From: LAND AND ITS USES
Edited by F.T. Last, M.C.B. Hotz, and B.G. Bell
(Plenum Publishing Corporation, 1986)

27

ECOLOGICAL LAND SURVEY AS BASIS FOR LAND RESOURCE PLANNING AND MANAGEMENT IN CANADA

J. Thie, E. B. Wiken and C.D.A. Rubec

Lands Directorate
Department of the Environment
Ottawa, Canada

ABSTRACT

Relationships of landscape ecology and land use planning and management are discussed. The significance of an ecological data base for national, regional and local planning is considered from a Canadian perspective, relating ecological land classification hierarchy to the various levels of management, and describing developments in survey methodology, remote sensing and computer information systems.

INTRODUCTION

In a global sense, Canada has some unique characteristics. It is one of the largest countries in the world, yet has a small but technically developed population. Its economy is largely based on the commercial use of its renewable and mineral resources. The cold northern climate combined with adverse physiography severely limit the capacity of the land to produce agricultural and forestry products. Only 7 % of Canada's 10 million sq. km of land is suitable for agriculture, and only 25 % of the country is covered by commercially useful forest.

Sound management and sustainable use of the natural resource base is therefore basic to Canada's economic and social well-being. Managing widely distributed resources with relatively few people, and consequently somewhat limited finances, requires a good understanding of all aspects of the resource management process, the decision making involved, and the information technology available. The resource management process can be generalized in several sequential phases: (i) opportunities (problems) are identified; (ii) resource inventories are carried out to support the process; (iii) policies and plans for the use of the resources are developed; then (iv) the plans are implemented; and finally, (v) operations and their environmental effects are monitored, and controlled. This process of management requires use of social, economic and environmental information for decisions at the various levels and often by numerous agencies. The effective use of our land resources thus depends to a great extent on delivering the right information, in the right format and at the right time to the right decision makers. If one of these criteria is not met valuable information may have little or no impact on the decisions. By understanding the overall information needs and information technology, such situations can be avoided.

INFORMATION NEEDS

In Canada, as in most other countries, specific levels of management and planning can be recognized. Nations develop and implement their economic, social and environmental policies, plans and strategies for the country as a whole. But, as well, these are linked both to more synoptic continental or global levels, and they reflect more specific regional, provincial and local perspectives. The information needs are consequently hierarchical. A national data base is required for national planning; provinces require more specific information, while local management needs a very detailed information base. This information hierarchy is schematically displayed in Table 1, which generalizes the relationship between type of information required at the various levels of decision making.

A similar information-need hierarchy, starting with general information for strategic and conceptual decision making, does not only apply to the planning and management of a country as a whole, but also to the planning of individual projects. In order to relate differing ecological levels to the information gathering processes the Canada Committee on Ecological Land Classification (CCELC) proposed levels of ecological generalization (Table 2). The relationship of these to the planning process and environmental impact assessment is shown in Table 3.

Although this hierarchy of information is essentially a simple concept, many nations, in particular large or developing countries, have difficulties finding the financial resources to obtain adequate and appropriate information. Usually it is information at the higher levels that is inadequate, which results in a lack of policy direction and leads to poorly developed strategies for the use of land. Indeed, misuse and mismanagement can often be attributed to this information void. Consequently the absence of consistent national and regional data bases lead to government interventions

Table 1: The type of information needed at different levels of decision making in Canada, its purpose, detail and cost

	NATIONAL	PROVINCIAL	REGIONAL	LOCAL
USE/PURPOSE	Scenarios; Strategic and Long term plans; Development of national policies and programmes	Strategic and long term planning of Provincial policies; development and implementation of national programmes	Planning of Regional Programme and services; Implementation of provincial plans and programmes	Local planning and services; Implementation of Regional Plans.
AREA INVOLVED	10×10^6 km^2	1×10^6 km^2	1×10^5 km^2	1×10^3 km^2
DETAIL	International, national and provincial statistics; low spatial resolution: 1:10 million	National, provincial and regional statistics, low resolution: 1:1 million - 1:500k	Provincial, regional local statistics; medium spatial resolution: 1:500k - 1:100k	Regional, Local and site statistics; high spatial resolution: 1:50k - 1:10k
CHARACTERISTICS	Comprehensive multi-disciplinary data base required which allows high amount of integration	Varying forms in between national and local		Often problem orientated and site specific; needs less comprehensive data base, often single disciplinary; less need for integration.
COST OF INFORMATION	Low per unit area, high for total country	relative low per km^2, high for total province	medium cost per km^2, medium for total area	high cost per unit area, relatively low total cost

of a primarily reactive problem solving nature. Paradoxically, the sum of local and project oriented decisions then becomes in fact the surrogate for national policies and plans. This same problem can occur at the project level; in their comprehensive analysis of the effectiveness of environmental impact assessments in Canada, Beanlands and Duinker (1983) found that poor assessments could usually be linked to a lack of ecological characterization and valuation of the areas affected, as well as failure to use such information in the conceptual planning of development projects.

INFORMATION DELIVERY SYSTEM

To make information an effective tool in the decision making process, the right information has to be delivered at the right time and in the right format. Although this sounds simple, practice shows persistent problems in this area. Decision maker and information 'scientist' do not often speak the same language; only when special efforts are made to improve communications is the gap between them

Table 2: The definition of the generalized ecological levels proposed by the Canada Committee on Ecological Land Classification (CCELC), and the criteria for their recognition.

Definitions for the levels of generalization.

ECOPROVINCE - an area of the earth's surface characterized major structural or surface forms, faunal realms, vegetation, hydrological soil and climatic zones.

ECOREGION - a part of an ecoprovince characterized by distinctive ecological responses to climate as expressed by vegetation, soils, water, fauna, etc.

ECODISTRICT - a part of an ecoregion characterized by a distinctive pattern of relief, geology, geomorphology, vegetation, soils, water, and fauna.

ECOSECTION - a part of an ecodistrict throughout which there is a recurring pattern of terrain, soils, vegetation, waterbodies, and fauna.

ECOSITE - a part of an ecosection having a relatively uniform parent material, soil and hydrology, and a chronosequence of vegetation.

ECOELEMENT - a part of an ecosite displaying uniform soil, topographical, vegetative and hydrological characteristics

LEVEL OF GENERALIZATION Common map scale*	COMMON BENCHMARKS FOR RECOGNITION					
	Geomorphology	Soils***	Vegetation#	Climate	Water##	Fauna
ECOREGION 1:3,000,000 to 1:1,000,000	Regional landforms or assemblages of regional landforms	Great groups or associations thereof	Plant regions or assemblages of plant regions	Meso or small scale macro	Water regime	High species diversity; may correspond either to a widely distributed species (eg deer mouse), or to the habitat of individuals within a species.
ECODISTRICT 1:500,000 to 1:125,000	Regional landform or assemblages thereof	Subgroups or associations thereof	Plant districts or assemblages of plant districts	Meso or large scale micro	Drainage pattern; water quality	
ECOSECTION 1:250,000 to 1:50,000	Assemblages of local landforms or a local landform	Family or associations thereof	Plant Associations or a plant association	Large scale micro to small scale micro	River reaches, lakes and shoreland	Less diverse species complement habitat requirements of typical species more restricted (eg beaver, otters); may coincide with specialized areas of animal total habitat (eg wintering area, calving grounds).
ECOSITE** 1:50,000 to 1:10,000	A local landform or portion thereof	Soil series or an association of series	Plant association or seral stage	Small scale micro	Subdivision of above	
ECOELEMENT 1:10,000 to 1:2,500	Portion of or a local landform	Phases of soil series or a soil series	Parts of a plant assoc. or sub-association	Small scale micro	Sections of small streams	Low species diversity habitat of smaller mammals, reptiles and amphibians etc., specialized areas of some fauna's habitat requirements (eg denning areas, local wintering deer yards).

* Map scales should not be taken too restrictively, as they will vary with the environment setting and objectives of the survey

** This level is frequently subdivided into phases according to the stage of plant succession.

*** Canadian System of soil classification, Agriculture Canada, 1979.

Table 3: The relationship of generalized ecological levels to planning stages in Canadian environmental assessment (Environmental Conservation Service, 1981).

PROJECT PHASE	EXAMPLES OF ACTIVITIES	SCREENING	INITIAL ENVIRONMENTAL EVALUATION (IEE)	ENVIRONMENTAL IMPACT STATEMENT (EIS)
CONCEPTION	Reconnaissance of resource opportunities; consider general design, magnitude and potential of activities	Ecoregions for Wide Areas	N/A	N/A
GENERAL PLANNING	Select resource areas, corridors, etc. Consider related activities	Ecodistricts for Project Area	N/A	N/A
DETAILED PLANNING	Design specifications; detailed route/site selection, and detailed site design	Ecodistricts for Project Area	Ecodistricts for Disturbed Locations	Ecodistricts for Project Area; Ecoelements for Disturbed Sites
DEVELOPMENT	Construction - e.g. roads, excavations	Ecosections for Project Area	N/A	Ecosites for Project Area; Ecoelements for Disturbed Sites
OPERATION AND MAINTENANCE	Mining, traffic, product storage, monitoring	Ecosites for Project Area to select monitoring Ecoelements	N/A	Ecosites for Project Area; Ecoelements for Disturbed Sites
ABANDONMENT	Staging of shut-down; Dispose of, remove or abandon equipment	Ecodistricts for Project Area	Ecosections for Project Area	Ecosections for Project Area; Ecoelements for Disturbed areas

closed. The problem rests with the difference in approach taken by both and the need to integrate and synchronize the technical and scientific data acquisition, analysis and interpretation with the planning process. Scientists prefer to work from the "bottom up" i.e. work from the base of the information hierarchy and generalize upward. Such a systems approach will provide the highest quality information. However, planners and decision makers usually choose to plan from the "top down" and need first of all the information at the top of a hierarchy for conceptual and general planning. The dilemma between "bottom up" and "top down" continually causes problems between the two groups, and is at the root of the reason why environmental science has had little impact on strategic and conceptual decision making of major projects. Only by combining a top down and bottom up approach can this problem of quality and timing be solved. To achieve this in Canada, an ecological land survey system has been developed which is hierarchic in concept and allows organization or classification of information from the top down as well as from the bottom up. The various planning levels can be paired with corresponding classification levels (Table 4).

Table 4: The relationship of generalized ecological levels to international and regional planning levels in Canada.

HIERACHY	LEVELS OF PLANNING
Ecoprovince	International, National
Ecoregion	National
Ecodistrict	Provincial
Ecosection	Sub-provincial
Ecosite	Community
Ecoelement	Site-specific

To satisfy the requirements of the resource management process, data gathering, integration, analysis, organization, classification, and formatting or reformatting of information for decision making is required. Some of the developments in these areas in Canada related to the use of ecological surveys, remote sensing and computer information system are described in the following sections.

ECOLOGICAL LAND SURVEY

Most of the settlement in Canada took place in the last 100 years. Very little technical information existed to guide settlers; accessibility by water and railway was the dominant factor in selecting lands for use, and if settlement occurred on good agricultural land, it was more often by accident than design (Coombs and Thie, 1979). In large countries, it is difficult to provide nationally consistent data bases which keep up with the speed of development. To deal with the land use problems and of conflicts created by indiscriminate settlement, the Canadian government launched the Canada Land Inventory (CLI) Programme in 1965. This programme is described in detail by Munn (see Chapter 24). The CLI provided a comprehensive multidisciplinary data base covering forestry, wildlife, agriculture, recreation, sport fishing, and land use for about 2.5 million square km of land. Use of this information indicated that further integration would be desirable; consequently a committee was set up to develop an integrated, ecologically based system for the 7 million square km of wilderness land not covered by the CLI. This committee subsequently evolved into the Canada Committee on Ecological Land Classification (CCELC) and produced the Ecological Land Classification System of Canada.

Ecological land survey is an integrated approach through which areas of land are classified and mapped as ecosystems according to their ecological unity. The classification process includes the description, comparison and synthesis of data related to the biological and physical characteristics of the land (Rowe, 1978). Land is treated in a holistic manner and is comprised of five main components (terrain, hydrology, climate, flora and fauna) and the relationships which exist among them (Wiken, 1979). By its integrative approach, ecological land survey provides basic information for a wide range of resource planners and users. There are several advantages: (i) planners and managers deal with the same basic ecological units rather than a series of maps with non-concordant boundaries and various levels of detail, (ii) users are provided with ecological, that is relational, information that fosters an appreciation of the interlocking effects of multiple uses, (iii) the description of basic units can be interpreted for a wide variety of uses, its comprehensiveness allowing a high degree of flexibility in responding to unanticipated questions, and (iv) an integrated team and data base minimize the costs of the surveys, data storage and data handling.

The objective of an ecological land survey is to map and describe ecologically significant parts of the land surface and organize this information in a format suitable for planning and management. To do this, the system uses a classification hierarchy that is related to the orders of planning and management (Table 4). The spatial and time requirements of the planning process are accommodated by its ability to classify both from above and below. Classification (or division) from above allows environmental scientists to meet the requirements of the conceptual or strategic nature of the higher orders of planning, and exerts influence on our strategies, policies and plans. Classification (or aggregation) from below is more attuned to the requirements of the implementation of plans. The two activities of subdivision and aggregation interact like the blades of scissors, together cutting up information into understandable and manageable pieces (Rowe, 1978). The various levels of generalization of ecological land classification together with examples of common recognition benchmarks are given in Table 2.

A large number of ecological land surveys have been carried out in Canada. The spatial extent of the mapping is shown in Figure 1. As might be expected, the largest number of ecological land surveys are carried out at the regional level. A comprehensive accounting of these is provided in the proceedings of the 1978 CCELC meeting (Rubec, 1979). National and provincial mapping is now expanding, and a macro-level ecological map is being prepared to serve as a basis for a national state-of-the-environment report (Wiken, 1982). Ecoregion and Wetland Region maps (prepared by working groups of the CCELC) are now being finalized for wide public distribution through the National Atlas of Canada map series, so as to foster a better public perception of the ecological characteristics of Canada. These maps will provide the opportunity to integrate ecological and socioeconomic information for strategic planning. A number of provinces and territories have published ecoregion maps and reports for the same reason.

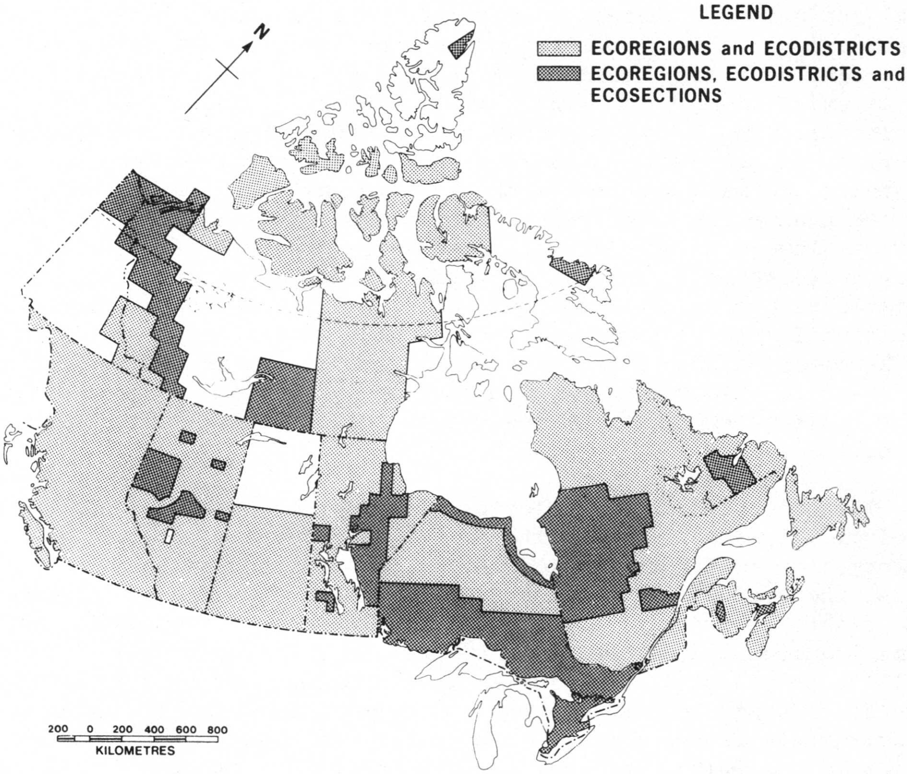

Figure 1: The extent to which different levels of ecological generalization have been mapped in Canada.

A national ecodistrict data base is being prepared by the Lands Directorate. This work is synchronized with the mapping of soil landscapes done by the Land Resources Research Institute of the Department of Agriculture. The maps and descriptors are stored in the Canada Land Data System (CLDS). The combination of complex ecological information and a computerized information system like the CLDS allows rapid analysis and reformatting of data. The CLDS, through its links with Statistics Canada (the national statistics centre), provides an effective means for spatially correlating and integrating the environmental information with socio-economic data.

At the national level, this has resulted in a greater environmental influence on long term socio-political decision making, for example, ecodistrict information has played an important role in negotiations between Canada and the U.S.A. on the effects of Long Range Transport of Air Pollutants (LRTAP) on terrestrial environments (Rubec and Wiken, 1983). In the Arctic, it is being used for regional planning studies in areas where detailed information is lacking.

A large number of more detailed surveys have been carried out at the ecosection and ecoelement level by federal and provincial agencies and private industries, and their results have been applied to national parks planning and management, forest site classification, hydro-electric power development, regional land use plans, environmental assessments, etc.

REMOTE SENSING

Air photo interpretation has played an important role in the development of environmental survey systems related to vegetation, surficial geology, soils and agriculture. Aerial photographs record the spatial distribution of patterns of vegetation, land use, surface materials and drainage. They provide relief and slope information in three dimensional stereoscopic form. Combining and correlating all these factors allow conditions not directly visible on photographs, such as soil conditions and vegetation succession, to be inferred (Thie, 1972). Following field description of selected sample areas, results can be extrapolated to non-sampled similar areas by photo-interpretation. With this approach, the total number of field investigations can be considerably smaller than in conventional surveys. Furthermore, the value of each field observation is much greater than in conventional surveys, so that its description and classification are more critical (Vink, 1974). In addition to increasing the efficiency of single-discipline surveys, airphoto interpretation allows effective integration of the various elements of land ecosystems. It has also stimulated the development of integrated biophysical surveys.

Besides the conventional aerial camera and film, the development of new sensors and sensor 'platforms' have provided a rapidly expanding technology: Remote Sensing. Sensors may be passive, such as multi-spectral line scanners, radiometers, infrared systems, spectrometers for the near infrared, visible and ultraviolet wave-bands, or active systems, such as lasers and microwave radars. They allow an expanding range of parameters or conditions to be mapped or measured from satellites or aircraft. These include surface temperature, moisture, ice-thickness, oil-detection, air pollutants, etc. In addition, repetitive remote sensing adds the important dimension of time to permit study of the natural dynamics of land ecosystems or man-caused changes. Weather satellites continuously monitor changing climatic conditions; resource satellites like the LANDSAT series and SPOT allow studies of seasonal vegetation changes, and monitor forest investigations and land use change. The experience gained from combining weather satellites, resource satellites and aerial and ground surveys in a multistage, multisensor approach indicates that a global environmental monitoring system is now within reach.

As a result of the increased application of technology, much of the imagery generated by airborne and satellite systems is now in digital form. Transforming these into visual images for human interpretation usually significantly reduces both the spectral information and the spatial resolution of the data. To obtain maximum benefit from the use of remote sensing data, a number of machine-aided approaches have been developed. In the earlier stages, colour additive viewers and image density slicers found some use. However, maximum use of remote sensing spectral information can be obtained by computer-aided analysis of digital spectral and spatial data. So-called 'supervised' and 'unsupervised' techniques have been developed. With the supervised technique, computers use the spectral characteristics of field-sampled training areas to classify and map areas with identical spectral signatures. In 'unsupervised' classification, the computer 'looks' for spectral clusters in a multidimensional space, and produces spectrally meaningful themes which may or may not have environmental significance. The user then assigns values to these themes and groups them in a meaningful way.

Computer interpretation of satellite imagery has met with varied success. A key element for the success of classification is that the object of interest should be spectrally different enough to allow for consistent separation over relative large areas. A second factor is the resolution of the sensor - the item of interest should be large enough so that it can be accurately outlined and its signature must not be altered spectrally by surrounding elements.

Practical experience shows that mapping of earth surface cover features, such as land use/land cover, crops, or forest stands can be done successfully using automated methods. The main problem encountered is the spatial resolution. Accuracy has often been improved by the use of multi-date imagery, and sometimes by combinations of visible and radar sensors. However, computers have difficulty analysing the spatial patterns so important in landscape ecology. In many applications, therefore, a combination of man and machine interpretation is recommended. The strengths of the computer (spectral discrimination, area estimates, correlation of temporal data) can then be combined with the interpreter's skills for spatial analysis and his reference knowledge of land ecosystems. In general, automated classification for ecological land surveys tends to be less effective in complex ecological areas, and in areas where land cover (surface reflection) does not correlate very well with the subsurface conditions essential to biological production or land use in general (Thie, 1976). Effective use of visual analysis of satellite and airborne imagery has been made in many such situations.

Most ecological surveys use a multistage approach involving several remote sensing data sources used simultaneously (Rubec, 1983) (Table 5). A typical example can be found in the preparation of Ecodistrict maps for northern land management in Canada (Wiken et

Table 5: The multi-stage remote sensing approaches used for the different ecological land survey levels.

	STAGE I	STAGE II	STAGE III	STAGE IV	STAGE V
	PREFIELD PREPARATION		FIELD INVESTIGATION		POST FIELD
	overview; pretype units selection of sample areas	study of selected sample areas	overview reconnaissance	field sampling within and outside sample areas	analysis; synthesis; classification; final delineation and description using results from stage III and IV and imagery of stage I and II.
ECOREGIONS 1:3 million- 1:1 million	satellite imagery	high and medium altitude airborne imagery	aerial reconnaissance	selected, extensive field sampling	
ECODISTRICTS 1:500k - 1:125k	high Altitude airborne and/ or satellite imagery	medium altitude airborne	aerial reconnaissance	selected, extensive field sampling	
ECOSECTION 1:200k - 1:50k	medium-high altitude airborne imagery	medium to low altitude airborne imagery	aerial reconnaissance	moderately intensive field sampling of selected areas	
ECOSITE 1:50k - 1:10k	medium and low altitude airborne imagery	low altitude imagery	aerial or ground reconnaissance	intensive field sampling	
ECOELEMENT 1:10k - 1:25k	low altitude imagery	low altitude imagery	ground survey	very intensive field sampling	

al., 1980). In this project about 250 000 km^2 of land was mapped at a cost of about 20 cents per km^2. Visual satellite imagery interpretation was used to delineate ecologically significant landscape components, aerial photographs (1:60 000) providing the description of land pattern. Field sampling and low-altitude aerial photographs provided more detailed knowledge of representative ecosystems.

Multistage remote sensing information also played a role in the preparation of an ecodistrict data base in Eastern Canada (1.5 million km^2 covered in 2 years) for describing terrestrial sensitivity to acid precipitation. Satellite imagery, medium level aerial photography and existing information formed the bases for delineation and description. One of the major benefits was that it proved to be an effective way of integrating existing data bases into a meaningful whole so as to display general levels of sensitivity to acid rain.

COMPUTER INFORMATION SYSTEM: THE CANADA LAND DATA SYSTEM (CLDS)

Conflicting demands on the land resource coupled with multiple use needs have made land use planning a complex decision-making process. Large amounts of data from various disciplines need to be analysed, integrated and presented in a format suitable for technical and political decision making. The inability or inefficiency of people to deal effectively with large amounts of multidisciplinary, multidimensional spatial data, has stimulated the use of computers.

In Canada this development started in 1963, as part of the Canada Land Inventory. The multi-disciplinary nature of the CLI (6 different themes: forestry, agriculture, wildlife, ungulates, recreation, and land use) and the large number of maps (about 20 000) made conventional manual analysis virtually impossible. The CLI therefore sponsored the development of a computer system to digitize, store, analyse and produce tabular and mapped data. The Canada Land Data System (CLDS), formerly known as the Canadian Geographic Information System, was designed to handle large volumes of mapped data for resource management and planning. To allow use of the data at national, provincial, regional and local levels, the system takes all of Canada into one continuous data base. The CLDS have 3 basic components: input, manipulation and output (Figure 2).

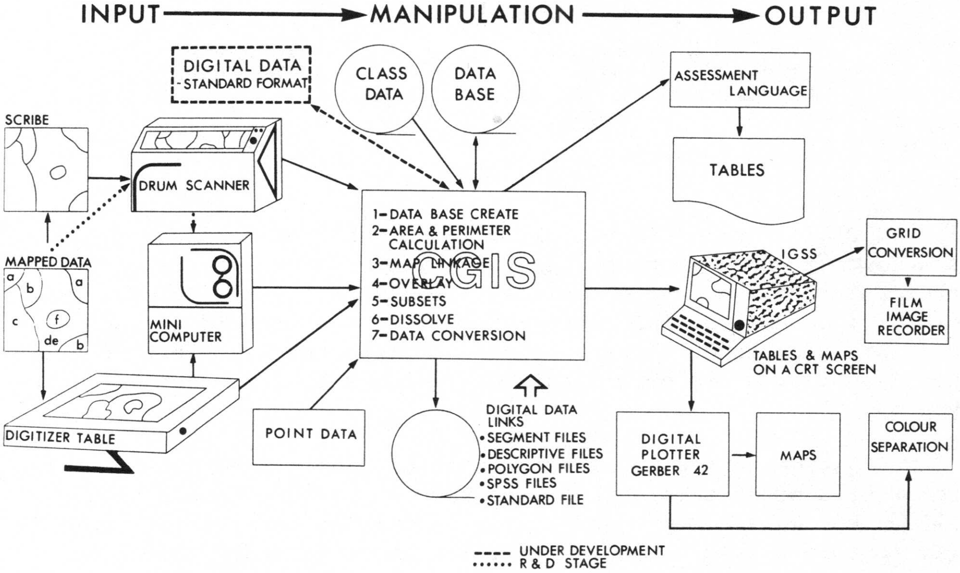

Figure 2: An overview of the Canada Land Data System showing the channels of data input, the manipulative phase of data base preparation and the format of data output. (SPSS = Statistical Package for the Social Sciences).

The input subsystem transforms the map image and its description into digital format. The main input device is an optical drum scanner which scans line (polygon) maps, and converts map unit lines (polygons) into binary data sets (image data sets). A descriptive data set containing all information/data pertaining to each polygon is merged with the image data set. The descriptive data set can be short and simple, as is often the case in land use maps, or very complex, for example in ecological land survey maps. The manipulation subsystem prepares the data base for analysis by users. It includes data base management to remove topological errors and arranges data in processing size chunks, area calculations, map linkage to link adjacent maps and dissolve map borders and an overlay capability to create composite coverage by overlaying various themes or maps. A total of eight themes may be overlayed at one time and each theme may cover a large geographic area. The output subsystem includes a series of interactive graphics terminals, printers, colour pen plotters and a high speed digital plotter. Information can be accessed through a series of regional terminals throughout Canada. Digital data in either polygon or grid form is provided in a number of formats including Digitworld, the Statistical Package for the Social Sciences (SPSS) and in a Standard Data Transfer Interchange Format, developed by several federal agencies in Canada.

In its 15 years of operation the Canada Land Data System has evolved from an inventory information system to a land resource planning and management system (Thie, et al., 1982). Initially its emphasis was on large volume map input for the Canada Land Inventory, and providing national and regional analysis of this multidisciplinary data base. Applications now include the development of national land use policies, international agreements related to migratory birds, and studies on the quality of land around urban centres. However, the largest number of data bases are now at the regional and local levels. Over one hundred data bases exist, reflecting the interest of a wide range of users and the increasing sophistication of analysis requirements. They are being used for the planning and management of national parks, selection of camp sites, roads, hazard areas, forest inventory and management, forest disease surveys, studies on the terrestrial sensitivity of acid precipitation, environmental impact assessment and northern development planning. Remote terminals and the use of micro- and minicomputers have speeded up the regional use of the system and increased the diversification and sophistication of its use. Crain and MacDonald (1983) have described this evolution; Table 6 summarizes their views.

The CLDS has proven particularly valuable for the storage and retrieval of ecological land survey information. Ecological maps usually have very complex map symbols, legends and descriptions, which discourage their use by planners. However, interactive graphic systems now allow users to pose numerous questions and to get immediate visual and statistical results, which can be rejected, or

Table 6: The three phases of evolution of a geographic information system, the primary activities associated with each and the user/supplier relationship.

	SYSTEM CAPABILITIES	PRIMARY ACTIVITY	USER/SUPPLIER RELATIONSHIP
INVENTORY PHASE	- data input - editing - simple retrieval - routine reporting	- data input	- clear division between client and supplier little interaction
ANALYSIS PHASE	all above plus: - complex retrievals - ad hoc queries - statistical processing - derived reporting (e.g. graphics) - derived data sets	- data retrieval and manipulation	- supplier involved in determining output needs - interactive retrievals and direct data access by user
MANAGEMENT PHASE	all above plus: - modelling, simulation - decision support tools (e.g. forecasting) - integration of local data sets	- data exploration and modelling	- user and supplier indistinguishable - fully interactive - distributed responsibility

refined and printed out as maps or reports. In particular, the Canadian National Parks Service, as a matter of policy, is preparing ecological land surveys for all its parks, and is storing maps in the CLDS for analysis by its planners and managers as required.

CONCLUSIONS

The combination of remote sensing, integrated ecological land surveys and computer information system is a very powerful tool. Remote Sensing allows the rapid and cost-effective data gathering essential for many projects. Ecological land classification organizes complex ecological data in relatively simple spatial planning units, with comprehensive and often complex descriptions. The computer provides the tool to analyse complex and extensive quantities of ecological data with a speed and efficiency not feasible before. By providing relatively simple units, that is, simple in comparison with those that are usually derived from a map overlay process, ecological land classification reduces computer processing costs considerably. In addition, through its links with other data bases and overlay capabilities, the computer allows the integration of information from a variety of sources. Indeed, the increasing use of computer assisted interpretation techniques of remotely sensed imagery will provide further impetus for the expansion of computer-based resource management systems, and the resulting information system will be even better able to serve the decision making process through its enhanced ability to provide the right information, in the right format and at the right time.

REFERENCES

Agriculture Canada, 1979, Canadian System of Soil Classification, Research Branch, Publication No. 1646, Agriculture Canada, Ottawa.

Beanlands, G.E., and Duinker, P.A., 1983, "An Ecological framework for Environmental Impact Assessment in Canada", Institute for Resource and Environmental Studies, Dalhousie University Halifax and Federal Environmental Assessment Review Office, Ottawa.

Coombs, D.B., and Thie, J., 1979, The Canada Land Inventory System, in: "Planning the Use and Management of Land", M. T. Beatty, G. W. Patersen, L.D. Swinsdale eds., Agronomy Series of the American Society of Agriculture, CCSA and SSSA, Madison, Wisconsin.

Crain, I.K. and MacDonald, C.L., 1983, From Land Inventory to Land Management, The Evolution of an operational GIS, *Proc. Auto-Carto Six*, 1:41.

Environmental Conservation Service (ECS), 1981, "Ecological Land Survey Guidelines for Environmental Impact Analysis", Ecological Land Classification Series No. 13, ECS and Federal Environmental Assessment Review Office, Lands Directorate, Ottawa.

Rowe, J.S., 1978, Revised Working Paper on Methodology/Philosophy of Ecological Land Classification in Canada, *in*: "Applications of Ecological (Biophysical) Land Classification in Canada", C.D.A. Rubec, ed., *Proceedings of the Second Meeting of Canada Committee on Ecological (Biophysical) Land Classification*, Lands Directorate, Environment Canada, Ottawa.

Rubec, C.D.A., (Ed.) 1979, "Applications of Ecological (Biophysical) Land Classification in Canada", *Proceedings of Second Meeting Canada Committee on Ecological Land Classification*, Ecological Land Classification Series No. 7, Lands Directorate, Environment Canada, Ottawa.

Rubec, C.D.A., 1983, Applications of Remote Sensing in Ecological Land Surveys in Canada, *Can. J. Rem. Sens.*, 9:19.

Rubec, C.D.A., and Wiken, E.B., 1983, Ecological Land Survey: a Canadian approach to landscape ecology, *Ekologia* (CSSR) 2:263.

Thie, J., 1972, Application of remote sensing techniques for description and mapping of forest ecosystems, *in*: "*Proceedings of First Canadian Symposium on Remote Sensing*", D. White, ed., Dept. of Energy, Mines and Resources, Ottawa.

Thie, J., 1976, An Evaluation of Remote Sensing Techniques for Ecological Land Classification in Northern Canada, *Proc. First Meeting CCELC*, Ecol. Land Classif. Ser., No. 1, Lands Directorate, Environment Canada, Ottawa.

Thie, J., Switzer, W.A., and Chartrand, N., 1982, Das Canada Land Data System und seine Anwendungsmoglichkeiten in Landschaftsplanung und Bewirtschaftung der Ressourcen. Natur und Landschaft 57:433.

Vink, A.P.A., 1974, "Field investigations and airphoto interpretation for the assessment of soil resources", I.T.C., Delft, Netherlands.

Wiken, E.B., 1979, Rationale and methods of ecological land surveys: An overview of Canadian approaches, in: Land/Wildlife Integration, D.G. Taylor, ed., Ecological Land Classification Series No. 11, Lands Directorate, Environment Canada, Ottawa.

Wiken, E.B., 1982, "Macro-level Ecological Map of Canada", Lands Directorate, Environment Canada, Ottawa.

Wiken, E.B., Pierce, T.W., and Ironside, G.R., 1980, Multistage remote sensing in exploratory ecodistrict land classification, in: Proceedings of the 6th Canadian Symposium on Remote Sensing, T. Alfoldi, ed., Canadian Aeronautics and Space Institute, Ottawa.