Continued advances in forest monitoring and remote sensing will be necessary to make the collection of such data practical. Second, advances in the implementation of conservation programs also are dependent on the technological advances already discussed. For example, the SFM initiatives open up the possibility of strategic, national-scale planning for conservation, but the efficiency and effectiveness of such planning depend heavily on suitable information infrastructures, as discussed in Section 9.3.3.1. If such infrastructures are lacking, it will be difficult, if not nearly impossible, to effectively translate strategic direction downward for coordinated implementation at regional and local scales.

9.3.6 Global variation in impacts of ICT

As discussed in Section 9.2.3.3, a substantial technology gap currently exists between developed countries and developing or underdeveloped ones with respect to the impacts of ICT on forest management. The situation with respect to major “hard” technologies such as those supporting forest operations, wood processing, and distribution is not likely to change appreciably in the next 10 to 20 years because of financial constraints in developing and underdeveloped countries that lack outside investment. However, the situation with respect to soft technologies, such as decision systems for forest management, could be quite different. Historically, most development of such systems has occurred in the developed countries, again primarily because development costs for such systems can be high. On the other hand, many of these systems have been developed by government agencies and are thus in the public domain and freely available. At the same time, availability of computing infrastructure needed to use such systems is now not nearly the barrier to technology adoption in developing countries that it once was. Computing power and computer storage have increased dramatically over the past 20 years, while equipment costs have steadily declined. Consequently, we expect to see a steadily increasing diffusion of advanced software system technologies for forest management from the developed to the developing and undeveloped countries over the next 10 to 20 years. The technology gap in this particular area is therefore likely to be much smaller 20 years from now.

9.4 Policy Considerations

Based on the main points from the previous section, we conclude with some considerations that we hope will inform decisions about policy formulation in relation to opportunities for continued systems development to support forest management:

- Decision support systems and expert systems, as well as the more traditional analytical tools for simulation and optimization, continue to provide the core competencies underlying support for decision making in forest management. Each of these technologies is likely to continue to evolve, spurred by continuing advances in the enabling technologies, but the greatest potential for these technologies to contribute to improved effectiveness and efficiency of forest management will probably come from research focusing on systems integration.
- Technologies for group decision support, and in particular those for remote collaboration, have advanced rapidly in the past 10 years, and are likely to continue to do so. Possibilities for realizing significant efficiencies in, and improved effectiveness of, complex planning programs are therefore substantial, but contemporary forest management has not fully capitalized on this potential. In large measure, failure to fully capitalize on these technologies can be attributed to a lack of familiarity with them within the forest management community. Research reporting, demonstrating the efficiency and effectiveness of such technologies, would aid the diffusion process.
- Systems development aimed at improving the effectiveness of public participation in planning processes for forest management (for example, Web-based services such as e-planning) could be instrumental in reducing, at least to some extent, the contentiousness in society that now surrounds forest management issues. However, developments in this area are quite recent, so there is little practical experience with the benefits or pitfalls associated with these kinds of technologies. The social sciences could therefore play an important role, documenting the extent to which current solutions are effective and how they might be improved.
- Forest ecologists have long emphasized the need to understand and manage forest ecosystems at multiple spatial scales. Unfortunately, there has been far more arm-waving about the subject than practical demonstrations of how multiscale management can be effectively implemented. A limited number of examples do exist, however, and these may provide a useful starting point for designing a formal theory with practical implications for implementation.
- Progress in the immediate future toward effective, integrated support for multiple ownerships is perhaps the most uncertain of the issues we have been considering. In large part, as discussed earlier, this uncertainty is a consequence of the perceived need for the confluence of perhaps multiple technologies. We think it would be a mistake, however, to relegate this area of research to a low priority. More critical, in-depth analyses of the topic could well lead to unanticipated breakthroughs in developments along these lines.
- Major international initiatives have been very successful at reaching agreement on the information that member countries need to collect in order to assess forest ecosystem sustainability at national and regional scales. In contrast, there has been far less progress on questions concerning the meaning of that information and how it could be applied to arriving at interpretations of sustainability. Lack of progress in this area is understandable. After all, interpretation is at least as much a matter of policy as it is of science. Research could help to formalize the respective roles of science and policy in interpretations of forest ecosystem sustainability, and this would be especially helpful if international agreements are ultimately intended as instruments for international policy.

- Availability of enabling technologies to support the implementation of verification in certification programs is not a limitation. It will primarily be an issue of following through with investments for implementation. On the other hand, much like the situation with international initiatives for assessing forest ecosystem sustainability, approaches to certification could likewise benefit from the application of formal specifications that would help ensure consistent application of standards.
- Increasingly, both public and private organizations have come to recognize knowledge as a valuable corporate asset. Consequently, the concept of managing knowledge to ensure its conservation and optimize its creation within an organization has received considerable attention in business management sciences in the past several years as a way of improving the effectiveness and efficiency of an organization. Experience with application of knowledge management in the context of natural-resource organizations is still very limited; thus, as we have already suggested, relative to studies on effectiveness of public participation processes, research into its application to forest management may be fruitful.
- Management for conservation is increasingly seen as an integral component of contemporary forest management. Inclusion of conservation indicators in SFM initiatives tends to strongly accentuate this trend. On the other hand, we have argued that conservation is simply forest management with particular emphases on certain values. Therefore, future advances in conservation management are very likely to be closely associated with ICT advances in forest management more generally.
- Finally, we have argued that the prospects for closing the technology gap between developed countries and those that are developing or even undeveloped are good with respect to forest management systems. In particular, it is likely that only modest subsidies from the developed countries would be required to assist with creating the required infrastructures. However, some further commitment from developed countries in the form of training programs would almost certainly be needed as well.

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