Conceptual Framework for Forestry Canada Mixedwood Management Decision Support Systems Development under the Green Plan:

Workshop Report

Prepared for

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Abstract

The federal Green Plan calls for the development of tools which will assist forest land managers to accomplish the objectives of sustainable forest management. Such tools are much needed to address the new resource management issues of increased recognition to consider non-timber values, greater public participation in decision making processes, the need to analyze the implications of resource management decisions over larger spatial and temporal scales, and the challenges arising from the potential shifts in global climatic conditions. Careful planning will be required, at a national scale, to implement a program for the development of decision support systems (DSSs) which avoids duplication of effort, and which builds upon the extensive expertise and knowledge of Forestry Canada scientists across the country. A three day workshop (August 13-15, 1991) was hosted in Edmonton by Forestry Canada, Northwest Region, to initiate the design of a conceptual model for the development of mixedwood management DSSs. This workshop report outlines a strategy which partitions research tasks into topic areas, based on decision types and other criteria. Identification of discrete DSS components is a prerequisite to developing DSSs at multiple centres, but it also requires that linkages between components and the scope of each component are well defined. The report emphasizes the need to carefully define the problems to which DSSs will be applied. There is also a need to clearly identify problem solving strategies, as the basis of work on the individual components of DSSs that employ these problem solving strategies. The report concludes with a set of 15 recommendations.

Acknowledgements

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1.0 Introduction

Over the past years, the public's awareness of environmental issues has grown significantly. We have recognized that our well-being depends heavily on our ability to sustain the environment of which we are a part. Resource managers are faced with increasing challenges of having to analyze and predict the effects of their actions on ecosystem components and over time horizons which, in the past, were considered outside their mandate or responsibility. Furthermore, society demands from forest ecosystems more than just the timber values which in the past were the focus of most management decisions. The need to sustain many ecosystem values is now recognized, but the knowledge and the technology to distinguish sustainable from non-sustainable activities is often lacking.

The Federal Government's Green Plan initiative provides an opportunity and the resources to undertake major developments of tools and scientific research to enhance our ability to manage forest ecosystems in an integrated, sustainable way. It is one stated objective of the Green Plan to demonstrate the principles of sustainable development in forest land management and to develop methods and tools to accomplish this goal.

Recent advances in computer technology make it feasible to construct computer-based decision support systems (DSSs). DSSs assist decision makers in arriving at solutions to problems in a more efficient and comprehensive way. Considerable research effort will be required to realize the potential of such systems, but because they may provide a key component towards solutions to many resource management problems, these research efforts are well justified. Research on DSSs is in progress in many parts of the world, including Canada, where Forestry Canada has played an active role in the development of such systems. In the future, DSS tools will form an integral part of resource management, and there is considerable potential for the export of the technology to other countries around the world.

The federal Green Plan provides new opportunities and challenges for the development of DSSs. In response, Forestry Canada is launching a national initiative to develop such systems. This workshop report summarizes the results of discussions on one component of this initiative: DSSs for boreal mixedwood management. The workshop, hosted by NoFC in Edmonton, brought together scientists and managers from Forestry Canada establishments across the country. They shared an interest in and a commitment to developing tools which can improve the forest land management process in Canada.

This workshop was the first time this particular group of scientists got together to launch the DSS program for boreal mixedwood management. The workshop preceded a meeting of the Forestry Canada Steering Committee for the DSS initiative (see Section 2.0), scheduled for October 1991, and the results and recommendations reflect some uncertainties about the direction of the national program. Notwithstanding, this report outlines a preliminary conceptual framework and summarizes the key concerns and issues raised by workshop participants. As such, it is an important first step towards a nationally coordinated DSS development initiative.

Although the focus of the report is on DSSs for boreal mixedwood forest management, much of what is said also applies to other aspects of the national DSS initiative.

Because of the need to await the results of the Steering Committee meeting, this workshop was not intended to allocate resources, review existing proposals, or develop a five year plan. Instead, the objective was to initiate a planning process which would outline the activities and issues associated with the development of a mixedwood management DSS for the boreal forest within the context of the federal Green Plan DSS initiative.

The workshop followed one week after a workshop hosted by Forestry Canada Northwest Region, whose objective was to plan the activities at Northern Forestry Centre for the development of Aspen and Mixedwood Decision Support Systems (Morrison and Kurz 1991). The earlier workshop focused on a conceptual framework for the development of mixedwood management DSSs for Alberta, Saskatchewan, and Manitoba.

1.1 A Vision of Integrated Forest Land Management

Four central demands are placed on today's forest land manager:

1. The public, the forest industry, and various interest groups must all be consulted in the development of forest land management plans;

2. management must be directed at ecosystems, not just at individual components of those ecosystems;

3. the effects of ecosystem-level management activities must be analyzed as to their forest- and landscape-level implications for all timber and non-timber values; and

4. the temporal dynamics at the ecosystem, forest, and landscape levels must be analyzed and considered.

What roles can decision support systems play in assisting forest land managers in the future? Computer-based DSSs are able to process large quantities of data, to assist in integration of information across both space and time, to bring together expertise from a variety of disciplines, and to provide communication aids by generating time-series of maps, tables, and three dimensional visualizations of alternative scenarios of forest dynamics at the stand and landscape levels. These and other features of DSS can assist forest managers in analyzing the trade-offs and consequences of choosing one set of decisions over another.

Decision support systems alone will not be able to solve the forest land management challenges of the future, but they can become important and essential elements in the decision making processes. Their potential contribution to the public participation and planning process lies in the ability of these systems to describe alternative futures resulting from the implementation of forest management plans which are aimed at meeting different objectives. This process will likely be iterative (Figure 1.1). Management objectives are set through consultation with the various interest groups. Using DSSs, forest- and ecosystem-level management plans are designed to meet these objectives, and the resulting scenarios of future development of valued components at the ecosystem and landscape levels are presented to the interest groups involved in the planning process. These scenarios must include analyses of both 'costs' and 'benefits' of various management plans. Forest managers, industry, and other interest groups can then revise and refine the original management objectives based on their assessment and evaluation of the alternative future scenarios.

There are many other levels of decision making processes to which DSS can contribute significantly. Silvicultural decision making at the stand level, for example, often requires a detailed knowledge of the ecology of the site and the species present, as well as a good understanding of the likely outcome of management actions. This outcome must then be compared against the (often multiple) objectives, at both the stand and the forest levels. While operational foresters often have a good understanding of the effects of management decisions at the stand level, they often find it challenging to address the implications of a decision for non-timber values. Furthermore, understanding the cumulative implications of many stand-level decisions at the forest level is generally difficult. DSSs can play important roles in the integration across disciplines, space, and time.

Forestry Canada is attempting to attain an international leadership role in the development of DSS for sustainable forest management. What will make the DSS initiative an international showpiece? First and foremost, the decision support systems must be able to address the right issues. It is therefore mandatory that efforts be made right from the onset of these projects, to identify the key land management issues which will need to be resolved in the future. Secondly, it is important that the DSSs are accepted by forest land managers, the scientific community, and the public. The ultimate success of DSS development lies in the acceptance and use of the tools in the decision making processes. It is therefore important to involve potential future users of the systems throughout the design, development, and testing process. The probability of acceptance of DSSs will be greatly enhanced, if the systems can demonstrate to both land managers and the public that they can improve decision making processes.

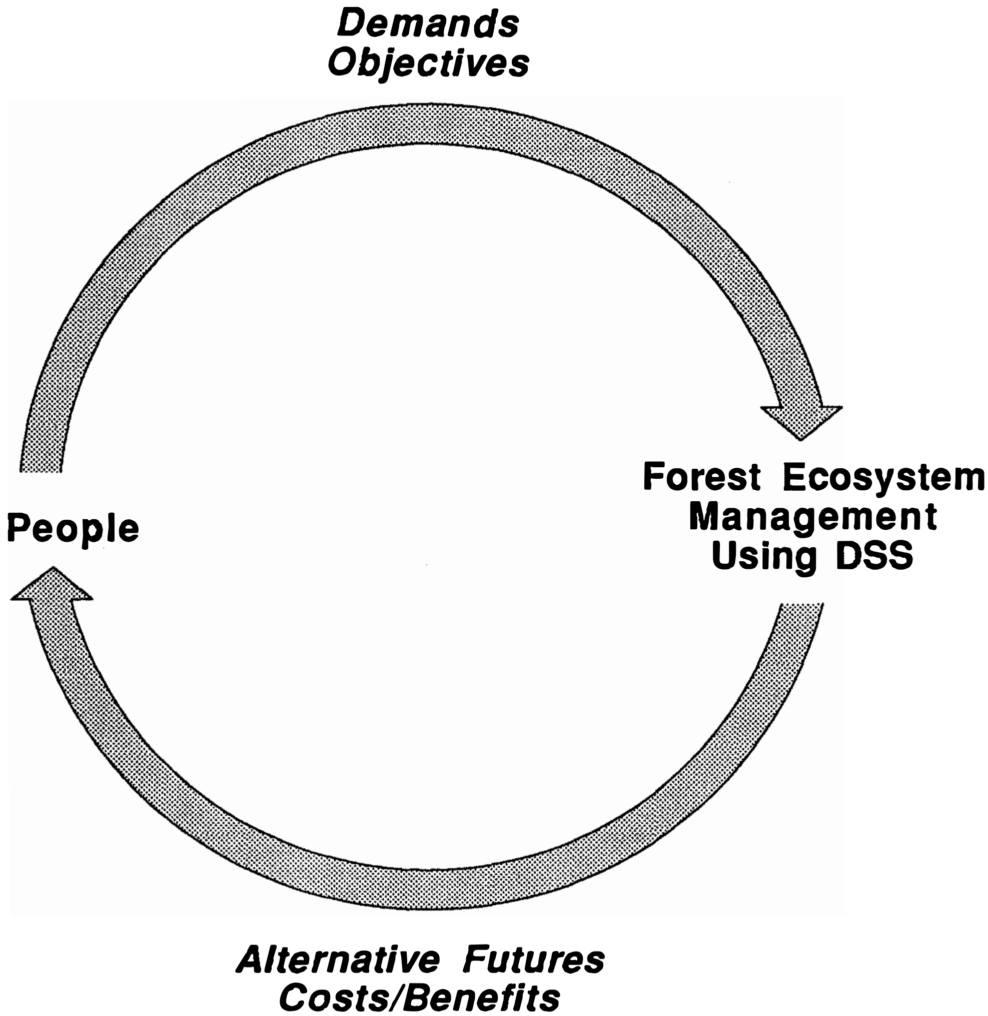

Figure 1.1: Conceptual model of the role of DSSs in the interaction between various interest groups (people) and forest land managers. DSSs are tools which can provide scenarios of alternative futures of various indicators which express the extent to which demands and management objectives are accomplished.

2.0 Green Plan DSS Initiative

At the beginning of the workshop, both Mr. Dennis Dubé and Dr. Dave Brand provided the participants with information about the federal Green Plan in general and the DSS initiative specifically. The Green Plan DSS initiative will contribute a total of $7 million for the development of DSS tools and the acquisition of the required computer hardware and software. The budget is increasing over the first few years: this first year's budget of $500,000 has been allocated to a small number of Forestry Canada DSS projects.

The institutional structure currently proposed for the DSS initiative includes a small steering committee comprised of 9 members from the private sector, universities, and Forestry Canada establishments. This committee will be chaired by Dr. Dave Brand. A somewhat larger technical committee will be struck to coordinate the many technical aspects which arise from the development of DSSs at multiple locations. This technical committee will review annual progress of the various components of the initiative and report to the steering committee.

The responsibility of the steering committee will be to review and modify or approve the proposed framework for the DSS initiative. The technical committee plans the details of the framework and the tasks required to accomplish the objectives of the Green Plan DSS initiative. The detailed plan is reviewed by the steering committee and resources are allocated to accomplish the plan. An annual review process will be implemented: the technical committee reviews the progress towards the objectives set by the steering committee. The steering committee receives annual review comments from the technical committee, reviews the objectives of the initiative, and reallocates resources based on past accomplishments and progress towards goals and objectives.

In this structure, clients would be represented at both committees, thus providing continuous input from future potential users of the products which are to be developed under the DSS initiative.

2.1 Links to Model Forests

The model forest initiative under the federal Green Plan will demonstrate the principles of sustainable development in forest management and provide examples of state-of-the-art approaches to forest management which will be of interest to forest managers around the world. Public participation in the decision making process will be one important component of model forest management. Model forests will generate a high demand for new tools in forest management. It is one objective of the Green Plan DSS initiative to meet this demand for new approaches and tools.

The model forests will provide several major opportunities for the DSS initiative: resources will be available for the acquisition of site, vegetation, soil, and other data which form the basis of land management decisions. These data can be provided in the form of GIS systems, forest inventories, and ecological classification systems.

Managers of model forests will require innovative management tools to accomplish the objectives of sustainable development. The anticipated high profile of the model forests and the associated activities will generate public and professional interest in the DSS tools which were developed for those forests.

The managers of model forests will be required to define management objectives which are consistent with the principles of sustainable management, in a process which will presumably involve some form of public participation. It is important that the indicators by which to judge whether the objectives have been accomplished be defined at the same time. These indicators will play an important role in the design of the problem solving strategies which form the foundation of DSS development. Once developed, one contribution of DSSs will be to provide managers of model forests with scenarios of alternative management strategies which can facilitate the communication with groups involved in the planning process.

The activities of the model forest and DSS initiatives should be coordinated to facilitate the information exchange between the two initiatives. Model forests should be selected to provide the widest possible range of ecological conditions and decision making challenges encountered in Canada. The DSS program should soon establish a list of data requirements from model forests, specifying the required accuracy of the data and their intended use in DSS models. Managers of model forests should be invited to participate in the definition of DSS needs and specifications, and should provide feedback and comments about the prototype DSS models developed in the initiative.

2.2 Links to Forest Practices

The Green Plan forest practices initiative will also have several links to the DSS initiative. During the development of DSSs, information gaps and research needs will be identified. For example, it is already clear that there are few data on the effects of alternative silvicultural and harvesting methods on forest stand dynamics and regeneration in boreal forest ecosystems. Other research questions will likely focus on the dynamics of stand break-up and the effects of clearcut sizes on forest regeneration. These research questions need to be communicated to the forest practices initiative.

Demonstration plots, field research, and monitoring programs can be established under the forest practices initiative to address these and other research questions which will need to be answered to obtain the knowledge base required for DSSs. Field measurements in experimental forests can provide additional data and test sites for the development of DSSs.

Management opportunities and constraints can be identified by DSS developers and tested under the forest practices program.

There are further links to other Green Plan initiatives which have not been discussed during the workshop. In general, all ongoing and proposed activities will benefit from communication of the intended actions and the information needs. Through careful coordination of those activities, duplication of efforts and omission of important issues can be minimized.

3.0 Forest Management Decision Support Systems Issues

On the first afternoon of the workshop the participants were asked to describe issues relating to the use of DSSs in forest management. From the issues (Table 3.1) three classes of information can be summarized:

1. forest management decisions,
2. objectives and indicators by which to measure the objectives; and
3. information sources required to help make decisions.

3.1 Forest Management Decisions

From the list of issues, a number of forest management decisions that could be the basis for a DSS emerged:

- harvest scheduling
- silviculture treatment
- stand management
- pest management
- road siting
- regeneration
- twenty year forest planning

3.2 Objectives and Indicators

From the issues, a number of forest management objectives emerged, as did indicators to measure those objectives:

- sustainability of wood supply
- economic benefits
- sustainable development
- tourism
- viewscapes
- biodiversity
- timber production
- recreation
- wildlife

3.3 Information Sources

Considerable information is required to support forest management decisions. This information may be basic data from stand inventories or may result from sophisticated analyses using computer models. From the issues, several key information sources were identified:

- growth and yield models
- stand succession models
- habitat supply models
- site characteristics
- ecosystem classification

Table 3.1: Forest management DSS issues identified by workshop participants. The issues were sorted into five topic areas.

1. **Matching silvicultural activities with site, vegetation, and multiple management objectives**

- silvicultural treatments should incorporate multiple objectives (need to be able to identify trade-offs at the stand level)
- more ecological understanding is required on how site and harvesting (method, season, stand age) affect seedling establishment, survival, and advanced regeneration
- need to define most appropriate harvest and regeneration prescription given ecotypes and management objectives
- DSS should consider the consequences and evaluation of different treatment options in terms of growth and yield
- DSS should address pre-harvest silviculture decisions
- DSS to decide on appropriate sites for stand conversion and shelterwood systems
- DSS should include harvesting sensitivity to road infrastructure and location and costs of road building

2. **Stand and forest-level interactions**

- integration of regional activities to province-level summaries (annual reporting, planning, and review process for provinces)
- a forest planning DSS should incorporate objectives, a range of alternatives, operational plans and implementation sequences
- a forest planning DSS should be used iteratively to compare different alternatives
- DSS should be able to integrate interest of stakeholders other than the forest managers (e.g wildlife, recreation, water quality)
- DSS should be able to search forest inventory for existing stands which meet criteria suitable for application of specific treatments (juvenile spacing, thinning, final & intermediate harvesting) - a separate module is required for regeneration issues
- need to develop tools to ensure that 20 year management plans are compatible with sustainable development objectives.
- need to be able to assess effects of particular management activities on biodiversity

Table 3.1: Continued.

- need to assess trade-offs between timber and other values (e.g. recreation, wildlife)
- need to balance timber supply objectives with other forest uses
- need to consider sedimentation impacts on streams
- need to consider impacts on recreation and tourism
- DSS should assist in the management of viewscapes
- DSS should be able to help with siting of roads and skidder operations
- goal should be to adequately address non-timber values
- DSS to identify and document how specific land management objectives can be implemented

3. Ecosystem dynamics

- DSS should be able to consider the effects of the intensity of management on the sustainability of the forest (e.g. long-term site productivity)
- for long-term predictions, potential climate change needs to be considered

4. Effects of pests on forest ecosystems

- pest management concerns need to be incorporated into DSS, particularly stand by stand decisions taken by district managers with respect to spraying and cutting
- pest manager should provide input into harvest scheduling
- DSS should incorporate risk identification
- DSS should incorporate salvage cutting decisions

5. General Considerations

- need to consider economic realities of the need to have a stable utilization of mills, impact of world price on demand for wood, and unexpected changes in wood supply -specific to mixedwoods systems because of existing mill technology- need flexible response system which can rapidly accommodate changes in supply or demand
- DSS should be available for daily decision making
- DSS should be flexible enough to accommodate users with different backgrounds and objectives
- DSS should use spatial information and data

4.0 Framework for Describing Decision Support Systems: Some Definitions

There was some confusion during the workshop regarding the terminology used to describe DSSs, the components of DSSs, and the approach to the Forestry Canada DSS program. Much of the ongoing and proposed research at Forestry Canada is directly relevant to the DSS program, but there will be a need to distinguish between activities which provide information required by DSSs and activities which develop the actual DSSs. It might be appropriate to establish a basic framework which can form the foundation for future discussions on DSS related activities.

In this section, we provide some simple definitions to help describe the various aspects of DSSs. It is useful to first distinguish between expert systems and DSSs.

Decision Support Systems and Expert Systems

A **decision support system** is an interactive, computer-based system designed to aid decision makers in utilizing data, narrative information, analytical tools, and mathematical models to address complex problems. Until recently, decision support systems were most commonly applied to assess the consequences of a number of different alternatives. With the advent of expert systems, decision support systems are now capable of recommending preferred alternatives. The incorporation of **expert systems** into decision support systems has allowed decision making models based on qualitative or heuristic reasoning to be combined with quantitative or algorithmic models.

Expert systems are currently being used to make greater use of the results of analyses performed by decision support systems.

Parts of Decision Support Systems

We are not concerned with the technical side (computer system side) of DSSs at this point. This discussion would apply equally well to a decision support system based solely on handbooks, maps, filing cabinets full of data, and a competent secretary. Thus the computer related issues of user-interfaces, systems integration, blackboard architectures, hardware platforms, and the like, are not considered at this point.

Decision support systems are composed of:

1. problem solving strategies;

2. models;

3. databases;

4. knowledge bases;

5. data acquisition systems; and

6. reporting systems.

Problem

A problem can be defined as a question or situation which presents uncertainty and which requires a solution. In the context of DSSs, the decision to solve a problem requires a specific set of information or recommendations. Examples of problems include finding a silvicultural prescription for specific stand conditions, developing harvesting schedules to meet certain objectives, or preparing a long-term forest land management plan.

A Problem Solving Strategy

A problem solving strategy is a set of steps required to solve a particular problem. The problem solving strategy can be represented as a flowchart that indicates what data are to be used, what calculations have to be done, and what computer models are to be used. An example of a problem solving strategy will be provided in section 5 of this report.

Models

Models include both dynamic simulation and assessment models, as well as simple mathematical functions (e.g. to calculate wildlife habitat suitability indices).

Databases

Databases include both relational databases and geographic information systems databases.

Knowledge Bases

Knowledge bases are collections of rules based on the judgement of human experts drawn from a number of fields. These rules are normally represented as IF -THEN logical statements. Knowledge bases are a major component of expert systems.

Data Acquisition Systems

Many decision support systems require automated data acquisition and processing. This is particularly true where data are acquired by remote sensing.

Reporting Systems

Reporting systems provide the desired result (i.e. information to support the decision) as well as the results of any intermediate analysis. Reports may be provided in text, graphical, tabular, video, or map based formats.

5.0 An Example of a Decision Support System

Most forest land management decisions must be seen in the context of decisions at other hierarchical levels. Forest harvest scheduling, for example, requires that decisions have been made earlier about land management objectives. The forest-level harvest schedule will in turn provide the basis for subsequent decision at the ecosite level (Figure 5.1). This decision making process also operates at different spatial scales: planning and scheduling occur at the forest level, while most of the implementation decisions operate at the ecosite level. The appropriateness of decisions can often only be assessed after the ecosite-level consequences have been integrated to forest-level implications, which in turn are compared against the original management objectives. Thus, DSSs should also be able to assist decision makers operating at more than one level of this iterative process. Different entry points may be required, depending on the type of problem to which the DSS will be applied. For this discussion, we use the 20-year planning objectives as example entry point to a DSS.

During the workshop a number of participants put forth ideas of how DSS could be used in a long-term forest planning context. These ideas are collected together in the context of the framework presented in Section 4.0. This example (Table 5.1) is not complete and a more rigorous specification will be required before it could guide the design and development of DSSs.

5.1 Problem Solving Strategy

The forest planning problem can be stated as the development of a 20-year plan. The problem solving strategy would involve the following steps:

1. develop a set of objectives;
2. develop a set of indicators to measures the objectives;
3. determine a management schedule;
4. for each stand, determine the silvicultural prescription;
5. for each stand, simulate stand dynamics based on site and vegetation influences, silvicultural prescription, fire hazard, and pest hazard;
6. for each stand, infer wildlife habitat based on ecological conditions and other factors;
7. for each stand, infer recreational potential based on ecological conditions and other factors;

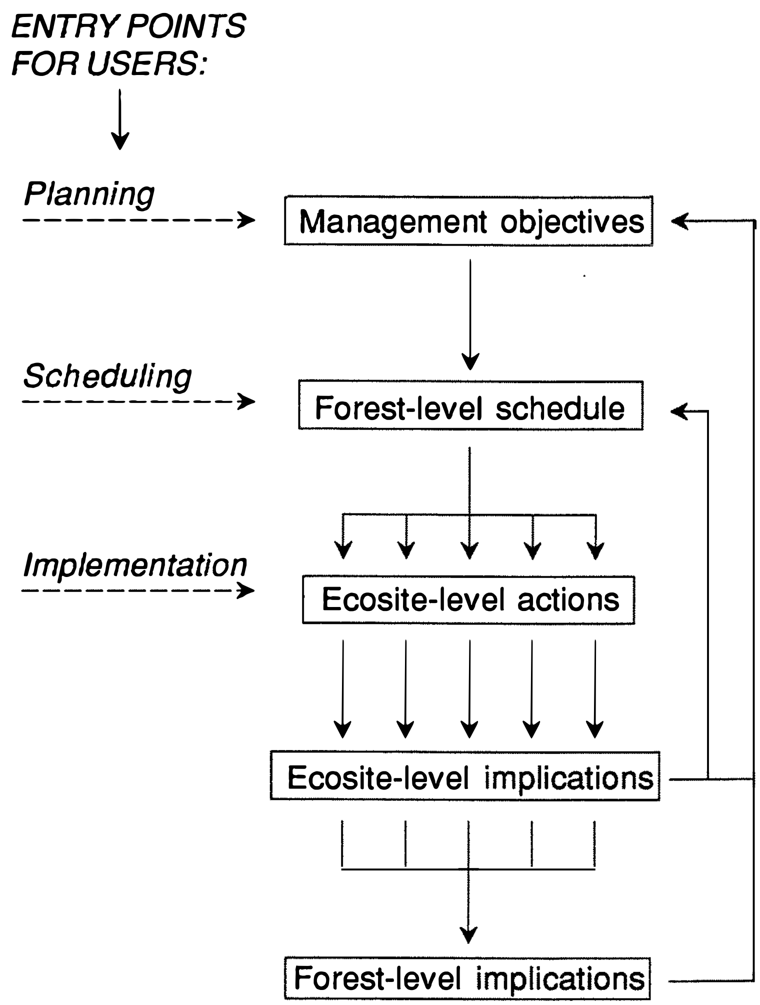

Figure 5.1: Schematic diagram of the entry points for users of forest land management decision support systems. Multiple entry points reflect the different levels at which decisions are required. Note the dependency of scheduling and implementation decisions on prior planning decisions.

Table 5.1: An example of a problem solving strategy employed by a DSS for the developement of long-term forest land management plans.

Problem Solving Strategy	Reports	Models/DSS	Data Bases
Goal: To develop a 20 year plan. 1. Define objectives	Objectives		
2. Define indicators	Indicators including measures of sustainability (site productivity, health)		
3. Determining management schedules	Set of alternative harvest schedules	Wood supply model	• Forest Inventory • Growth and Yield Tables • Roads and access to mill • Site characteristics
4. For each stand in the harvest schedule -- determine silvicultural prescription	For each harvest schedule: silvicultural prescriptions, management costs	Silvicultural DSS	• Site characteristics • Present stand conditions
5. Simulate stand dynamics based on prescription, fire and pest hazard	Timber yield Stand level indicators	Ecosystem model that simulates understory and overstory dynamics	
6. Infer wildlife habitat	Wildlife habitat	Terrestrial and aquatic habitat supply model	• Habitat needs by wildlife type • Site characteristics
7. Infer recreation potential	Recreation potential	Recreation and tourism supply model	• Recreational needs • Recreational facilities
8. Infer water supply	Water supply (quantity, quality)	Water supply model	• Site characteristics • Climate
9. Integrate stand level indicators	Wildlife habitat inventory Recreational potential Water supply	Integration algorithms	• rules for aggregation

8. for each stand, infer water quantity and quality based on ecological conditions and other factors;

9. integrate across all stands to develop forest-level indicators; and

10. using the indicators compare results against objectives.

Table 5.1 also identifies for each step listed above: a set of models to be used for analysis; a set of databases to provide input to the analyses; and a set of indicators to be reported.

5.1.1 Development Objectives

A logical first step is to define the objectives to be met by the forest land management plan. This is usually done in a multi-stakeholder process and normally leads to multiple objectives (e.g. sustainability of wood supply, maintenance of wildlife habitat and biodiversity, maximization of economic benefits, increased timber production, sustainable development, maintenance of recreation and tourism potential).

5.1.2 Defining Indicators

Along with the objectives, it is necessary to define a set of indicators to serve as measures of performance with respect to targets defined by the objectives. For example economic benefits are usually measured in terms of value added (change in GDP) or employment generation (jobs); recreation might be measured in potential for recreational use (use days); and biodiversity might be measured in terms of species diversity indices.

5.1.3 Determine a Management Schedule

Most decision support systems make projections in terms of these indicators based on scenarios that prescribe specific sets of management actions. Comparisons between sets of indicators facilitate the evaluation of different scenarios.

At this stage, the management schedule would likely define:

1. the extent and timing of harvesting activities;

2. areas to be protected from harvesting; and

3. areas to be managed for special uses.

Models to be Used

- wood supply model

Databases to be Accessed

- forest inventory
- site characteristics
- growth and yield tables
- road infrastructure and distances to mill

5.1.4 Silvicultural Prescription

For each stand, a silvicultural prescription would be developed. These prescriptions could be very simple or might require a sophisticated DSS designed specifically for the purpose of preparing the prescription.

Models to be Used

- silvicultural DSS

Databases to be Accessed

- site characteristics
- present stand conditions

5.1.5 Simulate Stand Dynamics

The key to DSSs is the ability to project future stand conditions from the present stand conditions based on the silvicultural prescriptions, fire hazard, and pest hazard. This requires a forest ecosystem model that simulates both understorey and overstorey dynamics.

Models to be Used

- a dynamic ecosystem simulation model

Databases to be Accessed

- site characteristics
- present stand conditions

5.1.6 Wildlife Habitat

Both the terrestrial and aquatic wildlife habitat would be estimated based on vegetation and site conditions. Simple or more complex models for each wildlife species would be used to calculate the habitat potential.

Models to be Used

- mathematical habitat supply models

Databases to be Accessed

- habitat would be based on the projections of stand conditions provided by the ecosystem model (step 5.1.5).

- habitat needs by species
- site characteristics

5.1.7 Recreational Potential

The potential for recreation would be estimated in a manner analogous to wildlife, i.e. through the use of recreational supply models. Models would be required for different types of recreational activities.

Models to be Used

- mathematical recreational supply models

Databases to be Accessed

- recreational potential would be based on the projections of stand conditions provided by the ecosystem model (step 5.1.5).

- recreational requirements by recreational type

5.1.8 Water Quality and Quantity

Water quantity would be estimated from estimates of precipitation, and stand and site conditions. Water quality would be estimated based on the site erosion potential as well as any stand treatments involving chemical inputs (fertilization, herbicides, etc.).

Models to be Used

- mathematical water supply models

Databases to be Accessed

- water supply and water quality would be based on the projections of stand and site conditions provided by the ecosystem model (step 5.1.5).
- climate data

5.1.9 Forest Level Indicators

Once steps 5.1.4 through 5.1.8 are completed for each stand, it will be necessary to integrate across all stands to develop a set of forest-level indicators. In some cases, it is simply a matter of summing across all stands (e.g. the estimate of the total timber volume); although in many cases it is not so simple (e.g. determining ungulate habitat).

5.1.10 Evaluate Indicators in Terms of Objectives

Once both the stand-level and forest-levels indicators have been determined, these need to be evaluated in terms of the objectives, set in 5.1.1. If the results are unsatisfactory, then one needs to return to step 5.1.3 and try another more refined management schedule.

5.2 Decision Making Context

During the workshop it became clear that the 20-year planning DSS would be used in a multi-stakeholder decision making context. The range of interests to be included in the process would vary from jurisdiction to jurisdiction but in general it was assumed the a broad range of stakeholders would participate. The DSSs must be able to accomodate the differences in the decision making context between provinces.

5.3 Designing, Developing, and Implementing a DSS

In early stages of development of a DSS, it is essential to specify the components of a DSS as outlined in Section 4. Emphasis must be placed on definition of the problem solving strategy. Without it the DSS collapses into a loose collection of models and databases with no direct applicability to decision making.

In large DSS projects, it is useful to distinguish between the overall development of the complete system and the development of a specific aspects of the system. The development of a model to simulate ecosystem dynamics, step 5 in our example, will contribute to the 20-year planning DSS but, by itself, is not a complete DSS.

In general, specific models and databases are not DSSs, but are simply models and databases that might be used as components of DSSs. This may seem like a fine point, but it is important one to make, in view of the goals of the Green Plan DSS program.

Thus in developing the program it is desirable to:

1. identify the DSS's to be developed;

2. specify the problem solving strategies, models, databases, knowledge bases, and reports required for each DSS to be developed; and

3. classify proposed and ongoing research projects as to whether they are directed to developing the complete DSS or whether they will contribute to the development of components.

6.0 The National Program on DSS for Boreal Mixedwood Management

The exact scope and delineation of a national program on the development of DSS for boreal mixedwood management was discussed during the workshop. Questions arose regarding the bounds of that program relative to other Green Plan DSS initiatives. Furthermore, the potential overlap in activities and the resulting duplication of effort was recognized. It was not the mandate of this workshop, however, to resolve these issues, which will be addressed at the upcoming meetings of the steering committee of the Green Plan DSS initiative.

The workshop participants did provide a conceptual framework which could assist the discussions of the steering committee. The conceptual framework was based on the following premises:

1. It is in the interest of the Green Plan DSS initiative to avoid duplication of effort to the extent possible.

2. DSS systems can be designed in modular form, such that modules can be developed concurrently at multiple centres.

3. Individual, discrete tasks for DSSs can be identified and accomplished at separate locations.

4. Different DSS modules will, at times, require access to similar information and databases, i.e. ecosystem dynamics or inventory information may be required by more than one module.

5. The expertise relevant to DSSs is distributed among Forestry Canada centres, with experts in different disciplines affiliated with different centres.

6. While the efficiency of a national program will increase through the development of modules at centres with greatest expertise, additional effort will be required for planning and coordination of activities.

7. Although many areas of decision making could benefit from DSSs, the initial focus should be on a few high priority topics for which DSSs can be developed within 1 to 3 years, and which may be of interest over a wide geographic region.

8. Generalized DSSs can be developed but may require adaptation and modifications to make them applicable to specialized issues of regional interest, to specific forest conditions, and to different jurisdictions.

6.1 Five topic areas for DSS research

One of the big challenges during the workshop was to break the topic of DSSs into smaller, discrete topic areas. The difficulties arise from the complex interactions and linkages between the topic areas, and that every attempt to identify components must be accompanied by the identification of linkages between those components.

For the conceptual model, five topic areas can be identified:

1. Ecosystem dynamics
2. Matching silvicultural activities with site, vegetation, and multiple management objectives
3. Stand and forest-level interactions
4. Effects of pests on forest ecosystems
5. Effects of fire on forest ecosystems

For each task, we describe the major issues, the linkage between tasks, and the existing expertise within Forestry Canada. (The latter point was developed from incomplete knowledge based on short presentations made by workshop participants and may require further input to adequately reflect Forestry Canada expertise.) In addition to these five topic areas, technical issues of computer hardware, software, and integration of computer programs need to be addressed.

6.1.1 Ecosystem dynamics

The ability to predict the dynamics of forest ecosystems is central to most DSS which are designed to assist in the sustainable management of the forest land base. There are specific management questions, such as short-term harvest schedules, for which the dynamics of ecosystems can be neglected, but decision support for most other issues requires a good understanding of ecosystems dynamics. The level of spatial resolution and the time horizon for which information on ecosystem dynamics is required will also vary between DSS issues.

Our focus is on the dynamics of forest ecosystems including the dynamics of understorey vegetation and non-commercial tree species. The predicted dynamics of the ecosystem, resulting from natural and anthropogenic influences (Figure 6.1), and the description of future ecosystem states will provide a major source of information for other DSS modules. For example, a wood supply analysis DSS requires information on future wood volume and its distribution across space and time. Wildlife habitat, recreational potential, and other non-timber values can generally be inferred from site and vegetation information provided by a module which simulates ecosystem dynamics.

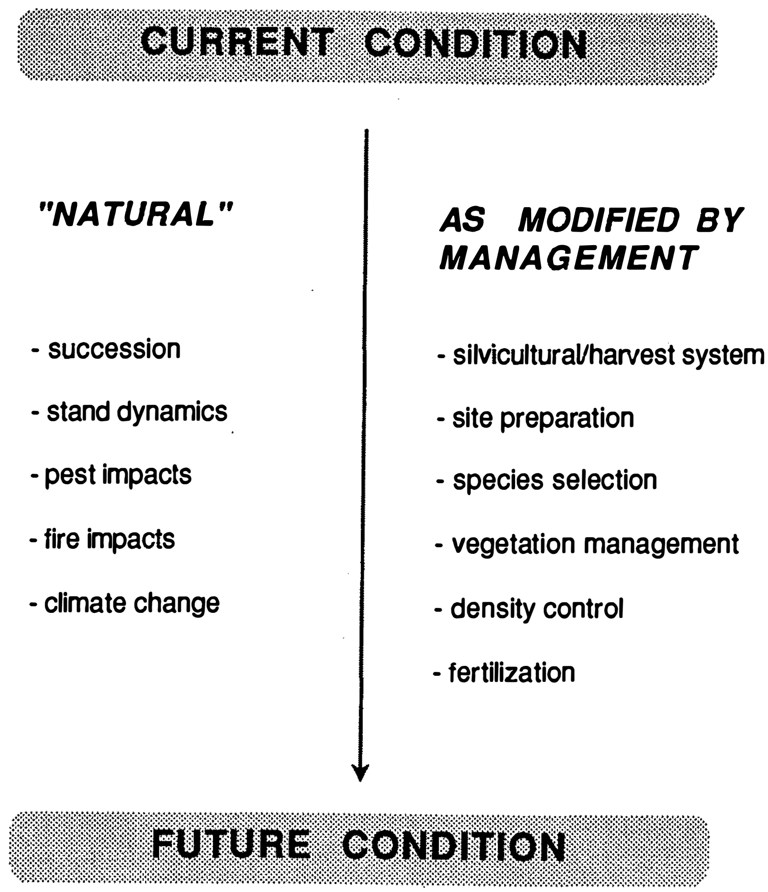

Figure 6.1: Major tasks of the ecosystems dynamics module: projecting current forest ecosystem conditions to future conditions as affected by natural influences and forest management. Models which accomplish this will be essential for many forest management DSSs.

Forest ecosystem dynamics are strongly affected by site characteristics. A good ecosystem classification system which identifies the major site influences on vegetation dynamics will play a significant role in the development of this DSS module. Forest ecologists and growth and yield specialists will have to collaborate to properly capture site effects on forest ecosystem dynamics.

Forest ecosystem dynamics could be addressed for three different stages of stand development: the regeneration phase following disturbance, the growth phase, and the stand break-up phase. Traditionally, the expertise for these different stages of stand development is represented by different scientists. Regeneration issues are typically addressed by silviculturists who investigate the effects of site preparation and harvesting methods on seedling and sapling growth. Early succession, including the dynamics of understorey vegetation and brush following harvesting and fire is often investigated by forest ecologists. The dynamics of forest growth are extensively studied in the various growth and yield programs in Canada. The stand break-up phase of forest dynamics has typically received less attention and may require increased emphasis to satisfy the information needs of DSSs and decision makers.

To properly address the issues of sustainable forest management, one component of the DSSs must be focusing on long-term forest dynamics and the associated successional changes in species composition. These are typically addressed through so-called gap-dynamics models which are developed to predict long-term forest dynamics.

The implications of a changing climate may also have to be considered when assessing long-term forest dynamics. Changes in species composition, disturbance regimes, and forest distributions will all have to be considered for many, long-term forest management decisions. The challenges to forest management which arise from global climate change have been recognized by Forestry Canada and other agencies and this recognition is reflected in the federal Green Plan.

When predicting the dynamics of individual forest ecosystems, assumptions have to be made about the risk of pest and fire occurrence in this ecosystem. Furthermore, the impacts of pest and fire on subsequent ecosystem dynamics must be assessed. DSSs could operate at various levels of sophistication. At the simplest level, fire and pest risks are assigned a constant probability (perhaps zero), which is independent of ecosystem characteristics, environmental conditions, and the state of surrounding ecosystems. At a more sophisticated level, the module predicting ecosystem dynamics could interact with the modules for fire and pest dynamics (described below) to obtain dynamic probabilities of fire and pest risk and the associated impacts.

The following is a partial list of Forestry Canada expertise which can contribute to ecosystem dynamics modules for boreal mixedwood forests DSSs:

- site classification: Ian Corns (NoFC), Bill Meades (NeFC), Richard Sims (GLFC)
- regeneration phase: Stan Navratil (NoFC), Bijan Payendeh (GLFC), Ian Corns (NoFC)
- growth dynamics: Imre Bella (NoFC), Bill Meades (NeFC)
- stand break-up: ????
- successional dynamics: Ian Corns (NoFC), Bill Meades (NeFC), Richard Sims (GLFC)
- climate change impacts: Mike Apps (NoFC), Jim Harrington (PNFI)
- others?
-

6.1.2 Matching silvicultural activities with site, vegetation, and multiple management objectives

A second group of tasks for which DSS modules will be required is the allocation of silvicultural activities to ecosites, given the characteristics of site and vegetation, and given multiple management objectives. This includes prescriptions for forest renewal, both through natural and artificial regeneration, and prescriptions for stand tending and development, given various management objectives and site characteristics. These issues are ideally suited for the development of DSSs, because significant expertise has been accumulated over the past decades. Much of the required expertise is held by scientists at NoFC and other Forestry Canada Centres. In addition, operational field foresters can contribute to the knowledge engineering process required for the development of DSS.

New challenges will be associated with the use of alternative, non-traditional silvicultural approaches for which expertise may at present be very limited. Equally challenging will be the information need on the effects of alternative harvesting practices. This new information may be available now from other jurisdictions (USA, Scandinavia), and in the future from newly established experiments under the model forest and forestry practices initiatives of the federal Green Plan.

Ecosystem classification and interpretation of ecosystem characteristics which will influence the choice of silvicultural decisions will play an important role in this DSS module. This module will interact extensively with the module on ecosystem dynamics to predict the effect of silvicultural activities on vegetation dynamics.

At a different level, this module could interact with forest-level planning and scheduling modules in their search of appropriate stands for application of silvicultural activities or harvests. The module can assist in identifying the stand and site characteristics desired to accomplish certain management goals.

The following is a partial list of Forestry Canada expertise which can contribute to silvicultural decision modules for boreal mixedwood forests DSSs:

- site classification and interpretation: Ian Corns (NoFC), Bill Meades (NeFC), Richard Sims (GLFC)
- silvicultural decisions: Stan Navratil (NoFC), J. Scarratt and R. Sutton (GLFC)
- thinning & fertilization effects: Imre Bella (NoFC)
- others?
-

6.1.3 Stand and forest-level interactions

The first two modules, described above, operate primarily at the stand-level. There is a need, however, to analyze the effects of stand-level dynamics at the forest or landscape-level.

For example, the contribution of a single stand to wildlife habitat can only be properly assessed if the spatial context of that stand is known. The value and significance of particular habitat can change as a function of the surrounding habitat. Furthermore, the change of wildlife habitat over time also needs to be considered.

There are two sets of interactions which need to be addressed by modules in this category. Forest-level management schedules need to be developed from stand-level information, resulting in the allocation and distribution of management activities at the stand level. Conversely, the results of stand-level activities need to be integrated in both space and time to assess the implications for timber and non-timber values.

Modules in this category will interact heavily with DSS modules in the other 4 categories. Stand-level dynamics need to be understood on a stand by stand basis in order to be able to provide integration in either space or time. The types of stand-level information required by the integration modules will depend on the issues addressed. Different information will be called for to assess impacts, for example, on regional water supply or wildlife habitat.

The fundamental premise of this approach is that algorithms and rules can be developed which allow the user of the DSSs to generate new insights by analyzing the spatial and temporal distribution of ecosystem characteristics.

Modules of this type are already developed or under development. Examples are the wood supply and habitat supply models which are developed at PNFI and other Forestry Canada centres.

The following is a partial list of Forestry Canada expertise which can contribute to integration modules for boreal mixedwood forests DSSs:

- wood supply: Tom Moore (PNFI), Dave McLean (MFC)
- wildlife habitat: Bill Meades (NeFC), Tom Moore (PNFI), new wildlife biologist (NoFC)
- water supply:
- recreational values:
- viewscape analyses:
- others?
-

6.1.4 Effects of pests on forest ecosystems

Forest pest are playing an important role in the dynamics of boreal forest ecosystems. Historically, pest and fire have been the two major agents of change in Canadian forests. For decades, Canadian agencies have been monitoring the extent and dynamics of forest pests. DSSs are required to assist in the management and control of forest pests in a cost-effective and environmentally acceptable way. Predictive models already exist which link the dynamics of forest pests to the spatial distribution of different forest conditions in specific regions. Research is required, however, to make these models applicable to large geographic areas.

There are many links to the other four topic areas described here. DSSs for integrated pest management require good information about current and future forest ecosystem conditions, because the susceptibility of a stand to insect attack is a function of both, the condition of the stand itself and of the surrounding forest. Silvicultural activities can alter the stand conditions, thus changing the probability of pest impacts. Conversely, high potential pest problems identified by the pest module can influence the decisions reached by the silvicultural DSS. The loss of wood volume to forest pests needs to be considered when integrating stand-level information to forest-level management plans. Finally, forest pests can significantly affect the distribution and conditions of forest fuels, thus altering fire risk and fire behaviour.

Because of the close link between the issues of integrated pest management and all other aspects of forest land management, there may be a tendency to develop forest pest management tools which incorporate many other aspects of forest management, such as harvest scheduling. While by itself, this may be appropriate and desirable, in the context of a national program for DSS development, duplication of effort and interaction between program components will have to be carefully planned and coordinated.

The following is a partial list of Forestry Canada expertise which can contribute to pest dynamics and management modules for boreal mixedwood forests DSSs:

- pest dynamics: Jan Volney (NoFC), Alan van Sickle (PFC), Malcolm Shrimpton (PFC), Dave McLean (MR)
- FIDS surveys
- others?
-

6.1.5 Effects of fire on forest ecosystems

Fires, like pests, significantly affect forest ecosystems in Canada. Canadian agencies have a long record of monitoring and managing forest fires. Advanced DSSs for fire management have been developed by Forestry Canada scientists and such systems continue to be developed with support from the federal Green Plan.

Major issues to be addressed by fire management DSS include the ability to continuously predict fire risks and to alert managers in charge of fire management tools to changes in fire risks. Fire management DSSs should also be able to provide information to other DSS modules about future fire rates and intensities, based on scenarios of climate change and vegetation response. Fire will likely be the biggest agent of change in the response of boreal forest ecosystems to global warming.

The linkages between fire management DSS and the other four topic areas, identified above, are very similar to those of the pest management DSS. Fire probabilities are affected by current and future ecosystem conditions. Fire in turn, changes ecosystem conditions and post-disturbance ecosystem dynamics. Silvicultural decisions can be affected by existing fire risks, and in turn can increase or reduce fire hazards. The effects of fire must be integrated over both space and time to understand the effects on forest-level issues such as wildlife habitat and wood-supply. Forest insects can change the forest fuel conditions, thus affecting future fire risks.

The following is a partial list of Forestry Canada expertise which can contribute to forest fire management DSS for boreal mixedwood forests DSSs:

- Brian Lee (NoFC)
- Peter Kourtz (PNFI), Charly van Wagner (PNFI), Mike Flannigan (PNFI)
- Brian Stocks (GLFC)
- Bruce Lawson (PFC), Steve Taylor (PFC)
- others?

6.1.6 Computers and software: technical and integration issues

As the program for the development of boreal mixedwood management DSS advances, an increasing number of technical issues related to computer hardware, software, and integration of computer tools will have to be addressed. It is appropriate to delay some of the technical decisions until the problem analysis and the analyses of the future application of computer tools have been completed. Any decision about hardware and software should be based on a sound analysis of the advantages and disadvantages of each of potentially suitable existing tools. The analysis should result in a close match between the needs of the Forestry Canada DSS initiative and the characteristics of the computer tools. The analysis requires considerable familiarity with the current 'state-of-the-art' in the rapidly evolving field of forest management DSS.

At the workshop, a demonstration version of the INFORMS DSS was presented. This framework for forest management DSS was developed at Texas A&M University and holds some promise as an integrating framework which could be adapted for the Forestry Canada DSS initiative. Two Forestry Canada scientists (Dr. Richard Yang, NoFC, and Dr. Mike Power, PNFI) are spending 6 months at Texas A&M University to collaborate with the group of computer scientists who developed INFORMS. A future report of the Forestry Canada scientists will be an important contribution to the review of existing computer tools. Mr. Harinder Hans, a computer scientists recently hired by NoFC, is also exploring existing DSS programs as to their suitability for the Forestry Canada DSS initiative. Mr. Hans will be collaborating with the NoFC Knowledge Engineer (to be hired) in the review and development of DSS systems.

- Richard Yang (NoFC), Harinder Hans (NoFC), Knowledge Engineer (NoFC - position vacant), Mike Power (PNFI)
- others?

7.0 Recommendations

These recommendations are based in part on statements by workshop participants. Other recommendations are made by the authors of this report, based on the discussions at the workshop and our own experience with forest management issues and in the development of DSSs.

Program Framework:

1. Forestry Canada's Green Plan DSS initiative is in need of a strong definition of the DSS activities and priorities for the first six years. This report and the framework described herein can form one starting point for the discussions. (Action: Steering Committee).

2. A strong and consistent framework for the development of forest management DSSs needs to be adopted by the steering and technical committees. (Action: Steering and Technical Committees).

3. Planning and problem definition must maintain a high priority if the objectives of no duplication of effort and national compatibility of activities are to be met. This requires that adequate resources are allocated to these two tasks. (Action: Steering Committee).

4. The success of this initiative will depend to a large extent on the effectiveness of the planning and coordination activities. There is a need to assign responsibilities of planning and coordination to someone who will also be provided with a strong 'mission statement'. (Action: Steering Committee).

5. The focus should be on a small number of adequately funded DSS projects with a high probability of success, e.g. stand dynamics modelling, silvicultural prescription DSS, forest-level wood supply, forest pest management systems, and fire management systems, to ensure that deliverables will be available within the 6-year timeframe of the program. (Action: Steering Committee).

6. The Technical Committee of the DSS initiative should explore how AI technology can best be applied in the problem solving strategies identified above. Research effort should be directed towards the methodology of combining different information technologies, AI, and computer models to useful DSSs. High-technology tools by themselves are not DSSs. (Action: Technical Committee).

Program Liaison:

7. Clients and potential future users of the DSS should be involved throughout all stages of DSS development: their current and future needs and their future willingness to use the DSS products for forest management will ultimately determine the success of the initiative. (Action: Steering Committee).

8. Although client input is crucial, Forestry Canada must ensure that the initiative maintains the broad and long-term objectives of developing tools for sustainable forest management. The Green Plan DSS initiative must resist potential pressures to solve industries' short-term management needs at the expense of meeting the broader, more long-term objectives of the initiative. (Action: Steering Committee).

9. The steering committee should communicate to the model forest initiative that the Green Plan DSS initiative will develop decision support tools for sustainable development and that opportunities for model forest managers arise from the DSS initiative. (Action: Steering Committee).

10. The steering committee should communicate to the model forest initiative that the choice of model forests should be such that different decision making and management approaches are represented by the various forests. For example, west-coast old-growth issues, native concerns for forest management, and other diverse issues can provide the full range of challenges of integrated management faced by today's forest managers. The development of DSSs can be directed to meet these challenges. (Action: Steering Committee).

11. Data needs for the development of DSS systems should be specified a.s.a.p. and those data needs should be communicated to the model forest initiative. Model forests will provide a major opportunity for data collection and model calibration. (Action: Technical Committee).

Program Coordination:

12. A comprehensive list of forest land management DSS activities, both existing and proposed, should be compiled immediately to assist in planning and identification of Canadian expertise. This list should identify expertise within Forestry Canada, Provincial Agencies, Universities, and the private sector. (Action: Technical Committee).

13. Breaking the topic of DSSs into a number of DSS topic areas will be required to manage a national DSS development program. Emphasis must be placed on the identification of linkages between components, and the scope of each component will have to be carefully defined to avoid excessive overlap between concurrent development activities. (Action: Technical Committee).

14. Decisions about software and hardware tools and techniques should be delayed as long as possible, until the problems and the problem solving strategies have been properly defined. (Action: Technical Committee).

15. A workshop of the technical committee and research collaborators should be held after agreement has been reached on the priority DSSs, the problem solving strategies, and the collaborators of the project(s). At that workshop, the scope of individual DSS components and the linkages between the components need to be clearly defined. (Action: Technical Committee).

8.0 References

Morrison, P.D.S. and W.A. Kurz. 1991. Forestry Canada aspen and mixedwood decision support system: workshop report. Prepared by ESSA Ltd., Vancouver, B.C. for Forestry Canada, Northwest Region, Edmonton, Alberta, 61 pp.

Appendix 1:

Forestry Canada Northwest Region Decision Support System Workshop Participants

List of Participants

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