A METHODOLOGICAL FRAMEWORK FOR VEGETATION COMMUNITY DESCRIPTION AND MAPPING IN RIDING MOUNTAIN NATIONAL PARK

by

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A METHODOLOGICAL FRAMEWORK FOR VEGETATION COMMUNITY DESCRIPTION AND MAPPING IN RIDING MOUNTAIN NATIONAL PARK

BY

MICHAEL R. ETCHES

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCES MANAGEMENT

ABSTRACT

The Study provides a methodological framework for the classification and thematic mapping of the terrestrial vegetation of Riding Mountain National Park (RMNP) through a case study of data currently available. The two databases used are: 1) a current field study of terrestrial vegetation associations conducted in RMNP and 2) a computerized thematic map of the forest species associations of RMNP. A cluster analysis (Hierarchical, percent difference association matrix, minimum increase in sum of squares algorithm) was conducted separately on both databases for tree species descriptions, and a 15 class classification compared between spatially paired descriptions. The association between classifications was tested initially through a Chi squared test of independence, and then specifically through a cross classification test of all classes (Cohen's Kappa) and separate classes (Cohen's Conditional Kappa). Association of the two classifications was low overall and low for individual classes, with the exception of coniferous dominated communities. A final reclassification of the original thematic map database was conducted on a subset of the data available at the 15 class level. Recommendations for methodologies employed and improved methodologies that could be used to meet the needs of Park managers are discussed.

ACKNOWLEDGMENTS

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1.0 CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

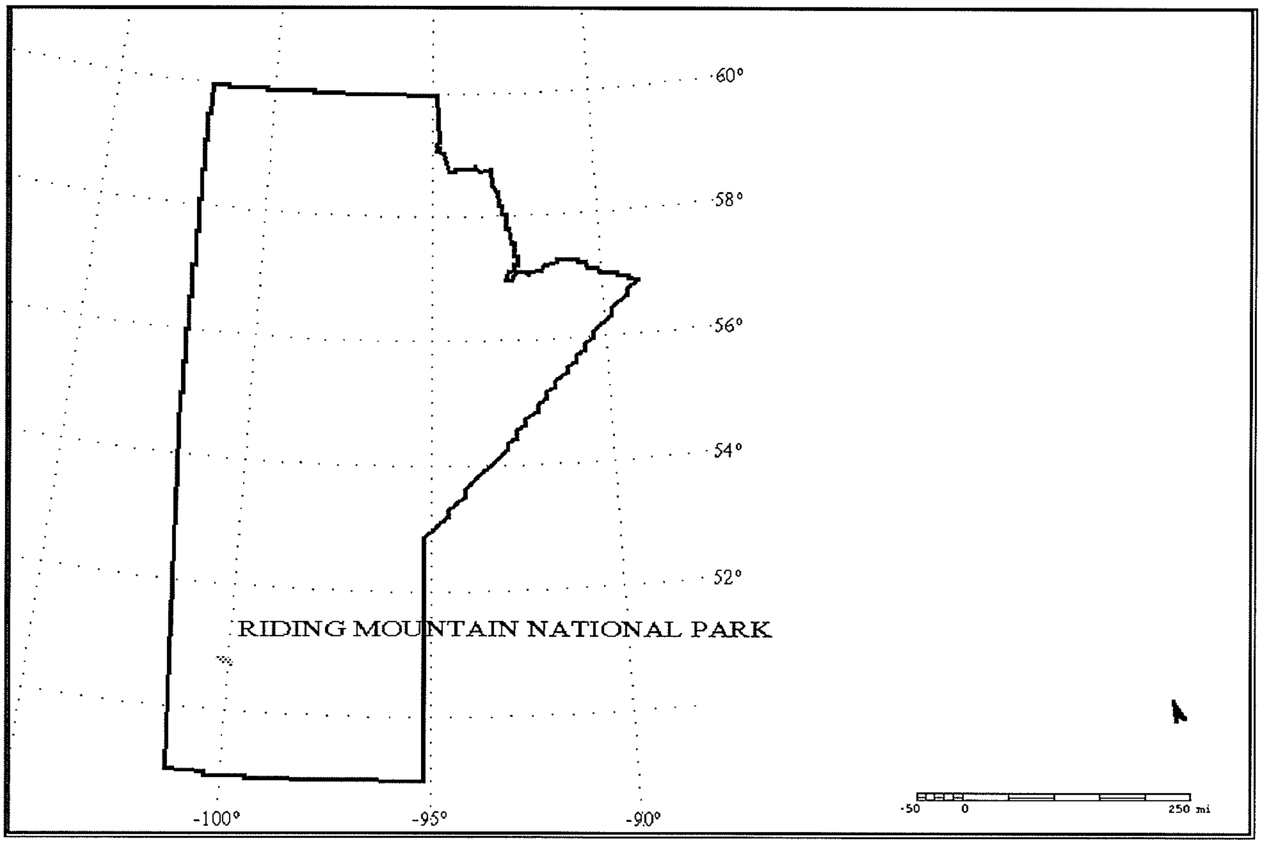
The purpose of this study is to develop and evaluate a methodological approach for the organization, analysis and mapping of a preliminary database describing the composition and areal extent of the terrestrial vegetation of Riding Mountain National Park (RMNP). This study represents one part of the RMNP Vegetation Classification and Stand Origin Study that started in the spring of 1992. The RMNP Vegetation Classification and Stand Origin Study was initiated to overcome "the absence of a useful vegetation inventory/classification scheme" that was limiting vegetation management planning in RMNP (Vanderschuit 1991). The larger RMNP Vegetation Classification and Stand Origin Study, itself, is only one component of the Canadian Parks Service's (CPS) recent move toward more active and integrated vegetation management. During its one hundred year history, the CPS has created and had access to a wide variety of sources providing information on the ecological components that make up the landscapes of National Parks. The current challenge for the CPS, is to combine these diverse information sources into usable and accurate integrated regional ecosystem information management systems (Environment Canada 1992a). These new systems for information management must, in turn, input into the CPS's

functional management approach. The functional management approach requires the planning, execution and monitoring of actions on an ecosystem to fulfil stated objectives. These objectives are related to the CPS's overall mandate within "natural" parks to restore and preserve representative examples of natural ecosystems (Government of Canada 1985).
When placed within the context of the CPS's mandate and integrated ecosystem management approach, vegetation management and the analysis of baseline data must necessarily fit into an overall ecosystem information management system, as well as input into the specific ecosystem management function of RMNP. Consequently, this study describes a methodological approach for organizing, analyzing and mapping existing terrestrial vegetation data from RMNP in a format that meets both of these requirements. It then evaluates this approach within the parameters of a limited case study and makes recommendations regarding the accuracy and utility of the methodology based on this evaluation.

1.2 STUDY AREA

The general study area for which the methodological approach has been constructed encompasses the landscape protected by the boundaries of RMNP. This Park is located in the southwestern corner of Manitoba (Figure 1). It incorporates sections of the Manitoba Lowlands, Manitoba Escarpment and Saskatchewan Plain geophysical land forms (Environment Canada, 1990a). RMNP is also representative of the Manitoba boreal plains and plateau ecological region that starts at the Manitoba escarpment and extends northwest into the Northwest Territories (Parks Canada 1984). The topography of the Park was shaped during the Wisconsian Ice Age.

Figure 1: Regional context of RMNP study area



It consists of a mosaic of flat hummocky till, clay and fluvial land forms interspersed with creeks, ponds and lakes. A mixture of vegetation communities that include aspen parkland, boreal forest, mixed forest, grassland, eastern hardwoods, rough fescue prairie remnants, wet meadows, and bogs exists within the 2978 square kilometre area of RMNP (Parks Canada 1984). Terrestrial vegetation are those plant species that normally exist on dryland. This type of vegetation covers approximately 70 percent of the Park's area and is the most common vegetation type found in RMNP (Parks Canada 1984).

The case study methodological approach for organizing, analyzing and mapping the current terrestrial vegetation data of RMNP was applied to a subset of the data available. Data used in the classification of tree species associations were selected from 400 locations throughout the Park. A final demonstration of methodological approach was applied to a single township range block within RMNP in order to evaluate the technique's accuracy and utility. The area chosen for this demonstration was the 92 kilometers squared township range block 2017 (Figure 2). The area was chosen because it is contained entirely within the boundaries of RMNP. In addition the block contains a high diversity of tree species associations allowing for a good demonstration of reclassification methods.

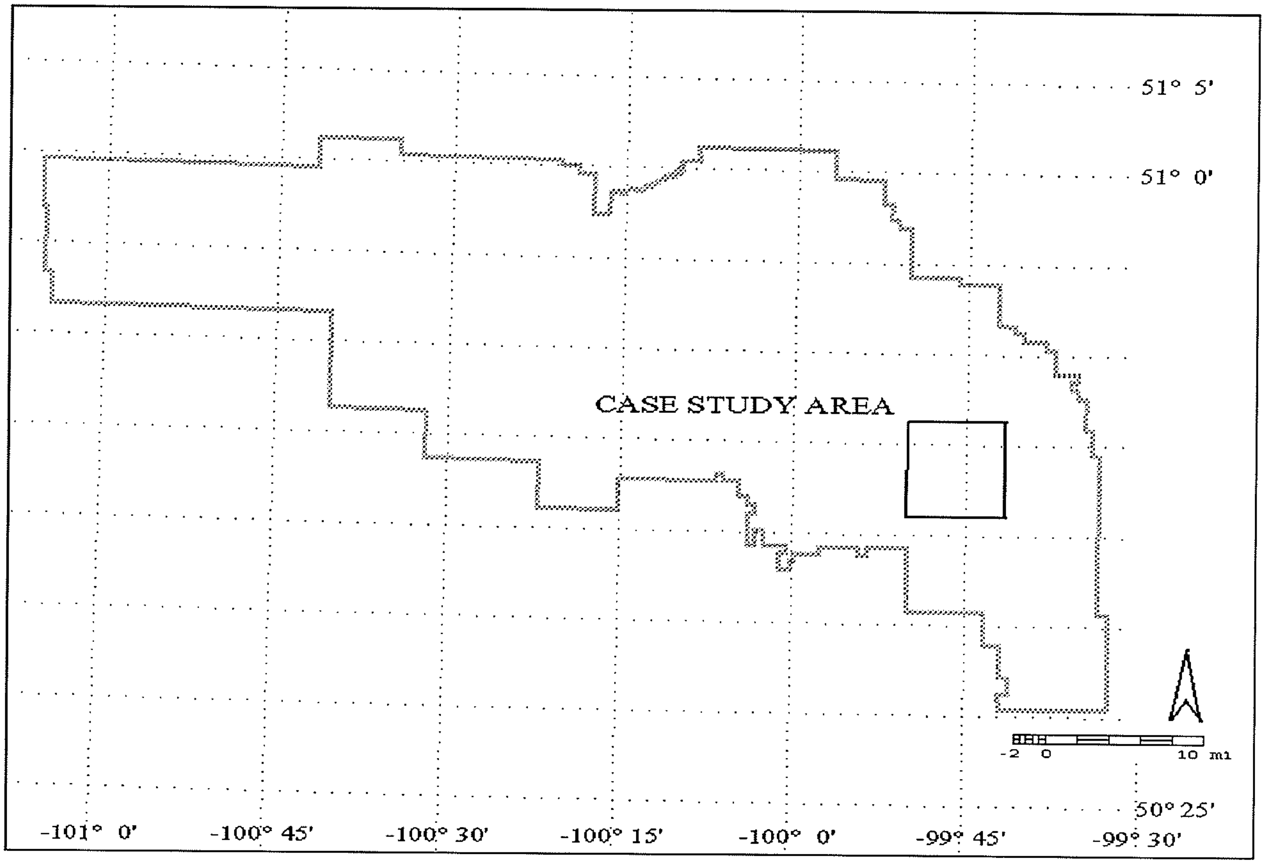
1.3 BACKGROUND

The Canadian Park Services's mission is to:

> commemorate, protect, and present places which are significant examples of Canada's cultural and natural heritage in ways that encourage public understanding, appreciation and provide enjoyment by present and future generations (Environment Canada 1990a).

Within Canada's National Park System, "natural" parks are

Figure 2: RMNP study area



mandated to protect representative segments of natural ecosystems while providing appropriate and meaningful visitor experiences (Environment Canada 1992a). The primary goal of protection within a "natural" park is therefore the maintenance of the integrity of the park's regional ecosystem. In this instance, ecosystem integrity is defined as:

> the (park ecosystem's) capability of supporting and maintaining a balanced, integrated adaptive community of organisms having a species composition and functional organization comparable to that of the natural habitat of the (surrounding) region (Karr and Dudley 1981).

Ideally ecosystem integrity should be maintained passively through natural processes, but in actuality human influences often necessitate an active management approach.

The maintenance of integrity within an ecosystem requires a large amount of information on the structures and processes that make up that system. The organization of this information as an input into a management function is an ongoing process that involves:

> that chain of operations that takes us from planning the observation and collection of data, to storage and analysis of the data, to the use of the derived information in some decision making process (Star and Estes 1992).

A structural component within an ecosystem, such as a stand of trees in a forest, can be easily visualized and understood when presented as a thematic map. Just as easily, an environmental process, such as the path of a fire through a grass meadow, can also be portrayed on a thematic map. These two maps can then be related to each other through geographical location. When most of the individual fragments of information about structural components and environmental processes in a given ecosystem are brought together, a composite map can be produced that approximates that ecosystem. As a basic ecosystem component "vegetation acts as an integrator of many of the physical and biological attributes of an area. A vegetation map can be used as a surrogate of ecosystems in conservation evaluations" (Austin 1991). Vegetation mapping is employed as a basic tool for understanding and managing ecosystems as a whole.

Canada's present system of National Parks incorporates landscapes that vary in their ecological integrity from fully functioning ecosystems with few human impacts, to moderately altered areas that have lost ecological components and functions due to past and present human activities (Environment Canada 1990b). RMNP protects a landscape that has been moderately affected by human influences. Originally set aside as a Federal Forest Reserve, RMNP attained National Park status in 1932. Since European colonization, the Park's regional ecosystem has been subjected to logging, grazing, haying, fire suppression, hunting, trapping and fishing (Environment Canada 1987). At present, an extensive transportation and recreational infrastructure in the Park also provides access to, and use by an estimated 960,000 visitors a year (Environment Canada 1987).

The specific mandate of RMNP is to "protect for all time an area of Canadian significance that represents the southern Boreal Plains and Plateaux natural region" (Environment Canada 1987). In order to fulfil this mandate, the managers of RMNP have identified the management of vegetation as a high priority in both <u>The RMNP Management Plan</u> (Environment Canada 1987) and in <u>The RMNP Park Conservation Plan</u> (Toews 1988). Historically, vegetation has been directly effected by the human activities of logging, haying and grazing of domestic animals within RMNP (Toews 1988). Indirectly, vegetation has been effected in the past and at present by alteration of fire cycles, introduction of exotic species, land development and human impacts on natural herbivores (Toews 1988). If they are to mitigate these types of impacts, RMNP managers require current baseline information as an input into an ecosystem management function (Vanderschuit 1991).

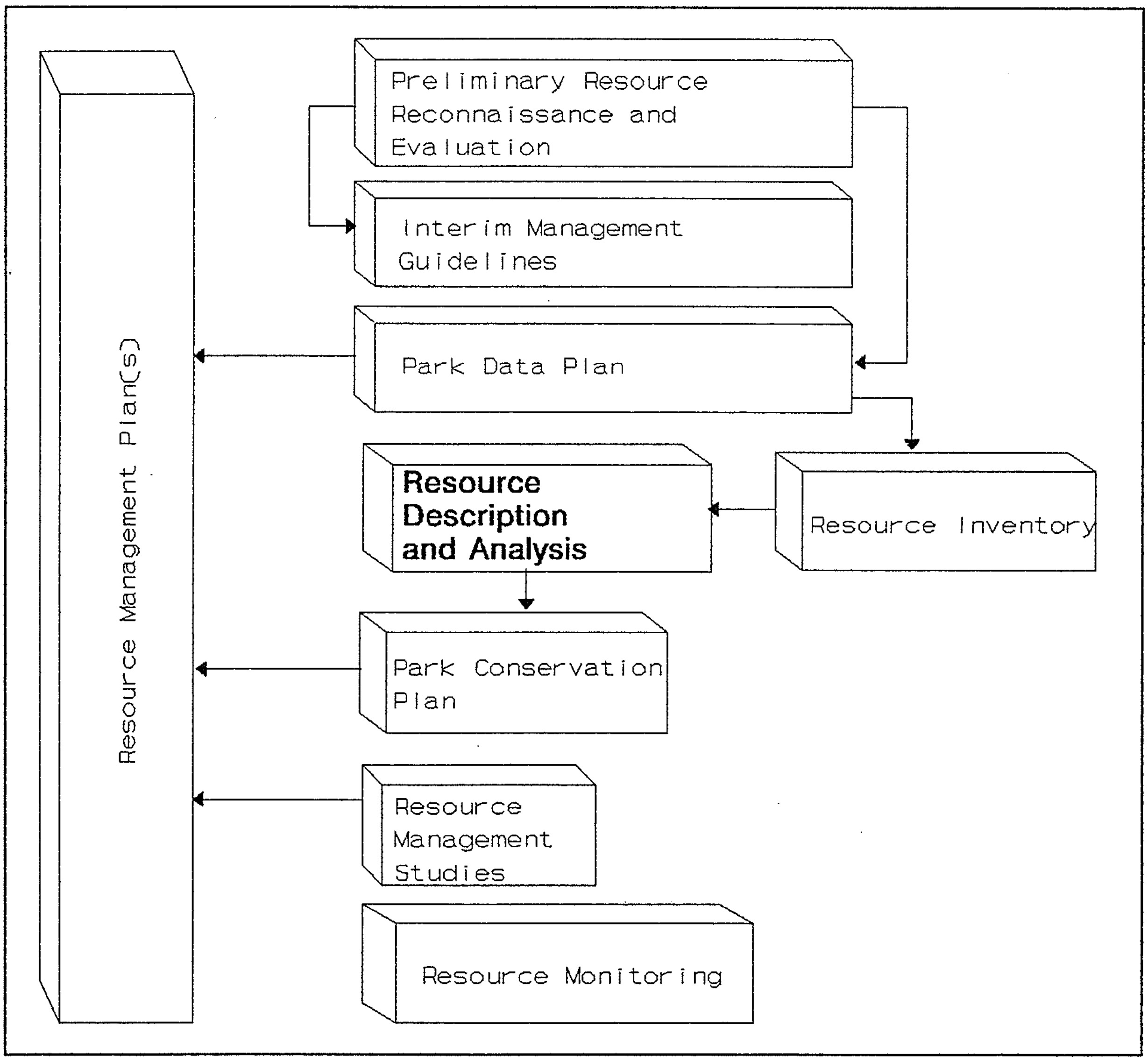
The Natural Resource Management Process (NRMP) was developed in the 1970s by the CPS to structure and direct the planning, research and management actions of park managers (Parks Canada, 1978). The NRMP outlines a stream of information collection (Resource Inventory, Resource Description and Analysis), issue analysis (Park Conservation Plan), research (Resource Management Studies), active management (Resource Management Plan(s)), and monitoring designed to deal with threats to ecosystem integrity (Figure 3). One of its main purposes, and the emphasis of this study, is to provide a "structured approach to collecting, storing and using natural resource data for a park" (Parks Canada 1978).

Currently, The RMNP Biophysical Inventory (Lombard North Group 1976) provides baseline information on ecological structures and processes in an integrated and hierarchal ecosystem model that classifies homogeneous sites based on a combination of climate, surficial geology, topography, soils and vegetation characteristics. The RMNP Resource Description and Analysis (RD&A) (Parks Canada 1984) summarizes the main components of The RMNP Biophysical Inventory and provides a limited analysis for management needs. Unfortunately, the tabular data and large scale static map format of both The RMNP Biophysical Inventory and The RMNP Resource Description and Analysis has made the ecological data they contain difficult for

RMNP managers to access for analysis:

> Employees were most critical of the Information area: there is no systematic method for defining what information is needed; no comprehensive knowledge of the state of our information base; hundreds of thousands of dollars of investment in information (maps, reports, etc.) that cannot be accessed and are not being maintained (Environment Canada 1992b).

Figure 3: Natural Resource Management Process



In an effort to rectify these deficiencies, the NRMP and the biophysical ecosystem model have been recently evaluated in the light of the integrated ecosystem management processes and the Geographic Information Systems (GIS) that are now available (Gauthier and Gutiw 1990).

As a result of this evaluation, the linear and compartmentalized design of the NRMP has been modified to a more cyclic and integrated approach when employed to vegetation management (REMS Research Ltd. 1991). Concepts from one of the new integrated ecosystem management processes, the Adaptive Environmental Management Process (Holling 1978), have been incorporated into recent applications of the NRMP. These concepts include: the detailed conceptual modelling of the managed ecosystem; the prediction of future ecosystem states based on alternative management actions; and the monitoring of the ecosystem to review predictions and fine tune management actions. The objective of the process is now not to create a model, but to "structure communication, force quantification of variables, integrate existing information, identify knowledge gaps, and test hypothesis" (Holling 1978). The key to the actual realization of this objective is a functional information management system. Geographical Information Systems fulfil one part of this role.

The spatial character of much of the ecological information that can act as an input into an ecosystem model for an integrated ecosystem management process is suitable for organization in a GIS. For spatial data described in terms of distinct points (single plants), lines (rivers) and polygons (plant communities), automated data management has developed the extensive field of computer based GISs. A GIS is "both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data" (Star and Estes 1992). The importance of a GIS in ecosystem management has been recognized by the CPS in a recent report, Vegetation Management for the Canadian Parks Service:

> To make the RD&A useful in terms of vegetation management, the basic description and inventory of resources (ie. the structure and pattern of the landscape and its components) needs to be entered into a GIS. This serves two purposes: as an inventory in the form of map polygons with listed attributes, and as a potentially dynamic database that can later be interfaced with simulation models during the adaptive management process. This basic layer of polygon (community), point and line information then needs to be complemented with other layers representative of how the vegetation is viewed (eg. from or by other values such as wildlife ie. habitat information) so that new polygons can be created that represent combinations of layers (REMS Research Ltd. 1991).

Besides acknowledging the importance of a GIS as an input into the revised NRMP, this report also identifies the computerized mapping of vegetation communities as the first step in a comprehensive ecosystem description. The managers of RMNP are currently moving towards the analysis of data using a GIS. GIS software is available on personal computers used by the Park's managers, and preliminary geographical data in the form of boundaries, rivers, lakes and roads has been entered into the system.

Additional data detailing the present areal extent and plant species composition of the terrestrial vegetation of RMNP have been made available to RMNP managers from two separate sources. The first source was provided by the Manitoba Department of Natural Resources. The provincial Forestry Branch has produced a series of Forest Cover Maps that describe both the tree species composition and the distribution of homogeneous tree associations identified from air photos of RMNP taken in 1978 (Forest Cover Map - Manitoba Forestry Branch 1993). Until recently, this database had been of only limited utility to RMNP managers because the thousands of tree associations it identified were unclassified and described in a complex static paper map and tabular format. These limitations have been overcome to some degree by the conversion of this database into a computerized format that makes the analysis and visualization of data easier through computer automation by a GIS. However, the Forest Cover Map database is still deficient in many respects. First, the database provides the description of species composition and abundance for tree species only. Ground cover and shrub species are not described. Second, it lacks a system of classification that would provide a more generalized view of the tree associations it describes. Finally, the degree of accuracy with which the Forest Cover Map database can be used to predict the tree species present in a given area has not yet been determined.

The second source of current data on the terrestrial vegetation associations of RMNP has been created by the RMNP Vegetation Classification and Stand Origin Study (Vanderschuit 1991). This Study was conducted over two consecutive field seasons during the summers of 1992 and 1993. The data collected by the Study accurately describes the location and composition of tree, shrub and ground vegetation for 1378 unclassified terrestrial vegetation associations within the Park. The data in its preliminary form is in a tabular format and not spatially defined.

1.4 PROBLEM STATEMENT

To be useful in an integrated and functional ecosystem management approach, RMNP managers must have the ability to classify, visualize and integrate ecosystem components at a scale and level of detail appropriate to a particular management action. At present, RMNP has access to two separate, but related terrestrial vegetation data sets. Each of these sources contain some of the information identified by RMNP managers as essential to their decision making process. The first source of information is a Forest Cover Map database of RMNP created by the Manitoba Department of Natural Resources. The second data set is a product of the RMNP Vegetation Classification and Stand Origin Study conducted by the RMNP Warden Service.

The Forest Cover Map database provides terrestrial vegetation information about RMNP in a thematic map format that can be easily visualized and used by RMNP managers. The limitation of this database is that the information it provides does not go beyond the forest species association level, nor is it classified into the plant communities necessary for generalization of its complex data set. Moreover, since the descriptions supplied by this database have not been ground truthed, their location and composition accuracy is untested.

In contrast, the descriptions provided by the RMNP Vegetation Classification and Stand Origin Study contain composition detail beyond the forest species level. The use of Global Positioning System location equipment with a ± 30 meter accuracy to obtain the majority of the Study's descriptions has also insured that these descriptions reflect a higher degree of location accuracy than the air photo based descriptions supplied by the Forest Cover Map database. However, the detailed and accurate terrestrial vegetation information resulting from the RMNP Vegetation Classification and Stand Origin Study is not spatially described and classified in a format that allows RMNP managers to easily visualize it, integrate it with other ecosystem data, or generalize from it. The general survey methods used in the vegetation study provide descriptions of plant associations at approximately the same scale as the Forest Cover Map polygons. There is a qualification in this correspondence between the two methods used to describe plant associations; the Vegetation Study utilizes generalized point descriptions at the ground level, while the Forest Cover Map utilizes the interpretation of 1:15,840 air photos.

Independently, neither the RMNP Vegetation Classification and Stand Origin Study, nor the Forest Cover Map database provide the classification and scale of information needed by RMNP managers in a format that they can easily utilize for Park management. A synthesis of these two data sets may provide a database that would both describe the areal extents of the terrestrial vegetation communities identified by the Forest Cover Map database at the scale of detail obtained in the RMNP Vegetation Classification and Stand Origin Study, and present this information in a series of visually accessible thematic vegetation maps. These maps could, in turn, be integrated with thematic maps representing other ecosystem components in order to create an integrated regional ecosystem information management system. Consequently, the creation and evaluation of a methodological approach for producing a synthesis of these two terrestrial vegetation data sets is currently needed by RMNP managers.

1.5 OBJECTIVES

The primary objective of this study was to create and evaluate a methodological approach for the community description and thematic mapping of the terrestrial vegetation of RMNP. The study's sub-objectives were:

1) to provide RMNP managers with a preliminary database of terrestrial vegetation information that can be accessed and manipulated to create thematic maps of the terrestrial vegetation of RMNP as an input into the Park's ecosystem modelling and management functions.

2) to provide RMNP managers with a description of the methodological approach employed in the construction of the RMNP terrestrial vegetation community database and thematic maps that will allow this methodological approach to be duplicated in further analysis.

3) to evaluate the accuracy of the methodological approach used to create the RMNP terrestrial vegetation community descriptions and thematic maps using a subset of the available data.

4) to make recommendations regarding the utility to RMNP managers of the methodological approach employed to create the RMNP terrestrial vegetation community descriptions and thematic maps.

1.6 METHODS

This study's methodological approach involves the following:

1) Organizing the RMNP Vegetation Classification and Stand Origin Study and Manitoba Provincial Forest Map databases in a relational database management system (dBase IV - Ashton-Tate 1990) and a spatial database management system (SPANS - InteraTydac 1993).

2) Classifying the tree species abundance attributes of the two databases into limited class descriptions through a hierarchical cluster analysis program (SYN-TAX 5.0 - Podani 1993) for a generalization and comparison of their common attributes. A park-wide sample of 400 location paired, tree species abundance descriptions was used for this classification.

3) Comparing the classes of the separate classifications of the two databases to define and quantify their level of independence through a preliminary Chi square test of agreement before a matching of like classes. After matching like classes, class correspondence of the location paired samples was determined using a calculation of Cohen's Kappa (Cohen 1960).

4) Reclassifying a demonstration area of the Forest Cover Map database based on the chosen classification descriptions and evaluating the new thematic map.

2.0 CHAPTER 2: REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

This review of related literature outlines specific areas that provide a conceptual and technical basis for a methodological approach to organizing, analyzing and mapping terrestrial vegetation data from Riding Mountain National Park (RMNP). The ecological information management approaches that are currently used by the Canadian Parks Service (CPS) to conceptualize ecosystems are examined and their application in RMNP is investigated. General concepts of vegetation community description and classification are reviewed to provide support for a community view of RMNP's vegetation. Automated vegetation community classification techniques that simplify a floristic classification of the large databases available to RMNP managers are also presented. Finally, the process of mapping and its potential as a means of visualizing the areal extents of vegetation communities is explored.

2.2 ECOLOGICAL MODELLING

Two types of ecological modelling are currently used by the CPS. The first of these, the Ecological Land Classification (ELC) process is gradually being superseded by the more dynamic

Geographic Information Systems (GIS).

2.21 Ecological Land Classification

The ELC process was adopted in the late 1970s by Parks Canada to avoid problems inherent in their earlier thematic approach to ecosystem inventory and description methods (Gauthier and Gutiw 1990). Prior to the use of the ELC process, inventories in National Parks were conducted only on individual ecosystem components, such as soils, vegetation or wildlife (Parks Canada 1980). The thematic data on individual components tended to overwhelm the potential user when more complex ecosystem interactions were examined. More importantly, these early inventories failed to show the interrelationships between components. The ELC method was supposed to solve these problems by integrating ecological information during the inventory operation. The process summarized a number of ecological components associated with a particular site into a general accessed description (Figure 4). However, the ELC process was not without its own inherent problems:

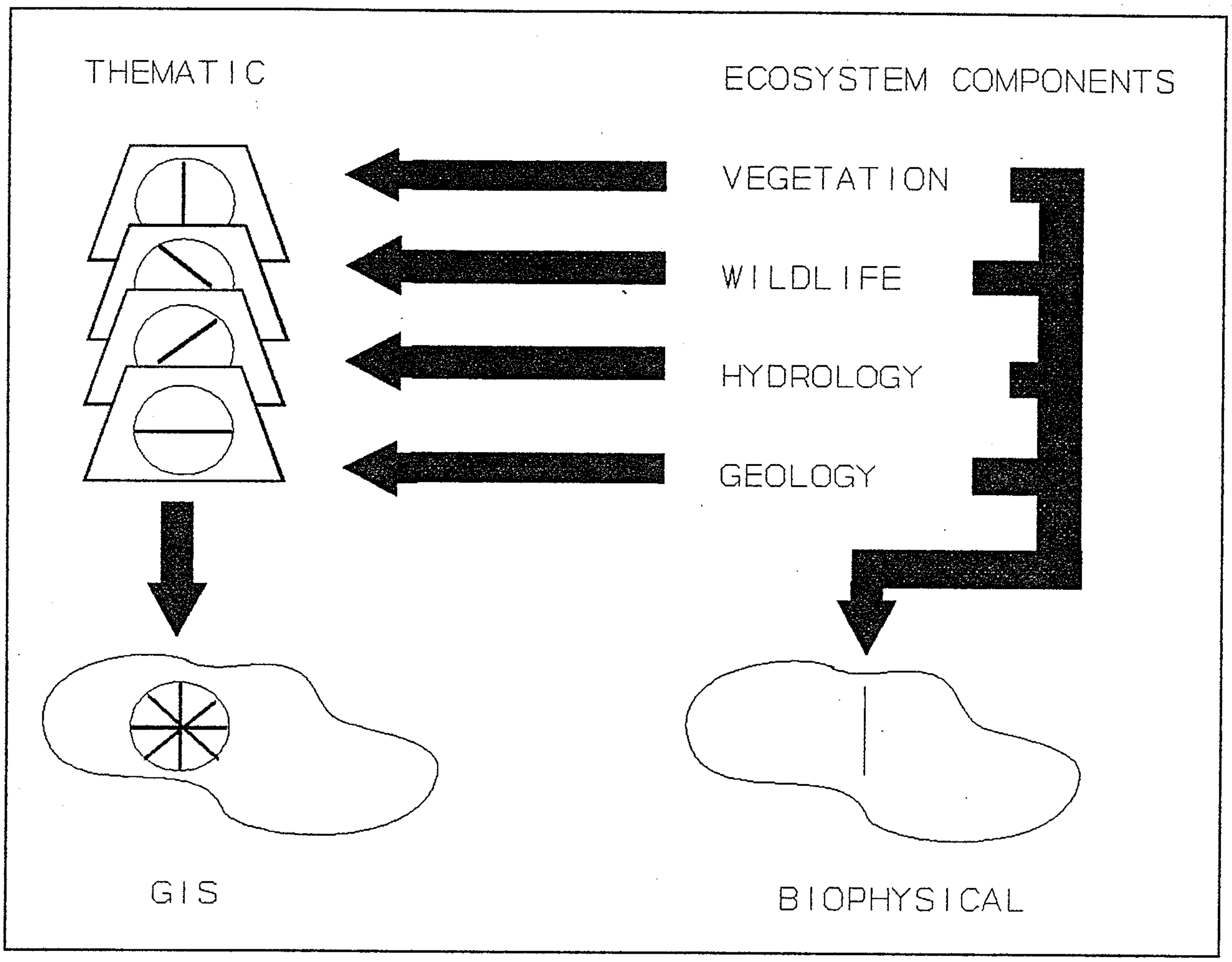
> An integrated system predetermines the way components are combined, makes value judgements about which are important and which are not, and thus limits its application to only those situations it was specifically designed for (Davis and Henderson 1976).

In addition, the subjective interpretation of biophysical data made the addition of current data to existing ELC inventories difficult (Lopoukhine 1988).

2.22 Geographic Information Systems

A GIS stores ecosystem information in separate thematic layers. Each layer describes one component of an ecosystem in cartographic structures, such as points, lines and polygons (Gauthier and Gutiw 1990). These cartographic structures are represented spatially in relation to a known coordinate system and are characterized through attributes that are linked to the cartographic spatial structures within the GIS. The relationship between the different thematic layers is defined by the georeferenced description of ecosystem components. The use of a GIS does, however, go beyond the geographical description of objects. Its uses include: the measurement of environmental parameters; the description of physical features on maps; the monitoring of changes in space and time; and the modelling of alternative actions and processes operating in the environment (Star and Estes 1992). GIS ecological models differ from ELC models by not generalizing individual components of a composite ecosystem model prior to overlaying of information layers. Each ecological component stands alone in a separate information layer in a GIS.

Figure 4: Thematic, biophysical and GIS ecosystem information management methods



The GIS ecosystem model has shown its utility in recent ecological management planning exercises. One such study used a GIS model to predict gaps in protected habitat areas for animal species (Scott et al 1993). Through the overlay of vegetation data classified by an animal habitat suitability model onto protected area extents, GIS `gap analysis' identified areas of suitable animal habitat outside of present protected areas. The authors of this study further suggested the utility of employing

GIS mapping to produce "a model of the recent vegetation of the study area from which predictions (could) be made about the probable pathways of future vegetation changes" (Scott et al 1993).

Within the CPS, the utility of the GIS model was examined in A Pilot Test of Prince Albert National Park Biophysical Resource Data Within the SPANS Geographical Information System (Gauthier and Gutiw 1990). This case study analyzed the effects of trail construction on vegetation by using a GIS to produce thematic maps of forest cover and plant associations within a predefined buffer distance from trails. The easy visualization of vegetation communities effected by trail construction lead to recommendations for the further operational use of a GIS in ecosystem modelling and management planning at the park level within the CPS.

2.3 RMNP BIOPHYSICAL INVENTORY

The most recent completed description of the vegetation in RMNP was produced in 1976 by an external consultant as part of The RMNP Biophysical Inventory (Lombard North Group 1976). Because the CPS had adopted the Ecological Land Classification process for the collection and classification of ecosystem components in the late 1970s (Parks Canada 1980), The RMNP Biophysical Inventory employed this method. The ELC process classified homogeneous areas of consistent biotic and abiotic features in a hierarchal format that could be examined at various levels of detail (Table 1).

Table 1: Ecological Land Inventory levels of integration

UNIT DESCRIBED	DOMINANT VARIABLE	SCALE
Land Region	Regional Climate	1:1,000,000 to 1:250,000
Land District	Physiography	1:250,000 to 1:125,000
Land System	Landform	1:125,000 to 1:50,000
Land Type	Surficial Deposit	1:50,000 to 1:10,000
Land Phase	Vegetation	1:10,000 to and greater

The RMNP Biophysical Inventory followed the ELC process through to classification at the level of "land type." The vegetation composition provided at this final level was presented only in a tabular data format (Table 2). The areal extent of "land types" were not described by a map.

Table 2: Example of the RMNP Biophysical Inventory Land Type description of the Birdtail Benchland Land System (adapted from Lombard North Group 1976)

General Land Description	Vegetation Cover Type	Plant Community		
		Tree Stratum	Shrub Stratum	Herb Stratum
level terrace with general gradient less than 5% drainage	grasses, some forbes and scattered shrubs.		shrub canopy cover:1 Rosa acicularis Symphoricarpo occidentalis Amelanchier alnifolia	herb cover:4 Poa pratensis Festuca scabrella Taraxacum officiale Achillea millefolium Aster levis Carex torreyi Cerastiumm arvense Stellaria longpipes Thalictrum venulsum

The existence of a variety of ecological information sources is problematic for Park managers wanting to look at ecological changes over time. The hierarchical approach that the RMNP Biophysical Inventory has used in this case does not preclude dividing the information it relays into different thematic layers in a format compatible with a GIS. This type of integration of information sources will be important to Park managers examining time series problems.

2.4 VEGETATION COMMUNITY CONCEPTS

The conceptualization of an ecosystem begins with the reduction of the whole ecosystem into its individual components of biotic and abiotic structures and processes. Intuitively this conceptualization starts with an examination of the most prominent physical structures within a given ecosystem. For the majority of terrestrial ecosystems the most prominent visual feature is the overall mosaic of vegetation. As the primary producer and basis of most food webs in the ecosystem, and as the habitat of many other organisms, vegetation is also a central ecosystem component (Kent and Coker 1992).

At the landscape level, vegetation can be visually classified into plant species associations. A mosaic of plant species associations can be seen in the alternation of grassland meadows and coniferous forest on the side of a mountain. A vegetation community, however, is more rigorously defined as "the collection of plant species growing together in a particular location that show a definite association or affinity with each other" (Kent and Coker 1992). In this definition, affinity "implies that certain species are found growing together in locations and environments more frequently than would be expected by chance" (Kent and Coker 1992).

Although the community model is not universally accepted amongst theorists (Whittaker 1962), many applied ecologists regard the community as a logical and appropriate level of concentration for ecosystem management (Kent and Coker 1992). The community level provides a scale (ie. 1:10,000) at which an ecosystem can be characterized by describing populations and individuals of plant species grouped together in a space of a few meters, or a few kilometres. Moreover, it is at the community scale that ecosystem managers can easily grasp the variation within an ecosystem.

2.5 VEGETATION DESCRIPTION

The use of a community concept to describe vegetation requires a means of classifying individual plant species into meaningful associations. A number of methods have been developed to describe vegetation, each depending on the scale and final use of the description. On a national or world scale general growth forms have been utilized in the Physiognomy approach (Raunkaier 1932) to classify plant communities that are similar in structure but vary in species composition or floristics. For regions with poor floristic diversity, the dominant vegetation stratum has been used in the Structural Dominance approach (Trass and Malmer 1978) to group plant associations into "sociations." The Floristic approach (Braun-Blanquet 1932; Dansereau 1972) uses the presence or absence of particular plant species in a homogeneous stand or releve to group associations into like communities. A plant association's structure and dominant species are not used to classify communities in this approach.

The manual manipulation of releves into like communities has recently been replaced by the computer automated procedures of cluster analysis (Pielou 1984). The proposed Canadian Vegetation Classification System (Strong, Oswald and Downing 1990) uses components of the Physiognomy, Structural Dominance and Floristics approaches in a hierarchial, eight level system (Table 3).

Table 3: The Canadian Vegetation Classification System hierarchal levels, classification approaches and example descriptors (adapted from Strong, Oswald and Downing 1990)

LEVEL	CLASSIFICATION APPROACH	EXAMPLE DESCRIPTOR
I	Physiognomy - Growth Form	Tree /Shrub /Herb
II	Physiognomy - Growth Form Subdivision	Evergreen /Deciduous
III	Physiognomy - Growth Form Ground Cover	Close /Open /Sparse
IV	Physiognomy - Growth Form Height	Very Tall /Tall /Intermediate /Low
V	Dominant Structure	Black Spruce
VI	Dominant Structure - Understorey	Labrador Tea
VII	Dominant Structure - Understorey Subdivision	Labrador Tea /Feather Moss

The types of vegetation classification that have been used by the CPS have reflected the needs of park managers. For large scale land use studies, the managers of Kluane National Park have collected plant species occurrence and abundance data for use in an automated classification process based on dominant species (Douglas 1974). When discussing consistent criteria for mapping vegetation in the CPS, Hodges (1976) used a strictly floristic approach to classifying vegetation. This view is supported by Bailey, Pfister and Henderson (1978), who favoured the natural floristic classification over the artificial classifications that are more suited for specialized needs. This study makes use of the floristic classification approach

2.6 VEGETATION CLASSIFICATION

The manual manipulation of floristic data for classification into unique vegetation types has limited utility when applied to large data sets. The large number of plant species that could be present at a particular location, the potential wide range of their abundances, and the great number of communities examined all combine to produce an unmanageable manual task. The solution to the problem of condensing the wealth of information gathered in an area as large as RMNP is the application of multivariate statistical analyses in the form of cluster analyses. Cluster analyses (Pielou 1984) group sets of vegetation samples into classes based on their floral characteristics (Kent and Coker 1992). Ideally, vegetation classes contain homogeneous vegetation samples that are heterogeneous across the entire classification. The groups of vegetation samples are then interpreted and used to define an overall set of plant communities for the study area. The many cluster analysis techniques available differ in the algorithms they use to group vegetation samples.

2.7 VEGETATION MAPPING

Classified vegetation associations can be represented as communities in coordinate space. The result of this type of representation is a map that illustrates both the areal extent of, and the relationship between these communities:

> The usefulness of a map is to display a large amount of data in a systematic and interrelated manner. Such presentations take advantage of techniques of print, colour, tone, symbols, and pattern to distinguish between areas of different vegetational types and relevant environmental conditions (Hodges 1976).

Viktorov (1964) has suggested three different map scales that are appropriate for integration of new maps with existing topographic and soils series maps. For RMNP these are: 1) the 1:100,000 - 1:1,000,000 scale to depict the entire Park; 2) the 1:50,000 scale to depict major communities; and 3) the 1:10,000 scale to depict detailed communities.

3.0 CHAPTER 3: METHODOLOGICAL APPROACH

3.1 INTRODUCTION

The case study methodological approach adopted in this study focuses on a subset of the data available for a larger practical application. The methodologies used in this case study centre around a Geographic Information Systems (GIS) and a multivariate statistical approach to modelling ecosystem components. The study compares a park-wide representative data set of 400 tree species abundance values from the Riding Mountain National Park (RMNP) Vegetation Classification and Stand Origin Study and the Manitoba Forest Cover Map databases. This comparison is used to provide classification criteria for a final forest species community thematic map demonstration within a GIS for a limited section of the landscape.

3.2 DESCRIPTION OF THE RMNP VEGETATION CLASSIFICATION AND STAND ORIGIN STUDY DATABASE

The RMNP Vegetation Classification and Stand Origin Study measured a range of environmental factors, and described terrestrial vegetation species composition and abundance at 1378 sites located throughout RMNP (Figure 5). These recorded attributes are described within a database that has been formatted into 111 data fields for each sample site (Table 4).

Figure 5: RMNP Vegetation Classification and Stand Origin Study sample site locations

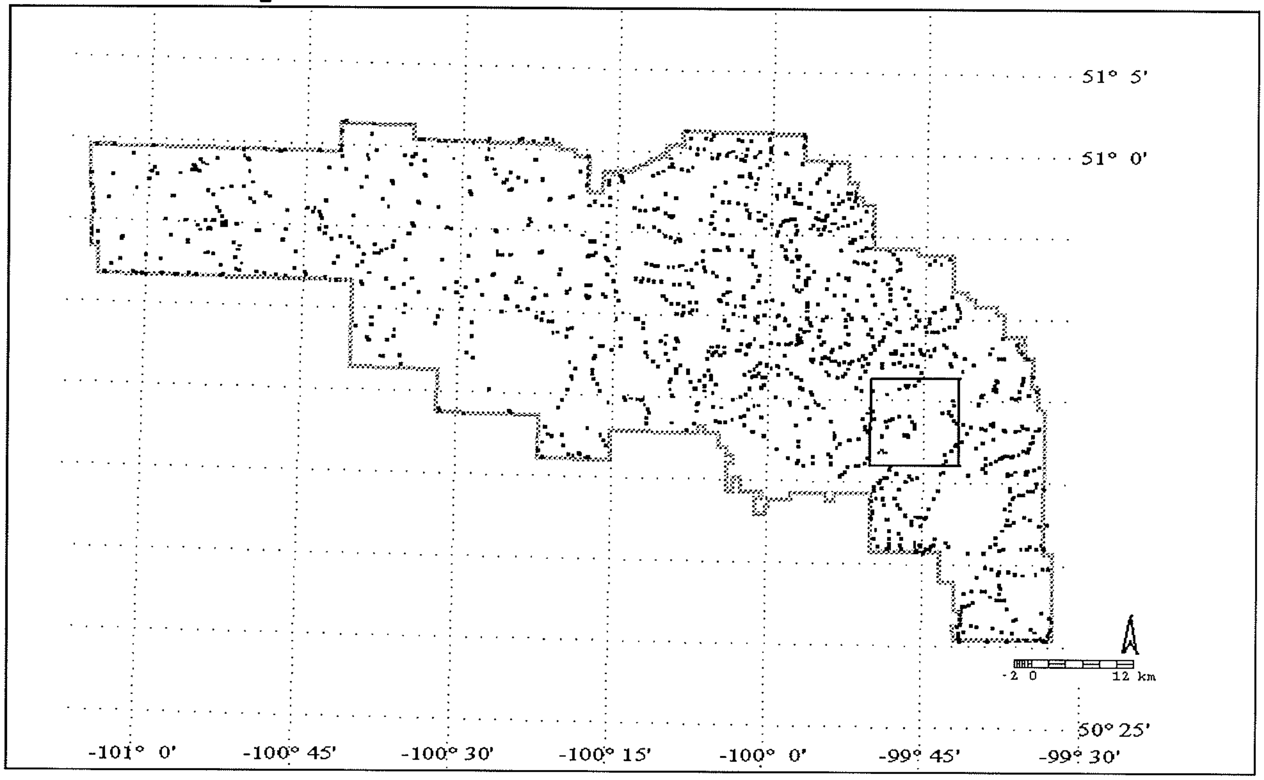


Table 4: RMNP Vegetation Classification and Stand Origin Study data fields

FIELD	DESCRIPTION
Reference #:	Year\Sample Line\Sample Point
Team:	Initials of Two Person Team
Time:	Year\Month\Day\Time (nearest half hour)
UTM1:	Easting (10m precision) GPS located
UTM2:	Northing (10m precision) GPS located
Error:	± UTM 1 and 2 Location error (m)
Elevation	meters above sea level
Aspect:	Facing slope (8 cardinal points)
Slope:	(degrees)
Site Position:	On slope (top, upper, middle, lower, bottom)
Surface:	(flat, elevated, depressed)

FIELD	DESCRIPTION
Drainage:	(good, imperfect, poor, undrained)
Soil	Texture: (organic, sand, clay, loam)
Litter:	Depth of course organic material in soil (cm)
Duff:	Depth of fine organic material in soil (cm)
Vegtype:	Site classification of vegetation association
Structure:	Tree Layer (even, 2 layers, uneven)
Tree CC:	Tree crown closure (% of sky blocked)
Shrubcover:	Shrub ground cover (% of ground covered)
Groundcover:	Herb, grass, and forb ground cover (% of ground covered)
Comments:	Unusual site condition comments
Disturb_A to D	Vegetation Disturbances (fire, insect, windfall, logging)
Evidenc_A to D	Vegetation disturbance evidence (eg. cut stumps, charcoal in soil)
Extent_A to D	Vegetation disturbance extent (ha)
Year_A to D	Year of disturbance
Comments_A to D	Comments on vegetation disturbances
Tree_A to G	Tree species present
Stems_A to G	Abundance of tree species present (% out of 100)
Position_A to G	Position of tree species present (overstorey, understorey, shrub)
Year_A to G	Age of tree species present
Shrub_A to H	Shrub species present
Cover_A to H	Abundance of shrub species present (% out of Shrubcover)
Ground_A to H	Ground species present
Gcover_A to H	Abundance of ground species present (% out of Groundcover)

The RMNP Vegetation Classification and Stand Origin Study was intended to be a first approximation of the variety and abundance of plant species present within the terrestrial vegetation associations found in RMNP. Due to the exploratory nature of the Study, only the prominent plant species that were commonly found at a given sample site were used to describe the species composition of that site (Appendix 1). The tree species that were the focus of the majority of the case study are described in Table 5. The abbreviations used were those created specifically for the Vegetation Study. The species abundance for each site was measured by visual estimation.

The 1378 sample site locations were preselected from a series of coloured air photos of RMNP that had been produced in 1978 at a 1:15,840 scale. Sample sites were subjectively located within apparently homogeneous stands on the air photos. These were spaced approximately 0.2 to 1.5 kilometers apart along survey lines that could be covered on foot by field workers in the course of a day. Survey lines were located throughout the Park. Their locations were, however, dependent on the access points and the means of transportation to these lines (ie. truck, horse, helicopter). The Universal Transverse Mercator (UTM) projection was used to describe point locations on topographic maps drafted at a scale of 1:50,000. In the field, sample sites were then found using a Global Positioning System (Trimble Basic and Basic Plus). The location accuracies of the sites sampled ranged from $\pm$ 30, to $\pm$ 300 meters depending on site topography and satellite configuration. The majority of the sample sites were located at the $\pm$ 30 meter accuracy level.

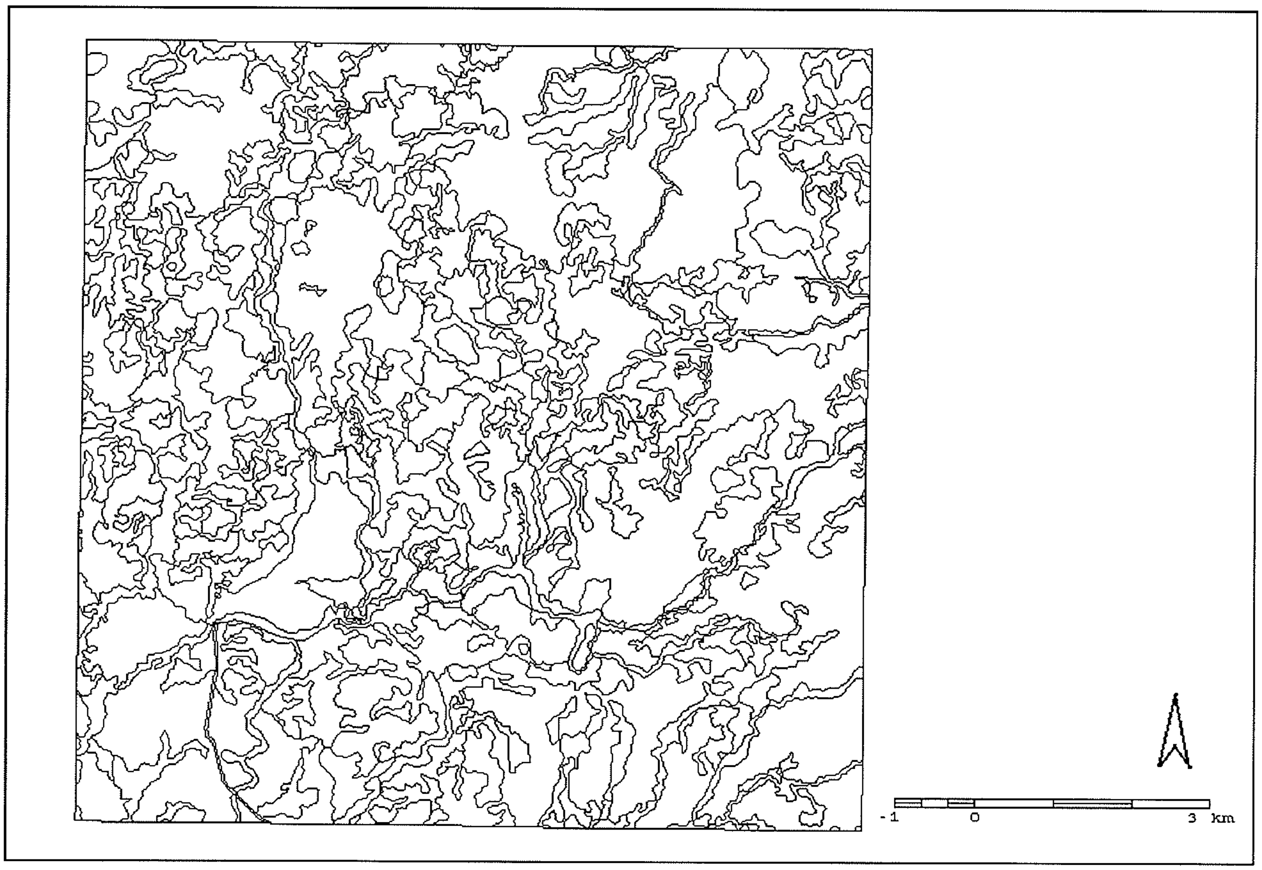
Table 5: Tree species attributes for the RMNP Vegetation Classification and Stand Origin Study and provincial Forest Cover Map databases

ABBREVIATION	COMMON NAME	GENUS/SPECIES
FIR	Balsam Fir	Abies balsamea
MAP	Manitoba Maple	Acer negundo
BIR	White Birch	Betula papyrifera
ASH	Green Ash	Fraxinus pennsylvanica
TAM	Tamarack\Larch	Larix laricina
WSP	White Spruce	Picea glauca
BSP	Black Spruce	Picea mariana
PIN	Jack Pine	Pinus banksiana
POP	Balsam Poplar	Populus balsamifera
ASP	Trembling Aspen	Populus tremuloides
OAK	Bur Oak	Quercus macrocarpa
MTN	Mountain Ash	Sorbus decora
ELM	White Elm	Ulmus americana

3.3 DESCRIPTION OF THE MANITOBA FORESTRY BRANCH FOREST COVER MAP DATABASE FOR RMNP

The Manitoba Department of Natural Resource's Forestry Branch Forest Cover Map database for RMNP incorporates a series of digital thematic maps that depict homogenous landscape associations in spatially defined polygons (Figure 6).

Figure 6: Example of Forest Cover Map database landscape polygons of township range block 2017



These polygons are described by an attribute file detailing polygon characteristics, such as area, perimeter length, and tree species composition and abundance (Appendix 2).

The Forest Cover Map database was created from a series of aerial photographs of RMNP taken in 1978. These photographs were manually processed and interpreted into polygons that incorporated both forest species composition and non-forested landscape features. The database's original classification scheme followed the requirements for the Manitoba Forestry Branch's management applications. As a result, the format of the Forest Cover Map database concentrates on forested species; providing some information that is extraneous to this study. Only a limited number of the fields within the database's attribute file are therefore employed in the current analysis (Table 6).

Table 6: Forest Cover Map database attribute fields and descriptions used in current study

ATTRIBUTE FIELD	DESCRIPTION
UNION_ID	A unique polygon identifier (2..N+1) used to associate the Forest Cover Map attribute descriptions with the Vegetation Study attribute descriptions located in that polygon
SPECIES	Tree species present in polygon (if forested) with associated proportion of total tree species present Ex. TA10 - Trembling Aspen composing 100% of the tree species
COVERTYPE	A 5 digit string representing tree crown closure in the last digit of the string Ex XXXX1 where 0 - 0% to 20% 2 - 21% to 50% 3 - 51% to 70% 4 - 71% and over for forested polygons
LND_ID	A 3 digit string representing: Forested land - 1 to 799 Productive land- 1 to 699 Non Productive - 700 to 799 Non Forested - 800 to 899 Water - 900

The Forest Cover Map database for RMNP is divided into 40 contiguous thematic maps and associated attribute files. These maps and fields are defined by township range blocks. The blocks encompass the entire RMNP landscape, as well as some of its surrounding area. Five blocks were not available for inclusion in the current study. These included two blocks that were excluded from the RMNP Vegetation Classification and Stand Origin Study because they contained the Wasagaming townsite, and three blocks that were unusable due to data corruption.

3.4 COMPUTER ORGANIZATION AND MANAGEMENT OF THE RMNP VEGETATION CLASSIFICATION AND STAND ORIGIN STUDY DATABASE AND THE MANITOBA FORESTRY BRANCH FOREST COVER MAP DATABASE

The database produced by the RMNP Vegetation Classification and Stand Origin Study was processed in the relational database management program dBASE IV (Ashton-Tate 1991). This database was then imported into the InteraTydac Spatial Analysis System (SPANS) GIS to produce a spatial representation of the Study's 1378 sample sites (InteraTydac 1993). The spatial representation was georeferenced to the GIS internal coordinate system through the sample sites' UTM location fields. The provincial Forest Cover Map database was imported directly into the SPANS GIS from its original GIS format in separate township range blocks. The original maps were georectified to ground control points. The Forest Cover Map database polygons in each block were georeferenced to the GIS internal coordinate system through their latitudinal and longitudinal location fields. The polygons were related to a UTM projection by SPANS.

The common georeferencing and projection of the two imported databases allowed for the location of the RMNP Vegetation Classification and Stand Origin Study sample sites within the Forest Cover Map database polygons. The spatial relations of all 1378 RMNP Vegetation Classification and Stand Origin Study sample sites and associated Forest Cover Map database polygons were exported to dBASE IV. The attributes of the two databases were then related to each other using a common UNION_ID field.

Finally, the two different attribute formats used to describe the tree species composition and abundance for sample sites and associated polygons were made compatible by changing the provincial Forest Cover Map database format to that employed by the RMNP Vegetation Classification and Stand Origin Study (Table 4). The product of this operation was a single joined dBASE IV attribute file for all RMNP Vegetation Classification and Stand Origin Study sample sites and their spatially associated provincial Forest Cover Map database polygons.

3.5 COMMUNITY CLASSIFICATION

The conversion of the Forest Cover Map database's tree species composition and abundance attribute format into the format employed by the RMNP Vegetation Classification and Stand Origin Study allowed for a direct comparison of attributes between spatially linked sample sites and polygons. A total of 1378 linked sample sites and polygons, approximately 800 of which were forested, did not allow for a simple comparison of attributes. Consequently, a community classification analysis was conducted separately on the tree species abundance attributes for both the RMNP Vegetation Classification and Stand Origin Study sample sites and the associated Forest Cover Map database polygons.

A hierarchical cluster analysis program provided in SYN-TAX 5 (Podani 1993) was employed to classify the tree species abundance attributes. A percent difference association matrix and minimum increase of sum of squares error clustering algorithm was used for the cluster analysis. Two, species abundance by object (sample site or polygon) matrices, compatible with SYN-TAX 5, were exported from the linked attribute file in dBASE IV. The objects for the analyses were chosen randomly from the 800 forested sample site and polygon pairs. Because SYN-TAX 5 can only process 400 objects at one time with the cluster analysis program employed, the number of sample site and polygon pairs used was limited to this number. Twelve tree species abundance measures common to both the databases were arrayed with 400 objects in each matrix analysis (Figure 7). The abundance of each tree species for each object was calculated from the formula:

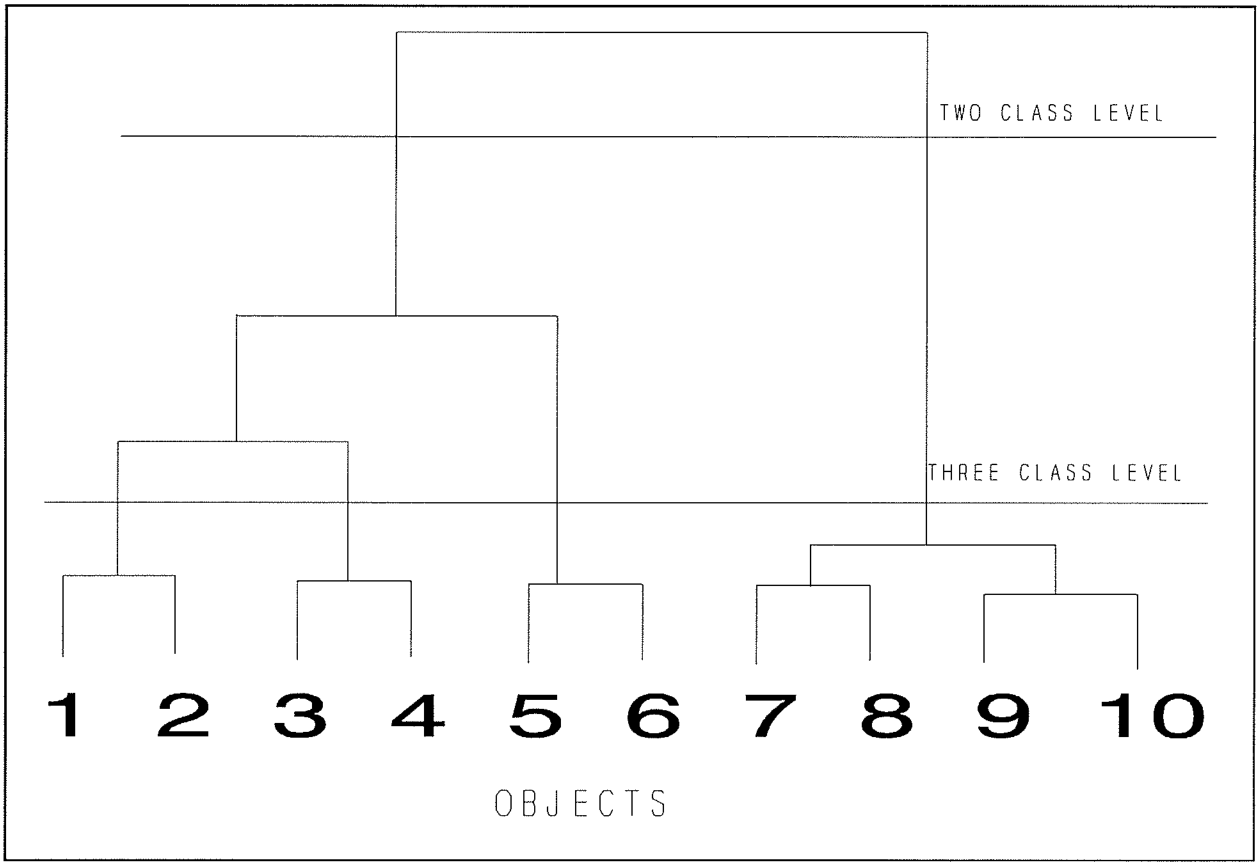
$$\frac{\text{(Tree Abundance * Tree Crown Closure)}}{100}$$

Figure 7: Example tree species abundance by sample site or polygon matrix.

	SPECIES											
OBJECT	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
POINT OR POLYGON												
. . .												

Each cluster analysis generated two products that were used to define different classes of objects. First, a sequence of objects was created for both the 400 sample sites and the 400 polygons examined. Second, a dendogram was created that associated these sequences of objects into a hierarchy of groups; with 400 separate objects at one extreme and one single group of objects at the other extreme (Figure 8). The procedure for grouping objects was based both on the objects' distance from one another in a mathematically created species space as defined by the association matrix, and on the algorithm used to join like objects (Podani 1993). The final results of the cluster analyses were two sequences of objects (sample sites and polygons) that had each been sorted into 20 class, 15 class, and 10 class classification levels. The dendograms for the Vegetation Study and Forest Cover Map classifications are illustrated in Appendix 3 and Appendix 4 respectively.

Figure 8: Example Dendogram



3.6 CORRELATION OF COMMUNITY CLASSIFICATIONS

A Chi squared test of independence (Ott 1988) was used both to assist in matching the classes generated from the separate cluster analyses of the RMNP Vegetation Classification and Stand Origin Study sample sites and their associated Forest Cover Map database polygons, and to determine an appropriate level of classification. The criteria used to select an appropriate level of classification were the greatest amount of community description detail possible (greatest number of classes within a classification), balanced against the highest correlation between sample site and associated polygon descriptions obtainable (greatest number of matched classes between classifications).

The sample site and associated polygon classifications were compared in a contingency table at the 20, 15, and 10 class levels. The Chi squared test statistic for each classification level comparison was standardized by the tabulated value of Chi squared at the value of alpha = 0.0001. This standardization permitted the comparison of test statistic values calculated for different degrees of freedom. The preliminary test of agreement allowed for a characterization of the agreement between the separate classifications of the sample sites and their associated polygons based on tree species abundance. Further, the Chi squared contingency table provided a means to visualize the correspondence of classes between the sample site and associated polygon classifications at different classification levels.

3.7 COMMUNITY DESCRIPTION AND EVALUATION

Final community classifications and descriptions for the 400 RMNP Vegetation Classification and Stand Origin Study sample sites and associated provincial Forest Cover Map database polygons were created and evaluated after the selection of an appropriate level of classification. The spatial correlation of the two databases permitted a crossclassification determination of the accuracy of the polygon classification with the sample site classification. The latter classification was assumed to be more accurate because the RMNP Vegetation Classification and Stand Origin Study's tree species descriptions and locations had been ground truthed.

The classes for the sample sites and associated polygons were described by both the average abundance values, and the range of these values for each tree species present in a particular class. The class descriptions, along with preliminary class matches found in the Chi squared contingency table, were used to match like class descriptions between the two separate classifications.

The degree of agreement between the matched sample site and associated polygon classifications (crossclassification) was examined in an error matrix. Cohens Coefficient of Agreement (Kappa - K) was used to quantify the degree of agreement for the entire crossclassification (Cohen 1960). The formula used was:

$$K = (d - q) / (N - q)$$

where d = Sum of objects which agree
q = Sum of objects expected for chance agreement
$q = \text{Sum } n_{row(i)} * n_{col(j)} / N$

Cohen's Kappa "measures the relationship beyond chance agreement of crossclassification in an error matrix" (Rosenfield and Fitzpatrick-Lins 1986). Cohen's Conditional Coefficient of Agreement (K_i) was used to further describe the degree of agreement between individual classes for those objects which had been placed in the i^{th} specific category (Bishop et al 1975). The formula used was:

$$K_1 = \frac{(N * d_{(i)}) - (n_{row(i)} * n_{col(j)})}{(N * n_{row(i)}) - (n_{row(i)} * n_{col(j)})}$$

The test values of Cohen's Kappa can range from 0,to 1; 0 indicating lowest level of agreement and 1 the highest. Acceptable levels of Kappa are approximately 0.85 and above.

3.8 COMMUNITY MAPPING

As a case study, a thematic map of the forest communities in the 2017 township range block was produced from the original provincial Forest Cover Map database. The thematic map was created by the reclassification of the original polygons into communities based on the classification produced through the cluster analysis of 400 park-wide tree species communities. Parameters for the reclassification of the block were based on the range of abundance values for tree species found in the 15 individual classes of the park-wide Forest Cover Map database polygon classification. The parameters were then used to reclassify the 2017 township range block from the original Forest Cover Map database LND_ID classification, to the newly synthesised forest community classification. Non-forested communities were excluded from the reclassification.

4.0 CHAPTER 4: RESULTS OF THE CASE STUDY

4.1 INTRODUCTION

The results of the case study were examined from two perspectives. The first examined the intermediary steps of the methodological process used to create the final product of the case study. In an evaluation of methodologies, the process is as important as the product. From a second perspective, the final product of the case study, a thematic map of 15 generalized tree species communities, was examined for its utility to Park managers.

4.2 COMMUNITY CLASSIFICATION

The classification based on the tree species abundance of the 400 Riding Mountain National Park (RMNP) Vegetation Classification and Stand Origin Study sample sites and associated provincial Forest Cover Map database polygons displayed a clear separation between the average values of grouped objects at the 15 class classification level (Appendix 5 and 6). The average values and range of values for the tree species abundances of each class of objects at the 15 class level are summarized in Table 7 for the Vegetation Study.

Table 7: **Summary of average abundance values and range of values for the 12 tree species common to the RMNP Vegetation Classification Stand Origin Study at the 15 class level of a cluster analysis**

CLUS	VEGETATION STUDY		
	SPECIES	MEAN	RANGE
1	ASP	75	100-58
	POP	2	27-0
	WSP	2	19-0
	MAP	1	16-0
2	ASP	45	70-30
	WSP	19	60-0
	POP	2	14-0
	BIR	1	7-0
3	ASP	51	60-42
	BIR	7	43-0
	POP	2	7-0
	WSP	2	7-0
	ASH	1	14-0
	MAP	1	14-0
4	ASP	40	53-18
	POP	21	45-12
	WSP	3	16-0
	ASH	1	16-0
	BIR	1	8-0
5	BSP	63	100-14
	TAM	12	72-0
	ASP	4	33-0
	PIN	3	32-0
	FIR	1	27-0
6	BIR	9	15-0
	WSP	6	18-0
	POP	6	20-0
	ASP	5	12-0
	ASH	1	6-0
	FIR	1	10-0
7	WSP	7	12-0
	POP	2	8-0
	BIR	2	5-0
	ASH	1	5-0

CLUS	VEGETATION STUDY		
	SPECIES	MEAN	RANGE
8	FIR WSP BIR ASP PIN ASH	46 9 8 1 1 1	81-30 24-0 12-6 7-0 6-0 7-0
9	PIN WSP ASP POP	43 11 7 3	90-21 35-0 21-0 9-0
10	BIR ASP POP WSP ASH	29 12 10 1 1	64-0 30-20 36-0 8-0 16-0
11	ASP OAK BIR POP MAP ELM BIR	18 16 11 5 3 2 2	49-0 90-0 35-0 25-0 3-0 2-0 2-0
12	ASP WSP OP BIR PIN	20 8 3 2 1	30-12 24-0 12-0 21-0 12-0
13	POP ASP WSP BIR	45 6 4 1	80-14 27-0 24-0 7-0
14	WSP ASP POP BIR	61 9 3 1	100-42 28-0 16-0 9-0
15	WSP POP ASP BSP BIR FIR	29 8 5 4 3 2	48-12 30-0 21-0 48-0 30-0 14-0

A better resolution of tree species associations would have been obtained if a twenty class classification level had been employed. The 20 class classification of the RMNP Vegetation Classification and Stand Origin Study sample sites demonstrated a clean separation of objects similar to that found at the 15 class level. For example, a specific community observed in the field, such as a tamarack stand, could be isolated at the 20 class classification level. At the 15 class level, this same stand was obscured within a general black spruce tree species class. The Forest Cover Map database's 15 class classification appeared to be capable of a similar subdivision, but with an unknown relationship to actual field conditions. Consequently, the separation of objects into a classification of 15 classes for the purposes of this case study appears arbitrary in relation to actual field conditions when based on the individual cluster analysis alone.

4.3 COMMUNITY CORRELATION

The class correspondence between the two databases showed a significant Chi Squared test statistic at the alpha = 0.001 level. When the number of classes compared was decreased from the 20, to the 10 class level, the Chi squared test of independence showed a decrease in the degree of independence between the RMNP Vegetation Classification and Stand Origin

Study's classifications and the provincial Forest Cover Map database's classifications (Table 8).

Table 8: Chi squared test of independence values (alpha=0.001) for point and polygon objects classified at the 20, 15, and 10 class level

GROUP LEVEL	X2 TEST VALUE	X2 TABLE VALUE a=.001
20	653.96	523.17
15	461.70	295.96
10	328.79	149.45

A general decrease in the degree of independence of the two classifications would be expected as the 400 objects were grouped into larger and larger classes. At the 20 class level the significant Chi squared value was not much greater than the table Chi squared value with a significance of alpha = 0.001. This degree of dependence between the two databases' tree species attributes was low considering that both sets of attributes measure tree species abundance for the same geographic locations. A visual examination of the paired tree species descriptions for common locations in both databases also showed a generally poor correspondence of tree species abundance descriptions.

The higher independence test statistics obtained when a larger number of classes were used to classify the paired RMNP Vegetation Classification and Stand Origin Study sample sites and Forest Cover Map database polygons indicated that a smaller number of classes should be used to describe the case study's tree species communities. The 15 class classification was chosen as a compromise between a higher level of class agreement, and the loss of community description detail that would have occurred if a smaller number of classes had been used for the final community description. The relatively poor agreement of tree species abundance attributes between the two classifications precluded the examination of further relationships between a classification based on all the species abundances recorded in the RMNP Vegetation Classification and Stand Origin Study, and a classification based only on the tree species abundances found in the Forest Cover Map database.

4.4 COMMUNITY DESCRIPTION AND EVALUATION

The RMNP Vegetation Classification and Stand Origin Study classes where matched to the Forest Cover Map classes both through the correspondence in a Chi squared contingency table, and the similarities in their average tree species abundance values (Table 9).

Table 9: Matched tree species association classes between the RMNP Vegetation Classification and Stand Origin Study and provincial Forest Cover Map

VEGETATION STUDY AVERAGE	FOREST COVER MAP	CLASS
75ASP/2POP/2WSP/1BIR	78ASP/5POP/2WSP	1
45ASP/19WSP/2POP/1BIR	57ASP/25WSP/4BSP	2
51ASP/2BIR/2WSP/1ASH/1FIR	65ASP/3OAK/3ASH/3BIR 2WSP	3
40ASP/21POP/3WSP/1ASH/1BIR	49ASP/15POP/10WSP/5BIR 3ASH/3FIR	4
64BSP/12TAM/4ASP/3PIN/1FIR	64BSP/5TAM/2ASP	5
9BIR/6POP/6WSP/5ASP/1ASH 1FIR	NO MATCH	6
7WSP/2POP/2BIR/1ASP	30WSP/24ASP/18FIR	7
46FIR/8BIR/9WSP/1POP/1PIN 1ASP	NO MATCH	8
43PIN/11WSP/7ASP/3POP	NO MATCH	9
29BIR/12ASP/10POP/1WSP 1ASH	NO MATCH	10
18ASP/10OAK/11ASH/5POP 3MAP/2ELM/2BIR	NO MATCH	11
20ASP/8WSP/3POP/2MAP/1PIN	22ASP/12WSP/1FIR	12
45POP/6ASP/4WSP/1BIR	NO MATCH	13
61WSP/9ASP/3POP/1BIR	53WSP/24ASP/5BSP/1POP	14
29WSP/8POP/5ASP/3BIR/2FIR	20WSP/12ASP/5BSP/1FIR	15
NO MATCH	64ASP/14WSP/7FIR	16
NO MATCH	41ASP/10WSP/5BSP/4FIR	17
NO MATCH	46ASP/16MAP/11BIR/8POP 2ASH	18
NO MATCH	32ASP/7POP/4FIR/2WSP 1BSP/1BIR	19
NO MATCH	35ASP/12BIR/9WSP/2BIR 2FIR/1OAK	20
NO MATCH	33WSP/25ASP/16BSP	21

A number of classes did not match well in either the Chi squared contingency table, or the species composition and abundance descriptions. These classes were not matched across the classifications because it was assumed that they were unique vegetation associations represented in only one of the two database classifications. The most notable unique vegetation associations were: 1) the balsam fir class (46FIR/8BIR/9WSP/1POP/1PIN/1ASP); 2) the jack pine class (43/PIN/11WSP/7ASP/3POP); 3) the white birch class (29BIR/12ASP/10POP/1WSP/1ASH); and 4) the hardwood class (18ASP/10OAK/11ASH/5POP/3MAP/2ELM/2BIR). Although these classes are significant tree species communities found throughout RMNP (Parks Canada 1984)and are also represented in the RMNP Vegetation Classification and Stand Origin Study database classification, they were not classified within the Forest Cover Map Database. This omission indicated a serious deficiency with the latter classification.

The matched classifications' overall degree of agreement as measured by Cohen's Coefficient of Agreement was a low value of K = 0.14. The individual class matches, as measured by the Conditional Coefficient of Agreement between classes, is represented in Table 10.

Table 10: The Conditional Coefficient of Agreement between matched classes of RMNP Vegetation Classification and Stand Origin Study and Forest Cover Map database classifications

MATCHED CLASSES	CONDITIONAL COEFFICIENT
1	0.27
2	0.21
3	0.09
4	0.06
5	0.67
7	0.02
14	0.39
15	0.16
6, 8-13, 16-21	0.16

The Conditional Coefficients of Agreement were uniformly low except for two matches: 1) Class 5 (64BSP/12TAM/4ASP/3PIN/1FIR) - (64/BSP/5TAM/2ASP); and 2) Class 14 (61WSP/9ASP/3POP/2MAP/1PIN) - (53WSP/24ASP/5BSP/1POP). These classes describe uniform coniferous communities easily identified on air photos (Author, personal observation).

4.5 COMMUNITY MAPPING

A 14 class thematic map of the forest species communities of township range block 2017 is presented in Figure 9. An area analysis of the individual classes is presented in Table 11.

Figure 9: A thematic map of the 2017 township range block within RMNP representing non-forested landscape features, classified tree species communities, and unclassified tree species communities

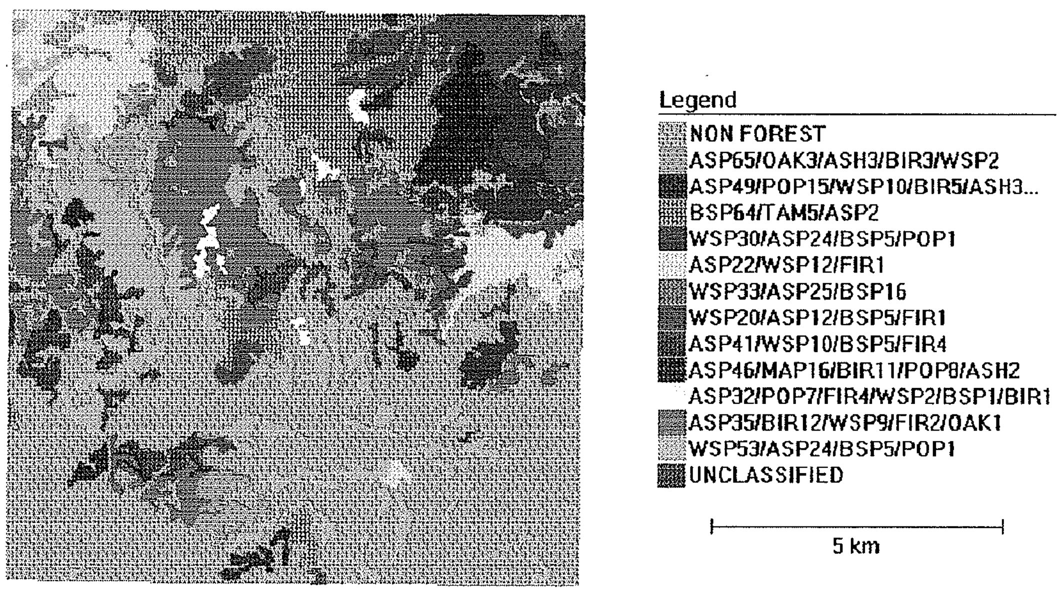


Table 11: An area analysis of the 14 classes constituting the non- forested landscape features, classified tree species communities, and unclassified tree species communities of 2017 township range block of RMNP

CLASS	LEGEND	AREA %	AREA CUMM
1	NON FOREST	45.85	45.85
4	ASP65/OAK3/ASH3/BIR3/WSP2	2.15	47.99
5	ASP49/POP15/WSP10/BIR5/ASH3.	0.70	48.69
6	BSP64/TAM5/ASP2/	7.96	56.66
7	WSP30/ASP24/BSP5/POP1	3.28	59.93
8	ASP22/WSP12/FIR1	5.84	65.77
9	WSP33/ASP25/BSP16	0.18	65.95
10	WSP20/ASP12/BSP5/FIR	6.68	72.63
12	ASP41/WSP10/BSP5/FIR4	0.79	73.41
13	ASP/46/MAP16/BIR11/POP8/ASH2	2.59	76.00
14	ASP32/POP7/FIR4/WSP2/BSP1 BIR1	0.66	76.66
15	ASP35/BIR12/WSP9/FIR2/OAK1	9.61	86.26
16	WSP53/ASP24/BSP5/POP1	9.97	96.24
17	UNCLASSIFIED	3.76	100.00

Of the 338 polygons that were defined in township range block 2017, 167 were classified as non-forested These 167 polygons contained landscape features, such as water, grasslands and bogs. A total of 23 polygons did not fit into the parameters extracted from the 400 Forest Cover Map database polygon classification, and were therefore not reclassified in the case study. A total of 148 polygons were reclassified to the 15 class level established in the Forest Cover Map database polygon classification. Twelve of the 15 classes that were identified on the original 15 class classification created through cluster analysis. The species associations that are illustrated in a thematic map format in Figure 9 are also represented as a thematic map layer within the InterTydac Spatial Analyis System GIS (1993).

5.0 CHAPTER 5.0: DISCUSSION AND RECOMMENDATIONS

5.1 INTRODUCTION

The primary objective of this study was to create and evaluate a methodological framework for the community description and thematic mapping of the terrestrial vegetation of Riding Mountain National Park (RMNP). The problem statement in the introduction stated that RMNP managers required a current description of RMNP terrestrial vegetation that would meet the needs of both a functional ecosystem management approach, and an integrated regional ecosystem information system that the Canadian Parks Service (CPS) is currently in the process of adopting. Previous Park vegetation surveys and maps had not meet these management needs; nor were they being meet by either the preliminary results of the RMNP Vegetation Classification and Stand Origin Study or the provincial Forest Cover Map databases. Separately, each of these databases provided only a portion of the vegetation information required by RMNP managers. A synthesis of the two current databases did, however, show the potential to provide the species composition detail, and the spatial relationships of terrestrial vegetation communities necessary for ecosystem modelling, planning and monitoring.

The primary objective of the study was partially met by the creation and evaluation of a methodological framework for the community description and mapping of the tree species communities of RMNP on a Geographic Information System (GIS). However, the methodology employed in the case study did not provide the level of composition detail required by RMNP managers. Deficiencies within the methodological approach and databases used in the case study were identified as a possible cause of this problem. Consequently, this chapter both discusses the results of the case study, and makes recommendation regarding the limitations, future applications and alternatives to the methodological approach presented.

5.2 TERRESTRIAL VEGETATION DATABASE CREATION

The methodology used in the case study produced two primary databases linked by location. The first of these databases contained measures of environmental factors, and descriptions of the terrestrial vegetation composition and abundance at 1378 RMNP Vegetation Classification and Stand Origin Study sample site locations. These data have been processed into two related database programs. The relational database program dBASE IV (Ashton-Tate 1991) will allow RMNP managers to filter and manipulate vegetation data in an automated tabular format. The spatial data base management system Spatial Analysis Systems (SPANS) (Intera-Tydac 1993) will allow RMNP managers to examine and model data relationships in geographic space.

The second database was produced from the provincial Forest

Cover Map tree species association polygon definitions and abundance attributes. This database has also been processed in the dBase IV and SPANS programs, and can be analyzed in the same fashion as the RMNP Vegetation Classification and Stand Origin Study database. In addition, the use of common attribute fields for both databases allows RMNP managers to compare other aspects of the two databases in order to more accurately describe the terrestrial vegetation of RMNP.

5.3 COMMUNITY CLASSIFICATION

The separate community classifications performed on the common RMNP Vegetation Study and Forest Cover Map database tree species abundance attributes demonstrated the utility of a hierarchal cluster analysis for classifying these large databases. A preliminary examination of species compositions for black spruce and tamarack communities identified by classification and observation in the field indicated a realistic separation of communities by the cluster analysis routines used in the case study. This observation was not verified and requires further investigation of the relationship between the database classification and actual field conditions. The classification methodology used in the case study does provide a means to examine the relationship between class size, composition and ecological properties of vegetation communities in the field.

5.4 COMMUNITY CORRESPONDENCE

The correspondence of community compositions across the separate database classifications for the common tree species attributes of the two databases was poor at the 15 class level. This correspondence could be improved by using a smaller number of classes. However, a large scale 5, or 10 class tree species map of the entire RMNP landscape does not meet the information requirements of RMNP managers. The utility of employing fewer classes is also contradicted by the detailed separation of communities that is exhibited in the RMNP Vegetation Classification and Stand Origin Study's classification at the 20 class level. This detailed separation is supported by a preliminary examination of the composition of communities within the classification and by field observations.

The case study assumes that the use of Global Positioning System location equipment and ground level observations by the RMNP Vegetation Classification and Stand Origin Study makes this database more accurate than its Forest Cover Map counterpart. Location errors within the Forest Cover Map database would result in a lack of correspondence of individual polygon tree species descriptions with the RMNP Vegetation Classification and Stand Origin Study sample site descriptions. This would not, however, account for the general lack of correspondence in class descriptions at the 20, 15 and 10 class level. A 400 object random sample of sample sites and associated polygons should provide a suitable data set for a representative classification for both databases. This assumption can be verified by repeating the cluster analysis on a series of randomly selected samples.

Beyond the refined classes that could be produced in a repetition of cluster analysis methods, there exists a general lack of correspondence between the tree species of the two databases. There is an obvious lack of correspondence at a 15 class level with significant balsam fir and jack pine communities appearing in the RMNP Vegetation Classification and Stand Origin Study classification, and not in the Forest Cover Map database classification. The best correspondence between the two classifications at the 15 class level was between black spruce and white spruce dominated classes. These communities are readily identifiable on air photos of RMNP. In contrast, the heterogenous coniferous and deciduous mixed communities are not easily identified. This observation suggests that the interpretation of air photos used to produce the Manitoba Forest Cover Map database did not allow for an accurate evaluation of all the vegetation types found in RMNP.

Potential inaccuracies in the subjective interpretation of air photos to describe and define the plant species composition and abundance in RMNP may indicate that an alternative remote sensing technology is needed. The production of a large number of accurate ground truthed control points in the Vegetation Study provides a means of classifying spectral reflectance values measured by the Landsat and Spot satellite series. This method may provide a more accurate measure of broader vegetation communities within RMNP.

The assumption that the RMNP Vegetation Study database is the more accurate of the two databases must, however, be examined in the light of the actual application of the methodology of this case study. A good deal of error correction was required prior to the use of the Vegetation Study database. Location errors were common along with inconsistencies in the recording of tree species abundance at the field and data input level. A number of different datums were used in recording locations in the field. These datums did not always agree with the North American Datum 27 used to locate the Forest Cover Map database. This type of error can offset locations by approximately 127 meters. Error correction conducted during the case study was not exhaustive, therefore some errors in the RMNP Vegetation Classification and Stand Origin database could potentially have been missed.

The scales at which the two databases were observed must also be taken into consideration. Air photos that have been interpreted at a scale of 1:15,840 may describe vegetation associations very differently than ground observations. The Vegetation Study's description of general vegetation species abundances over a large observed area, rather than a limited quadrat, makes this database more subjective as well as more general. These factors will effect the correspondence between air photo interpreted vegetation associations and ground observed associations.

5.5 COMMUNITY MAPPING

The methodological framework employed in the case study was used to produce a 14 class thematic map of the tree species associations of township range block 2017. The map's classes were based on Forest Cover Map database tree species attributes whose accuracy of classification had been quantified through comparison with RMNP Vegetation Classification and Stand Origin Study ground truthed data. The low accuracy of the Forest Cover Map database classification necessarily carried over into thematic map representation of the classes of that classification. Despite this error, the creation of a thematic map served to demonstrate the utility of a reclassification of tree species associations based on parameters taken from a park-wide classification. The reclassification parameters, based on the range of tree species abundance values described in individual classes of the Forest Cover Map database, reclassified 148 of the 171 tree species associations within township range block 2017. Twenty three tree species associations fell outside of the parameters set within the Forest Cover Map classification. The parameters could be improved by re-sampling from the original Forest Cover Map database to refine the reclassification parameters by making them more representative of the Park as a whole.

The methodological process employed to produce a thematic map for a single township range block of RMNP could be performed on the entire land area of the Park through an iteration of this methodological process for each of the 40 township range blocks contained in the Forest Cover Map database. The individual thematic maps and attributes could then be joined together in the SPANS GIS. The resulting composite 17 class thematic map would represent the tree species communities of RMNP at the level of error determined in the case study. The non-forested landscape features could also be included in the reclassification of the original Forest Cover Map database, but with an unknown degree of accuracy. Another approach to representing the terrestrial communities of RMNP would be to reclassify the polygons of the Forest Cover Map database using community classes determined by a classification of all the plant species sampled in the RMNP Vegetation Classification and Stand Origin Study. This method would not allow for an extensive representation of the vegetation communities throughout RMNP. It would, however, describe a greater level of species composition detail with greater accuracies than allowed by a reclassification based on the original Forest Cover Map database's tree species data.

5.6 CONCLUSIONS AND RECOMMENDATIONS

The case study's approach to the community classification and mapping of one component of the vegetation of RMNP has demonstrated the utility of a number of methodologies. The preliminary classifications of the large databases used in the case study were made possible through the use of cluster analysis routines provided in SYN-TAX 5.0 (Podani 1993). The thematic mapping of tree species communities produced by the cluster analysis was readily accomplished once reclassification parameters had been defined. The final thematic product is a dynamic information layer that will provide Park managers with a functional management tool. The benefits of this tool are fourfold. First, the information layer that was produced can be used to model predicted changes in ecosystem components through management actions, or human and natural effects. Second, it will be able to incorporate future information changes caused by actual variations in the environment. Third, the visual format and strong analysis capabilities of the infomation in a GIS layer will make information sharing with stakeholders simple and effective. Last, the methodological approach used to create this tool can be applied to other ecological components in RMNP, in the surrounding regional ecosystem, and throughout the CPS.

The potential utility of the methodologies employed in this case study must be tempered with the actual problems encountered during their application. The control of error is important in the extended process of large databases analysis. This was evident in the original level of recording error found in the recording and processing of field observations in The RMNP Vegetation Study. Potential interpretation error in the original provincial Forest Cover Map database has also reduced its utility to Park managers. Finally, unquantified error, in the translation of various software formats for the storage and manipulation of data will add a further unknown degree of error to these processes.

The recommendations that follow are a summary of the alternatives presented in the main body of the discussion. They are examined from the perspective of their utility to RMNP managers in providing a detailed terrestrial vegetation map of the Park.

1) Park managers should conduct a thorough error check of the RMNP Vegetation Classification and Stand Origin Study database. Errors to be checked should include Universal Transverse Mercator attributes and species abundance attributes. If serious errors are detected and corrected in the database, then a reapplication of the methodologies used in this case study should improve the correspondence between the RMNP Vegetation Classification and Stand Origin Study database and provincial Forest Cover Map database.

2) It is possible that an error check of the RMNP Vegetation Classification and Stand Origin Study database will not improve its correspondence with the Forest Cover Map database. Accepting the Vegetation Study database as an accurate representation of the terrestrial vegetation of RMNP will open further avenues for the spacial representation of that data. An alternative remote

sensing technology could be used with the RMNP Vegetation Classification and Stand Origin Study data as a source of ground descriptions. An objective characterization of terrestrial vegetation by the spectral reflectance levels collected by satellites could be described by the ground truthed points. The objective characterizations of this method could improve on the subjective methods used in the provincial Forest Cover Map photo interpretation. Although the discrimination of different tree species and understorey species is not perfect for remotely sensed characterizations, this avenue should provide RMNP managers with an alternative for producing an accurate thematic map of terrestrial vegetation.

3) As a last alternative RMNP mangers could use the thematic maps generated by the methodological approach in this case study, while recognizing the limitations of the information due to its inaccuracies. A classification using a smaller number of classes would improve the accuracy of the final thematic map produced using the case study methodologies, but with a loss of detail required by Park managers.

4) The classification of the Vegetation Study data using cluster analysis should be further examined beyond the 10, 15, and 20 class levels used in this case study. Preliminary observations verifying some of the 20 class communities in the field should be examined for all classes.

6.0 REFERENCES CITED

Austin M.P. 1991. Vegetation: data collection and analysis. in: Nature conservation: cost effective biological surveys and data analysis. C.R. Margules, and M.P. Austin (eds). Australia CSIRO, East Melbourne. pp 37-41.

Bailey, R.G., R.D. Pfister, and J.H. Henderson. 1978. Nature of land and resource classification. Journal of Forestry 76 (10): 650-655.

Bishop, Y.M.M., S.E. Feinberg, and P.W. Holland. 1975. Discrete Multivariate Analysis: Theory and Practise. The MIT Press, Cambridge, Mass.

Braun-Blanquet, J. 1932. Plant Sociology. G.D. Fuller, and H.S. Conard (translators). McGraw-Hill Book Co, New York.

Canadian Parks Service. 1990. National Parks System Plan. Environment Canada. Ottawa.

Clements, F.E. 1916. Plant Succession. An Analysis of the Development of Vegetation. Carnagie Institute, Washington, Publication 242, Washington.

Cohen, J. 1960. A coefficient of agreement of nominal scales. Educational and Psychological Measurment 20 (1):37-46.

Dansereau, P. 1972. Biogeographie dynamique du Quebec. in: Etudies sur la geographie du Canada: Quebec. F. Grenier (ed). University of Toronto Press, Toronto. pp 74-110.

Davis, L. S., and J. A. Henderson. 1976. A classification and information system for management of wildland ecosystems: The conceptual framework. Utah State University, Logan.

dBase IV - Ashton-Tate. 1990. Ashton-Tate Corporation. Torrance, California.

Douglas, G. W. 1974. A Reconnaissance Survey of the Vegetation of Klune National Park. Environment Canada, Edmonton.

Environment Canada. 1992A. Strategic framework to sustain the integrity of ecosystems. Environment Canada. Ottawa.

---. 1992B. Science in Decision Making. Environment Canada. Winnipeg.

Environment Canada. 1990A. Environment Canada Canadian Parks Service Strategic Plan. Environment Canada, Ottawa.

---. 1990B. State of the Parks - 1990 Report. Environment Canada. Ottawa.

---. 1987. Riding Mountain National Park Management Plan. Environment Canada. Winnipeg.

Forest Cover Maps - Manitoba Forestry Branch. 1993. Government of Manitoba. Winnipeg.

Gauch, H.G., and R.H. Whittaker. 1981. Hierarchical classification of community data. Journal of Ecology 69:135-52.

Gauthier David A., and KatherineGutiw. 1990. A pilot test of Prince Albert National Park Biophysical Resource Data within the SPANS Geographical Information System. Canadian Parks Service, Waskiseu.

Gleason, H.A. 1937. The individualistic concept of the plant association. Bulletin of the Torrey Botanical Club 43:92-110.

Government of Canada. 1985. National Parks Act. Canada.

Grumbine, R.E. 1990. Viable population, reserve size, and Federal lands management: a critique. Conservation Biology 4:127-134.

Hodges, J. A. 1976. Criteria for mapping vegetation in Canada's National Parks. Parks Canada, Ottawa.

Holling, C.S. (ed). 1978. Adaptive Environmental Assessment and Management. John Wiley and Sons, Toronto.

Jensen, J.R. 1986. Introductory Digital Image Processing: A Remote Sensing Perspective. Prentice-Hall, Englewood Cliffs. pp 225-229.

Karr, J.R., and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Kent, M., and P. Coker 1992. Vegetation Description and Analysis. Belhaven Press, London. 363 p.

Lombard North Group. 1976. Riding Mountain National Park Biophysical Inventory. Natural Resource Conservation Section, Parks Canada, Prairie Region. Winnipeg.

Lopoukhine, N. 1988. Vegetation management in National Parks: Workshop Proceedings. Environment Canada, Ottawa.

Ott, L. 1988. An Introduction to Statistical Methods and Data Analysis. Third ed. PWS-Kent Publishing Company, Boston.

Parks Canada. 1984. Riding Mountain National Park Resource Description and Analysis. Natural Resource Conservation Section, Parks Canada, Prairie Region. Winnipeg, Manitoba.

---. 1980. Ecological inventories in National Parks. Parks Canada, Ottawa.

---. 1978. Natural Resource Management Process. Environment Canada. Ottawa.

Pielou, E.C. 1984. The Interpretation of Ecological Data: A Primer on Classification and Ordination. New York, Wiley.

Raunkaier, C. 1932. The Life Forms of Plants and Statistical Plant Geography. Clarendon Press, Oxford.

REMS Research Ltd. 1991. Vegetation Management Framework for the Canadian Parks Service. Environment Canada. Fredricton, N.B.

Rosenfield, G.H., and K. Fitzpatrick-Lins. 1986. A coefficient of agreement as a measure of thematic classification accuracy. Photogrammetric Engineering and Remote Sensing 52 (2):223-227.

Rowe, J.S. 1961. The level of integration concept and ecology. Ecology 42:420-427.

Scott, M.J., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, J.T.C. Edwards, J. Ulliman, and G.R. Wright. January 1993. Gap analysis: A geographic approach to protection of biological diversity. Wildlife Monographs 57 (123).

SPANS-InterTydac. 1993. 5.2. InteraTydac, Ottawa.

Star, J., and J. Estes 1992. Geographic Information Systems: an Introduction. Prentice Hall, Enlewood Cliffs, New Jersey. p 3.

Strong, W.L., E.T. Oswald, and D. J. Downing. 1990. Canada Committee on Ecological Land Classification. The Canadian vegetation classification system. Environment Canada. Ottawa.

SYN-TAX 5 - Podani, J. 1993. 5. UNIDO. Trieste Italy.

Toews, C. 1988. Riding Mountain National Park Conservation Plan. Environment Canada. Wasagaming.

Trass, H., and N. Malmer. 1978. North European Approaches to Classification. in: Classification of Plant Communities. R.H. Whittaker (ed). W. Junk Publishers, The Hague, Boston.

Vanderschuit, W. 1991. The Riding Mountain National Park Vegetation Classification and Stand Origin Study. Canadian Parks Service. Wasagaming.

Viktorov, S.V. 1964. A Short Guide to Geo-botanical Surveying. MacMillan Co., New York.

Whittaker. J.R. 1962. Classification of plant communities. Botanical Review 28:1-239.

APPENDIX 1

ABBREVIATION	COMMON NAME	GENUS\SPECIES
TREE SPECIES		
FIR	Balsam Fir	Abies balsamea
MAP	Manitoba Maple	Acer negundo
BIR	White Birch	Betula papyrifera
ASH	Green Ash	Fraxinus pennsylvanica
TAM	Tamarack	Larix laricina
WSP	White Spruce	Picea glauca
BSP	Black Spruce	Picea mariana
PIN	Jack Pine	Pinus banksiana
POP	Balsam Poplar	Populus balsamifera
ASP	Trembling Aspen	Populus tremuloides
OAK	Bur Oak	Quercus macrocarpa
MTN	Mountain Ash	Sorbus decora
ELM	White Elm	Ulmus americana
SHRUB SPECIES		
MOM	Mountain Maple	Acer glabrum
ALD	Alder	Alnus spp.
SSK	Saskatoon Berry	Amelanchier alnifolia
BAR	Bearberry	Arctostaphylos uva-ursi
DWA	Dwarf Birch	Betula pumila
DOG	Dogwood	Cornus stolinifera
HAZ	Beaked Hazel	Corylus cornuta
HAW	Hawthorn	Crataegus chrysocarpa
JUN	Juniper	Juniperus communis
HEA	Heather	Ledum groenlandicum
CHE	Choke Cherry	Prunus virginiana
GOO	Goosberry	Ribes oxyacanthoides
CUR	Currant	Ribes spp.
ROS	Wild Rose	Rosa acicularis
WIL	Willow	Salix ssp.
BUF	Buffaloberry	Shepherdia canadensis
HON	Snowberry	Symphoricarpos ssp.
BLU	Blueberry	Vaccinium myrtilloides
VIB	Viburnum	Viburnum spp.

APPENDIX 1 (cont'd)

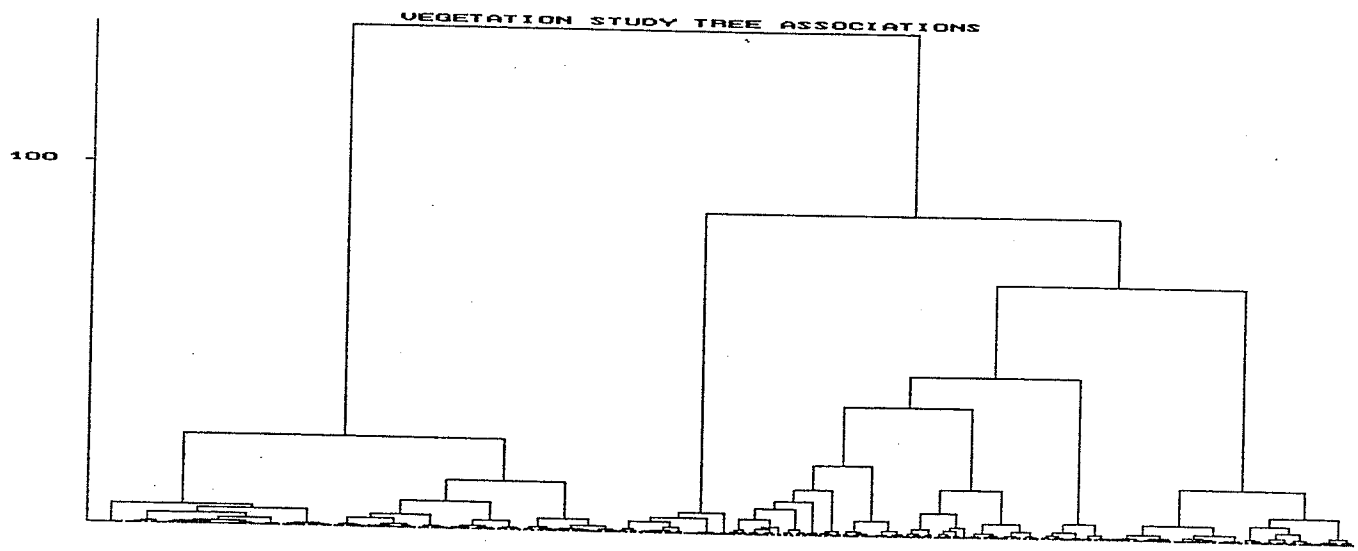
ABBREVIATION	COMMON NAME	GENUS\SPECIES
HERB SPECIES		
MOF	Feather Moss	Phenrozium spp.
MOS	Sphagnum Moss	Sphagnum spp.
YAR	Yarrow	Achillea millefolium
BAN	Baneberry	Actaea rubra
HYS	Giant Hysop	Agastache foeniculum
ANE	Anemone	Anemone spp.
COL	Columbine	Aquilegia canadensis
SAS	Wild Sarsaparilla	Aralia nudicaulis
AST	Aster	Aster spp.
MAR	Marsh Marigold	Caltha palustris
SEG	Sedge	Carex spp.
BUN	Bunchberry	Cornus canadensis
MUS	Mustard	Cruciferae
FRW	Fireweed	Epilobium angustifolium
EQU	Equisetum	Equisetum spp.
FES	Rough Fescue	Festuca campestris
STR	Strawberry	Fragaria virginiana
BED	Bedstraw	Galium spp.
AVE	Aven	Geum triflorum
GRS	Grass	Gramineae
COW	Cow Parsnip	Heracleum lanatum
TWN	Twinflower	Linnaea borealis
PUC	Hoary Puccoon	Lithospermum canescens
MOC	Club Moss	Lycopodium spp.
MIN	Mint	Mentha arvensis
BUK	Buckbean	Menyanthes trifoliata
BEL	Bluebell	Mertensia paniculata
ORC	Orchid	Orchidaceae
CLT	Colt's Foot	Petasites spp.
FRN	Fern	Polypodiaceae
POT	Potentilla	Potentilla spp.
PYR	Wintergreen	Pyrola spp.
BUT	Buttercup	Ranunculus spp.
POI	Poison Ivy	Rhus radicans
CLB	Cloudberry	Rubus chamaemorus
DEW	Dewberry	Rubus idallus
SNA	Sanicula	Sanicula marilandica
SOL	False Solomon's Seal	Smilacina stelabo
GLD	Goldenrod	Solidago spp.
DDL	Dandelion	Taraxacum officinale
RUE	Meadow-rue	Thalictrum venulosum
STA	Starflower	Trientalis borealis
CLO	Clover	Trifolium spp.
CAT	Cattail	Typha latifolia
VET	Vetch	Vicia spp.
VIO	Violet	Viola spp.

APPENDIX 2

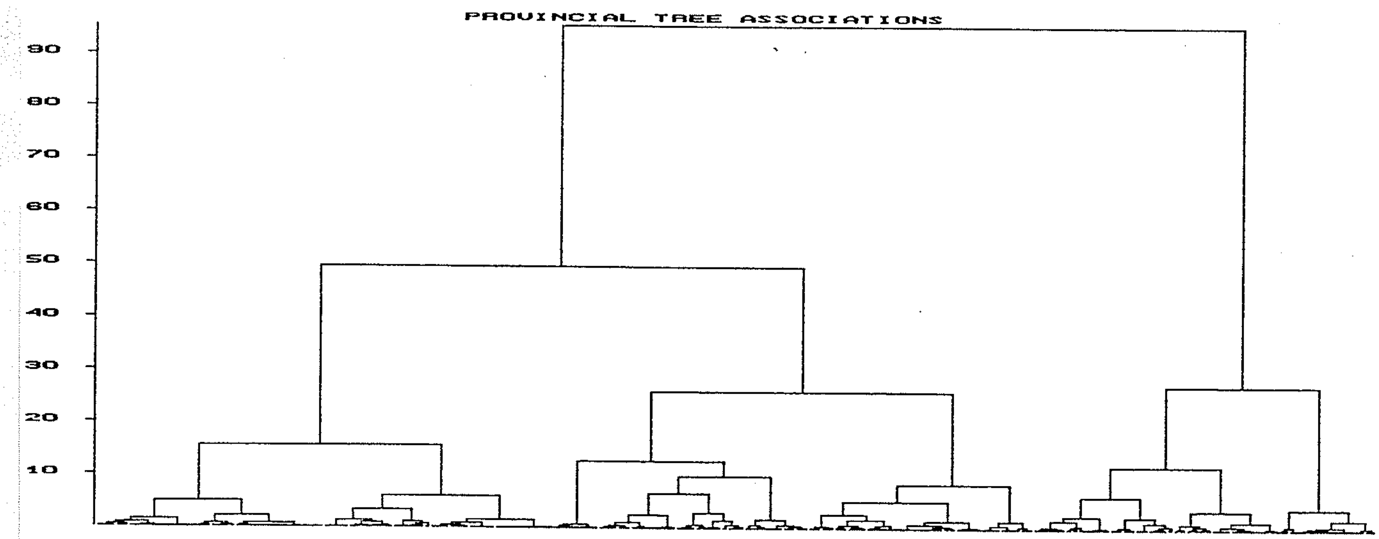
#	ATTRIBUTE FIELD	CONTENTS
1	ENTITY	Unique polygon identifier
2	SRC_ID	Source identification
3	AREA	Area of polygon (ha)
4	PERIMETER	Perimeter of polygon (m)
5	CLASS	Polygon classification as sequentially entered into GIS.
6	REC_NUM	Record number (1..n)
7	UNION_NUM	Polygon union number (1..n)
8*	UNION_ID	Polygon union ID (2..n+1)
9*	LND_ID	Land identification
10	OWN_ID	Land ownership
11	ST_ID	Stand identification
12	MU_ID	Management unit identification
13*	SPECIES	Tree species abundance
14*	COVERTYPE	Tree species community type and tree species crown closure
15	HECTARES	Polygon area (ha)
16	BALHECT	Not known
17	STDSET	Not known
18	YEAR_ORG	Year of origin

*Attribute fields used in analysis

APPENDIX 3: RMNP Vegetation Classification and Stand Origin Study Dendogram



APPENDIX 4: Provincial Forest Cover Map Dendogram



APPENDIX 5: RMNP Vegetation Classification and Stand Origin Study 15 Class Classification

CLU	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	100	0	0
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	100	0	0
1	0	0	0	0	0	0	0	0	0	100	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	9	0	0	0	0	0	0	81	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	0	0	0	0	72	8	0
1	0	9	0	9	0	0	0	0	0	72	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	0	0	0	8	0	0	0	72	0	0
1	0	0	8	0	0	0	0	0	0	72	0	0
1	0	0	0	18	0	0	0	0	0	63	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	8	0	8	0	64	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	0	4	0	0	0	0	0	67	0	0
1	0	0	0	0	0	9	0	0	0	81	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	0	7	0	0	0	0	0	63	0	0
1	0	0	0	0	0	8	0	0	0	72	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	16	0	0	0	0	0	0	64	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	0	0	0	10	0	0	0	90	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	0	0	0	0	69	1	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	9	0	0	9	81	0	0
1	0	0	0	0	0	8	0	0	0	72	0	0
1	0	0	0	0	0	18	0	0	0	72	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	0	0	0	0	0	0	0	81	9	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	0	0	0	17	0	0	0	68	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	0	0	0	0	72	8	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	19	0	0	0	76	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	14	0	0	0	0	0	0	56	0	0
1	0	0	16	0	0	0	0	0	0	64	0	0
1	0	0	9	0	0	0	0	0	0	81	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	9	0	0	0	0	0	0	77	0	0
1	0	0	0	0	0	8	0	8	0	64	0	0
1	0	0	0	9	0	0	0	0	0	81	0	0
1	0	0	0	0	0	0	0	0	0	80	0	0
1	0	0	8	0	0	0	0	0	0	72	0	0
1	0	0	0	0	0	0	0	0	0	70	0	0
1	0	0	0	0	0	9	0	0	0	81	0	0
1	0	0	0	0	0	0	0	0	9	81	0	0
1	0	0	0	0	0	0	0	0	20	80	0	0
1	0	0	0	0	0	0	0	0	8	72	0	0
1	0	0	0	0	0	0	0	0	8	72	0	0
1	0	0	0	0	0	0	0	0	7	63	0	0
1	0	0	0	0	0	0	0	0	8	72	0	0
1	0	0	0	0	0	0	0	0	10	90	0	0
1	0	0	0	0	0	0	0	0	9	81	0	0
1	0	0	0	0	0	0	0	0	8	72	0	0
1	0	0	0	0	0	0	0	0	9	81	0	0

APPENDIX 5: RMNP Vegetation Classification and Stand Origin Study 15 Class Classification (cont'd)

	CLU	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	1	0	0	0	0	0	0	0	0	7	63	0	0
	1	0	0	0	0	0	0	0	0	18	72	0	0
	1	0	0	0	0	0	0	0	0	16	64	0	0
	1	0	0	0	0	0	0	0	0	7	63	0	0
	1	0	0	0	0	0	0	0	0	27	63	0	0
	1	0	0	0	0	0	8	0	0	8	64	0	0
AVERAGE				1			2			2	75		
HIGH RANGE				16			19			27	100		
LOW RANGE				0			0			0	56		
	2	0	0	0	0	0	0	0	0	0	40	0	0
	2	0	0	0	0	0	21	0	0	0	49	0	0
	2	0	0	0	0	0	60	0	0	0	40	0	0
	2	0	0	0	0	0	12	0	0	0	48	0	0
	2	0	0	0	0	0	14	7	0	0	49	0	0
	2	0	0	0	0	0	54	0	0	0	36	0	0
	2	0	0	0	0	0	14	0	0	14	42	0	0
	2	0	0	0	0	0	18	0	0	0	42	0	0
	2	0	0	0	0	0	4	0	0	0	36	0	0
	2	0	0	6	0	0	12	0	0	0	42	0	0
	2	0	0	0	0	0	15	0	0	0	60	0	0
	2	0	0	5	0	0	5	0	0	0	40	0	0
	2	0	0	0	0	0	12	0	0	0	48	0	0
	2	0	0.	0	0	0	10	0	0	0	40	0	0
	2	0	0	0	0	0	30	0	0	0	30	0	0
	2	0	0	0	0	0	24	0	0	0	56	0	0
	2	0	0	0	0	0	28	0	0	0	42	0	0
	2	0	0	0	0	0	16	0	0	8	56	0	0
	2	0	0	0	0	0	12	0	0	12	36	0	0
	2	0	0	0	0	0	24	0	0	0	56	0	0
	2	0	0	0	0	0	12	0	0	0	48	0	0
	2	0	0	0	0	0	27	0	0	0	63	0	0
	2	0	0	0	0	0	12	0	0	6	42	0	0
	2	0	0	0	0	0	18	0	0	9	63	0	0
	2	0	0	7	0	0	13	0	0	0	46	0	0
	2	0	0	0	0	0	21	0	0	0	49	0	0
	2	0	0	0	0	0	24	0	0	0	36	0	0
	2	0	0	0	0	0	24	0	0	6	30	0	0
	2	0	0	0	0	0	21	0	0	0	49	0	0
	2	0	0	0	0	0	40	0	0	0	40	0	0
	2	0	0	0	0	0	0	0	0	0	40	0	0
	2	0	0	0	0	0	10	0	0	0	40	0	0
	2	0	0	0	0	0	12	0	0	6	42	0	0
	2	0	0	0	0	0	20	0	0	10	70	0	0
	2	0	0	0	0	0	40	0	0	0	40	0	0
	2	0	0	0	0	0	21	0	0	0	49	0	0
AVERAGE				1			19			2	45		
HIGH RANGE				7			60			14	70		
LOW RANGE				0			0			0	30		
	3	0	0	6	0	0	0	0	0	6	48	0	0
	3	0	0	21	0	0	0	0	0	0	49	0	0
	3	0	0	0	0	0	6	0	0	6	48	0	0
	3	0	0	7	0	0	7	0	0	0	56	0	0
	3	0	0	0	0	0	0	0	0	0	50	0	0
	3	0	0	0	0	0	0	0	0	0	60	0	0
	3	0	0	0	0	0	0	0	0	0	56	4	11
	3	0	0	0	0	0	6	0	0	0	54	0	0
	3	0	0	0	0	0	0	0	0	0	50	0	0
	3	0	0	6	0	0	0	0	0	0	54	0	0
	3	0	0	43	0	0	0	0	0	0	43	0	0
	3	0	14	0	0	0	4	0	0	4	49	0	0
	3	0	0	0	0	0	0	0	0	5	45	0	0
	3	0	0	0	0	0	0	0	0	0	50	0	0
	3	0	0	0	0	0	0	0	0	0	50	0	0
	3	0	0	7	0	0	0	0	0	7	56	0	0
	3	0	0	0	0	0	5	0	0	0	45	0	0
	3	0	0	21	0	0	0	0	0	0	49	0	0
	3	0	0	0	0	0	0	0	0	0	60	0	0

APPENDIX 5: RMNP Vegetation Classification and Stand Origin Study 15 Class Classification (cont'd)

	CLU	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	3	0	0	32	0	0	0	0	0	0	48	0	0
	3	0	0	0	0	0	6	0	0	0	54	0	0
	3	0	0	7	14	0	0	0	0	7	42	0	0
	3	0	0	0	0	0	0	0	0	0	60	0	0
	3	0	0	14	0	0	7	0	0	7	42	0	0
AVERAGE			1	7	1		2			2	51		
HIGH RANGE			14	43	14		7			7	60		
LOW RANGE			0	0	0		0			0	42		
	4	0	0	0	0	0	0	0	0	18	42	0	0
	4	0	0	0	0	0	8	0	0	24	48	0	0
	4	0	0	0	0	0	0	0	0	45	45	0	0
	4	0	0	0	0	0	0	0	0	14	56	0	0
	4	0	0	0	0	0	7	0	0	14	49	0	0
	4	0	0	0	0	0	0	0	0	30	20	0	0
	4	0	0	0	0	0	5	0	0	15	30	0	0
	4	0	0	0	0	0	0	0	0	36	54	0	0
	4	0	0	0	0	0	4	0	0	18	49	0	0
	4	0	0	0	0	0	0	0	0	15	30	5	0
	4	0	0	0	0	0	18	0	0	24	18	0	0
	4	0	0	0	0	0	0	0	0	15	35	0	0
	4	0	0	0	0	0	0	0	0	18	42	0	0
	4	0	0	0	0	0	0	0	0	24	36	0	0
	4	0	0	0	0	0	12	0	0	18	30	0	0
	4	0	0	0	0	0	0	0	0	14	56	0	0
	4	0	0	0	7	0	0	0	0	14	49	0	0
	4	0	0	4	0	0	0	0	0	18	49	0	0
	4	0	0	0	0	0	0	0	0	35	35	0	0
	4	0	0	6	0	0	6	0	0	18	30	0	0
	4	0	0	0	0	0	8	0	0	16	56	0	0
	4	0	0	0	0	0	12	0	0	18	24	6	0
	4	0	0	0	0	0	4	0	0	16	20	0	0
	4	0	0	8	0	0	0	0	0	24	48	0	0
	4	0	0	0	0	0	0	0	0	21	49	0	0
	4	0	0	0	0	0	4	0	0	25	42	0	0
	4	0	0	0	0	0	6	0	0	30	24	0	0
	4	0	0	0	18	0	0	0	0	18	54	0	0
	4	0	0	0	0	0	0	0	0	12	48	0	0
	4	0	0	0	0	0	0	0	0	28	42	0	0
AVERAGE				1	1		3			21	40		
HIGH RANGE				8	18		18			45	53		
LOW RANGE				0	0		0			12	18		
	5	0	0	0	0	0	0	70	0	0	0	0	0
	5	27	0	0	0	0	0	63	0	0	0	0	0
	5	0	0	0	0	0	8	40	32	0	0	0	0
	5	0	0	0	0	0	0	80	0	0	0	0	0
	5	0	0	0	0	27	0	63	0	0	0	0	0
	5	0	0	0	0	0	0	80	0	0	0	0	0
	5	0	0	0	0	0	0	90	0	0	0	0	0
	5	0	0	0	0	0	0	25	0	0	25	0	0
	5	0	0	0	0	6	0	54	0	0	0	0	0
	5	0	0	0	0	0	0	90	0	0	0	0	0
	5	0	0	0	0	4	0	67	0	0	0	0	0
	5	0	0	0	0	16	0	64	0	0	0	0	0
	5	0	0	0	0	0	0	90	0	0	0	0	0
	5	0	0	0	0	24	0	56	0	0	0	0	0
	5	0	0	0	0	8	0	64	0	0	0	0	0
	5	0	0	0	0	0	0	63	27	0	0	0	0
	5	0	0	0	0	6	0	24	0	0	0	0	0
	5	0	0	0	0	0	0	60	0	0	0	0	0
	5	0	0	0	0	9	0	81	0	0	0	0	0
	5	0	0	0	0	0	0	90	0	0	0	0	0
	5	0	0	0	0	0	0	60	20	10	10	0	0
	5	0	0	0	0	0	0	100	0	0	0	0	0
	5	0	0	0	0	8	0	72	0	0	0	0	0
	5	0	0	0	0	0	0	100	0	0	0	0	0
	5	0	0	0	0	0	0	62	0	0	33	0	0
	5	0	0	0	0	0	0	56	0	0	24	0	0

APPENDIX 5: RMNP Vegetation Classification and Stand Origin Study 15 Class Classification (cont'd)

	CLU	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	5	0	0	0	0	0	0	40	0	0	0	0	0
	5	0	0	0	0	0	0	90	0	0	0	0	0
	5	0	0	0	0	7	0	56	0	0	0	0	0
	5	0	0	0	0	0	0	80	0	0	0	0	0
	5	0	0	0	0	0	0	50	0	0	0	0	0
	5	0	0	0	0	48	0	32	0	0	0	0	0
	5	0	0	0	0	56	0	14	0	0	0	0	0
	5	0	0	0	0	72	0	18	0	0	0	0	0
AVERAGE		1				12		63	3	0	4		
HIGH RANGE		27				72		100	32	10	33		
LOW RANGE		0				0		14	0	0	0		
	6	0	0	4	1	0	0	0	0	0	5	0	0
	6	0	0	12	0	0	12	0	0	8	8	0	0
	6	0	0	0	0	0	0	0	0	5	5	0	0
	6	0	0	10	5	0	5	0	0	0	5	5	0
	6	0	0	15	0	0	15	0	0	20	0	0	0
	6	0	0	10	0	0	10	0	0	20	10	0	0
	6	0	0	8	0	0	2	0	0	0	8	2	0
	6	0	0	8	0	0	4	0	2	6	0	0	0
	6	0	0	5	0	0	0	0	0	0	5	0	0
	6	10	0	15	5	0	10	0	0	5	0	0	5
	6	0	0	0	0	0	0	0	0	0	10	0	0
	6	6	0	12	0	0	18	0	0	12	12	0	0
	6	0	0	12	0	0	2	0	0	4	2	0	0
	6	9	0	12	6	0	3	0	0	0	0	0	0
	6	0	0	9	0	0	9	0	0	3	9	0	0
	6	0	0	15	0	0	3	0	0	9	3	0	0
	6	0	0	6	0	0	6	0	6	6	6	0	0
AVERAGE		1		9	1		6		0	6	5	0	0
HIGH RANGE		10		15	6		18		6	20	12	5	5
LOW RANGE		0		0	0		0		0	0	0	0	0
	7	0	0	5	0	0	5	0	0	0	0	0	0
	7	0	0	0	0	0	10	0	0	0	0	0	0
	7	0	0	0	5	0	5	0	0	0	0	0	0
	7	0	0	0	0	0	2	0	0	0	0	0	0
	7	0	0	4	0	0	8	0	0	8	0	0	0
	7	0	0	0	0	0	10	0	0	0	0	0	0
	7	2	0	2	0	0	12	0	0	4	0	0	0
AVERAGE		0		2	1		7			2			
HIGH RANGE		2		5	5		12			8			
LOW RANGE		0		0	0		0			0			
	8	30	0	6	0	0	24	0	0	0	0	0	0
	8	49	0	7	0	0	0	0	0	7	7	0	0
	8	42	0	7	7	0	7	0	0	7	0	0	0
	8	81	0	9	0	0	0	0	0	0	0	0	0
	8	30	0	12	0	0	12	0	6	0	0	0	0
AVERAGE		46		8	1		9		1		1		
HIGH RANGE		81		12	7		24		6		7		
LOW RANGE		30		6	0		0		0		0		
	9	0	0	0	0	0	0	0	21	9	0	0	0
	9	0	0	0	0	0	0	0	54	0	6	0	0
	9	0	0	0	0	0	0	0	90	0	0	0	0
	9	0	0	0	0	0	7	0	49	7	7	0	0
	9	0	0	0	0	0	12	0	30	0	18	0	0
	9	0	0	0	0	0	35	0	28	7	0	0	0
	9	0	0	0	0	0	21	0	28	0	21	0	0
AVERAGE							11		43	3	7		
HIGH RANGE							35		90	9	21		
LOW RANGE							0		21	0	0		
	10	0	0	32	0	0	4	0	0	4	0	0	0
	10	0	0	20	0	0	0	0	0	5	25	0	0

APPENDIX 5: RMNP Vegetation Classification and Stand Origin Study 15 Class Classification (cont'd)

	CLU	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	10	0	0	28	0	0	8	0	4	0	0	0	0
	10	0	0	24	0	0	0	0	0	0	16	0	0
	10	0	0	16	0	0	0	0	0	0	24	0	0
	10	0	0	8	0	0	0	0	0	8	24	0	0
	10	0	0	20	0	0	0	0	0	15	15	0	0
	10	0	0	24	16	0	0	0	0	16	16	0	8
	10	0	0	15	0	0	0	0	0	5	30	0	0
	10	0	0	36	0	0	0	0	0	24	0	0	0
	10	8	0	64	0	0	8	0	0	0	0	0	0
	10	0	0	36	0	0	0	0	0	24	0	0	0
	10	0	0	20	0	0	0	0	0	0	20	0	0
	10	0	0	63	0	0	0	0	0	7	0	0	0
	10	0	0	15	0	0	0	0	0	10	25	0	0
	10	0	0	48	0	0	0	0	0	12	0	0	0
	10	0	0	10	0	0	0	0	0	15	25	0	0
	10	0	0	24	0	0	0	0	0	36	0	0	0
	10	0	0	40	0	0	0	0	0	0	10	0	0
	10	0	0	30	0	0	5	0	0	15	0	0	0
AVERAGE				29	1		1			10	12		0
HIGH RANGE				64	16		8			36	30		8
LOW RANGE				0	0		0			0	20		0
	11	0	0	0	35	0	0	0	0	0	35	0	0
	11	0	0	0	0	0	0	0	0	0	42	18	0
	11	0	9	0	18	0	0	0	0	18	36	0	9
	11	0	0	0	10	0	0	0	0	15	15	0	10
	11	0	0	0	0	0	0	0	0	0	9	21	0
	11	0	0	0	15	0	0	0	0	25	0	5	5
	11	0	0	0	0	0	0	0	0	0	0	40	0
	11	0	0	0	0	0	0	0	0	0	42	18	0
	11	0	0	21	0	0	0	0	0	7	21	21	0
	11	0	0	0	28	0	0	0	0	14	14	0	14
	11	0	0	12	16	0	0	0	0	4	0	8	0
	11	0	0	0	0	0	0	0	0	0	0	10	0
	11	0	0	0	0	0	1	0	0	0	0	9	0
	11	0	0	0	7	0	0	0	0	0	49	14	0
	11	0	0	12	0	0	0	0	0	0	12	36	0
	11	0	0	0	35	0	0	0	0	0	35	0	0
	11	0	25	0	25	0	0	0	0	0	0	0	0
	11	0	18	0	27	0	0	0	0	18	18	0	9
	11	0	0	0	0	0	0	0	0	0	0	90	0
	11	0	0	0	0	0	0	0	0	0	25	25	0
AVERAGE			3	2	11		0			5	18	16	2
HIGH RANGE			25	21	35		1			25	49	90	14
LOW RANGE			0	0	0		0			0	0	0	0
	12	0	0	0	0	0	6	0	0	3	21	0	0
	12	0	0	6	0	0	0	0	0	0	24	0	0
	12	0	0	0	0	0	1	0	0	0	19	0	0
	12	0	0	0	0	0	0	0	0	6	24	0	0
	12	0	0	0	0	0	15	0	0	0	15	0	0
	12	0	0	0	0	0	9	0	0	3	18	0	0
	12	0	0	0	0	0	0	0	0	0	20	0	0
	12	0	0	0	0	0	12	0	0	0	28	0	0
	12	0	0	12	0	0	24	0	0	0	24	0	0
	12	0	0	0	0	0	16	0	0	4	20	0	0
	12	0	0	4	0	0	8	0	0	12	16	0	0
	12	0	0	21	0	0	21	0	0	7	21	0	0
	12	0	0	0	0	0	6	0	0	6	12	0	0
	12	0	0	0	0	0	3	0	0	0	27	0	0
	12	0	0	0	0	0	0	0	0	0	20	0	0
	12	0	0	0	0	0	5	0	10	5	30	0	0
	12	0	0	4	0	0	16	0	0	0	20	0	0
	12	0	0	0	0	0	8	0	0	8	16	0	0
	12	0	0	0	0	0	9	0	0	0	12	9	0
	12	0	0	0	0	0	0	0	0	9	21	0	0
	12	0	0	0	0	0	4	0	12	0	24	0	0
	12	0	0	0	0	0	8	0	0	0	12	0	0
	12	0	0	0	0	0	20	0	0	0	20	0	0

APPENDIX 5: RMNP Vegetation Classification and Stand Origin Study 15 Class Classification (cont'd)

	CLU	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	12	0	0	4	0	0	8	0	4	0	24	0	0
AVERAGE				2			8		1	3	20	0	
HIGH RANGE				21			24		12	12	30	9	
LOW RANGE				0			0		0	0	12	0	
	13	0	0	5	0	0	5	0	0	35	5	0	0
	13	0	0	0	0	0	11	0	0	60	0	0	0
	13	0	0	3	0	0	9	0	0	15	3	0	0
	13	0	0	0	0	0	3	0	0	27	0	0	0
	13	0	0	0	0	0	3	0	0	27	0	0	0
	13	0	0	0	0	0	0	0	0	80	0	0	0
	13	0	0	6	0	0	6	0	0	48	0	0	0
	13	0	0	0	0	0	0	0	0	14	0	0	0
	13	0	0	0	0	0	0	0	0	54	6	0	0
	13	0	0	0	0	0	0	0	0	49	21	0	0
	13	0	0	0	0	0	5	0	0	15	5	0	0
	13	0	0	7	0	0	0	0	0	42	21	0	0
	13	0	0	0	0	0	0	0	0	28	12	0	0
	13	0	0	0	0	0	8	0	0	24	8	0	0
	13	0	0	0	0	0	24	0	0	56	0	0	0
	13	0	0	0	0	0	0	0	0	63	27	0	0
	13	0	0	0	0	0	0	0	0	21	9	0	0
	13	0	0	0	0	0	21	0	0	49	0	0	0
	13	0	0	0	9	0	0	0	0	72	9	0	0
	13	0	0	0	0	0	0	0	0	63	7	0	0
	13	0	0	0	0	0	0	0	0	70	0	0	0
	13	0	0	0	0	0	0	0	0	80	0	0	0
AVERAGE				1	0		4			45	6		
HIGH RANGE				7	9		24			80	27		
LOW RANGE				0	0		0			14	0		
	14	0	0	0	0	0	85	0	0	0	0	0	0
	14	0	0	0	0	0	72	0	0	0	18	0	0
	14	0	0	0	0	0	70	0	0	0	0	0	0
	14	0	0	0	0	0	72	0	0	0	8	0	0
	14	0	0	7	0	0	63	0	0	0	0	0	0
	14	0	0	0	0	0	64	0	0	8	8	0	0
	14	0	0	0	0	0	63	0	0	0	7	0	0
	14	0	0	0	0	0	70	0	0	0	0	0	0
	14	0	0	0	0	0	63	0	0	7	0	0	0
	14	0	0	0	0	0	72	9	0	0	9	0	0
	14	0	0	0	0	0	80	0	0	0	0	0	0
	14	0	0	4	0	0	64	0	0	4	8	0	0
	14	0	0	0	0	0	72	0	0	8	0	0	0
	14	0	0	0	0	0	63	0	0	0	7	0	0
	14	0	0	0	0	0	63	0	9	9	9	0	0
	14	0	0	0	0	0	72	18	0	0	0	0	0
	14	0	0	0	0	0	72	0	0	0	8	0	0
	14	0	0	0	0	0	100	0	0	0	0	0	0
	14	0	0	0	0	0	64	0	0	16	0	0	0
	14	0	0	0	0	0	72	9	0	0	9	0	0
	14	0	0	9	0	0	63	0	0	9	9	0	0
	14	0	0	0	0	0	54	0	0	0	6	0	0
	14	0	0	0	0	0	42	0	0	0	28	0	0
	14	0	0	0	0	0	56	0	0	16	8	0	0
	14	0	0	0	0	0	56	0	0	0	14	0	0
	14	0	0	0	0	0	49	0	0	0	21	0	0
	14	0	0	0	0	0	49	0	0	0	21	0	0
	14	0	0	0	0	0	42	0	0	7	21	0	0
	14	0	0	0	0	0	56	0	0	4	11	0	0
	14	0	0	0	0	0	40	0	0	0	10	0	0
	14	0	0	0	0	0	48	0	0	0	12	0	0
	14	0	0	0	0	0	54	0	0	0	6	0	0
	14	0	0	0	0	0	48	0	0	12	0	0	0
	14	0	0	0	0	0	54	0	0	0	6	0	0
	14	0	0	0	0	0	56	0	0	0	24	0	0
	14	0	0	0	0	0	54	0	0	0	6	0	0
	14	0	0	8	0	0	48	0	0	12	12	0	0
	14	0	0	0	0	0	56	0	0	8	16	0	0

APPENDIX 5: RMNP Vegetation Classification and Stand Origin Study 15 Class Classification (cont'd)

	CLU	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	14	0	0	0	0	0	42	0	0	0	18	0	0
	14	0	0	0	0	0	49	0	0	7	14	0	0
	14	0	0	0	0	0	54	0	0	0	6	0	0
	14	0	0	0	0	0	40	0	0	0	10	0	0
	14	0	0	0	0	0	54	0	0	6	0	0	0
AVERAGE				1			61			3	9		
HIGH RANGE				9			100			16	28		
LOW RANGE				0			42			0	0		
	15	0	0	6	0	0	18	0	0	0	6	0	0
	15	0	0	0	0	0	35	14	0	7	14	0	0
	15	0	0	4	0	0	32	0	0	0	4	0	0
	15	0	0	0	0	0	20	0	0	0	0	0	0
	15	0	0	4	0	0	28	0	0	6	2	0	0
	15	0	0	0	0	0	18	0	0	6	6	0	0
	15	0	0	5	0	0	45	0	0	0	0	0	0
	15	0	0	0	0	21	21	21	0	0	7	0	0
	15	0	0	0	0	0	36	45	0	0	9	0	0
	15	3	0	30	0	0	30	0	0	0	0	0	0
	15	0	0	21	7	0	42	0	0	0	0	0	0
	15	0	0	0	0	0	20	0	0	8	12	0	0
	15	0	0	0	0	0	36	0	0	4	0	0	0
	15	5	0	0	0	0	25	10	0	0	10	0	0
	15	12	0	8	0	0	16	0	0	0	4	0	0
	15	0	0	0	0	0	32	0	0	8	0	0	0
	15	0	0	9	0	0	18	0	0	3	0	0	0
	15	0	0	0	0	0	32	0	0	8	0	0	0
	15	0	0	0	0	0	21	0	0	0	9	0	0
	15	0	0	0	0	0	36	18	0	6	0	0	0
	15	0	0	16	0	0	20	0	0	4	0	0	0
	15	0	0	0	0	0	32	48	0	0	0	0	0
	15	0	0	0	0	0	36	0	0	12	12	0	0
	15	0	0	0	0	0	12	0	0	18	0	0	0
	15	0	0	0	0	0	35	0	0	14	21	0	0
	15	0	0	0	0	0	42	0	0	21	7	0	0
	15	0	0	0	0	0	25	0	0	20	5	0	0
	15	0	0	5	0	0	20	0	0	25	0	0	0
	15	0	0	0	0	0	36	0	0	12	12	0	0
	15	0	0	0	0	0	36	0	0	18	6	0	0
	15	0	0	0	0	0	24	0	0	30	6	0	0
	15	0	0	0	0	0	35	0	0	14	21	0	0
	15	0	0	0	0	0	35	0	0	10	5	0	0
	15	14	0	0	0	0	35	0	0	14	7	0	0
	15	0	0	0	0	0	25	0	5	15	5	0	0
AVERAGE		2		3			29	4		8	5		
HIGH RANGE		14		30			48	48		30	21		
LOW RANGE		0		0			12	0		0	0		

APPENDIX 6: Provincial Forest Cover Map 15 Class Classification

	CLUS	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	1	9	0	0	0	0	17	0	0	0	60	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	9	0	0	0	0	9	0	0	0	68	0	0
	1	17	0	0	0	0	17	0	0	0	51	0	0
	1	26	0	0	0	0	0	0	0	0	60	0	0
	1	9	0	0	0	0	17	0	0	0	60	0	0
	1	9	0	0	0	0	9	0	0	0	68	0	0
	1	9	0	0	0	0	9	0	0	0	68	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	9	0	0	0	0	9	0	0	0	68	0	0
	1	9	0	0	0	0	17	0	0	0	60	0	0
	1	9	0	0	0	0	17	0	0	0	60	0	0
	1	9	0	0	0	0	9	0	0	0	68	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	9	0	0	0	0	9	0	0	0	68	0	0
	1	9	0	0	0	0	17	0	0	0	60	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	17	0	0	0	0	9	0	0	0	60	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	17	0	0	0	0	9	0	0	0	60	0	0
	1	9	0	0	0	0	17	0	0	0	60	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	6	0	0	0	0	0	0	0	0	54	0	0
	1	9	0	0	0	0	17	0	0	9	51	0	0
	1	0	0	0	0	0	17	0	0	0	68	0	0
	1	9	0	0	0	0	17	0	0	0	60	0	0
AVERAGE		7					14			0	64		
HIGH RANGE		26					17			9	68		
LOW RANGE		0					9			0	51		
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	34	0	0	0	51	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	9	0	0	51	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	9	0	0	51	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	17	9	0	9	51	0	0
	2	0	0	0	0	0	17	9	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	9	0	0	51	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	9	0	0	51	0	0
	2	0	0	0	0	0	26	9	0	0	51	0	0
	2	0	0	0	0	0	17	9	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	26	9	0	0	51	0	0
	2	9	0	0	0	0	34	0	0	0	43	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	9	0	0	0	0	34	0	0	0	43	0	0
	2	0	0	0	0	0	0	26	0	0	60	0	0
	2	0	0	0	0	0	17	9	0	0	60	0	0
	2	0	0	0	0	0	34	0	0	0	51	0	0
	2	0	0	0	0	0	17	9	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0

APPENDIX 6: Provincial Forest Cover Map 15 Class Classification (cont'd)

	CLUS	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	2	0	0	0	0	0	34	0	0	0	51	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	17	9	0	0	60	0	0
	2	0	0	0	0	0	17	17	0	0	51	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
	2	0	0	0	0	0	17	9	0	0	60	0	0
	2	0	0	0	0	0	26	0	0	0	60	0	0
AVERAGE							25	4			57		
HIGH RANGE							34	26			60		
LOW RANGE							0	0			43		
	3	0	0	0	9	0	0	0	0	0	60	17	0
	3	0	0	17	0	0	0	0	0	0	68	0	0
	3	0	0	0	0	0	0	0	0	17	68	0	0
	3	0	0	9	0	0	0	0	0	9	60	9	0
	3	9	0	0	0	0	0	0	0	9	68	0	0
	3	0	0	0	0	0	0	0	0	26	60	0	0
	3	0	0	0	0	0	9	0	0	17	60	0	0
	3	0	0	0	0	0	17	0	0	0	51	17	0
	3	0	9	0	0	0	0	0	0	26	51	0	0
	3	0	0	17	0	0	0	0	0	0	68	0	0
	3	0	0	0	0	0	9	0	0	9	68	0	0
	3	0	0	9	0	0	0	0	0	0	68	9	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
	3	0	0	0	0	0	9	0	0	9	68	0	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
	3	0	0	0	0	0	0	0	0	17	68	0	0
	3	0	0	17	0	0	0	0	0	0	68	0	0
	3	0	0	0	0	0	0	0	0	26	60	0	0
	3	0	0	17	0	0	0	0	0	0	68	0	0
	3	0	0	0	9	0	9	0	0	0	51	17	0
	3	0	0	0	0	0	0	0	0	17	68	0	0
	3	0	0	0	0	0	9	0	0	0	68	9	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
	3	0	0	0	0	0	0	0	0	17	68	0	0
	3	0	0	0	0	0	0	0	0	0	68	17	0
	3	0	0	0	0	0	9	0	0	17	60	0	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
	3	0	0	0	0	0	9	0	0	17	60	0	0
	3	0	0	17	0	0	0	0	0	0	68	0	0
	3	0	9	0	0	0	0	0	0	17	60	0	0
	3	0	0	0	9	0	0	0	0	9	68	0	0
AVERAGE			0	3	3		2				65	3	
HIGH RANGE			9	17	9		17				68	17	
LOW RANGE			0	0	0		0				51	0	
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	9	0	0	0	0	0	0	0	77	0	0
	4	0	0	0	0	0	0	9	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	0	85	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	9	0	0	0	0	0	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	0	85	0	0
	4	0	0	0	0	0	0	9	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	9	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	0	85	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0

APPENDIX 6: Provincial Forest Cover Map 15 Class Classification (cont'd)

	CLUS	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	4	0	0	9	0	0	0	0	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	0	85	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	0	85	0	0
	4	0	0	0	0	0	0	0	0	0	85	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	9	0	0	0	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
	4	0	0	0	0	0	0	0	0	9	77	0	0
AVERAGE			0	0			2			5	78		
HIGH RANGE			9	9			9			9	85		
LOW RANGE			0	0			0			0	77		
	5	0	0	0	0	0	11	0	0	0	25	0	0
	5	0	0	0	0	0	11	0	0	0	25	0	0
	5	0	0	0	0	0	14	0	0	0	21	0	0
	5	0	0	0	0	0	11	0	0	0	25	0	0
	5	0	0	0	0	0	11	0	0	0	25	0	0
	5	4	0	0	0	0	11	0	0	0	21	0	0
	5	7	0	0	0	0	11	0	0	0	18	0	0
	5	4	0	0	0	0	11	0	0	0	21	0	0
	5	0	0	0	0	0	14	0	0	0	21	0	0
	5	0	0	0	0	0	11	0	0	0	25	0	0
	5	0	0	0	0	0	11	0	0	0	25	0	0
	5	0	0	0	0	0	11	0	0	0	25	0	0
	5	4	0	0	0	0	11	0	0	0	21	0	0
	5	0	0	0	0	0	14	0	0	0	21	0	0
	5	0	0	0	0	0	14	4	0	0	18	0	0
AVERAGE		1					12				22		
HIGH RANGE		7					14				25		
LOW RANGE		0					11				18		
	6	0	0	0	0	0	18	0	0	0	42	0	0
	6	0	0	0	0	0	18	0	0	0	42	0	0
	6	6	0	0	0	0	12	0	0	0	42	0	0
	6	6	0	0	0	0	0	12	0	0	42	0	0
	6	6	0	0	0	0	0	12	0	0	42	0	0
	6	6	0	0	0	0	0	12	0	0	42	0	0
	6	0	0	0	0	0	0	18	0	0	42	0	0
	6	12	0	0	0	0	0	6	0	0	42	0	0
	6	0	0	0	0	0	12	0	0	0	48	0	0
	6	6	0	0	0	0	0	12	0	0	42	0	0
	6	0	0	0	0	0	12	0	0	0	48	0	0
	6	0	0	0	0	0	18	0	0	0	42	0	0
	6	0	0	0	0	0	12	0	0	0	48	0	0
	6	0	0	0	0	0	18	0	0	0	42	0	0
	6	0	0	0	0	0	18	6	0	0	36	0	0
	6	12	0	0	0	0	0	6	0	0	42	0	0
	6	12	0	0	0	0	0	6	0	0	42	0	0
	6	0	0	0	0	0	18	6	0	0	36	0	0
	6	0	0	0	0	0	24	6	0	0	30	0	0
	6	0	0	0	0	0	18	6	0	0	36	0	0
	6	12	0	0	0	0	6	0	0	0	42	0	0
	6	6	0	0	0	0	12	0	0	0	42	0	0
	6	6	0	0	0	0	0	12	0	0	42	0	0
	6	0	0	0	0	0	24	0	0	0	36	0	0
AVERAGE		4					10	5			41		
HIGH RANGE		12					24	18			48		
LOW RANGE		0					0	0			30		

APPENDIX 6: Provincial Forest Cover Map 15 Class Classification (cont'd)

	CLUS	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	7	0	0	0	0	0	0	0	0	0	35	0	0
	7	0	0	0	0	0	7	0	0	0	28	0	0
	7	0	0	0	0	0	0	0	0	0	35	0	0
	7	0	0	0	0	0	0	0	0	18	42	0	0
	7	0	0	0	0	0	6	0	0	12	42	0	0
	7	0	0	0	0	0	0	7	0	0	28	0	0
	7	0	0	0	0	0	0	0	0	0	35	0	0
	7	0	0	0	0	0	4	0	0	0	32	0	0
	7	0	0	0	0	0	0	7	0	0	28	0	0
	7	0	0	6	0	0	6	0	0	12	36	0	0
	7	0	0	0	0	0	6	0	0	12	42	0	0
	7	12	0	6	0	0	0	0	0	12	30	0	0
	7	12	0	6	0	0	0	0	0	12	30	0	0
	7	0	0	0	0	0	7	4	0	7	18	0	0
	7	18	0	0	0	0	0	0	0	12	30	0	0
	7	0	0	0	0	0	4	0	0	11	21	0	0
	7	0	0	0	0	0	4	0	0	0	32	0	0
	7	12	0	6	0	0	0	0	0	12	30	0	0
	7	18	0	0	0	0	0	0	0	12	30	0	0
	7	7	0	0	0	0	0	0	0	0	28	0	0
	7	0	0	0	0	0	6	0	0	12	42	0	0
AVERAGE		4		1			2	1		7	32		
HIGH RANGE		18		6			7	7		18	42		
LOW RANGE		0		0			0	0		0	18		
	8	6	0	12	6	0	0	0	0	0	36	0	0
	8	0	0	12	0	0	12	0	0	0	36	0	0
	8	6	0	12	0	0	12	0	0	0	30	0	0
	8	0	0	6	0	0	0	0	0	0	48	6	0
	8	0	0	12	0	0	6	0	0	0	42	0	0
	8	6	0	12	0	0	12	0	0	0	30	0	0
	8	12	0	12	0	0	0	0	0	0	36	0	0
	8	0	6	12	0	0	6	0	0	6	30	0	0
	8	0	0	12	0	0	12	0	0	0	36	0	0
	8	0	0	12	0	0	6	0	0	0	42	0	0
	8	0	0	12	0	0	12	0	0	0	36	0	0
	8	0	0	12	0	0	12	0	0	0	36	0	0
	8	0	0	12	0	0	12	0	0	0	36	0	0
	8	6	0	12	0	0	12	0	0	0	30	0	0
	8	0	0	12	0	0	18	0	0	0	30	0	0
	8	6	0	12	6	0	0	0	0	0	36	0	0
	8	0	0	12	0	0	0	0	0	0	42	6	0
	8	6	0	12	0	0	12	0	0	0	30	0	0
	8	0	0	12	0	0	18	0	0	0	30	0	0
	8	0	0	12	0	0	18	6	0	0	24	0	0
AVERAGE		2		12			9			0	35	1	
HIGH RANGE		12		12			18			6	48	6	
LOW RANGE		0		6			0			0	24	0	
	9	0	0	0	0	0	17	0	0	17	51	0	0
	9	0	0	0	0	0	9	0	0	17	43	17	0
	9	0	0	9	0	0	17	0	0	17	43	0	0
	9	0	0	0	0	0	17	0	0	17	51	0	0
	9	9	0	0	0	0	9	0	0	17	51	0	0
	9	0	0	0	0	0	26	0	0	9	51	0	0
	9	9	0	0	0	0	9	0	0	17	51	0	0
	9	0	0	0	0	0	17	0	0	17	51	0	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	0	17	0	0	0	0	0	17	51	0	0
	9	0	0	0	9	0	0	0	0	17	51	9	0
	9	0	0	17	0	0	0	0	0	17	51	0	0
	9	0	0	9	0	0	0	0	0	17	51	9	0
	9	9	0	9	0	0	26	0	0	9	34	0	0
	9	0	0	0	0	0	17	0	0	17	51	0	0
	9	0	0	17	0	0	0	0	0	17	51	0	0
	9	0	0	17	9	0	9	0	0	9	43	0	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	0	17	0	0	9	0	0	0	60	0	0

APPENDIX 6: Provincial Forest Cover Map 15 Class Classification (cont'd)

	CLUS	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	9	17	0	0	0	0	9	0	0	17	43	0	0
	9	0	0	9	0	0	0	0	0	17	51	9	0
	9	0	0	9	0	0	17	0	0	17	43	0	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	0	9	0	0	9	0	0	17	51	0	0
	9	9	0	0	0	0	9	0	0	17	51	0	0
	9	9	0	0	0	0	9	0	0	17	51	0	0
	9	0	0	9	0	0	17	0	0	17	43	0	0
	9	0	0	0	0	0	17	0	0	9	60	0	0
	9	9	0	0	0	0	9	0	0	17	51	0	0
	9	9	0	9	0	0	9	0	0	9	51	0	0
	9	0	0	0	9	0	17	0	0	9	51	0	0
	9	9	0	9	0	0	9	0	0	9	51	0	0
	9	0	0	0	0	0	17	0	0	17	51	0	0
	9	17	0	0	0	0	9	0	0	17	43	0	0
	9	17	0	0	0	0	9	0	0	17	43	0	0
	9	0	0	9	0	0	9	0	0	17	51	0	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	9	0	9	0	0	0	0	17	43	9	0
	9	9	0	0	0	0	9	0	0	17	51	0	0
	9	0	0	17	9	0	9	0	0	9	43	0	0
	9	0	0	0	9	0	9	0	0	17	43	9	0
	9	9	0	9	0	0	9	0	0	9	51	0	0
	9	0	0	0	0	0	17	0	0	17	51	0	0
	9	0	0	0	9	0	17	0	0	17	43	0	0
	9	0	0	9	0	0	0	0	0	17	51	9	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	0	0	0	0	17	0	0	17	51	0	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	0	0	9	0	9	0	0	17	51	0	0
	9	0	0	17	9	0	9	0	0	9	43	0	0
	9	0	0	9	0	0	0	0	0	17	51	9	0
	9	0	0	17	9	0	17	0	0	0	43	0	0
	9	0	0	9	0	0	9	0	0	17	51	0	0
	9	0	0	17	0	0	9	0	0	9	51	0	0
AVERAGE		3		5	3		10			15	49	1	
HIGH RANGE		17		17	9		26			17	60	17	
LOW RANGE		0		0	0		0			0	43	0	
	10	0	9	17	9	0	0	0	0	0	51	0	0
	10	0	17	0	0	0	0	0	0	17	51	0	0
	10	0	17	0	0	0	0	0	0	17	51	0	0
	10	0	42	0	0	0	0	0	0	0	18	0	0
	10	0	9	17	9	0	0	0	0	0	51	0	0
	10	0	9	17	0	0	0	0	0	17	43	0	0
	10	0	17	17	0	0	0	0	0	9	43	0	0
	10	0	17	0	0	0	0	0	0	17	51	0	0
	10	0	17	17	0	0	0	0	0	9	43	0	0
	10	0	17	17	0	0	0	0	0	9	43	0	0
	10	0	17	0	0	0	0	0	0	17	51	0	0
	10	0	17	17	0	0	0	0	0	9	43	0	0
	10	0	9	17	9	0	0	0	0	0	51	0	0
	10	0	9	17	9	0	0	0	0	0	51	0	0
	10	0	17	17	0	0	0	0	0	0	51	0	0
AVERAGE			16	11	2					8	46		
HIGH RANGE			42	17	9					17	51		
LOW RANGE			9	0	0					0	18		
	11	12	0	0	0	0	24	0	0	0	24	0	0
	11	24	0	0	0	0	36	0	0	0	0	0	0
	11	17	0	0	0	0	34	0	0	0	34	0	0
	11	17	0	0	0	0	34	9	0	0	26	0	0
	11	18	0	12	0	0	24	0	0	0	6	0	0
	11	17	0	0	0	0	51	0	0	0	17	0	0
	11	18	0	0	0	0	18	0	0	0	24	0	0
	11	17	0	0	0	0	34	9	0	0	26	0	0
	11	12	0	0	0	0	24	0	0	0	24	0	0
	11	9	0	0	0	0	34	9	0	0	34	0	0

APPENDIX 6: Provincial Forest Cover Map 15 Class Classification (cont'd)

	CLUS	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	11	17	0	0	0	0	34	9	0	0	26	0	0
	11	26	0	0	0	0	26	0	0	0	34	0	0
	11	17	0	0	0	0	34	0	0	0	34	0	0
	11	18	0	0	0	0	24	0	0	0	18	0	0
	11	12	0	0	0	0	24	0	0	0	24	0	0
	11	18	0	0	0	0	18	0	0	0	24	0	0
	11	17	0	0	0	0	34	0	0	0	34	0	0
	11	12	0	0	0	0	24	0	0	0	24	0	0
	11	12	0	0	0	0	24	0	0	0	24	0	0
	11	17	0	0	0	0	51	0	0	0	17	0	0
	11	26	0	0	0	0	34	0	0	0	26	0	0
	11	51	0	0	0	0	17	0	0	0	17	0	0
	11	12	0	0	0	0	24	0	0	0	24	0	0
	11	9	0	0	0	0	43	9	0	0	26	0	0
AVERAGE		18					30				24		
HIGH RANGE		51					51				34		
LOW RANGE		9					17				0		
	12	12	0	0	0	0	24	12	0	0	12	0	0
	12	12	0	0	0	0	24	12	0	0	12	0	0
	12	7	0	0	0	0	14	0	0	0	14	0	0
	12	12	0	0	0	0	24	12	0	0	12	0	0
	12	0	0	0	0	0	25	0	0	0	11	0	0
	12	7	0	0	0	0	14	0	0	0	14	0	0
	12	0	0	0	0	0	14	14	0	0	7	0	0
	12	4	0	0	0	0	25	0	0	0	7	0	0
	12	6	0	0	0	0	24	12	0	0	18	0	0
	12	7	0	0	0	0	14	0	0	0	14	0	0
	12	6	0	0	0	0	30	6	0	0	18	0	0
	12	0	0	0	0	0	25	0	0	0	11	0	0
	12	0	0	0	0	0	18	7	0	0	11	0	0
	12	0	0	0	0	0	21	0	0	0	14	0	0
	12	7	0	0	0	0	14	4	0	0	11	0	0
	12	12	0	0	0	0	18	12	0	0	18	0	0
	12	0	0	0	0	0	21	0	0	0	14	0	0
	12	12	0	0	0	0	24	12	0	0	12	0	0
	12	0	0	0	0	0	21	0	0	0	14	0	0
AVERAGE		5					20	5			12		
HIGH RANGE		12					30	12			18		
LOW RANGE		7					14	0			7		
	13	0	0	0	0	0	51	9	0	0	26	0	0
	13	0	9	0	0	0	51	0	0	0	26	0	0
	13	0	0	0	0	0	43	0	0	0	43	0	0
	13	0	0	0	0	0	51	0	0	0	34	0	0
	13	0	0	0	0	0	43	17	0	0	26	0	0
	13	0	0	0	0	0	51	0	0	0	34	0	0
	13	0	0	0	0	0	51	0	0	9	26	0	0
	13	0	0	0	0	0	68	9	0	0	9	0	0
	13	0	0	0	0	0	68	0	0	0	17	0	0
	13	0	0	0	0	0	60	17	0	0	9	0	0
	13	0	0	0	0	0	42	6	0	0	12	0	0
	13	0	0	0	0	0	60	0	0	0	26	0	0
AVERAGE							53	5		1	24		
HIGH RANGE							68	17		9	34		
LOW RANGE							42	0		0	9		
	14	0	0	0	0	0	30	12	0	0	18	0	0
	14	0	0	0	0	0	24	12	0	0	24	0	0
	14	0	0	0	0	0	34	34	0	0	17	0	0
	14	0	0	0	0	0	30	6	0	0	24	0	0
	14	0	0	0	0	0	30	12	0	0	18	0	0
	14	0	0	0	0	0	30	6	0	0	24	0	0
	14	0	0	0	0	0	34	17	0	0	34	0	0
	14	0	0	0	0	0	30	18	0	0	12	0	0
	14	0	0	0	0	0	34	17	0	0	34	0	0
	14	0	0	0	0	0	34	17	0	0	34	0	0
	14	0	0	0	0	0	34	26	0	0	26	0	0

APPENDIX 6: Provincial Forest Cover Map 15 Class Classification (cont'd)

	CLUS	FIR	MAP	BIR	ASH	TAM	WSP	BSP	PIN	POP	ASP	OAK	ELM
	14	0	0	0	0	0	34	34	0	0	17	0	0
	14	0	0	0	0	0	30	6	0	0	24	0	0
	14	0	0	0	0	0	30	12	0	0	18	0	0
	14	0	0	0	0	0	30	12	0	0	18	0	0
	14	0	0	0	0	0	36	0	0	0	24	0	0
	14	0	0	0	0	0	30	12	0	0	18	0	0
	14	0	0	0	0	0	34	17	0	0	34	0	0
	14	0	0	0	0	0	34	17	0	0	34	0	0
	14	0	0	0	0	0	34	26	0	0	26	0	0
	14	0	0	0	0	0	24	12	0	0	24	0	0
	14	0	0	0	0	0	24	12	0	0	24	0	0
AVERAGE							33	16			25		
HIGH RANGE							34	34			34		
LOW RANGE							24	0			12		
	15	0	0	0	0	0	0	35	0	0	0	0	0
	15	0	0	0	0	0	0	60	0	0	0	0	0
	15	0	0	0	0	0	17	60	0	0	9	0	0
	15	0	0	0	0	0	26	60	0	0	0	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	0	77	0	0	9	0	0
	15	0	0	0	0	0	34	51	0	0	0	0	0
	15	0	0	0	0	0	0	68	0	0	0	0	0
	15	0	0	0	0	0	9	77	0	0	0	0	0
	15	0	0	0	0	0	0	77	0	0	9	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	17	51	0	0	17	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	0	77	0	0	0	0	0
	15	0	0	0	0	0	0	77	0	0	9	0	0
	15	0	0	0	0	0	0	35	0	0	0	0	0
	15	0	0	0	0	0	0	34	0	0	0	0	0
	15	0	0	0	0	0	0	25	0	0	11	0	0
	15	0	0	0	0	0	0	26	0	0	0	0	0
	15	0	0	0	0	0	0	68	0	0	0	0	0
	15	0	0	0	0	0	26	60	0	0	0	0	0
	15	0	0	0	0	0	17	60	0	0	9	0	0
	15	0	0	0	0	0	0	77	0	0	0	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	0	68	0	0	0	0	0
	15	0	0	0	0	0	0	85	0	0	0	0	0
	15	0	0	0	0	0	0	17	0	0	0	0	0
AVERAGE							5	64			2		
HIGH RANGE							34	85			17		
LOW RANGE							0	17			0		