University of Alberta

Retention of wooded ecosystems and plant and lichen diversity on a First Nations Reserve compared to three other land uses in the Central Boreal Mixed-wood of northeast Alberta, Canada.

by

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DEDICATION

In memory of

my grandfather, Joseph Riley Young (1920-2012),
who gave me the nudge I needed to pursue higher education

and

my mother, Angela Michele Young (1957-2013),
who was always very proud of me.

ABSTRACT

This thesis represents the first inquiry into the retention of wooded ecosystems and plant and lichen diversity in a First Nation compared to three other land use units within the boreal mixed-wood of Canada. Forest retention was highest in the Provincial Park, followed by the Métis Settlement and the First Nations Reserve, as compared to the surrounding agro-environment. The Park stands were mostly coniferous yet stands in all other land use units were predominantly deciduous. The First Nation was primarily unforested. The Park site housed two distinct forest types, accounting for the highest floral diversity levels. Next to the Park, fragmentation metrics in the Settlement were most favourable to the protection of regional diversity and the First Nation plots contributed the most rare species. We conclude that forest stands in the two aboriginal land use units offer valuable contributions to the flora of the region.

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LIST OF SYMBOLS AND ABBREVIATIONS

α	alpha
AANDC	Aboriginal Affairs and Northern Development Canada
^{o}C	degrees Celsius
CharLog	charred log
CMin	Carbon concentration in the soil mineral horizon
COrg	Carbon concentration in the soil organic horizon
CWD	Coarse Woody Debris
Da	log whole and undecayed, bark intact
Db	log sound, wood hard, with no bark remaining
DBH	diameter at breast height (1.3m)
Dc	log sound, wood hard with 50% of bark remaining
Dd	wood soft in places with 50% of bark remaining
De	wood soft with crevices, little or no bark remaining
Df	large wood fragments lost, outline of trunk slightly deformed
Dg	wood mostly well decayed
Dh	humification nearly 100%
EBc	living tree: *Betula papyrifera* creviced
EBs	living tree: *Betula papyrifera* smooth
EOc	Living tree: *Populus balsamifera* creviced
EOs	Living tree: *Populus balsamifera* smooth
EPb	Living tree: *Pinus banksiana*
EPg	Living tree: *Picea glauca*

ES	European Settlement
ETc	living tree: *Populus tremuloides* creviced
ETM+	Enhanced Thematic Mapper +
ETs	living tree: *Populus tremuloides* smooth
FN	First Nation(s)
GC	ground substrate: coniferous
GD	ground substrate: deciduous
GN	ground substrate: exposed mineral soil
GR	ground substrate: rock
ISODATA	Iterative Self-Organizing Data Analysis Technique
LPI	Largest Patch Index
LSI	Landscape Shape Index
MS	Métis Settlement
NMDS	Non-metric Multidimensional Scaling
NMin	Nitrogen concentration in the soil mineral horizon
NOrg	Nitrogen concentration in the soil organic horizon
Oldpost	Old fence post
P	the level of significance used in statistical testing, reflecting the probability of a type I error
P/A	Perimeter/Area ratio
PD	Patch Density
PP	Provincial Park
S	Species richness
ShrLic	*Salix* sp. or other shrub host to lichen species

SI_p	Shape Index
SPOT	Satellite Pour Observation de la Terre

CHAPTER 1

General Introduction

Traditional Aboriginal Land Use and Ecological Knowledge

The first peoples of northern North America have occupied the land for millennia. Based on artifacts such as stone arrow points and tools uncovered through archeological digs, researchers have ascertained that Aboriginal history in Canada extends back at least 18,000 years, since the end of the last ice age when the retreat of the glaciers allowed people, plants and animals to penetrate the landscape. Aboriginal populations in Alberta date back at least 12,000 years (Berry & Brink, 2004, pg. 1).

In Canada, First Nations bands in the Boreal region are distinguished by two distinct language groups; the Algonkian-speaking tribes inhabit roughly the eastern half of Canada, from the Innu in northern Quebec and Labrador to the Ojibwa of northern Ontario and the Cree of Saskatchewan and north central Alberta. The Dene or Athapascan-speaking tribes occupy northwestern Canada and Alaska, from the Chipewyan in northern Alberta to the Tahltan in northern BC and the Koyukon in Alaska (Johnson, Kershaw, MacKinnon & Pojar, 1995, pg. 18).

The subsistence strategies of the Aboriginal people living in what are today the 3 Prairie Provinces were based on exploitation of natural resources. Traditionally, they led a mobile way of life, following the herds of Bison and other large game along seasonal migration routes dictated by the availability of forage. Spry describes a hunter-gatherer society whose members enjoyed a plentiful resource base and diversified daily activities that required skill and profound knowledge of the environment (1991, pp. 82-83). It is estimated that 95-97% of the diet of Aboriginal people was comprised of meat; the remaining 3-5% was derived from plant sources (Johnson et al., 1995, pg. 19). Plant use in traditional aboriginal societies was extensive. Food was varied; they had access to a wide variety of seasonal fruit (e.g. berries), leafy shoots of herbaceous species as well as roots, tubers, and rhizomes, an important source of carbohydrates that were required to supplement a protein-rich diet of lean meat. Plants were used for clothing and they provided shelter; trees for tipi poles and conifer boughs for bedding. Along with 'buffalo chips' (dung), wood was used as fuel. Weapons, such as bows, arrows, and spears that were made from wood were indispensable for hunting and fishing. Pine trees lashed together made a travois for transporting meat and other heavy loads. Young tree stems and branches were fashioned into baskets, providing storage for food and other household items and drying racks that ensured a supply of preserved fish and meat throughout the long winters. Even the smallest plants were used; the antibacterial and absorbent properties of moss made it ideal for sanitary purposes.

Another important use of plants by first peoples was for medicinal and spiritual purposes. Dickason highlights the wealth and subtleties of Amerindian botanical knowledge for medicinal and other purposes (1991, pp. 11-34). That knowledge also included the ability to use poisonous plants, either by extracting the toxins or cooking/baking, and aspects related to multiple uses of a plant such as recognizing appropriate stages of development and seasonal collection times (Dickason, 1991, pg. 25). Aboriginal traditional knowledge was not recorded in texts. Accumulation of this extensive botanical knowledge occurred through oral transmission from one generation to the next, a dynamic process of learning from elders (Marles, Clavelle, Monteleone, Tays, & Burns, 2000, pg. 1). Thus, prior to European contact, "The land, including 162 million ha of prairie blanketing the Great Plains, […] had materially and spiritually nurtured the Aboriginal peoples of North America for millennia" (Dormaar & Barsh, 2000, pg. 1).

Modern Aboriginal Land Use and Ecological Knowledge

With European contact came an explosion in resource exploitation in the Canadian Prairies. By the end of the 19th century the fur trade had decimated the bison population (Carter, 1999, pg. 112). By 1821, there were not enough animals in many places to support a traditional aboriginal lifestyle (Ward, 1995, pg. 60). Furthermore, aboriginal people working in the fur trade industry had an increased dependence on white European society, "Encouraged by the imperatives of commerce, they had chosen specialized roles for themselves-hunters, trappers, and intermediaries-but by doing so, they had unwittingly become dependent on the Hudson's Bay Company. When those roles were no longer viable, they became dependent on the government." (Ward, 1995, pg. 61).

The British North America Act enacted in 1867 gave the federal government exclusive authority to government and thus jurisdiction over First Nations people;

Section 91 provided for "legislative jurisdiction for Indians and lands reserved for Indians" (Carter, 1999, pg. 111). The second half of the 19th century saw a push to 'civilize' the fertile west, to create one nation stretching from the east to the west coast (Kermoal, 2006, pg. 40). Coupled with the influx of colonization were treaty negotiations, designation of 'Indian lands', and the implementation of the Indian Act in 1876. The Indian act of 1876 solidified the exclusive legislative authority over the aboriginal inhabitants of the country and First Nations in Canada became a 'managed people'. Between 1871 and 1921 eleven treaties were signed and reserve land was set aside for various First Nations groups within a region extending from eastern Yukon Territory to northern Quebec. As a direct result of this government management regime, the 20th century saw nefarious cultural and sociological changes for First Nations people.

The process whereby governments assumed greater responsibility for aboriginal groups, together with increased movement away from the land into urban centers led to a phenomenon dubbed 'land alienation' (Johnson et al., 1995, pg. 19). Currently, 54% of aboriginal Canadians live in an urban center (Statistics Canada, 2013). The 2006 Census reported the total Aboriginal identity population (self-identification as either First Nations, Métis, Inuit or a combination) as 1,172,790 (Statistics Canada, 2013). Today, Aboriginal people live in cities and towns throughout the province of Alberta as well as in 141 'Aboriginal lands' (Reserve, Settlement or village) (Aboriginal Affairs and Northern Development Canada, 2013b, pp. 1-10). These landbases vary in size and are located across the province. Some of these communities are in highly populated or developed areas of the province, for example the Enoch Cree Nation (IR440) adjacent to the capital city, Edmonton, while others are in remote regions, such as the Dene Tha' Reserve (IR448) near Hay-Zama Lakes Wildland in the Northwest corner of the province.

In the present context, aboriginal land management practices are those of the people living on Reserve or Settlement lands, and specifically lands in the southern portion of the Central Boreal Mixed-wood Region of Alberta. I do not purport to draw generalizations on aboriginal management across Canada, as I recognize the diversity of First Nations, hailing from different regions of the country and/or urban and rural environments. In this sense, I also attempt to avoid overuse of the term *euro-Canadian*, opting instead to use the term *mainstream* to designate the dominant practices, for example, with respect to private ownership. Therefore 'aboriginal land management' pertains to the management practices on aboriginal land, whether by members of the aboriginal communities themselves or government representatives. Aboriginal people claim the right to maintain traditional land-use practices, including harvesting rights (Russell, 2007, pg. 16); however, reality dictates that elements of this lifestyle occur within a larger, contemporary framework. Furthermore, 'stewards of the earth' hail from all sides, government, environmentalists, and citizens of all walks of life recognize the importance of conservation, and are compelled to protect the flora and fauna of our natural areas from anthropogenic abuses and non-sustainable initiatives.

Objectives of the Thesis

The goal of this study is to determine if the land use practices on a First Nations Reserve are conserving ecosystems and plant and lichen diversity that was an integral part of their subsistence strategies. This goal is achieved by comparing ecosystem and plant and lichen diversity conservation on a First Nations Reserve to three other land management practices in a highly developed region of the Central Boreal Mixed-wood of Alberta, Canada and by answering the following questions. Firstly, how does retention of wooded stands on a First Nation compare with other public and private land uses in a region of the Central Boreal Mixed-wood that has been severely altered by agricultural and other industrial development? Secondly, does the present First Nations land use contribute to the conservation of vulnerable ecosystems and plant and lichen diversity at a regional scale in this altered landscape? The three other land uses are: a Provincial Park, a Métis Settlement, and the surrounding mainstream land development. To my knowledge, no studies have compared wooded retention and plant and lichen biodiversity on First Nations land with other land use areas in severely altered landscapes.

Study Area

Alberta provides a unique location to attempt this study since it is the only Canadian province where both First Nations and Métis possess land. The region surrounding Bonnyville, Alberta was further selected since it contains the four land uses of interest: Moose Lake Provincial Park, Kehewin First Nations Reserve, and Elizabeth Métis Settlement all within a highly developed landscape of crop and cattle farming. This region is part of the Central Mixed-wood zone of the boreal forest.

Prior to European Settlement, the mixed-wood landscape was dominated by forested areas of cold-hardy tree species. A mosaic of Aspen, mixed-wood, and white Spruce forests occurred on mesic uplands with jackpine stands on coarser, more xeric soils such as sand. Canopy cover was normally continuous on uplands with some gaps produced by fire, insect outbreaks, disease, and at a more localized level small canopy gaps resulting from the death of individual trees (Chavez & Macdonald, 2010). Wetlands were a dominant component and cover 16 percent of the land area (103,000 km^2) and small lakes accounted for approximately 3 percent (16,800 km^2) (Alberta Environment and Sustainable Resource Development, 2013). Some wetlands such as marshes and some fens as well as water bodies and their shorelines also produced canopy gaps at the landscape level.

Plant and Lichen Diversity in the Boreal Forest

Aspen species have been accorded high conservation value at an international level (Edenius, Ericsson, Empe, Bergstrom, & Danell, 2011). European Aspen has been designated a keystone species for biodiversity conservation in Sweden (Martikainen, 2001; Watson, 2003), and Trembling Aspen, the closely related North American species, is recognized as the dominant hardwood species of the Canadian boreal forest (Peterson & Peterson, 1992; Zegler, Moore, Fairweather, Ireland, & Fule, 2012). Aspen-dominated forests of the Boreal Mixed-wood are a major contributor to plant biodiversity (Kuhn, Safford, Jones, & Tate, 2011) and as such are characterized by high levels of species richness (Bertemucci, Messier, & Canham, 2006), particularly in the herbaceous layer of the understory (Gilliam, 2007; Barbier, Gosselin, & Balandier, 2008; Hart & Chen, 2008). This is largely attributed to increased availability of resources, such as light (Messier, Parent, & Bergeron, 1998) and soil nutrients (Legare, Pare, & Bergeron, 2005; Peterson & Peterson, 1992). The intrinsic link between diversity and function of the herbaceous layer and soil biota is highlighted in a study conducted in an Aspen forest in southwest Alberta (Eisenhauer et al., 2010); the authors stress the reciprocal nature of above and belowground processes, specifically the correlations between plant species richness, plant density and soil biota performance and functions. The heterogeneous understory environment typical of the Boreal Mixed-wood is also due to gaps in the canopy cover. The ecological succession of aspen to conifer species leads to decreasing levels of plant species biodiversity (Kuhn et al., 2011). Conversely, increasing conifer canopy cover during successional change favours the presence of non-vascular plant species (Kembel & Dale, 2006) that are also a major contributor to understory biomass levels in the boreal forest.

Lichen diversity is added to this study along with that of vascular plants as it has been shown that they have narrow ecological requirements and that certain species are valuable as indicator species of ecosystem fragmentation (Bartok, 1999; Norden, Paltto, Gotmark, & Wallin, 2007). Some research from Canada suggests that the linear fragments typical of managed environments are insufficiently wide to maintain the integrity of epiphytic lichen communities (Gignac & Dale 2005), particularly with respect to biomass accumulation (Boudreault, Bergeron, Drapeau, & Mascarua Lopez, 2007; Pettersson, Ball, Renhorn, Esseen, & Sjoberg, 1995). The effects of high structural contrast at the forest edge in managed environments is linked to increased wind and tree branch breakage and changes to the microclimatic conditions such as fluctuations in light and humidity levels, which can in turn result in a reduction in substrate availability, and hinder the metabolic activity of poikilohydric organisms such as lichens (Campbell & Coxson, 2001; Zechmeister, Tribsch, Moser, Peterseil, & Wrbka, 2003; Boudreault et al., 2007; Fritz, Gustafsson, & Larson, 2008).

In a study of natural and managed boreal forests, Dettki & Esseen (1998) found that substrate availability and stand age are two key factors related to lichen richness and abundance. Lichen abundance in the canopies of natural and selectively logged boreal forest stands in northern Sweden has been related directly to the number and biomass of invertebrates such as *Acari* (mites), *Araneae (*spiders*)*, *Diptera* (True flies) and *Lepidoptera* (moths), organisms which serve as a critical food source for overwintering non-migratory birds (Pettersson et al., 1995). Boutin, Jobin, Belanger, & Choiniere (2002) also emphasized the strong link between plant diversity and healthy animal and invertebrate populations. The complexity of assessing species responses to the effects of habitat fragmentation is stressed by Ewers, Didham, Wratten, & Tylianakis (2005), particularly with respect to considerations such as individual species traits and life history strategies as well as variations in spatial and temporal scales.

Threats to the Boreal Mixed-wood

Lenton et al. (2008) highlight the complexity of the boreal system, with respect to the interplay between permafrost, fire and tree physiology, and stress its vulnerability to large-scale, climate-induced die-back through increased vulnerability to disease, fire, low reproduction rates, and elevated mortality rates caused by water- and summer heat stress. In fact, they rank the boreal forest along with the Greenland ice sheet, Atlantic thermohaline circulation, and Amazon rainforest, as one of the 7 most vulnerable systems on earth. In recent years, scientists in North America have expressed concerns over elevated aspen mortality rates. In 2008, American researchers coined the term Sudden Aspen Decline (SAD) in response to large-scale dieback in Colorado and other parts of the United States (Worrall et al., 2008). Other instances of heavy mortality have been documented in Canada and the southwestern United States (Anderegg, Anderegg, Sherman & Karp, 2012; Kuhn et al., 2011; Michaelian, Hogg, Hall & Arsenault, 2011), in response to climate-induced drought and in conjunction with, or exacerbated by other factors, such as insect infestations causing defoliation and stem damage. Hogg, Brandt, & Michaelian (2008) established a large-scale study entitled Climate Impacts on Productivity and Health of Aspen (CIPHA) to examine the effects of a severe, regional drought in western Canada and concluded that aspen forests of the boreal forest and adjacent aspen parkland in the western Canadian interior are suffering from moisture limitations and there is cause for concern with respect to warming under future climate models.

Mainstream Land Use of the Boreal Mixed-wood Forest

Although the losses of boreal aspen forests in western Canada because of global warming are worrisome, the most significant cause for concern is the degradation of ecosystems and floral and lichen diversity that results from agricultural development. In Canada, European Settlement began approximately 300 years ago in the east and spread west throughout the Prairie Provinces; currently 80 percent of the agricultural land base of Canada is concentrated in the three Prairie Provinces (Chetner, 2003). As a result, much of the Boreal Mixed-wood Forest has been cleared for agriculture resulting in a patchy fragmented landscape comprised of woodlots and areas such as wetlands that are unsuitable for agriculture, within a matrix of farm fields. Although the northern portions of the

Canadian prairies are more heavily forested than the southern portions, this area has recently experienced some of the highest rates of deforestation found in the world (Fitzsimmons, 2002; Hobson, Bayne, & Van Wilgenburg, 2002). The flora and fauna of the original forest are, for the most part, reduced to surviving in woodlots, hedges, riparian forests and national and provincial parks. Agriculture intensification over the past few decades in Canada has been linked to a decrease in woodlot size (Belanger & Grenier, 2002). A number of studies indicate that plant and lichen biodiversity is negatively affected by the resulting fragmentation and isolation of remnant forest stands in agro-environments (Boutin et al., 2002; Freemark, Boutin, & Keddy, 2002; Gignac & Dale, 2007; Harper et al., 2005).

Agricultural and urban development is particularly harmful because effects persist for centuries rather than 60 to 90 years, as is the case for clear cutting for forestry. In fact, agriculture is responsible for 23% of endangered species, 15% of species at risk and 16% of vulnerable species among plant species found in Canada (Committee on the Status of Endangered Wildlife in Canada [COSEWIC], 1994). Current agricultural practices introduce such deleterious effects as grazing and trampling of vegetation by livestock, soil compaction caused by heavy machinery, an increase in field width (and distance between forest fragments) to accommodate wider farming equipment used in crop monocultures, nutrient loading from fertilizers, the deposition of agrochemicals on the surrounding native vegetation and the threat to endemic plant species by agricultural insect pests (Boutin et al., 2002; Jensen, Linke, Dickhauser, & Feige, 1999; Ruoss, 1999; Vagts & Kinder, 1999). Thus, the woodlots, hedges and riparian forests that remain on the landscape have an important function in preserving biodiversity in vast areas of our country (Freemark et al., 2002).

Métis Land Use

Alberta is the only province or territory in Canada where Métis people have been granted rights to their own land that was designated differently than Reserve land for Status Indians. Métis people claim a distinct identity and social organization, born of an alliance between men of the fur trade and aboriginal women since the 17th century (Peterson, 1985). Métis Settlements on the shores of the Great Lakes date back to 1690 (Kermoal, 2006, pg. 37), but the heartland of Métis national identity is certainly the Red River Valley in southern Manitoba. The Métis settled in homesteads on elongated strips of land meeting a river or water source. Supplying the trading posts with furs and pemmican, fishing, salt mining, and farming were primary industries. Kermoal (2006, pg. 74) described a pre-1870s semi-nomadic lifestyle that centered on the bison hunt. Aside from consumption of bison meat, bison pelts provided warmth and bedding, along with straw and feathers. Bison grease was used for oil lamps. Before glass was available, skins were stretched over window openings while still taut allowing light to pass through (Kermoal, 2006, pg. 71). Oak, aspen, birch, and conifer species were used for construction of log homes, carts, and other necessities such as snowshoes and drying racks. Plants and herbs were collected for food and medicinal purposes. Berries and wild fruit were consumed in abundance and many other types of vegetation, such as mint, Labrador tea, wild turnips, and kinnikinnick added variety to the diet (Kermoal, 2006, pp. 62-63).

Through the Manitoba Act that was signed in 1870, the federal government set aside 567, 000 hectares of land for the Métis people and sanctioned separate schools and equality of the French and English languages (Kermoal, 2006, pg. 45). Albeit small, in 1870 the 'postage stamp' province of Manitoba was essentially a Métis Settlement: 82 percent of the population was Métis. However, due to a wave of European immigration that soon followed, "the Métis began to leave Manitoba in droves. By 1882, they had been allotted less than 243,000 hectares of the 567,000 hectares promised." (Carter, 1999, pg. 109). More than 80 percent of the Métis population had left Manitoba by 1885 (Carter, 1999, pg. 109). Métis presence was further diminished, to 6 percent, in 1901 (Kermoal, 2006, pg. 47). Manitoba had transitioned to a British-Ontarian society and the Métis felt like strangers in their own land. In addition, the Manitoba Act wasn't specific on how the land was to be allocated and in 1874 'scrip' was implemented. Heads of families could choose either money scrip, in the form of a $160 payout, or land scrip of 160 acres (Kermoal, 2006, pg. 50). Problems with scrip abounded, for example, acreages were drawn out of a ballot box and were often hard to locate and unsuitable for agriculture. Furthermore, the federal government did not recognize the Métis as a distinct ethnic group. They were simply seen as Canadians of low social standing (Kermoal, 2006, pg. 51). For these reasons, Métis people dispersed and settled in areas further west in the prairie provinces of Saskatchewan and Alberta.

The Métis Settlements of Alberta are all located in the northern portion of the province; currently 8 Settlements collectively encompass an area within the Boreal Mixed-wood of 1.25 million acres. Each Métis Settlement is governed by a Settlement council, elected from members of that Settlement. This council has powers analogous to those of a municipality, including the enactment of by-laws concerning management, health, safety, parks, recreation, business, water and sewage connections, and land-use planning and development. The Métis Settlements Act enacted in 1990 provides that the Alberta Planning Act does not apply to the geographic area of the Métis Settlements. A co-management regime has been developed so that planning agencies (comprised of provincial government and Métis representatives) are responsible for the planning and regulation of land usage on Settlement lands (Bell, 1994, pg. 60). The Memorandum of Provisional Métis Title specifies one of the "basic rules for keeping this grant: you cannot do anything to the land that does long term damage to it or other land in the Settlement area" (Bell, 1994, pg. 65).

Natural Areas and the Protection of Regional Plant Diversity

Although upland habitats have been severely altered through urban and agricultural development, many protected areas still exist within the Boreal Mixed-wood Forest in Alberta. Those areas include National Parks, several

Provincial Parks, and Recreation Areas (Alberta Parks, 2013). Ostensibly, the parks and recreation areas should protect plant and lichen diversity in severely altered landscapes. However, even though some natural areas can be found in most regions and thus protect plant diversity and act as a source of propagules for woodlots in the agricultural matrix, they are not immune to natural disturbances, such as fire, drought, or insect damage, in which case the regional diversity would consequently suffer. Also, the distance between these protected areas is an important consideration, for example with regards to the dispersal limitations of the native vegetation and resulting metapopulation dynamics (Hadenas & Ericson, 2008).

Structure of the Thesis

I seek to answer the goals of this thesis by using currently accepted practices in the field of remote sensing of Geographical Information Systems (GIS) and of plant ecology. Remote sensing and GIS techniques are used to quantify the area covered by different ecosystems for all four land uses at a regional level. Results of that part of the study are presented in Chapter 2. I also employ ecological field sampling methods and perform data and statistical analyses on plant species diversity and abundance as well as environmental data collected at a smaller scale at the site level. The ecological framework and analyses of plant biodiversity at the site-level are presented in Chapter 3.

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CHAPTER 2

Retention of Wooded Ecosystems on a First Nations Reserve Compared to Three Other Land Uses in a Developed Landscape in the Central Boreal Mixed-wood Forest of Northeast Alberta

INTRODUCTION

The subsistence strategies of the Aboriginal people living in what are today the three Prairie Provinces were based on exploitation of natural ecosystems. Traditionally, they led a mobile way of life, following the herds of bison and other large game along seasonal migration routes dictated by the availability of forage. Spry describes a hunter-gatherer society whose members enjoyed a plentiful resource base and diversified daily activities that required skill and profound knowledge of the environment (1991, pp. 82-83).

With European contact came an explosion in resource exploitation in the Canadian Prairies. By the end of the 19th century the fur trade had decimated the bison population (Carter, 1999, pg. 112). By 1821, there were not enough animals in many places to support a traditional aboriginal lifestyle (Ward, 1995, pg. 60). Furthermore, aboriginal people working in the fur trade industry had an increased dependence on white European society, "Encouraged by the imperatives of commerce, they had chosen specialized roles for themselves: hunters, trappers, and intermediaries-but by doing so, they had unwittingly become dependent on the Hudson's Bay Company. When those roles were no longer viable, they became dependent on the government." (Ward, 1995, pg. 61).

The British North America Act of 1867 gave the federal government jurisdiction over Indians (Carter, 1999, pg. 111). The second half of the 19th century saw a push to ‘civilize’ the fertile west, to create one nation stretching from the east to the west coast (Kermoal, 2006, pg. 40). Coupled with the influx of colonization were treaty negotiations, designation of ‘Indian lands’, and the implementation of the Indian Act. The 20th century saw dramatic cultural and sociological changes for First Nations people. The process whereby governments assumed greater responsibility for aboriginal groups, together with increased movement away from the land into urban centers led to a phenomenon dubbed ‘land alienation’ (Johnson, Kershaw, Mackinnon & Pojar, 1995, pg. 19).

In the present context, aboriginal land management practices are primarily those of the people living on Reserve or Settlement lands. ‘Aboriginal land management’ pertains to the management practices on aboriginal land, whether by members of the aboriginal communities themselves or government representatives. Aboriginal people claim the right to maintain traditional land-use practices, including harvesting rights (Russell, 2007). However, reality dictates that elements of this lifestyle occur within a larger, contemporary framework of Canadian society. Furthermore, ‘stewards of the earth’ hail from all sides, government, environmentalists, and citizens of all walks of life recognize the importance of conservation and are compelled to protect the flora and fauna of natural areas from anthropogenic abuses and non-sustainable initiatives.

Therefore, the goal of this study is to determine if the present First Nations land use retains vulnerable forest stands as well as ecosystem diversity in a landscape severely altered by agricultural and other industrial development. This goal is achieved by comparing deciduous and coniferous forest land cover on a First Nations Reserve to three other land use units in a highly developed agricultural region using Landsat imagery. The three other land-uses are: a Provincial Park, a Métis Settlement, and the surrounding area.

The study focuses on the central mixed-wood region of the boreal forest in northeast Alberta since that area contains all four land uses within a relatively small area. Prior to European Settlement, the mixed-wood landscape was dominated by forested areas of cold-hardy tree species. A mosaic of aspen, mixed-wood, and white spruce forests occurs on mesic uplands with jackpine stands on coarser, more xeric soils such as sand. Canopy cover is normally continuous on uplands with some gaps produced by fire, insect outbreaks, disease, and, at a more localized level, small canopy gaps resulting from the death of individual trees (Chavez & Macdonald, 2010). Wetlands are a dominant component and cover 16 percent of the land area (103,000 km^2) and small lakes account for approximately 3 percent (16,800 km^2) (Alberta Environment and Sustainable Resource Development, 2013). Some wetlands such as marshes and some fens as well as water bodies and their shorelines produce canopy gaps at the landscape level.

Since the arrival of European settlers, much of the Central Boreal Mixed-wood Forest has been cleared for agriculture resulting in a patchy fragmented landscape comprised of woodlots and areas such as wetlands that are unsuitable for agriculture, within a matrix of farm fields (Fitzsimmons, 2002). The integrity of the original ecosystems has been severely unhinged since the flora and fauna of the original forest are, for the most part, reduced to surviving in woodlots, hedges, riparian forests, and national and provincial parks. A number of studies indicate that plant and lichen biodiversity is negatively affected by the resulting fragmentation and isolation of remnant forest stands in agro-environments (Boutin, Jobin, Belanger, & Choiniere, 2002; Freemark, Boutin, & Keddy, 2002; Gignac & Dale, 2007; Harper et al., 2005). Agricultural and urban development is particularly harmful because effects persist for centuries rather than 60 to 90 years, as is the case for clear cutting for forestry. In fact, agriculture is responsible for 23% of endangered species, 15% of species at risk and 16% of vulnerable species among plant species found in Canada (Committee on the Status of Endangered Wildlife in Canada [COSEWIC], 1994).

Current agricultural practices also introduce such deleterious effects as grazing and trampling of vegetation by livestock, soil compaction caused by heavy machinery, an increase in field width (and distance between forest fragments) to accommodate wider farming equipment used in crop monocultures, nutrient loading from fertilizers, the deposition of agrochemicals on the surrounding native vegetation, and the threat to endemic plant species by agricultural insect pests (Boutin et al., 2002; Jensen, Linke, Dickhauser, & Feige, 1999; Ruoss, 1999; Vagts & Kinder, 1999). Agriculture intensification over the past few decades in Canada has been linked to a decrease in woodlot size (Belanger & Grenier, 2002). Thus, the woodlots, hedges and riparian forests that remain on the landscape have an important function in preserving ecosystems in vast areas of the boreal mixed-wood (Freemark et al., 2002).

Other detrimental land uses in the Central Boreal Mixed-wood Forest of northeastern Alberta include significant conifer and aspen harvesting for softwood and pulp production as well as intensive petroleum exploration and development (conventional oil and gas production in the northwest and oil sands extraction in the northeast) (Natural Regions Committee, 2006, pg. 139). Petroleum exploration and development produces linear disturbances such as roads, seismic lines, and pipelines as well as cleared pads for oil and gas extraction.

Levin, Shmida, Levanoni, Tamari, & Kark (2007) emphasize the challenges associated with attempts to quantify forest diversity, for example through labour intensive and expensive ground sampling endeavours, and highlight the usefulness of satellite imagery as a complementary tool in biodiversity research, especially for covering large and inaccessible areas. In the present study, I use Landsat ETM+ images for groundcover characterization in a region of northeast Alberta. Through the methods outlined in this chapter, the proportion of the study area that is currently covered by forest stands is quantified. This analysis is followed by a comparison of upland forest cover and landscape metrics in the four land use units of interest (Modified Surround, Provincial Park, Métis Settlement and First Nations Reserve). Specifically, the objectives of the remote sensing/GIS analyses are as follows: (1) to perform an IsoData unsupervised classification at 60 clusters on a subset of the Landsat image that encompasses our study area; (2) to reclassify the image into four landcover types - Water, Deciduous Forest, Coniferous Forest and Non-Forest (which includes, but is not limited to, roadways, oil & gas well sites, urban areas and agricultural crop/range land); (3) to determine the amount (in pixels and in percentage) of each cover type and (4) compare these values between each of the four land use units (Provincial Park, Métis Settlement, First Nations Reserve, and the area surrounding those land uses [Modified Surround]).

I predict an intermediate amount of total forest cover at Kehewin Reserve, due in part to third party grazing leases, to the relative length of time the Reserve has been populated and to development born of agricultural initiatives, housing and other community infrastructure. I expect to find a higher proportion of coniferous forest in the Provincial Park, as it may be that areas set aside for parks are commonly regions unfit for agricultural develepment (e.g. sandy or boggy soils), as opposed to the more desirable upland aspen forest ecozones. I also anticipate a higher proportion of non-forested area in the Modified Surround, due to high intensity urban, agricultural and oil & gas sector development in the northeastern boreal mixed-wood of Alberta. Similarly, I expect to find a more fragmented landscape in the Study Surround, characterised by a higher proportion of smaller forest patches than in the other three land use units.

METHODS

Study Area

The study area covers approximately 2100 km^2 around the town of Bonnyville, in northeast Alberta. The Bonnyville area was chosen because it is typical of northern prairie Settlement of the past 100 years. Agriculture (crop and cattle) and oil & gas development are the primary industries and although much of the landscape has been developed it retains relatively undisturbed lands such as a Provincial Park and adjacent Recreation area as well the Kehewin First Nations Reserve and the Elizabeth Métis Settlement (Figure 2-1).

Trembling aspen (*Populus tremuloides*) is the dominant tree species in the well-drained upland stands, but moderate quantities of balsam poplar (*Populus balsamifera*), and white spruce (*Picea glauca*) are also found. The understory typically consists of Saskatoon berry (*Amelanchier alnifolia*), choke cherry (*Prunus virginiana*), prickly rose (*Rosa acicularis*), and willows (*Salix* spp.). The landscape is typical of the boreal mixed-wood, a mix of deciduous and coniferous forest stands interspersed with wetlands and small lakes. On sandy more xeric sites, the overstory is dominated by jack pine (*Pinus banksiana*) and low shrubs such as blueberry (*Vaccinium myrtilloides*). The mean annual precipitation in the area ranges from 400 mm to 450 mm, with higher levels to the north and west. Mean temperature varies from -17ºC in January to 15.5ºC in July (Chetner, 2003).

The dominant soils are Dark Grey Chernozomics and Dark Grey-Grey Luvisols to the north and west; Grey Luvisols and Organics to the south and east (Strong & Leggat, 1981).

Landcover Classification

Landsat satellite images were obtained from the Earth Science data Interface (ESDI) of the Global Land Cover Facility Website (Global Land Cover Facility, 2009). The Enhanced Thematic Mapper Plus (ETM+) sensor has a nominal spatial resolution of 28.5 m; adequate for a study of Agricultural land, deemed Classification Level 2 by the U.S. Geological Survey (Jensen, 2007, pg. 450). Landsat ETM+ sensor data of Path 41 Row 22, were selected (granule ID 043-471). The image was taken in September 1999, thus the deciduous trees still had their leaves. The GEOTiff image files had a WRS-2 reference system and the registered projection system was Universal Transverse Mercator zone 12 north. Atmospheric correction was not necessary as the image was cloud free.

Image classification was conducted using an iterative technique that involves clustering pixels based on spectral characteristics. An unsupervised classification was performed using the algorithm Iterative Self-Organizing Data Analysis Technique (ISODATA) in the ENVI 4.3 software package (ITT Visual Information Solutions, 2007). Since the study area is smaller than the Landsat image, the ISODATA classification was conducted on all spectral bands at 60 clusters and with a maximum of 10 iterations on a subset of the Landsat image.

The 60 clusters returned by the classification were merged into the following four classes: water, deciduous forest, coniferous forest and non-forest. Masks of the four land-use areas were built and applied. The masks of the Provincial Park, First Nations Reserve, and Métis Settlement were drawn according to the boundaries of each. A mask of the entire study area was created and labeled 'Study Surround'. This Study Surround refers to a polygon that was manually drawn around all the land use units. Because of the spatial distribution of the 3 delineated land use units, this polygon is a rectangle. Thus, a total of four masks were built and applied to the reclassified subset image (Provincial Park, First Nations Reserve, Métis Settlement, and Study Surround). The number of points and percent cover values of the four classes for all four masks were then extracted. To reduce noise in the reclassified image, a moderate majority analysis filter (3 x 3 kernels) followed by a clump operation (3 rows x 3 columns) was applied using ENVI (ITT Visual Information Solutions, 2007).

In order to estimate the accuracy of the land cover classification, a Kappa Analysis was conducted (Jensen, 2005). The K_{hat} Coefficient of Agreement is a standard classification statistic used in land cover mapping (Young, Sanchez-Azofeifa, Hannon & Chapman, 2006) that expresses the measure of agreement between a classification map and reference data. A proportional random sample (N=300) was generated from a subset of the original Landsat ETM+ image using the ArcMap component of ArcGIS (ESRI, 2010). An error matrix was then compiled to evaluate the probability of correctly labeling a given pixel when compared with the classification and determine the Producer's Accuracy (errors of omission) the User's Accuracy (errors of commission) and overall accuracy (K_{hat} statistic).

Landscape Metrics

The following landscape metrics were calculated for each land use unit as well as the entire study area: Patch Density (PD), a Landscape Shape Index (LSI), and a Largest Patch Index (LPI). Patch density measures the number of patches divided by total landscape area and indicates habitat heterogeneity. LSI is an aggregation metric that measures habitat complexity where higher values indicate patch types that are more dispersed. LPI measures the percent of landscape that the largest patch occupies. Landscape metrics were calculated using Fragstats (McGarigal, Cushman, Neel, & Ene, 2002). Values of the Study Surround minus the values of the other three land use units were calculated and labelled 'Modified Surround'. Due to the relatively small size of the three land use units in proportion to the entire study region, the difference in land cover values between the Study Surround and the Modified Surround units was marginal. Therefore, it was not necessary to isolate both variables in the fragmentation analyses and only the Study Surround was used in the calculation of fragmentation metrics.

RESULTS

Satellite Image Classification and Accuracy Assessment

The ISODATA unsupervised classification returned 60 clusters after 10 iterations. These clusters were reclassified into four land cover classes, based on satellite imagery, ground knowledge of the area, and spatial proximity. The classes were as follows: Water, Deciduous Forest, Coniferous Forest and Non-Forest (which includes, but is not limited to, roadways, oil & gas well sites, urban areas, and agricultural crop/range land) (Fig. 2-2). A land use unit represents the entire unit of interest, for example, the land use unit labeled Settlement is the entire Elizabeth Métis Settlement. The reclassified images of the four land use units display characteristics of each. The central portion of Kehewin First Nations Reserve is largely unforested, with the majority of the forested area comprised of deciduous forest along the west-south-east perimeter (Fig. 2-3a). The Provincial Park is heavily forested, with substantial coniferous cover (Fig. 2-3b). The Métis Settlement is also heavily forested, although the forest cover is primarily deciduous. Non-forested patches are more prevalent in the northern and western portions and include roadways that also extend into the center of the Settlement. Patches of coniferous stands are scattered throughout this landscape, with a swath extending roughly east-west in the northern tip (Fig. 2-3c). The southern and eastern portion of the Modified Surround is more heavily forested, consisting of a roughly triangular area starting in the south central portion of the polygon and opening towards the east (Fig. 2-2). This swath of forest is comprised primarily of deciduous cover. Coniferous cover in the Modified Surround occurs predominantly in patches of conifer forest extending from the west and north shores of Moose Lake Provincial Park into the northwest corner of the polygon.

Table 2-1 shows producer's and user's accuracies for the four land cover classes. All accuracies reported are ≥ 84% and the overall accuracy for the land cover classification is 86.3%. Kappa statistic values of 0.81 and greater are considered to be in almost perfect agreement (Landis & Koch, 1977).

Land Cover Values

Absolute land cover values were calculated from the masks built in ENVI and are found in Table 2-2. The Modified Surround covered the largest portion of the Study Surround followed by the Métis Settlement, First Nations Reserve, and Provincial Park. The Park is an order of magnitude smaller than the next smallest unit. Total forest cover for the Study Surround and Modified Surround was slightly higher than the non-forested area. In fact, forest cover exceeded non-forested areas for all land uses with the exception of the First Nations Reserve. Coniferous forest cover was the smallest of any other cover class for the entire landscape as well as for all land use units with the exception of the Provincial Park. The Reserve had the smallest coniferous forest cover. The deciduous forest cover followed the same pattern as total area; the Provincial Park had the smallest followed by the Reserve, Settlement, and Modified Surround.

As the land use units differed in size, relative land cover values (percent cover) were also calculated, excluding the water class, as a percent of the study area (Fig. 2-4). As a result, percent cover values as represented in the figures do not always sum to 100% for each land use unit. The Provincial Park has the highest proportion of total forest cover , followed by the Métis Settlement, whereas the total forest cover in the First Nations Reserve, Modified Surround and Study Surround was less than half of the total area. The highest proportion of coniferous forest is found within the Provincial Park (60%) (Fig. 2-5). Coniferous cover values in the other land use units all fall under 10%. Cover in the Métis Settlement (9%) more closely resembles that found within the Modified Surround and Study Surround (7%). The lowest value for the coniferous cover class is in the First Nations Reserve (3%). In contrast to this division, deciduous cover in the study area follows more of a gradient. The Métis Settlement contains 55% deciduous forest cover, followed by the Study Surround (41%), the Modified Surround (39%), the First Nations Reserve (35%) and the Provincial Park (26%). Finally, the First Nations Reserve is primarily unforested (60%). Non-forest cover values in the Study Surround and Modified Surround fall just under half (43% and 44%, respectively), followed by 32% in the Métis Settlement and 5% in the Provincial Park.

Fragmentation Metrics

Patch density is highest in the Provincial Park, followed by the Métis Settlement, the Study Surround and lastly the First Nations Reserve (Table 2-3). Highest LSI values were found in the study surround, followed by the Métis Settlement, the First Nations Reserve, and finally the Provincial Park. LPI in the First Nations Reserve was highest, representing the Non-Forest class (Fig. 2-6). The Study Surround LPI was also within the Non-Forest cover class. Both the Provincial Park and Métis Settlement LPI values were of the deciduous forest class.

DISCUSSION

Classification and Validation Methods

The ISODATA unsupervised classification and subsequent reclassification of the Landsat satellite imagery was efficient overall in quantifying the four land cover classes of interest in a study area comprising approximately 2100 km^2 within a highly developed region of the Central Boreal Mixed-wood Forest in northeast Alberta (Table 2-1). The method of using medium resolution (~30 m) imagery to quantify land cover was enhanced by direct *in situ* knowledge of the landscape and contributed to the solid accuracy assessment values. Other studies of forest cover using Landsat data in agricultural landscapes of northern Alberta reported similar accuracy values (Grossman, 2008; Young et. al., 2006). Because the study region is highly fragmented by private and public roadways, seismic lines, and oil & gas wells, care was taken with the choice of smoothing operations. In the present study a 3x3 kernel majority analysis was chosen as it was found with the 5x5 kernel majority analysis that roadways were lost and thus land cover (e.g.

forest cover) values were slightly exaggerated. The Clump function at 3 rows x 3 columns effectively defined the landscape patches for input into the FRAGSTATS software package. The Landsat ETM+ grain size of 28.5 m was somewhat problematic in the areas of the Study Surround of intensive crop production as the narrow (~5-10 m wide) hedgerows located between quarter sections that are typical of this environment were inaccurately represented or omitted altogether. Furthermore, under this classification scheme, ‘treed’ areas with active cattle grazing (e.g. large tracts of third party grazing leases) were classed as forest.

Land Cover

The results of the % of the total land cover analysis clearly show a trend in forest cover. As expected the Provincial Park is proportionally the most forested area, followed by the Métis Settlement, the First Nation Reserve, and the Modified Surround (Fig. 2.4). The hypothesis that a moderate amount of total forest cover would be present in the Reserve land use unit was supported, although the level is somewhat lower than anticipated and less than all the other units. Parts of the Kehewin Reserve more closely resemble the region developed for agriculture that surrounds it (Fig. 2-2). The most important cover class for the Reserve land use unit was non-forest and its relative value was the highest of all land use units, even surpassing levels in the Study Surround by a considerable margin (Table 2-2). The central portion of this unit is primarily non-forested and resembles the surrounding agricultural matrix with clusters of homes on cleared lots, fenced cattle rangeland and an area under consideration for a gravel pit operation. However, it remains that deciduous forest cover values in the First Nations land use unit were much higher than in the Provincial Park (Fig. 2-5). This finding is significant because Kehewin Reserve is over 11 times larger than Moose Lake Park. Actual surface area data shows that deciduous forest cover in the Reserve land use unit is over 15 times greater than in the Provincial Park unit (Table 2-2). The more heavily forested southern portion of the Reserve contrasts the more open northern portion.

Apart from the Modified Surround, the Elizabeth Settlement is the largest land unit studied (Table 2-2); it is also the most recently designated. Forest cover in the Métis Settlement was largely in the deciduous cover class, with only a small amount falling in the coniferous class (Fig. 2-5). There was also a considerable amount of non-forested land in this unit. The non-forest cover class in this study includes developed and naturally occurring non-forested areas, for example in the form of wetlands, shorelines, and meadows. It is a relatively natural environment with low levels of development for infra-structure (Fig. 2-3c). Wildlife such as bears and moose inhabit the Settlement, and in fact hunting does occur on this land (personal observation). It is however, fragmented by a number of oil & gas wells and associated roadways.

As predicted, the Provincial Park forest stands were predominantly coniferous (Fig. 2-5). Coniferous forest cover in the Park vastly exceeded levels in all the other land use units. Large portions of Moose Lake Provincial Park consisted of jack pine stands on sandy soils as well as some smaller stands of black spruce (*Picea mariana*). The Provincial Park also contained a proportionally high deciduous forest area but less than any other land-use area. The Park contains a relatively small proportion of non-forested land.

The Modified Surround occupies the largest area on the landscape and contains by far the highest amount of either forest type (Table 2-2). Surprisingly, the amount of forest cover exceeds that of the non-forested area. As a result, the hypothesis that a higher proportion of the area would be non-forested is false. Proportionally it contains less total forest cover than any other unit with the exception of the First Nations Reserve (Fig. 2-4). However, it contains proportionally more deciduous forest cover than all land-use areas other than the Métis Settlement (Fig. 2-5).

Fragmentation Metrics

In its natural state, the Central Boreal Mixed-wood Forest is a patchy mosaic of diverse cover types. Deforestation for agricultural purposes has further resulted in a fragmented landscape comprised of woodlots and areas such as wetlands that are unsuitable for agriculture, within a matrix of farm fields. The Study Surround land use unit was isolated as a sample area of the Central Boreal Mixed-wood of northeast Alberta.

The Landscape Shape Index (LSI) was used in this study as an indicator of landscape complexity. The calculated LSI value for the Surround unit is quite high (Table 2-3), indicating the study region is complex. The LSI for the Métis Settlement is also high, relative to the other two land use units, illustrating the heterogeneity of the ecosystem under Métis control. Although the entire region has been fragmented by 100+ years of agricultural and industrial development, large forest stands remain on the landscape. Largest Patch Indices (LPI) for both the Provincial Park and Métis Settlement are higher than the study surround and are represented by the deciduous cover class. Despite the fact that forest cover in the Provincial Park is predominantly coniferous, it retains a relatively large patch of deciduous forest. However, the fact that the actual surface area of the Métis Settlement is much larger than the Provincial Park emphasizes the absolute size of the deciduous forest patch in the Métis Settlement. This means the Métis Settlement houses the largest intact stand of aspen dominated forest in the study region. Conversely, the highest LPI value is in the First Nations Reserve and corresponds to the Non Forest cover class. The largest patch in the study surround is also non-forested. Although not reported in the tables, the water class was removed in the FRAGSTATS analysis thus high Non Forest LPI values in the Surround and Reserve units are not large water bodies such as lakes. A landscape comprised of a variety of forest patches is linked to higher heterogeneity values. The Patch Density (PD) metric is used in this study as an indicator of habitat heterogeneity. Our results show the Provincial Park land use unit is the most heterogeneous environment, followed by the Métis Settlement, the Study Surround and finally the First Nations Reserve.

Land Management and Wooded Ecosystem Retention

Kehewin Reserve is the least heterogeneous environment and its largest patch is non-forested. Neither of those attributes is indicative of the original Central Boreal Mixed-wood Forest in northeastern Alberta. Although there remains a relatively large patch of deciduous forest, discussions with band members indicated that hunting/trapping was occurring off-Reserve and concerns over water contamination from agricultural run-off was impacting harvesting from waterbodies (personal communication). Currently cattle grazing initiatives are conducted on Kehewin First Nation, operated through both band-owned and third party lease arrangements. These operations resemble those typically found in mainstream agricultural environments, consisting of large cleared areas where the livestock are contained by fences and can access and graze within small forest patches located in the forage area. Hay cultivation is also occurring in this part of the land use unit. An area under consideration for a gravel pit operation is in close proximity to the farmed areas. My research suggests the management regime on First Nations land that has contributed to higher fragmentation and lower proportions of forest stands identified as vulnerable within this developed landscape may well be a direct result of past land management practices, since the implementation of the Reserve system in the late 19th century.

The Indian Act stipulates that an Indian Reserve is “a tract of land, the legal title to which is vested in Her Majesty, that has been set apart by Her Majesty for the use and benefit of a band” (Indian and Northern Affairs Canada, 1982a, pg. 1). This is the basis for the usufructuary rights; that so-called Indian Lands are owned by the crown and all decisions must be approved by the Minister, Superintendant or other representative of Her Majesty. Aboriginal Affairs and Northern Development Canada (AANDC-previously *Indian and Northern Affairs Canada*) is the federal department responsible for the government of aboriginal affairs. The Minister can act “in any way that it thinks will help the ‘progress and development’ of the Indians” (Indian and Northern Affairs Canada, 1982a, pg. 27) and that “the Government decides what is best for the benefit of the band” (Indian and Northern Affairs Canada, 1982a, pg. 23).

Essentially, Indian land can only pass between members of that particular band, members are issued “Certificates of Possession” which give them the right to use and occupy lands on a Reserve. Land can be leased to third parties (e.g. for agricultural or grazing purposes) by the Minister, for the benefit of the person in possession of the land, however, “the money made from farming shall be used to pay rent to the Indian who owns the land. The value of any improvements that have been made to the land is taken out of the rent. What is left over after this rent has been paid is paid into the band’s funds” (Indian and Northern Affairs Canada, 1982b, pg. 22). This example is indicative of the general nature of land management practices, although these practices vary from one band to another, based on whether or not treaties have been signed, or if other special arrangements between a band and AANDC have been made. In theory, a band council has the right to control land use on Reserve land: "If a band asks for it, the Government can give the band the right to the amount of control over its lands that the Government thinks is desirable" (Indian and Northern Affairs Canada, 1982c, pg. 23).

In contrast to the First Nations Reserve, the Elizabeth Métis Settlement is a heterogeneous environment as indicated by a high patch density. Farming operations are small scale; cattle grazing occurs on site, however, much of this consists of cows wandering up and down the roadsides rather than in fenced sections of cleared land.   Municipal infrastructure is low level and residential development is on large lots (acreages) that retain substantial forest cover. Hunting, even for large game such as moose, occurs within the Settlement, and care is taken to hunt selectively (personal communication). This research suggests the higher level of retention of wooded ecosystems on the Métis Settlement could facilitate the conservation of the original ecosystem, efforts that would be further enhanced by the more contemporary management regime in place on Métis land.

Each Métis Settlement is governed by a Settlement council, elected from members of that Settlement. This council has powers analogous to those of a municipality, including the enactment of by-laws concerning management, health, safety, parks, recreation, business, water and sewage connections, and land-use planning and development. Land title to individual members of the Métis Settlement is limited in size to the equivalent of one hamlet lot (total 175 acres); additional land (167 acres) for the purposes of farming or conducting a business can be acquired upon request to the Settlement council. The holder of Métis title can lease his or her land, but must obtain approval if the lease is to non-Settlement members or for a duration of more than 10 years. Other limitations are outlined, for example with respect to use of timber and other non-renewable surface resources (sand, gravel, clay, etc); these resources cannot be sold for use off-Settlement. The Métis Settlements Act provides that the *Alberta Planning Act* does not apply to the geographic area of the Métis Settlements. A co-management regime has been developed so that planning agencies (comprised of provincial government and Métis representatives) are responsible for the planning and regulation of land usage on Settlement lands (Bell, 1994, pg. 60). The Memorandum of Provisional Métis Title specifies one of the "basic rules for keeping this grant: you cannot do anything to the land that does long term damage to it or other land in the Settlement area" (Bell, 1994, pg. 65). Seemingly, as a result of these management practices, fragmentation is reduced and conservation of the original ecosystems is promoted.

Some of the purposes of the Provincial Park system in Alberta, as specified in the original Provincial Parks and Protected Areas Act of 1930 were that parks be for the propagation, protection, and preservation of wild animal life and wild vegetation, for the recreation and general benefit of the inhabitants of the Province and for the protection and preservation of objects of geological, ethnological, historical, or other scientific interest (Mason, 1987, pg. 55). In the study area, coniferous forests occupy the least amount of space on the landscape and as a result may be the most vulnerable forest ecosystem in the region. By conserving a relatively large patch of coniferous forest, Moose Lake Provincial Park fulfills one of its primary roles, that of protecting wild vegetation. Provincial Parks in general do not permit any development that can potentially lead to reduced patch sizes or the removal of any plant material and those attributes considerably reduce the negative effects of fragmentation. Furthermore, the Park also protects a stand of deciduous forest, albeit of reduced size, but this forest is not as rare on the landscape as the coniferous forest.

The sole criticism of Moose Lake Provincial Park is its relatively small size. However, this criticism does not only apply to Moose Lake Provincial Park but to all provincial parks in Alberta. Mason argues that parks in Alberta have been regarded as “luxury items” by the provincial government, being that park expansion and development has been closely linked with periods of economic prosperity (Mason, 1987, pg. 55). For example, when the oil boom of the 1970s dwindled, the recession of the 1980s brought a $6 million parks budget decrease. As a result, Alberta is often criticized as having the weakest parks legislation in Canada and lacking long-term vision through management plans: currently only 58 parks have plans, many of which are over 10 years old. Furthermore, only

4.2% of the land in Alberta is designated as a provincial protected area (Canadian Parks and Wilderness Society [CPAWS], n.d.).

With respect to the Modified Surround unit, the land is usually managed for economic gain rather than for landscape conservation values. As a result, the single largest patch is non-forested and the forest is cut in order to facilitate the use of machinery for crop cultivation and grazing for livestock. However, surprisingly, the total forest cover marginally exceeded that of the non-forest. The total area covered by both deciduous and coniferous forests in the Modified Surround is greater than in any other land-use albeit the % cover of coniferous forest is proportionally less than the park and the cover of deciduous forest is less than the Elizabeth Settlement.

Almost all of the forested land in the Modified Surround is non-private and includes: publicly owned land, a second Métis Settlement, and two other First Nations Reserves. Among publicly owned lands there is a Recreation Area to the southwest of the Provincial Park that is dominated by coniferous forest (Fig. 2-2). Also, the large tracts of deciduous forest located to the south and east of Kehewin Reserve up to the western boundary of the Elizabeth Métis Settlement (Fig. 2-2) are Crown land that is leased to third parties for agricultural purposes, principally livestock grazing. Third Party Leases of Crown land also account for a substantial portion of the forested area located to the northwest of Moose Lake Provincial Park. That area includes a mixture of both coniferous and deciduous forests.   Forested ecosystems that are grazed by cattle are typified by reduced understory vegetation and limited biodiversity due to increased wind and light penetration (Hobson, Bayne, & Van Wilgenberg, 2002). Thus, leased Crown land which occupies most of the forested area in the Modified Surround has lost much of its ecological integrity and is therefore of limited value from an ecosystem conservation perspective.

Cold Lake First Nations Reserve extends north of Elizabeth Métis Settlement while Puskiakiwenin and Unipouheous are small reserves located on the south east side of the study area (Fig. 2-2). Land use is similar to that on the Kehewin Reserve and as a result, the % of land covered by deciduous forest is similar. Fishing Lake Métis Settlement is located directly south of the Elizabeth Settlement and extends of the map in Figure 2-2. Forest cover and land use on Fishing Lake Settlement is very similar to that on the Elizabeth Settlement. Thus, the largest area of relatively intact deciduous forest in the Modified Surround is located on the Fishing Lake Métis Settlement. Therefore, despite our initial perception when viewing a large swath of forest in the Modified Surround (Fig 2-2), the proportion of this forest having useful conservation value is relatively small and is mostly composed of land on the Fishing Lake Métis Settlement.

In the remaining generally non-forested areas of the Modified Surround, the landscape metrics indicate that the area is highly fragmented. Field observations indicate that many of the remaining forest stands are typically linear shelterbelts, lowland thickets dominated by willows (*Salix* spp.) or circular stands located in the fields that contain large rocks removed by the farm machinery. Although there are efforts to increase the number of treed stands in the agricultural matrix through shelterbelt planting initiatives, typically the focus is on blocking the wind and reducing soil erosion. From an ecosystem conservation perspective, limitations of planted hedgerows include the lack of a remnant seed bank and the tendency to favour coniferous species over a mixture of deciduous and conifers (Boutin et al. 2002). Furthermore, it is common practice to clear the understory of these stands, for example by mechanical removal or herbicide application, in the interest of private landscaping aesthetics or in order to reduce competition of planted tree species with herbaceous species for soil moisture, nutrients and light (Alberta Agriculture, Food and Rural Development, 2007; Prairie Farm Rehabilitation Administration, n.d., pg. 8). In rural agricultural areas of Alberta, land management falls under the jurisdiction of the Municipal District. Local government in some cases provides fence line clearing initiatives to assist farmers in maximizing cultivation on their land and/or replacing the existing vegetation with planted shelterbelts (Municipal District of Bonnyville, 2013). Despite the intensive agricultural development, there still exist sizeable tracts of land in this study area that could be the subject of protection initiatives. Because less than 50% of the agricultural land use-unit contains any forest at all, identifying areas of interest could be an important next step.

CONCLUSION

The Kehewin First Nations Reserve does not retain forested ecosystems very well. In fact, because its largest patch is non-forest, the Reserve most closely resembles the Modified Surround land use unit, where wooded ecosystem conservation is a low priority. Conversely, the Elizabeth Métis Settlement more closely resembles the Provincial Park than the Modified Surround, suggesting a management regime more conducive to ecosystem conservation.

This research yielded interesting results that warrant further attention. It would be relevant to expand this study and include other First Nations Reserves, Métis Settlements and Parks & Protected areas. Due to the diversity (e.g. differences in size and location) of Aboriginal lands in Canada, a comparison with other First Nations Reserves and Métis Settlements may or may not reveal similar results. If results similar to the preliminary results presented within were obtained, it would be logical to conclude that land under aboriginal control, particularly land under Métis control, is in fact helping to maintain the ecological integrity of our landscape in an area typical of the northern prairies of Western Canada.

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Table 2-1: Summary of all Landsat ETM+ classification accuracies based on the calculated error matrix for testing pixels (N=300). Shown are producer's accuracy (omission error) and user's accuracy (commission error).

Class	N of Testing Pixels	Producer's Accuracy	User's Accuracy
Non-Forest	126	91.3	85.2
Deciduous	120	81.7	85.2
Coniferous	25	84.0	84.0
Water	29	86.2	100.0

Table 2-2: Total area and land cover values (ha) of the land use units after an ISODATA unsupervised classification at 60 clusters. The Study Surround unit represents the entire study area, including all land use units. Surround Modified values represent the study unit minus the values from the other 3 land use units. Values for total forest cover are the sums of deciduous and coniferous forest cover type.

Land Use Unit	Total area	Non-forest	Coniferous	Deciduous	Total Forest
Study Surround	217836	93887	16556	89530	106086
Surround Modified	185150	81096	13701	73690	87391
Provincial Park	746	36	445	194	639
Metis Settlement	23563	7587	2121	12983	15104
F. Nations Reserve	8376	5050	209	2923	3133

Table 2-3: Land cover metrics for 4 land use units in the Bonnyville region of northeast Alberta, Canada. The land use units are: Moose Lake Provincial Park, Elizabeth Métis Settlement, Kehewin First Nations Reserve and Study Surround. Largest Patch Index includes calculated value and associated cover type. (D) indicates deciduous forest cover and (NF) indicates the non-forest cover class.

Land Use Unit	Patch Density	Largest Patch Index	Landscape Shape Index
Provincial Park	9.23	54.4849 (D)	5.88
Metis Settlement	7.73	44.5927 (D)	27.32
F. Nations Reserve	4.33	61.7157 (NF)	10.84
Study Surround	5.75	33.7852 (NF)	61.43

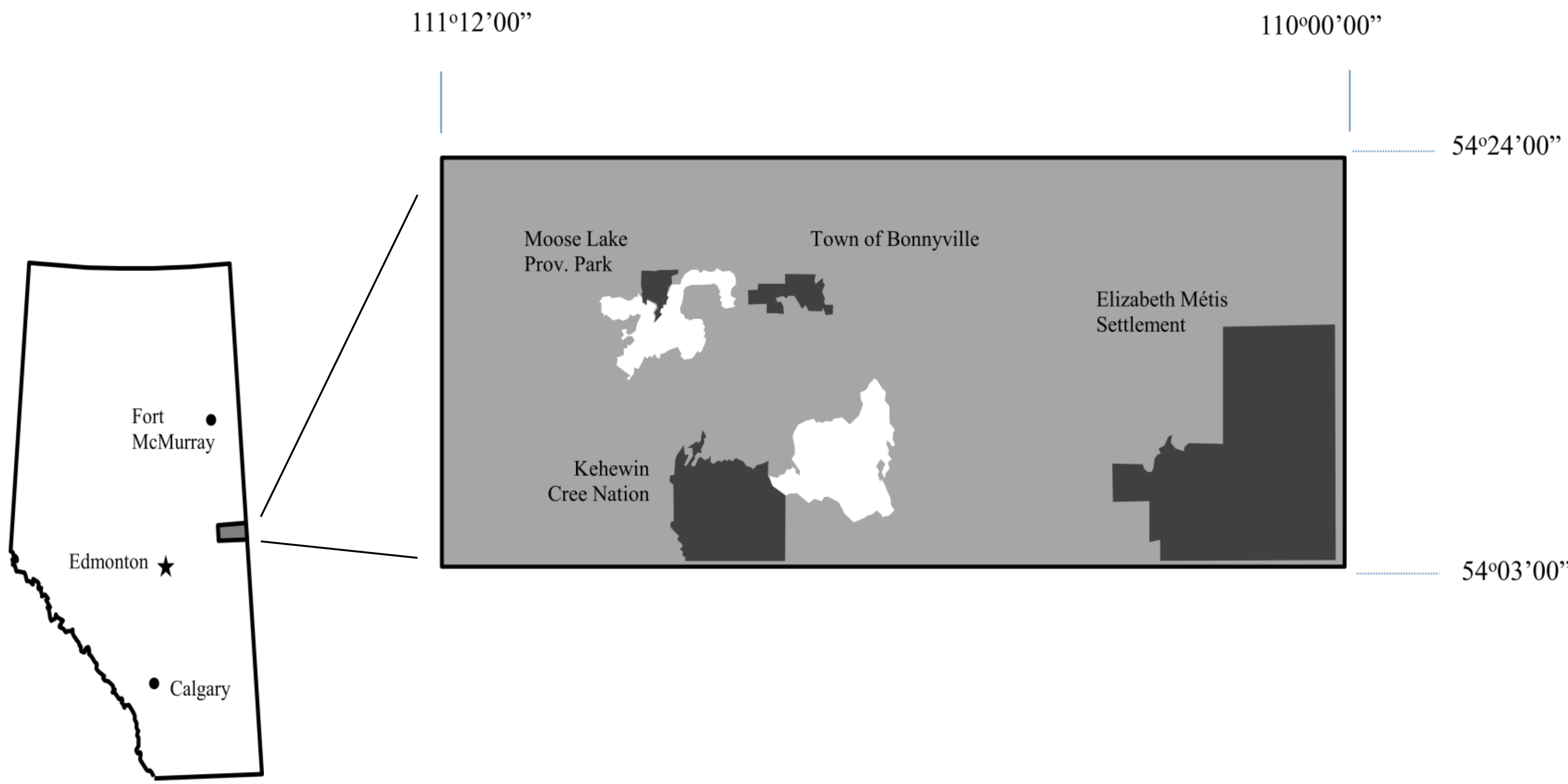

Figure 2-1: Map showing the location of the study area in northeast Alberta, Canada.

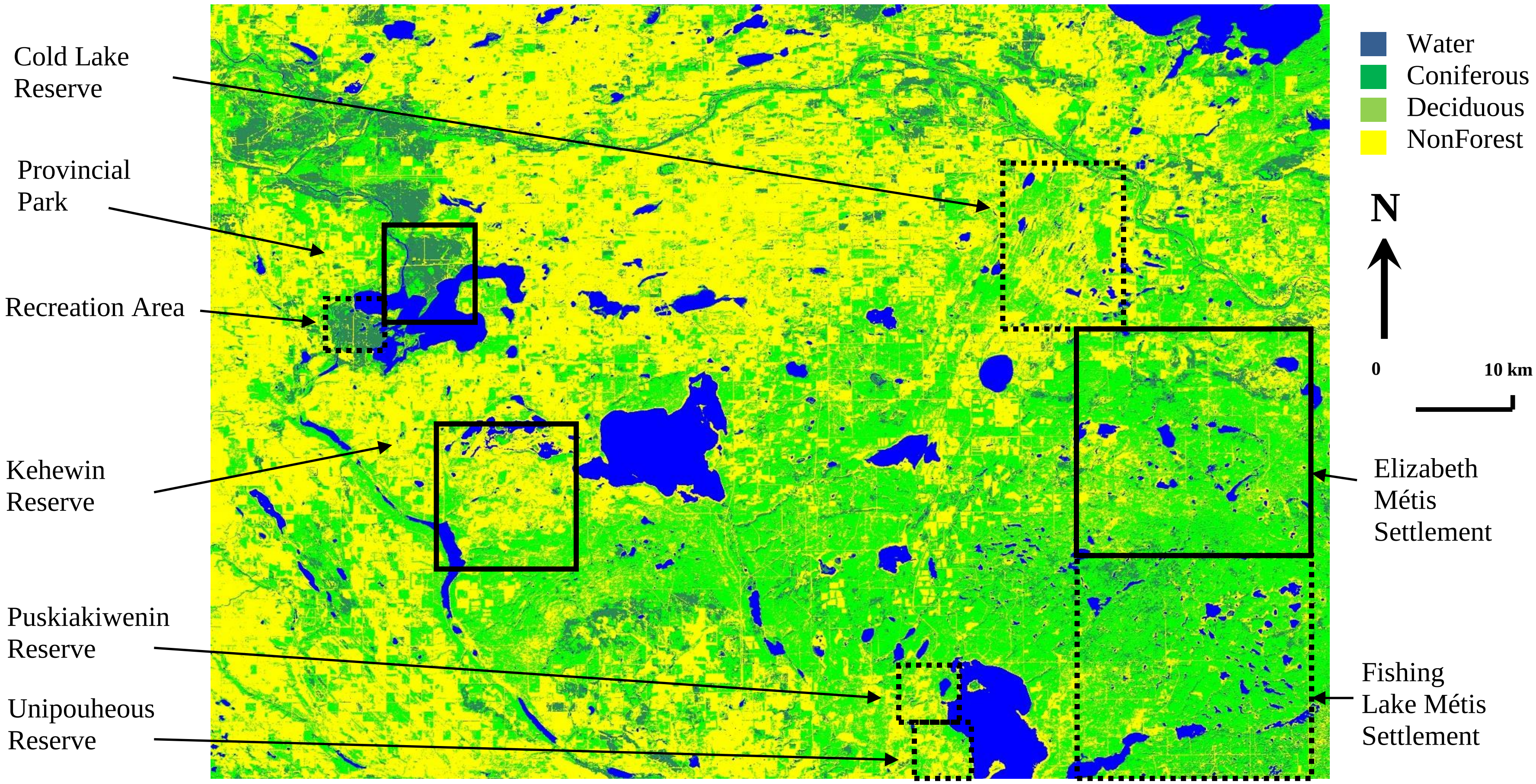

Figure 2-2: ISODATA unsupervised classification of the entire study region at 60 clusters and reclassified into four land cover classes: water, coniferous forest, deciduous forest, and non-forest.

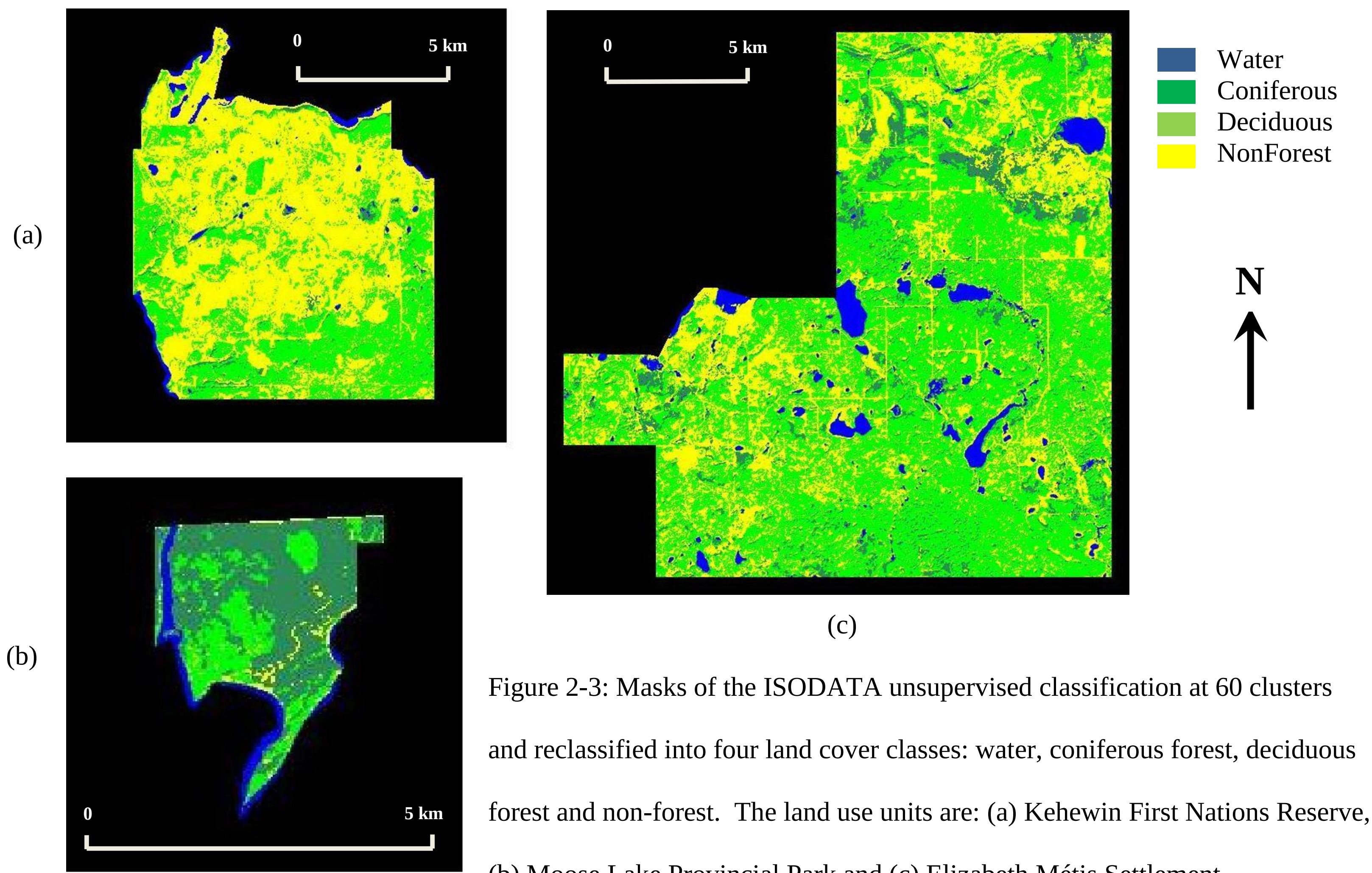

Figure 2-3: Masks of the ISODATA unsupervised classification at 60 clusters and reclassified into four land cover classes: water, coniferous forest, deciduous forest and non-forest. The land use units are: (a) Kehewin First Nations Reserve, (b) Moose Lake Provincial Park and (c) Elizabeth Métis Settlement.

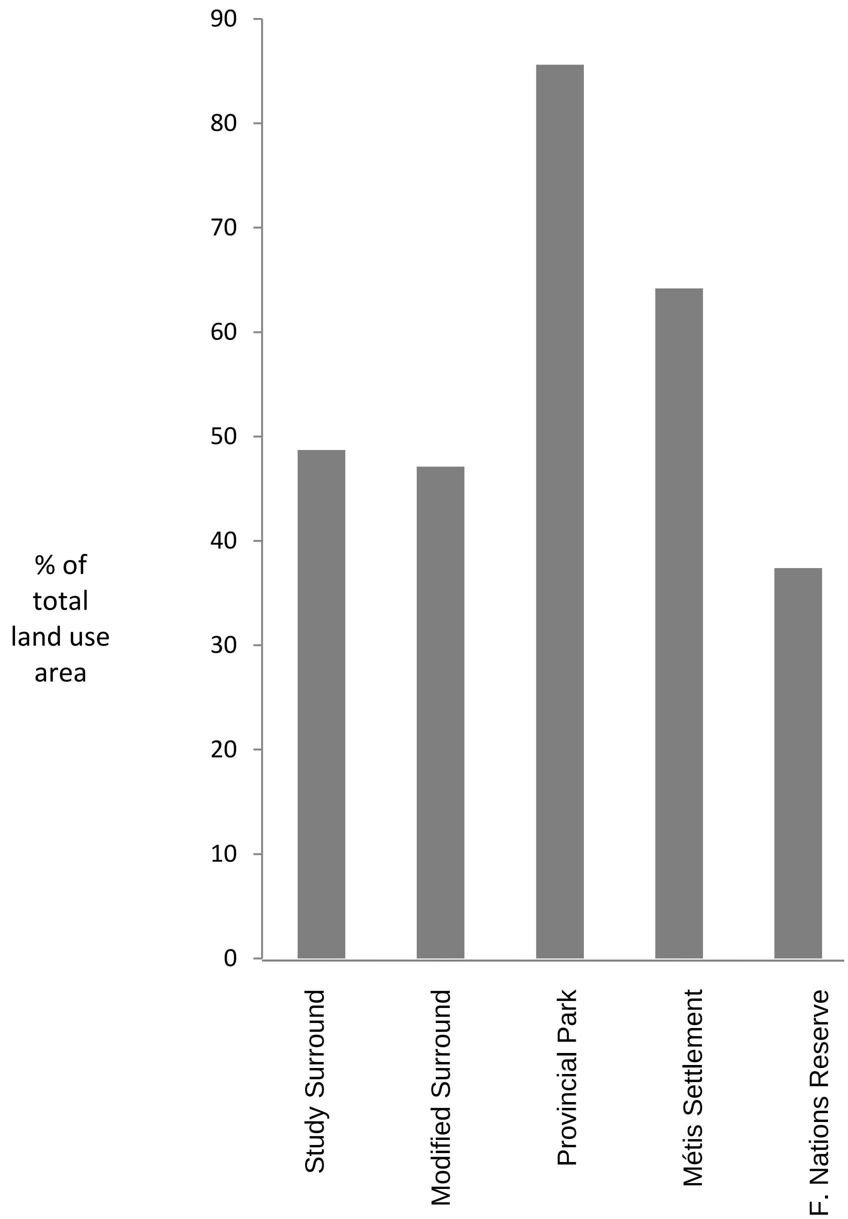

Figure 2-4: Relative forest cover values (coniferous + deciduous) as a percent of total area in the respective land use units. The Study Surround unit represents the entire study area, including all land use units. Modified Surround values represent the study unit minus the values from the other 3 land use units.

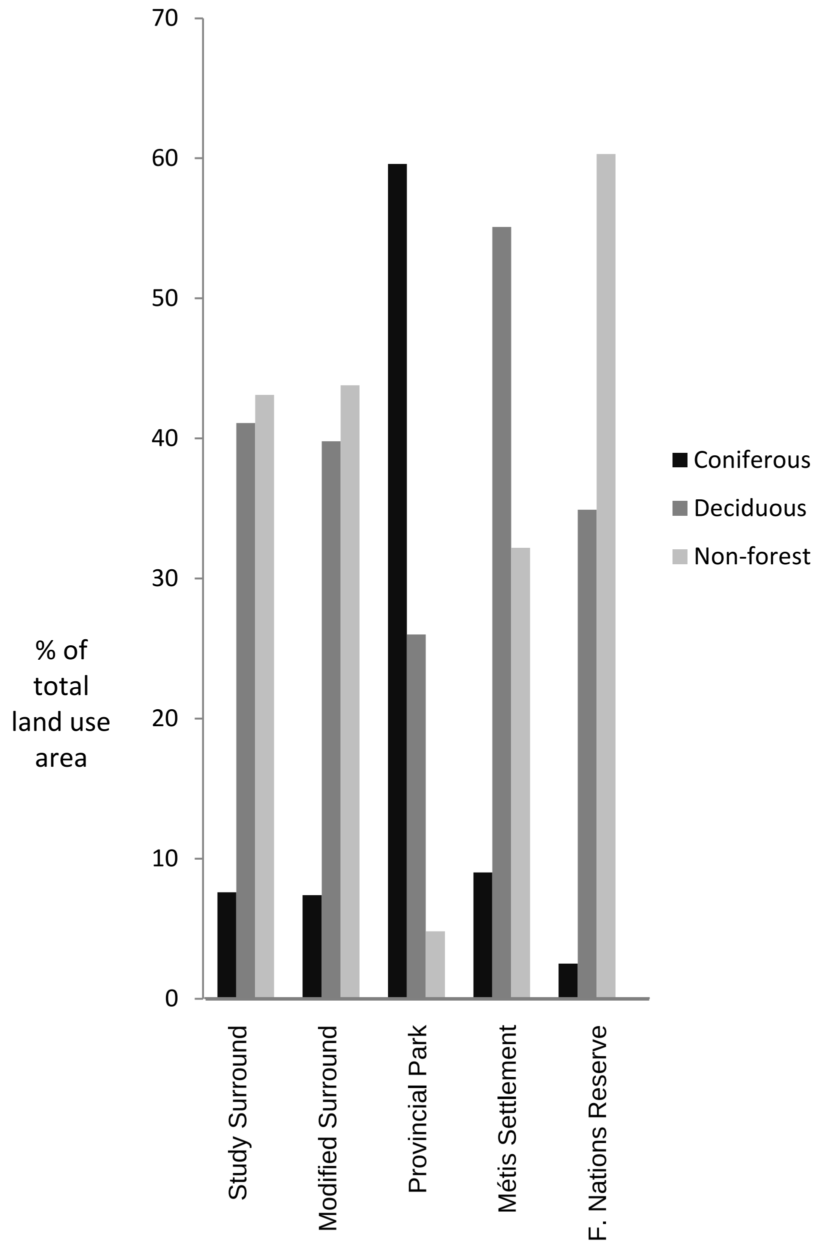

Figure 2-5: Relative values of 3 land cover classes as a percent of total land use area. The Study Surround unit represents the entire study area, including all land use units. Modified Surround values represent the study unit minus the values from the other 3 land use units.

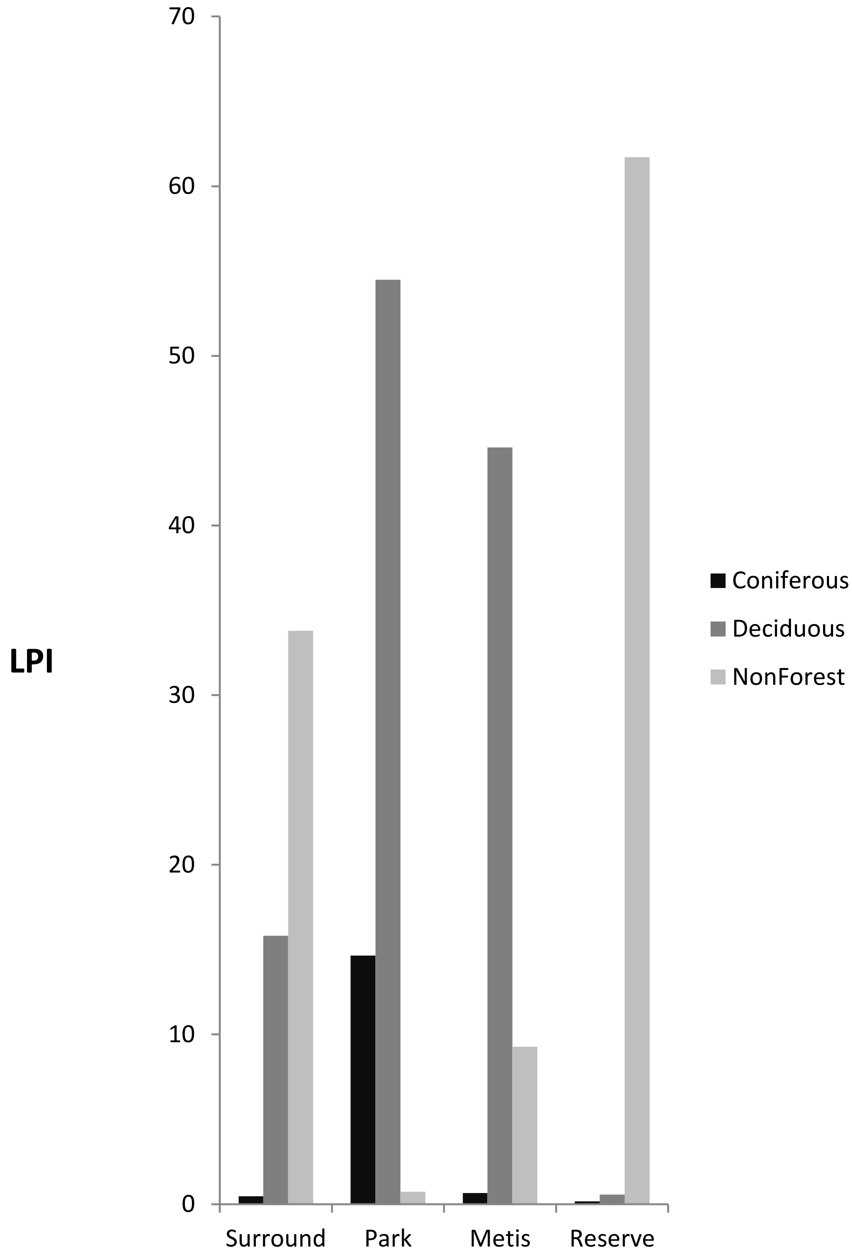

Figure 2-6: Largest Patch Index (LPI) by cover class in 4 land use units in the Bonnyville region of northeast Alberta, Canada. The land use units are: Study Surround, Moose Lake Provincial Park, Elizabeth Métis Settlement, and Kehewin First Nations Reserve.

CHAPTER 3

Plant and Lichen Diversity in Wooded Stands on a First Nations Reserve Compared to Three Other Land Uses in a Developed Landscape in the Central Boreal Mixed-wood Forest of Northeast Alberta

INTRODUCTION

The Natural Regions Committee of the Government of Alberta distinguishes 6 ecoregions in Alberta (Natural Regions Committee, 2006). Among these is the Boreal Forest Natural Region, a vast network of deciduous, mixed-wood, and coniferous forests interspersed with extensive wetlands and lakes that covers 58 percent of the province (381,046 km^2). This region contains 25 percent (110) of Alberta's rare vascular plant species (Natural Regions Committee, 2006, pg. 126). It covers the northern half of Alberta and is divided into 8 natural subregions: Dry Mixed-wood, Central Mixed-wood, Lower Boreal Highlands, Upper Boreal Highlands, Athabasca Plain, Peace-Athabasca Delta, Northern Mixed-wood, and the Boreal Subarctic.

The Central Mixed-wood Natural Subregion encompasses the area of interest of this study. It is the largest subregion in Alberta and covers 44 percent (167,856 km^2) of the Boreal Forest Natural Region. It is composed of a mosaic of aspen, mixed-wood, and white spruce forests that occur on mesic uplands with jack pine stands on coarser materials (i.e. sand). Wetlands are an important component and cover 16 percent of the land area (103,000 km^2) and small lakes account for approximately 3 percent (16,800 km^2) (Alberta Environment and Sustainable Resource Development, 2013). Land use includes significant conifer and aspen harvesting for softwood and pulp production, intensive petroleum exploration and development (conventional oil and gas production in the northwest and oil sands extraction in the northeast), and agricultural land use which includes crops and livestock grazing (Natural Regions Committee, 2006, pg. 139).

The most significant cause for concern of the degradation of ecosystems and floral and lichen diversity in the Central Mixed-wood Subregion results from agricultural development. In Canada, European Settlement began approximately 300 years ago in the east and spread west throughout the Prairie Provinces. Currently 80 percent of the agricultural land base of Canada is concentrated in the three Prairie Provinces (Chetner, 2003). Much of the southern portion of the Boreal Mixed-wood forest has been cleared for agriculture resulting in a patchy fragmented landscape comprised of woodlots and areas such as wetlands that are unsuitable for agriculture, within a matrix of farm fields. Although the northern portions of the subregion are more heavily forested than the southern portions, this area has recently experienced some of the highest rates of deforestation found in the world (Fitzsimmons, 2002; Hobson, Bayne, & Van Wilgenburg, 2002).

A number of studies indicate that plant and lichen diversity is negatively affected by the resulting fragmentation and isolation of remnant forest stands in agro-environments (Boutin, Jobin, Belanger, & Choiniere, 2002; Freemark, Boutin, & Keddy, 2002; Gignac & Dale, 2007; Harper et al., 2005). Agricultural and urban development is particularly harmful because effects persist for centuries rather than 60 to 90 years, as is the case for clear cutting for forestry. In fact, agriculture is responsible for 23% of endangered species, 15% of species at risk and 16% of vulnerable species among plant species found in Canada (Committee on the Status of Endangered Wildlife in Canada [COSEWIC], 1994). Current agricultural practices introduce such deleterious effects as grazing and trampling of vegetation by livestock, soil compaction caused by heavy machinery, an increase in field width and distance between forest fragments to accommodate wider farming equipment used in crop monocultures, nutrient loading from fertilizers, the deposition of agrochemicals on the surrounding native vegetation, and the threat to endemic plant species by agricultural insect pests (Boutin et al., 2002; Jensen, Linke, Dickhauser, & Feige, 1999; Ruoss, 1999; Vagts & Kinder, 1999). Agriculture intensification over the past few decades in Canada has been linked to a decrease in woodlot size (Belanger & Grenier, 2002). Thus, the woodlots, hedges and riparian forests that remain on the landscape have an important function in preserving biodiversity in vast areas of our country (Freemark et al., 2002).

Treed uplands principally aspen dominated uplands were targeted in this study because they are the first ecosystems to disappear in agro-environments in the southern Central Boreal Mixed-wood Forest since their soil is the most suitable for agriculture. Aspen is recognized as the primary boreal forest tree host of host-specific species of cryptogams and invertebrates (Hadenas and Ericson, 2008). Lichen diversity is included along with that of vascular plants as it has been shown that they have narrow ecological requirements and that certain species are valuable as indicators of fragmentation (Bartok, 1999; Norden, Paltto, Gotmark,

& Wallin, 2007). Some research suggests that the linear fragments typical of managed environments are insufficiently wide to maintain the integrity of epiphytic lichen communities (Gignac & Dale, 2005), particularly with respect to biomass accumulation (Boudreault et. al., 2007; Pettersson, Ball, Renhorn, Esseen, & Sjoberg, 1995). The effects of high structural contrast at the forest edge in managed environments is linked to increased wind and tree branch breakage and changes to the microclimatic conditions such as fluctuations in light and humidity levels, which can in turn result in a reduction in substrate availability, and hinder the metabolic activity of poikilohydric organisms such as lichens (Campbell & Coxson, 2001; Zechmeister, Tribsch, Moser, Peterseil & Wrbka, 2003; Boudreault et al., 2007; Fritz, Gustafsson, & Larsson, 2008). In a study of natural and managed boreal forests, Dettki & Esseen (1998) found that substrate availability and stand age are two key factors related to lichen richness and abundance. Lichen abundance in the canopies of natural and selectively logged boreal forest stands in northern Sweden has been related directly to the number and biomass of invertebrates such as *Acari* (mites), *Araneae (spiders)*, *Diptera* (True flies) and *Lepidoptera* (moths), organisms which serve as a critical food source for overwintering non-migratory birds (Pettersson et al., 1995). Boutin et al. (2002) also emphasize the link between plant diversity and healthy animal and invertebrate populations.

Although upland habitats have been severely altered through urban and agricultural development, many protected areas still exist within the Central

Boreal Mixed-wood Forest in Alberta. Those areas include National Parks, several Provincial Parks, and Recreation Areas. Ostensibly, the parks and recreation areas should protect plant and lichen diversity in severely altered landscapes. However, even though some natural areas can be found in most regions, they are not immune to natural disturbances, such as fire, and as a result may burn in which case the regional diversity would consequently suffer. Also, the distance between these protected areas is an important consideration, for example with regards to the dispersal limitations of the native vegetation and resulting metapopulation dynamics (Hadenas & Ericson, 2008).

The subsistence strategies of the First Nation people living in what are today the three Prairie Provinces were based on exploitation of natural resources. Plant use in traditional aboriginal societies was extensive (Marles, Clavelle, Monteleone, Tays, & Burns, 1999). Food was varied; they had access to a wide variety of seasonal fruit (e.g. berries), leafy shoots of herbaceous species as well as roots, tubers and rhizomes, an important source of carbohydrates that were required to supplement a protein-rich diet of lean meat (Johnson, Kershaw, MacKinnon, & Pojar, 1995). Plants were used for clothing and they provided shelter; trees for tipi poles and conifer boughs for bedding. Along with ‘buffalo chips’ (dung), wood was used as fuel. Weapons, such as bows, arrows and spears that were made from wood were indispensable for hunting and fishing. Pine trees lashed together made a travois for transporting meat and other heavy loads. Young tree stems and branches were fashioned into baskets, providing storage for food and other household items and drying racks that ensured a supply of preserved fish and meat throughout the long winters. Even the smallest plants were used; the antibacterial and absorbent properties of moss made it ideal for sanitary purposes. Lichens have also been used by aboriginal people in North America for a number of purposes including food, fibers for clothing, and dyes. Fruticose lichen taxa such as *Usnea*, *Bryoria* and *Alectoria* are widely recognized for their absorptive and antiseptic properties (Brodo, Duran Sharnoff, & Sharnoff, 2001, pg. 83). Another important use of plants and lichens by first peoples was for medicinal and spiritual purposes. Dickason highlights the wealth and subtleties of Amerindian botanical knowledge for medicinal and other purposes, for example, the ability to use poisonous plants, either by extracting the toxins or cooking/baking, and aspects related to multiple uses of a plant such as recognizing appropriate stages of development and seasonal collection times (Dickason, 1991, pg. 25). Thus, a loss of plant diversity could affect to some degree the First Nation's traditional subsistence strategy as well as their cultural heritage.

Study Objectives

Through this research, I attempt to answer the following questions. How does diversity among vascular plants and lichens of upland wooded stands in the southern portion of the Central Boreal Mixed-wood Forest on a First Nations Reserve differ from the following land uses: predominantly agricultural, a Provincial Park, and a Métis Settlement? Could Aboriginal lands protect plant and lichen diversity in much the same way as Provincial Parks do in severely altered landscapes? In other words, does the present First Nations land use contribute to the conservation of vulnerable ecosystems and plant diversity at a regional scale in this altered landscape? To my knowledge, no studies have compared plant and lichen diversity on Aboriginal land with other protected areas and/or agro-environments in the aspen-dominated uplands of the boreal Mixed-wood forest of the Canadian Prairies.

MATERIALS AND METHODS

Study Area

The study area covers approximately 2100 km^2 around the town of Bonnyville, in northeast Alberta. The area surrounding Bonnyville is ideally suited for this study, since much of the original Boreal Mixed-wood Forest has been cleared for agriculture or grazing but it also retains other land uses such as a Provincial Park and adjacent Recreation Area as well the Kehewin First Nations Reserve and the Elizabeth Métis Settlement (Fig. 3-1).

The landscape is typical of the Central Boreal Mixed-wood Subregion, a mix of deciduous and coniferous forest stands interspersed with wetlands and small lakes. Trembling aspen (*Populus tremuloides*) is the dominant tree species in the well-drained upland stands, but moderate quantities of balsam poplar (*Populus* *balsamifera*) and white spruce (*Picea glauca*) are also found. On sandy more xeric upland sites, the overstory is dominated by jack pine (*Pinus banksiana)*. The mean annual precipitation in the area ranges from 400 mm to 450 mm, with higher levels to the north and west. Mean temperature varies from -17ºC in January to 15.5ºC in July (Chetner, 2003). The dominant soils are Dark Grey Chernozomics and Dark Grey-Grey Luvisols to the north and west; Grey Luvisols and Organics to the south and east (Strong & Leggat, 1981).

Site and Plot Selection

The study sites were chosen by quarter sections (approx. 800 m x 800 m) based on the cadastral system used on the Municipal District of Bonnyville no. 87 County map (Anonymous, 2005). A site was defined as an area covering approximately 5.75 km^2 (3 quarter sections x 3 quarter sections) within each land use unit, based on the size of the smallest unit (Moose Lake Provincial Park). Since, the smallest unit was bordered on one side by a lake (2 sections with lake frontage), all possible sections that satisfied those criteria were identified on the map and numbered. From this pool of available units, five sites were randomly selected one in each land use unit with two from the agricultural matrix since it was the largest unit. Sites were identified as follows: Moose Lake south of the Provincial Park; Sinking Lake in the northwest corner of Kehewin First Nation Reserve; Chandler Lake in the southwest portion of Elizabeth Métis Settlement; Angling Lake adjacent to the village of Beaverdam in the agricultural matrix; and Jessie Lake south of the town of Bonnyville also within the agricultural matrix.

Sample plots were randomly selected for each study site. Each sample plot measured 50 m X 50 m and was selected by laying a numbered grid having the dimensions of the quarter section where each grid cell was 50 m X 50 m. Each grid cell was numbered and a plot was randomly selected from the grid. Based on this method, 15 sample plots were identified: 6 plots located within the agricultural matrix and 3 plots in each of the remaining land use units. A Garmin Model Global Positioning System (GPS) unit with positional accuracies of up to 5m was used to locate the plot UTM (Universal Transverse Mercator) coordinates in the field. If the selected sample plot fell on an unsuitable habitat such as a wetland, pond, or field, the selection was repeated until an upland forested fragment was found. Sample plots were studied during the 3-month field season extending from June 1 to the end of August 2008.

Sampling Design

Each 50 m X 50 m sample plot was divided into 2 transects perpendicular to each other starting at the centre and extending 25 m on either side. If the forest covered only a portion of the sample plot, the GPS was used to plot the perimeter of the fragment. A continuous belt transect design was used where ten circular quadrats (5m diameter) were placed adjacent to one another along each transect. Abundance (percent cover) of vascular plant species was visually estimated to a minimum of 1% as was the presence of corticolous (up to a height of 2m) and epixylic lichen species. Vascular plants were grouped according to the following life forms: trees, shrubs, forbs, and graminoids (Chen, Légaré, & Bergeron, 2004). Lichen species were grouped into three life form classes: crustose (flat), foliose (leaf) and fruticose (branched). Nomenclature follows Johnson, Kershaw, MacKinnon, & Pojar (1995) for the majority of vascular and common lichen species, Royer & Dickinson (1999) for introduced and weedy species, Brodo et al. (2001) for lichen species, and Moss (1967) for rare vascular species.

The substrate on which each lichen species grew, was identified according to the following categories: 1) living tree (bark smooth or creviced); 2) snag; 3) *Salix spp*. or other shrub; 4) stump; 5) old fence post; 6) charred log; and 7) coarse woody debris. Coarse woody debris was further subdivided into 8 microhabitat classes based on degree of decay. Classes were defined as 1) log whole and undecayed, bark intact; 2) log sound, wood hard, with no bark remaining 3) log sound, wood hard with 50% of bark remaining; 4) wood soft in places with 50% of bark remaining; 5) wood soft with crevices, little or no bark remaining; 6) large wood fragments lost, outline of trunk slightly deformed; 7) wood mostly well decayed; and 8) humification nearly 100% (Soderstrom, 1988). Microhabitat classes for the ground were: 1) leaf litter; 2) dung; 3) exposed mineral soil; and 4) rocks. Also, such canopy characteristics as tree species and DBH as well as the presence of all microhabitat classes where lichens were not found were noted.

At the centre of each plot, a soil core was taken and the depth of each soil horizon measured to a maximum of 20 cm. Samples were bagged in plastic bags on-site and transported to the lab where the organic and mineral horizons were separated and individually air-dried on paper plates. Samples were then sent to the Natural Resources Analytical Laboratory (NRAL) of the University of Alberta where the following analyses were performed: Total Carbon and Total Nitrogen (TCTN) concentrations in each of the organic and mineral layers as well as gravimetric analyses of percent sand, clay, silt, and combined clay/silt (see NRAL 2013 for method details).

Landscape Metrics

The following landscape metrics were calculated for each of the 15 study plots: Perimeter, Area, Perimeter/Area ratio, and Shape Index (SI_p), calculated as $SI_p = P/2(S\pi)^{1/2}$, where P is the plot perimeter and S is the plot area (Forman & Godron, 1986). Values of shape index range from 1 (a perfect circle) to higher values, which represent increasing shape irregularity. Shape indexes, along with Area, Perimeter, and Perimeter/area ratio metrics have been used by other researchers to evaluate the level of landscape fragmentation (Aznar, Dervieux, & Grillas, 2003; Gignac & Dale, 2007; Young, Sanchez-Azofeifa, Hannon, & Chapman, 2006). Values of Perimeter and Area for all sample plots were manually generated using Google Earth Pro for Windows Version 7.1.1.1580 (Google Inc., 2013). That freeware application uses base imagery of 30 m LANDSAT multispectral imagery pan sharpened to 15 m as well as in some cases high resolution SPOT imagery with a resolution of up to 2.5 m. Error values of the ‘measure’ function are estimated at -0.112%, based on the recorded and actual lengths of the equator

(Google Inc, 2013). Google Earth image acquisition dates were ± 4 years of the 2008 field season. In the case when the image acquisition date fell after the field season, values obtained with the manual digitization process were cross referenced with perimeter waypoint measurements and photographs taken at the time of field study to ensure that, for example, deforestation had not occurred since the time of sampling thus reducing the fragment size and/or shape.

Data Analyses

Duncan's Multiple Range test was used to analyze the differences in the means of the following eight soil parameters for each study plot: percent Carbon in each of the organic and mineral layers, percent Nitrogen in each of the organic and mineral layers and percent Sand, Clay, Silt and combined Clay/Silt of each soil core. Duncan's Multiple Range Test is a Multiple Comparison Procedure (MCP) which incorporates a standard pairwise comparison to identify relative differences in sample means and assign a grouping variable (SAS Institute Inc., 2011). Duncan's Multiple Range test was carried out using SAS software for Windows Version 9.3 (SAS Institute Inc., 2011).

Non-Metric Multidimensional Scaling (NMDS) ordinations based on plant species mean abundance and lichen incidence were used to differentiate sample plots from each other. NMDS is a non-parametric ordination technique that places sample objects in ordination space according to a rank order of the intersample dissimilarities (Minchin, 1987). As the NMDS procedure does not have the assumptions of linear and unimodal response models, it does not suffer from distortions present in eigenvector methods (Minchin, 1987). Given the very low relative abundance levels of lichen species with respect to woody and herbaceous species, lichen presence data was converted to an abundance level of 1% (the lowest unit employed in the measurement of vascular species) for the ordination (Chen, Légaré, & Bergeron, 2004; Locky & Bayley, 2007). All values were log transformed to improve the normality of the distribution. The Sorenson (Bray-Curtis) distance measurement (Faith, Minchin, & Belbin, 1987) was chosen in the application of ecological dissimilarity in the NMDS ordinations. All ordinations were conducted in PC-ORD Version 6 (McCune & Mefford, 2011).

Environmental variables were not directly used to structure the sample ordination. Instead correlations between variables for each plot and the plot scores in the NMDS ordination were used to determine the importance of each variable within the ordination axes. The correlation matrix was presented in its own ordination diagram such that each variable was depicted as a vector where the angle and length of the vector represented the direction and strength of the relationship. The following abiotic variables were included in this data analysis: microhabitat data collected in the field, as well as the study site fragmentation metrics and soil analysis data. Correlations between variable values and sample scores were performed using SAS software for Windows Version 9.3 (SAS Institute Inc., 2011). Other researchers have plotted environmental variables as passive vectors on NMDS ordination space. This passive overlay technique has been used successfully to describe floristic diversity in post-agricultural aspen plantations (Soo, Tullus, Tullus, Roosaluste, & Vares, 2009) and epiphyte communities (Lewis & Ellis, 2010) in Europe. Puchniak Begley, Gray & Paszkowski (2012) also correlated axis scores and habitat characteristics in a study of avian habitat in the Canadian prairies.

RESULTS

Environmental variables

Fragmentation Metrics

The 15 study plots were located within forest stands that varied in surface area from a 350 m^2 shelterbelt, Plot B in the Bonnyville area to a 5,463,490 m^2 forest stand in the Provincial Park (Table 3-1). The latter stand housed two of the Park plots, Plots C and D. The Provincial Park had the biggest stand, followed by all the plots on the Métis Settlement, Plot A in the Kehewin Reserve, and plots located in the Bonnyville and Beaverdam area within the agricultural matrix. Area values for the agricultural patches were lower than the non-agricultural stands with the exception of Plot B in the Beaverdam area that had a greater surface area than Plot B on the Kehewin Reserve, the smallest non-agricultural stand. The dimensions of the plots affected the number of quadrats that were analyzed up to a maximum of 20. The number of quadrats was lowest for the plots in the Bonnyville and Beaverdam area with the exception of plot D in the Bonnyville area. The number of plots analyzed on the remaining land uses was at the maximum with the exception of plot B on the Métis Settlement.

The Perimeter/Area ratio values follow a similar trend as the surfucial dimensions. Perimeter/Area values for the agricultural patches on the Bonnyville and Beaverdam sites exceeded 0.04, whereas all the remaining plots had P/A values below 0.04. Plots B and C in the Kehewin Reserve had the two highest P/A values of all the non-agricultural sites, with values much higher than those for the remaining 7 plots. The agri-matrix forest patches were more irregularly shaped than the non-agricultural stands, with SI_p values exceeding 2.0 in all cases except Bonnyville site D. Conversely, the non-agricultural stands were more regularly shaped, with $1 < SI_p < 2.0$ in all cases except for the stand in which Plot C of the Kehewin Reserve was located.

Soil Characteristics

Statistical analyses of the soil variables obtained from cores taken from the centre of each study plot showed that the Provincial Park plots were significantly different from the other 4 sites for the gravimetric variables, % Silt, % Sand, and % Clay/Silt (Table 3-2). Percent clay levels in the Provincial Park plots were significantly lower than those on the First Nations Reserve, whereas the remaining sites were statistically similar to both those land uses. Percent carbon in the mineral layer (CMin) was significantly lower for the Park compared to the Beaverdam site. In the case of mineral carbon concentrations (CMin), the results of the Duncan's Multiple Range Test identified the Provincial Park, Kehewin, Métis, and Bonnyville sites as a statistically similar group and the Kehewin, Métis, and both the Bonnyville and Beaverdam agricultural sites as another distinct but statistically similar group. No significant difference among sites was found for either the mineral layer nitrogen content (NMin) or the organic layer nitrogen, carbon concentrations (NOrg and COrg), and pH.

Lichen Microhabitats

Most classes of coarse woody debris were found on almost all plots with the exception of plot A in the Bonnyville area (Table 3-3). That plot was exceptional in that it was lacking several decay classes. Plots that lacked one decay class were: Plots C and D in the Provincial Park; Plot B on the Métis Settlement; Plot B in the Bonnyville area; and Plot C in the Beaverdam area. With the exception of Plot C in the Provincial Park, the frequency of poorly decomposed debris (Da and Db) was generally higher than other decay classes.

Deciduous litter dominated all plots with the exception of Plot A in the Provincial Park that had a high occurrence of coniferous litter. The occurrence of soil without litter was generally rare on most plots with the exception of Plot A in the Provincial Park and Plot B in the Beaverdam area. Rocks were not found on any quadrat in the Provincial Park, but were found on all other plots with the exception of Plot A in the First Nation Reserve. It is noteworthy that several plots had very high rock content including: Plot B in the Métis Settlement, Plot B in the Bonnyville area, and all plots in the Beaverdam area.

Plot B in the Provincial Park and Plot A on the Métis Settlement were exceptional because they contained almost all the bark microhabitats, whereas the remaining plots lack 4 or more of those habitats. With the exception of Plot A in the Provincial Park and Plot D in the Bonnyville area, all plots had a high frequency of *Populus tremuloides* bark either creviced or smooth or both. The former plot had high occurrence of *Pinus banksiana* bark while the latter had a high frequency of creviced *Populus balsamifera* bark. Shrubs were fairly common (> 40% occurrence) on all plots with the exception of Plot A in the Bonnyville area. Snags were also fairly to highly common on all plots. Stumps were found on all plots with the exception of Beaverdam Plot A. As for the remaining microhabitats, charred logs and dung were the most common, occurring on 4 plots each.

Vascular Plant and Lichen Diversity

Species Richness and Composition

A total of 238 species were identified, of which 168 were vascular plants, including 8 trees (> 2 m height), 27 shrubs (woody species < 2 m in height), 104 forbs (non woody species), and 30 graminoids (grasses and sedges). Seventy lichen species were also identified. A complete list of vascular plant species abundance and lichen species occurrence in each of the 15 study plots is located in Appendix I.

Populus tremuloides was the most common species found in this study and was found on all plots with the exception of Plot A in the Provincial Park (Table 3-4). *Populus balsamifera* was also common, occurring on 10 of the 15 plots. Together, those species dominated all other tree species on all plots with the exception of Plots A and D in the Provincial Park and Plot A in the Métis Settlement. Plot A in the Provincial Park was dominated by *Pinus banksiana* while the other two plots had a variety of species that were co-dominant. Plot D in the Provincial Park had three species, *Pinus banksiana*, *Picea glauca*, and *Populus tremuloides* with similar % cover values, while Plot A in the Métis Settlement had greater cover of *Alnus rugosa* and similar values for *Picea glauca*, *Populus balsamifera*, and *Populus tremuloides*. The least abundant species were *Alnus crispa* and *Betula papyrifera* since they occurred on only two or three plots respectively and always with low cover values.

The mean Diameter at Breast Height (DBH) of the trees varied considerably between plots (Table 3-4). Mean DBH was highest in Plot B in the Bonnyville area followed by Plots D and A in the Provincial Park and Plot A in the Bonnyville area. The smallest mean DBH was found on Plot B on the Métis Settlement followed by Plot A in the Bonnyville area and Plots B and C on the

Kehewin Reserve. Mean DBH values on the remaining plots were similar and ranged between 29.6 and 23.6 cm.

Plots A and B in the Bonnyville area had the lowest species richness resulting from relatively low numbers of forbs, graminoids, and fruticose lichens (Table 3-5). Plot A in the Provincial Park and Plot B in the Métis Settlement also had low species richness. Plot A in the Provincial Park had only 19 vascular plant species the lowest among all plots including those in the Bonnyville area but compensated by having the highest number of lichens particularly foliose and fruticose species. Plot B on the Métis Settlement on the other hand had relatively low numbers of vascular plants and lichens. Plot A on the Métis Settlement and Plot C on the Kehewin Reserve had the highest species richness. Plots C and D in the Provincial Park as well as Plot B in the Beaverdam area also had relatively high species richness. The remaining plots had between 60 and 70 species.

Rare Species

With the exception of Plot D on the Métis Settlement, all plots contributed species that were only found on one plot (Table 3-6). Plot A in the Provincial Park had more than double the number of rare species and contributed more rare forbs and foliose and fruticose lichens than any other plot. Plots C in the Provincial Park and C on the Kehewin Reserve also contributed more than the average number of rare species. Both those plots added more graminoids than the other plots. Plots in the Bonnyville and Beaverdam areas contributed several rare forbs to the total but no species from the other functional groups.

Among the taxa studied, crustose lichens were the most common and were found on all plots. Also, species among fruticose lichens were relatively common with only 5 species that were found on only one plot. Conversely, 27 forbs were only found on one plot and contributed by far the most to the rare species list. The remaining functional groups contributed 7 or 8 species to the pool of rarer species. See Appendix II for a complete list of rare species.

Plants, Lichens, and Environmental Parameters

The NMDS ordination based on vascular plant abundance (n = 168 species) returned a 2-dimensional solution with a final stress of 6.3968 ($p = 0.0040$). Plots in the Beaverdam and Bonnyville agricultural areas were distributed on the left of the ordination while the Provincial Park plots were on the right (Fig. 3-2). With the exception of Plot A on the Métis Settlement, plots on the Kehewin Reserve and the Métis Settlement were located in the middle of the ordination space. Plots in the Reserve were closer to the agricultural plots along axis 1 while those in the Métis Settlement were marginally closer to those in the Provincial Park along that axis. Plot A on the Métis Settlement was aligned more with the Provincial Park plots along axis 1 but was much lower than those plots along axis 2. Plot A in the Provincial Park that was located on the far right of the ordination was only distantly associated with the other 2 plots from that site. A group of soil variables were significantly ($p \leq 0.05$) correlated with the plot scores on axis 1. The sand vector was positively associated with the first axis and Clay, Silt, and Clay/ Silt were negatively related to that axis. The perimeter vector was also significantly positively correlated with the first axis. Diameter at Breast Height (DBH) is the only variable that is significantly negatively correlated with axis 2.

The NMDS ordination based on the presence/absence of lichens (n = 70 species) returned a 2-dimensional solution with a stress of 3.1917 (p = 0.0040). Plot A in the Provincial Park was isolated on the far right side of the ordination (Fig. 3-3). With the exception of Plot B, the Métis Settlement plots were clustered with Plots C and D in the Provincial Park on the positive side of axis 1. Plot B on the Métis Settlement was located at the negative end of axis 1 along with Plot A in the Bonnyville area. Apart from Plot A in the Bonnyville area, there was a close association between plots on the First Nations Reserve with the agricultural plots in the Beaverdam and Bonnyville areas in the middle of the ordination.

Almost all microhabitat variables were significantly ($p \leq 0.05$) related with either axis 1 or axis 2, although the bark microhabitat was only represented by 2 of the 9 variables: EPb, *Pinus banksiana* bark, and ETs, smooth *Populus tremuloides* bark. *Pinus banksiana* bark (EPb), coniferous ground litter (GC), and the coarse woody decay classes Df and Dg vectors were more closely positively related to axis 1 than axis 2. The deciduous ground cover (GD) vector was negatively related to axis 1. The remaining microhabitat classes including Da, Dh, rock substrate (GR), snag, and old fence post (OldPost) were more closely positively related to axis 2 than axis 1. Sand concentration in the soil was positively related with axis 1 while Clay, Silt and Clay/Silt were negatively associated with that axis. The Area and Perimeter vectors were negatively more closely associated with axis 2 while the Shape Index was positively related to that axis. The DBH variable was positively associated with axis 1.

The NMDS ordination combining vascular abundance and lichen presence/absence (n = 238 species) returned a 2-dimensional solution with a stress of 8.3519 (p = 0.0040). With the exception of Plot A in the Métis Settlement, plots were organized by land use (Fig. 3-4). As was the case for the vascular plant ordination, plots in the Beaverdam and Bonnyville agricultural areas were distributed on the left of the ordination while the Provincial Park plots were on the right, with the Kehewin Reserve and Métis Settlement plots in the middle. Plot A in the Métis Settlement was situated directly above Plot B in the Provincial Park along axis 1. Also, as in the plant ordination, plots in the Reserve were closer to the agricultural plots while those on the Métis Settlement were marginally closer to those in the Provincial Park along axis1.

The primary gradients of variation in the vascular and lichen ordination space were all more closely related to axis 1 than axis 2. The microhabitat variables *Pinus banksiana* bark (EPb), Dg, Df, coniferous ground litter (GC), and charred logs (CharLog) vectors were positively associated with axis 1 while rocks (Gr) were negatively associated with that axis. Other vectors that were positively associated with axis 1 included Perimeter and Sand. P/A, Silt, Clay, and Clay/Silt vectors were all negatively related to axis 1 plot scores.

DISCUSSION

Land Use and Environmental Variables

Forest Fragmentation

The upland forest in the southern Central Boreal Mixed-wood Subregion was largely contiguous before European Settlement with some non-forested areas produced by fire or insect infestations (Chavez & Macdonald, 2012). Post European Settlement, forests were cut for agricultural purposes and the remaining forest stands occupied smaller areas with smaller perimeters. As forest areas decreased, perimeter relative to the area increased and as a result P/A and SI_p values increased. Thus, in the southern Central Boreal Mixed-wood Forest, smaller perimeters and areas and high P/A and SI_p values for forest patches are associated with European Settlement.

The result of agricultural development was evidenced in this study by the plots in the agricultural matrix in the Beaverdam and Bonnyville areas which had lower values for perimeter and area and higher P/A and SI_p values than the three other land uses (Table 3-1). The only exception was Plot B on the Kehewin Reserve that had smaller perimeter and area than two of the Beaverdam plots. That exception was also probably the result of agricultural development on the Reserve. Conversely, the Provincial Park plots where agriculture was not permitted had the greatest values for perimeter and area than any other land use. With the exception of Plot B on the Kehewin Reserve all plots on the Métis Settlement and Kehewin were intermediate to those in the agricultural matrix and those in the Provincial Park. That would indicate that fragmentation and agricultural development were not as severe on the Métis Settlement and Kehewin Reserve as in the agricultural matrix.

Soils

Soils in the study area can impact land use since sandy soils are not suitable for agricultural development. Conversely soils with higher silt and clay content are much more suitable for raising crops and livestock (Tchir, Johnson & Miyanishi, 2004). As a result, soils with high sand content (> 80%) were found on the Provincial Park where there was no agricultural development (Table 3-2). However, soils with less sand content that were found on all the other land uses including those on the Kehewin Reserve had some form of agricultural development as indicated by the fragmentation metrics.

Lichen Microhabitats

Among all the lichen microhabitats, rocks on the surface of the ground (GR) can be most directly linked to agricultural development and fragmentation. Forest fragments in agro-environments are often used by farmers as a convenient place to place large rocks or boulders which would otherwise interfere with heavy machinery such as combines or bailers. As a result, there were no rocks found on the soil surface in the Provincial Park whereas they were found in all other plots with the exception of Plot A on the Kehewin Reserve (Table 3-3).

The availability of some downed woody debris microhabitat classes are also impacted by agriculture. Dettki & Esseen (1998) found lower substrate availability, particularly the De, Df, Dg decay classes, in forest patches in an agricultural matrix. The reduced number of Df and Dg microhabitats in the plots in the Bonnyville and Beaverdam areas could thus be taken as a sign of agricultural impact on those stands (Table 3-3). The high proportion of Dh decay class in the agricultural matrix was an unexpected result.

Tree Canopy

Tree cover was considered an environmental parameter since it could affect the below canopy vegetation depending if the canopy was closed or not (Crites & Dale, 1998). Low DBH values for *Populus* species indicates young trees that produce an open canopy whereas large diameter trees usually have closed canopies and a more shaded environment (Cavard, Bergeron, Chen, & Pare, 2011; Crites & Dale, 1998). In agricultural environments, the age of the trees could depend on a recent fire or on land use where young trees indicate a field that is no longer cultivated and is being reclaimed by forest. The presence of charred logs in a plot indicates a relatively recent fire whereas their absence probably indicates a reclaimed field. Plot A in the Bonnyville area, Plot B on the Métis Settlement, and Plots B and C on the Kehewin Reserve were all dominated by *Populus tremuloides* and had relatively low DBH values (Table 3-4). As a result, they were considered as young stands. Charred logs on Plot B on the Métis Settlement and Plot C on the Kehewin Reserve (Table 3-3) indicated that they were relatively recently burned. Conversely, Plot A in the Bonnyville area and Plot B on the Kehewin Reserve had no evidence of fire.

Land Use and Plant and Lichen Richness and Composition

In all ordinations (Figs. 3-2, 3-3, and 3-4), the proximity of the plots relative to each other indicates the similarity of the vegetation and lichens since their position is entirely determined by the abundance or presence/absence of each species (McCune & Mefford, 2011). Thus, plots that are distant from each other in ordination space, have dissimilar vegetation and lichen composition and abundance, whereas plots that are in close proximity to each other have very similar species composition and abundance. Axis 1 always indicates the principal axis of variation of the plots while axis 2 indicates a second axis of variation that is not normally related to the first (McCune, Grace, & Urban, 2002). Vectors that are correlations between plot scores and the environmental variables that qualify each plot indicate by their direction whether they are positively or negatively correlated to the scores. Those vectors are presented on separate figures in this study for clarity but could be superimposed on the ordination itself. Thus, a vector who's direction extends to the right of the ordination along axis1 is positively correlated with the site scores on axis 1 and its values increase along that axis. Conversely, if the vector extends to the left side of the ordination along axis 1, it is negatively correlated with score values and its values decrease along the axis. The same holds for vectors in proximity to the second axis.

With one exception, the three Provincial Parks plots were located on the far right side of the axis 1 and were followed along that axis by the plots on the Métis Settlement in all three ordinations (Figs. 3-2, 3-3, and 3-4). In fact, Plot A in the Settlement was always superimposed directly above or below Plot C in the Park. Thus, the plant and lichen composition, abundance or presence in Plot A on the Settlement was very similar to those on Plot C in the Park. The exception was Plot B on the Settlement that was situated of the far left of the lichen ordination. Conversely, with the exception Plot A on the Settlement, plots in the agricultural matrix were on the far left of axis 1 on all ordinations. Those plots were closely followed towards the center along axis 1 by plots on the Kehewin Reserve as in Figures 3-2 and 3-4, or they were mixed together as in Figure 3-3. That would indicate that plant composition and abundance and lichen presence on the Reserve was similar to plant composition and abundance and lichen presence in the agricultural matrix.

Soil composition was an important factor in determining the vascular plant distribution and abundance, since the Sand, Silt, Clay, and Clay/Silt vectors were significantly correlated with the distribution of plots in ordination space along axis 1 in Figures 3-2 and 3-4. The importance of soil in the distribution of plants was also indicated by the isolated position of Plot A in the Provincial Park along the right side of axis 1 in those ordinations. That plot that had the highest soil sand content (Table 3-2). Coarse sandy soils support a different plant community than soils containing more carbon, silt, and clay (Johnson et al., 1995, pg.13). Forest stands with coarse sandy soils are dominated by *Pinus banksiana* (Johnson et al., 1995, pg.13) as is the case for Plot A in the Provincial Park in this study (Table 3-4). The vascular plant community on Plot A in the Park also contained a different suite of shrubs and forbs as indicated by the number of species that were only found on that site (Table 3-6). Similar to other sites dominated by coniferous trees (Cavard, Bergeron, Chen, & Pare, 2011; Kuhn, Safford, Jones, & Tate, 2011), Plot A in the Park had fewer species than any other plot in the study area including Plots A and B in the Bonnyville area, the most severely fragmented of all plots (Table 3-5). Plot D in the Park that also had a relatively high sand content, was also somewhat isolated along the right side of axis 1 but to a lesser degree than Plot A. Plot D in the Park that had an intermediate sand concentration when compared to Plots A and C on the same site, contained some *Pinus banksiana* but also some *Populus tremuloides* and *P. balsamifera*.

The dominance of *Populus tremuloides* and/or *P. balsamifera* was indicative of almost all the remaining sites including Plot C in the Park that had higher clay and silt content than the other two Park plots. With the exception of Plot A on the

Métis Settlement, the remaining plots that had statistically similar soil characteristics were located to the left of the Provincial Park plots along axis 1 in both Figures 3-2 and 3-3. Plot A on the Métis Settlement had a similar position as Plot C in the Park along axis 1.

Fragmentation impacted plant and lichen composition and abundance since at least one fragmentation variable was significantly correlated with the distribution of plots on all three ordinations (Figs. 3-2, 3-3, and 3-4). Fragmentation impacts vegetation and lichen diversity by increasing edge effects in forest patches thus reducing the area of forest, core area that is not impacted by the surrounding land use (Boudreault et al., 2007; Gignac & Dale, 2007; Mascarua Lopez, Harper, & Drapeau, 2006). Forest cores have plant and lichen species that are distinct from those along the edges and as a result increase species richness in the fragment. In order to provide an adequate forest core, Gignac & Dale (2007) recommended that P/A ratios do not exceed 0.25 m/m^2 for the purpose of plant and lichen conservation. In this study, that value was exceeded only on Plots A and B in the Bonnyville area (Table 3-1). Both those plots had lower species richness than any other plots in the study area (Table 3-5).

Almost all lichen microhabitats played a significant ($p \leq 0.05$) role in the distribution of lichens as indicated by significant correlations of microhabitat variables with the distribution of plots in Figure 3-3. Soil parameters affect lichen distribution indirectly through the plants they support and the quality of their litter. Thus, Ground cover Deciduous (GD) and Ground cover Coniferous (GC) were both significantly correlated with the plot distribution. Lichens must use sunlight to photosynthesize and thus do not grow when they are covered by litter (Brodo et al., 2001; Vitt, Marsh & Bovey 1988 pg. 156; Johnson et al., 1995, pg. 332). In deciduous stands where a great deal of litter is produced annually lichens grow on surfaces that position them above the ground and avoiding to some extent being covered by litter. Thus downed woody debris, rocks, snags, old fence posts, tree trunks all provide suitable habitats for lichens. The ordination in Figure 3-3 acknowledged the role of deciduous litter and those habitats by placing most of them on the left side of axis 2. Conversely, coniferous stands produce very little litter and have much greater areas of bare soil on which lichens can grow. As a result, species diversity, particularly foliose and fruticose species, was much greater on Plot A in the Provincial Park that was dominated by *Pinus banksiana* than on any other plot (Table 3-5).

The DBH vector was significantly negatively correlated with the plot distribution along axis 2 in the vascular plant ordination (Fig. 3-2). Thus, the youngest plots with the smallest trees, Plot A in the Bonnyville area and Plot B on the Métis Settlement (Table 3-3), were located at the top of the ordination. The distribution of the plots along this axis indicated that plots dominated by *Populus* species were affected more by DBH than those that had *Pinus banksiana* on them, Plots A and D in the Park, since the former were spread along axis 2 while the latter were distributed along axis 1. Thus, the age of plots affected plant diversity on *Populus* dominated stands. The DBH vector was also positively correlated with the plot distribution along axis 1 in the lichen ordination (Fig. 3-3). Thus, the two plots with the smallest trees, Plot A in the Bonnyville area and Plot B on the Métis Settlement, were located on the far left of the lichen ordination. Both those plots had the fewest number of lichens particularly fruticose species (Table 3-5).

Species that were only found on one plot may be locally abundant, that is found on several quadrats within the plot, but must be considered as regionally rare since they were not found on any other plot. All plots with the exception of Plot D on the Métis Settlement contributed rare species to the regional diversity (Table 3-6). The Provincial Park contributed the most species than any other land use. Plot A in the Park in particular had more rare species than all plots from any other land use combined. As a result, the Provincial Park fulfilled part of its mandate in protecting and preserving regionally rare vascular plant and lichen communities and species as well as a more common stand dominated by *Populus* species (Mason, 1987, pg. 55). Among the remaining land uses, plots on the Kehewin Reserve had slightly more rare species than the Métis Settlement mainly because one transect on Plot C in the Reserve descended into a more humid environment, thus introducing species of fruticose lichens (*Cladonia* sp.), sedges (*Carex* sp.) and rushes (*Juncus* sp.).

The highly fragmented plots in the agricultural matrix contributed 14 rare species none of which were lichens. Unfortunately, among those species were *Axyris* *amaranthoides*, *Erysimum cheiranthoides*, *Melilotus officinale*, and *Stellaria media* that were all introduced species (Johnson et al., 1995). There were other introduced species in the study area, but they were found on two or more plots. However, all introduced species were found on either the Beaverdam or Bonnyville plots. Introduced species are not considered desirable since they may compete with native species and eliminate them from the environment or reduce the abundance.

CONCLUSION

Plots in the Kehewin Reserve were underlain by soils that had relatively high clay and silt content and were statistically similar to those found on all other land uses with the exception of the plots in the Provincial Park. The Kehewin plots also showed signs of fragmentation since they were located in forest stands that had smaller surface areas than plots in either the Métis Settlement or the Provincial Park. The size of the plots on the Reserve was closer to those in the agricultural matrix than those of the other two land uses. However, fragmentation was not as severe as on most of the plots in the agricultural matrix. Also, the age of the plots varied from relatively young stands that were either destroyed by fire or reclaimed from fields and older patches. All plots on the Reserve were dominated by *Populus tremuloides* with some *P. balsamifera* and the vascular plant and lichen communities that they supported were more similar to those in the agricultural matrix than were those in the Provincial Park and the Métis Settlement. However, one of the three plots on the Reserve had higher species richness than any other plot in this study with the exception of one on the Métis Settlement. Also, although the three plots on the Reserve did not contain a unique plant and lichen community as did the Provincial Park, they did contribute 10 species to the regional plant and lichen richness and diversity. Although impacted to some extent by fragmentation, forest stands on the Kehewin Reserve and the Métis Settlement are of particular interest because of their valuable contributions to the flora of the region.

The Kehewin First Nations study site was situated in the northwest corner of the Reserve where development for residential and farming purposes had created a landscape that was primarily non-forested and resembled the surrounding agricultural matrix. The more heavily forested southern portion of the Reserve was not sampled due to the random sampling design. Therefore results from this analysis may not entirely reflect the contribution of the Reserve to the regional vascular plant and lichen diversity.

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Table 3-1: Dimensions and fragmentation metrics of forest patches that contained 15 upland plots on 5 sites located in the southern Central Boreal Mixed-wood Forest in northeast Alberta. P/A = Perimeter area ratio; SI_p = Shape Index. * denotes plots located within a same forest stand. n = number of quadrats analysed per plot.

Plot	Perimeter (m)	Area (m^2)	P/A	SI_p (m^{-1})	n
Provincial Park					
A	7,740	1,243,520	0.006	1.96	20
C*	11,875	5,463,490	0.002	1.43	20
D*	11,875	5,463,490	0.002	1.43	20
First Nations Reserve					
A	2,040	237,501	0.009	1.18	20
B	808	22,477	0.036	1.52	20
C	1,648	46,849	0.035	2.15	20
Métis Settlement					
A	4,113	379,711	0.011	1.88	20
B	4,079	720,932	0.006	1.36	15
D	5,834	739,626	0.008	1.91	20
Bonnyville area					
A	402	980	0.410	3.62	10
B	150	350	0.429	2.26	10
D	451	8,643	0.052	1.37	20
Beaverdam area					
A	260	1,277	0.204	2.05	13
B	1,924	25,139	0.077	3.42	12
C	1,677	9,838	0.170	4.77	10

Table 3-2: Soil molecular and particle size for 15 plots on 5 study sites within the southern Central Boreal Mixed-wood Forest of northeast Alberta. % NMin = % nitrogen in mineral layer; % CMin = % carbon in mineral layer; %NOrg = % nitrogen in organic layer; % COrg = % carbon in organic layer; % Clay = % clay in mineral layer; % Silt = % silt in mineral layer; % Sand = % sand in mineral layer; % Clay/Silt = % clay and silt combined in mineral layer. pH values are for quadrats where n is as in Table 3-1. Superscript letters denote significant differences ($P < 0.05$) between sites according to Duncan's multiple range test.

Plot	% NMin	% CMin	% NOrg	% COrg	% Clay	% Silt	% Sand	% Clay/Silt	pH
Provincial Park									
A	0.01	0.36	0.37	11.25	0.72	4.87	94.41	5.59	6.2 ± 0.8
C	0.03	0.59	1.89	36.06	2.43	5.98	91.59	8.41	6.2 ± 0.6
D	0.02	0.40	0.45	11.28	1.63	10.84	87.53	12.47	6.4 ± 0.4
Mean	0.02 ± 0.01	0.4 ± 0.1 [a]	0.9± 0.9	19.5 ± 14.3	1.6 ± 0.9[a]	7.2 ± 3.2[a]	91.2 ± 3.5[a]	8.8 ± 3.5[a]	6.2 ± 0.6
First Nations Reserve									
A	0.83	9.95	2.38	37.86	32.15	49.91	17.93	82.07	6.6± 0.3
B	0.20	2.83	1.37	23.58	11.94	30.77	57.30	42.70	6.5 ± 0.2
C	0.13	1.60	1.33	21.90	17.39	27.66	54.94	45.06	6.5 ± 0.3
Mean	0.39 ± 0.38	4.8 ± 4.5 [ab]	1.7 ± 0.6	27.8 ± 8.8	20.5 ± 10.4[b]	36.1 ± 12.1[b]	43.4 ± 22.1[b]	56.6 ± 22.1[b]	6.5 ± 0.3

Table 3-2 continued

Plot	% NMin	% CMin	% NOrg	% COrg	% Clay	% Silt	% Sand	% Clay/Silt	pH
Elizabeth Métis Settlement									
A	0.14	2.02	1.34	19.00	17.93	41.48	40.60	59.40	6.5 ± 0.2
B	0.04	0.65	1.77	28.01	4.23	34.78	60.99	39.01	6.5 ± 0.2
D	0.05	0.84	1.49	24.17	3.20	25.88	70.92	29.08	6.7 ± 0.2
Mean	0.08 ± 0.05	1.2 ± 0.7 ^{ab}	1.5 ± 0.2	23.7 ± 4.5	8.5 ± 8.2^{ab}	34.0 ± 7.8^{b}	57.5 ± 15.5^{b}	42.5 ± 15.5^{b}	6.6 ± 0.2
Bonnyville area									
A	0.17	2.30	1.54	27.33	29.49	33.02	37.49	62.51	6.3 ± 0.2
B	0.56	6.84	0.00	0.00	9.79	36.68	53.53	46.47	6.7 ± 0.2
D	0.14	2.08	2.00	33.45	16.36	32.97	50.67	49.33	6.9 ± 0.1
Mean	0.29 ± 0.23	3.7 ± 2.7 ^{ab}	1.2 ± 1.1	20.3 ± 17.8	18.6 ± 10.0^{ab}	34.2 ± 2.1^{b}	47.2 ± 8.6^{b}	52.8 ± 8.6^{b}	6.7 ± 0.3
Beaverdam area									
A	0.41	5.62	0.25	3.54	9.18	16.01	74.80	25.20	6.7 ± 1.0
B	0.47	5.55	2.18	31.97	28.22	29.02	42.77	57.23	6.6 ± 0.2
C	0.36	5.33	2.15	34.15	12.02	38.27	49.71	50.29	6.8 ± 0.1
Mean	0.41 ± 0.06	5.5 ± 0.2 ^{b}	1.5 ± 1.1	23.2 ± 17.1	16.5 ± 10.3^{ab}	27.8 ± 11.2^{b}	55.8 ± 16.9^{b}	44.2 ± 16.9^{b}	6.7 ± 0.2

Table 3-3: Mean percent occurrence of lichen microhabitat classes on 15 plots found on 5 sites located in the southern Central Boreal Mixed-wood Forest of northeast Alberta. A complete description of microhabitat classes is presented in the methods section. n = number of quadrats.

	Provincial Park			*Kehewin Reserve*			*Elizabeth Métis*			*Bonnyville area*			*Beaverdam area*		
	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Coarse Woody Debris															
Da	100	35	50	100	60	100	100	100	100	100	100	100	100	100	100
Db	100	80	90	95	75	100	100	100	100	80	100	100	100	92	100
Dc	60	55	90	65	15	45	100	0	75	40	90	38	38	8	30
Dd	65	80	95	85	85	70	100	93	90	0	100	92	92	75	70
De	80	80	90	85	70	70	100	53	80	0	100	46	46	75	40
Df	90	80	100	90	25	60	100	20	85	0	30	15	15	50	10
Dg	85	65	100	90	15	40	100	6	90	0	0	7	8	8	0
Dh	90	0	0	85	90	85	50	93	70	70	100	92	92	100	100
Ground substrate															
Ground litter-conifer	100	30	90	0	0	0	60	0	0	0	0	0	0	0	0
Ground litter-deciduous	0	95	90	100	95	100	100	100	95	90	100	100	100	100	100
Ground-no litter	90	0	0	5	0	30	0	0	0	10	30	0	8	100	0
Ground-rock	0	0	0	0	10	35	5	87	20	50	100	10	100	92	100

Table 3-3 continued

	Provincial Park			*Kehewin Reserve*			*Elizabeth Métis*			*Bonnyville area*			*Beaverdam area*		
	A	B	D	A	B	C	A	B	D	A	B	D	A	B	C
Bark microhabitat															
B. papyrifera creviced	5	5	0	0	0	0	15	0	0	0	0	0	0	0	0
B. papyrifera smooth	5	10	0	0	0	0	20	0	0	0	0	0	0	0	0
Picea glauca	15	15	40	0	0	0	45	0	0	0	0	0	0	0	0
Pinus banksiana	95	0	35	0	0	0	0	0	0	0	0	0	0	0	0
P. balsamifera creviced	0	20	0	0	0	0	65	0	0	10	60	80	0	67	0
P. balsamifera smooth	0	10	0	50	0	10	10	40	0	20	0	10	0	50	0
P. tremuloides creviced	0	70	60	95	85	100	55	0	100	70	40	20	92	25	100
P. tremuloides smooth	0	90	65	80	100	50	40	100	25	90	10	5	69	100	100
Shrub	45	100	100	95	100	95	95	100	100	10	100	45	46	100	70
Other microhabitat															
Snag	55	75	75	65	80	100	95	80	90	70	90	70	92	92	100
Stump	20	75	60	40	5	30	60	27	10	40	30	20	0	83	20
Charred log	60	0	0	0	0	20	0	60	15	0	0	0	0	0	0
Dung	0	0	0	0	0	25	0	0	15	0	20	0	0	50	0
Old fencepost	0	0	0	0	0	0	0	0	0	0	10	0	0	0	40
n	20	20	20	20	20	20	20	15	20	10	10	20	13	12	10

Table 3-4. Mean percent cover ± s.d. of tree species on 15 plots on 5 sites located in the southern Central Boreal Mixed-wood Forest in northeast Alberta. n = number of quadrats. Tree species are: Alncri = *Alnus crispa*; Alnrug = *Alnus rugosa*; Betpap = *Betula papyrifera*; Picgla = *Picea glauca*; Picmar = *Picea mariana*; Pinban = *Pinus banksiana*; Popbal = *Populus balsamifera*; Poptre = *Populus tremuloides*. DBH = mean tree diameter at breast height (cm).

Plot	n	DBH	Alncri	Alnrug	Betpap	Picgla	Picmar	Pinban	Popbal	Poptre
Provincial Park										
A	20	38.0			1.8 ± 7.8	3.2 ± 10.6		44.8 ± 28.2		
C	20	24.5	0.2 ± 0.7		1.5 ± 5.6	1.8 ± 24.8			5.7 ± 11.7	37.4 ± 26.4
D	20	41.5				17.4 ± 29.0	2.3 ± 10.1	9.1 ± 18.3	2.0 ± 8.9	17.0 ± 18.9
First Nation Reserve										
A	20	31.5							15.2 ± 16.9	38.6 ± 28.0
B	20	16.9								65.4 ± 25.9
C	20	17.7							0.1 ± 0.5	57.7 ± 28.5

Table 3-4 continued

Plot	n	DBH	Alncri	Alnrug	Betpap	Picgla	Picmar	Pinban	Popbal	Poptre
Métis Settlement										
A	20	26.7	4.5 ± 8.8	45.5 ± 21.2	5.1 ± 11	15.9 ± 24.3	1.9 ± 8.3		24.5 ± 20.9	18.7 ± 18.3
B	15	8.8							5.5 ± 8.0	62.7 ± 19.3
D	20	29.6								83.0 ± 9.1
Bonnyville area										
A	10	12.0							6.2 ± 11.5	70.2 ± 18.6
B	10	46.4							36.7 ± 37.8	16.0 ± 20.1
D	20	36.0							53.6 ± 34.9	14.6 ± 27.8
Beaverdam area										
A	13	30.5								77.6 ± 26.5
B	12	27.5							40.8 ± 30.5	40. 3± 22.0
C	10	23.6								71.5 ± 14.0

Table 3-5: Species richness (S) of vascular plants and lichens on 15 plots located on 5 study sites within the southern Central Boreal Mixed-wood Forest of northeast Alberta. Total species is the sum of all vascular plants and lichens.

	Provincial Park			*Kehewin Reserve*			*Elizabeth Métis*			*Bonnyville area*			*Beaverdam area*		
	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Vascular plants															
Shrubs	5	17	10	9	7	8	15	10	8	8	7	10	9	11	10
Forbs	12	30	28	38	34	47	40	29	30	17	11	41	33	39	27
Graminoids	2	9	4	5	7	16	11	9	8	2	2	4	5	12	9
Total	19	56	42	52	48	71	66	48	46	27	20	55	47	62	46
Lichens															
Crustose	3	6	6	6	5	6	6	5	6	5	6	6	6	6	6
Foliose	14	13	15	11	11	12	16	11	14	9	9	11	9	11	9
Fruticose	30	18	24	11	6	13	15	2	12	4	6	5	8	8	4
Total	47	37	45	28	22	31	37	18	32	18	21	22	23	25	19
Total species	66	93	87	80	70	102	103	66	78	48	41	77	70	87	65

Table 3-6: Number of vascular plant and lichen species found on only 1 plot among 15 plots located on 5 sites within the southern Central Boreal Mixed-wood Forest of northeast Alberta. Total species is the sum of all vascular plants and lichens.

	Provincial Park			*Kehewin Reserve*			*Elizabeth Métis*			*Bonnyville area*			*Beaverdam area*		
	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Vascular plants															
Shrubs	2	1	1	0	0	0	1	2	0	0	0	0	0	0	1
Forbs	5	1	2	0	2	1	1	2	0	2	3	2	3	2	1
Graminoids	0	3	0	0	0	3	1	0	0	0	0	0	0	0	0
Total	7	5	3	0	2	4	3	4	0	2	3	2	3	2	1
Lichens															
Crustose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foliose	4	0	1	0	2	0	0	0	0	0	0	0	0	0	0
Fruticose	2	1	0	1	0	1	0	0	0	0	0	0	0	0	0
Total	6	1	1	1	2	1	0	0	0	0	0	0	0	0	0
Total species	13	6	4	1	4	5	3	4	0	2	3	2	3	2	2

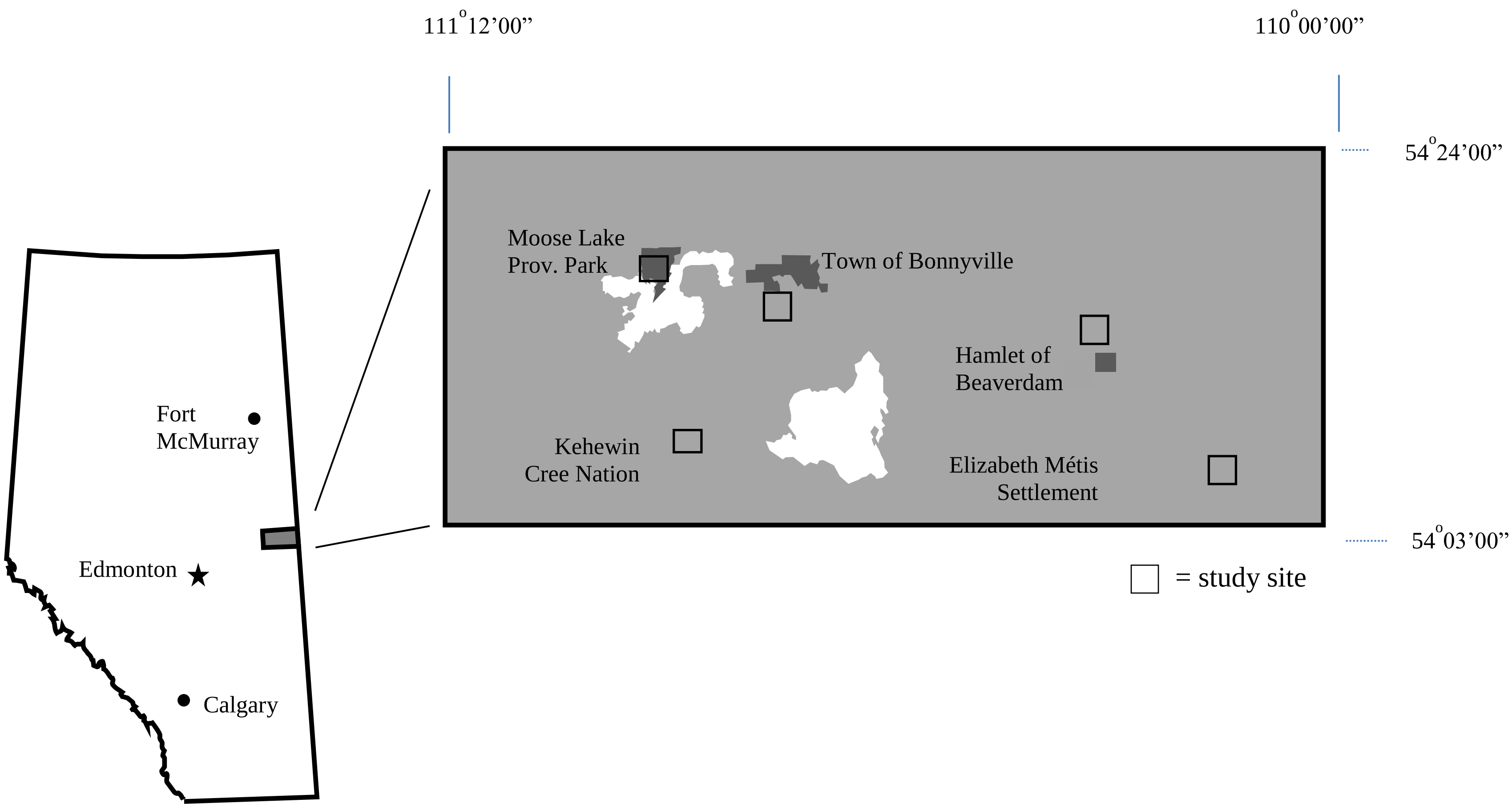

Figure 3-1: Map showing the location of the study sites in northeast Alberta, Canada.

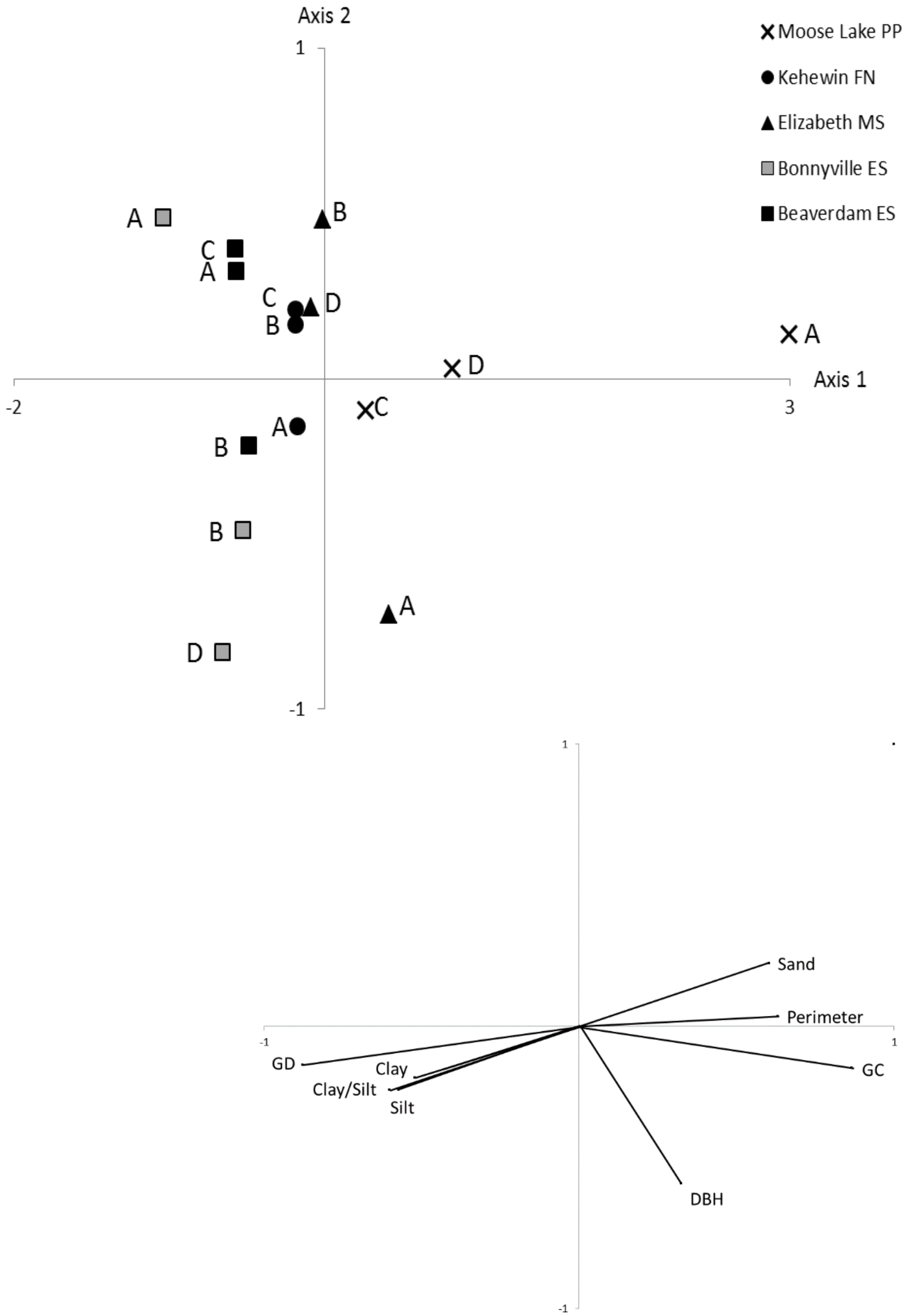

Figure 3-2. NMDS ordination of study plots based only on vascular plant abundance. Insert shows results of the correlation matrix between environmental variables and plot NMDS scores.

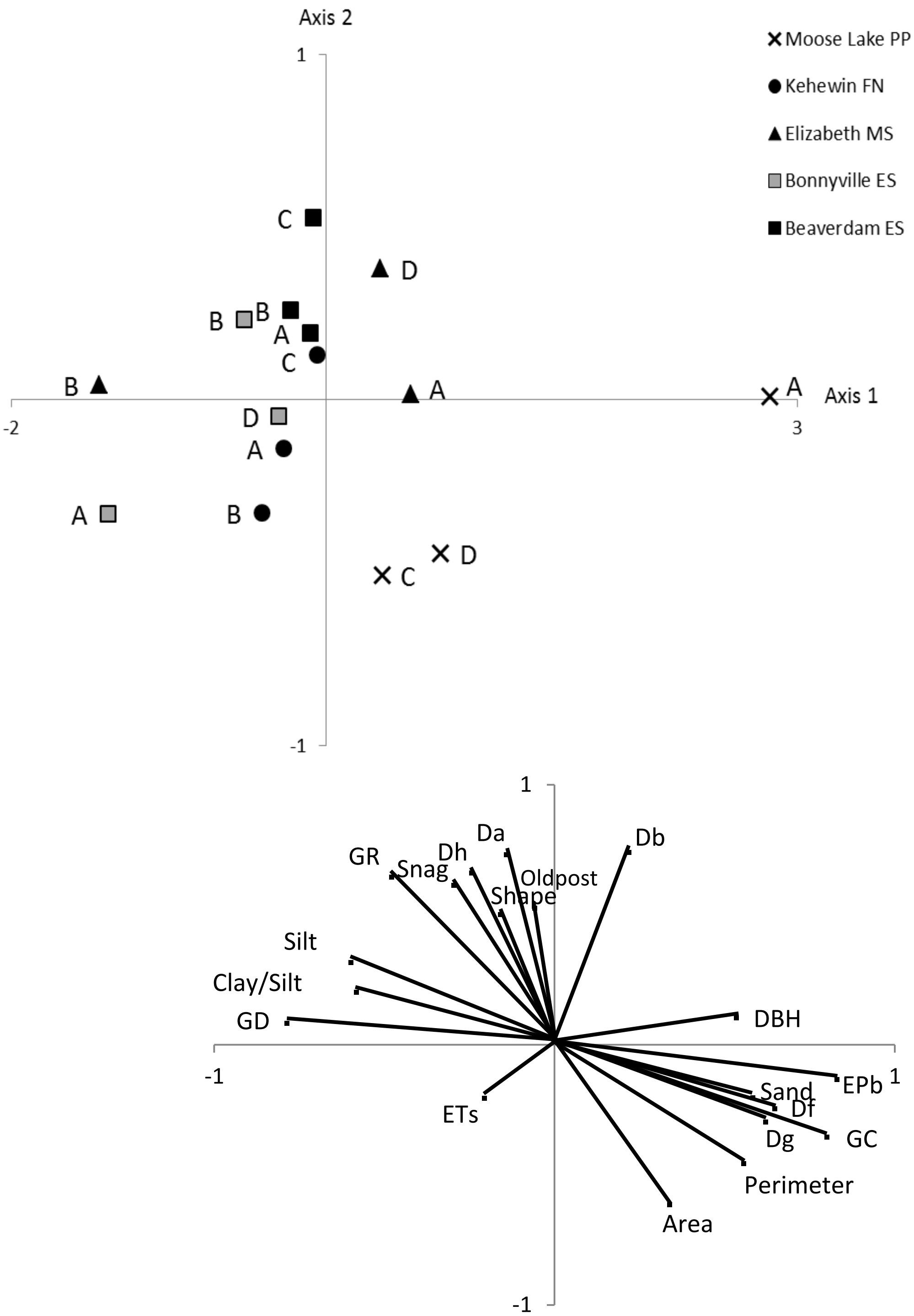

Figure 3-3. NMDS ordination of study plots based only on lichen species incidence. Insert shows results of the correlation matrix between environmental variables and plot NMDS scores.

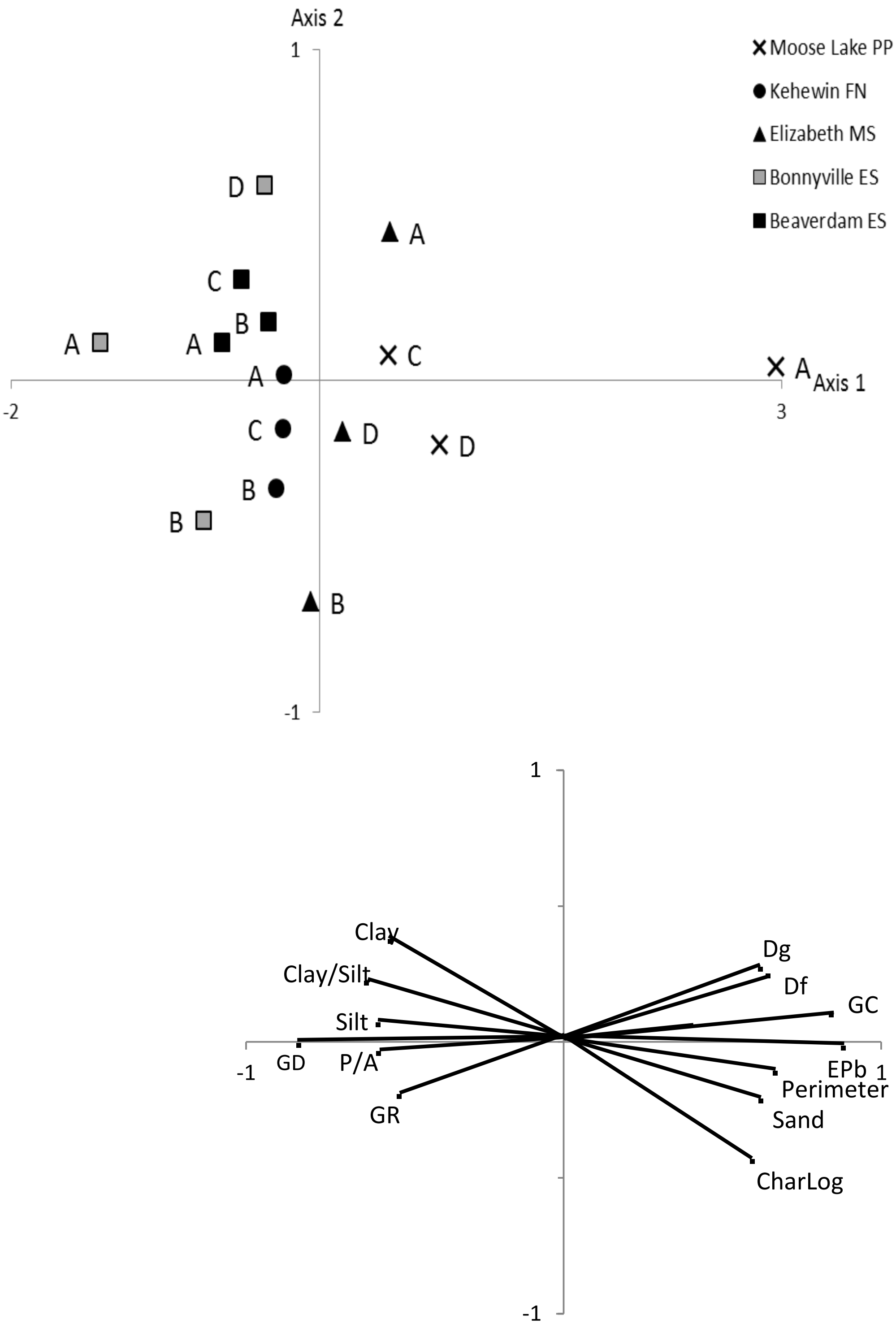

Figure 3-4. NMDS ordination of study plots based on both vascular plant species abundance and lichen species incidence. Insert shows results of the correlation matrix between environmental variables and plot NMDS scores.

CHAPTER 4

Overall Thesis Discussion and Conclusion

Review and Synthesis

"O Canada, our home and native land" – the opening verse of the Canadian national anthem instantly conveys the integral place of *our land* to the people inhabiting this vast nation. It is a primary source of food, shelter, economic gain and recreation. It is the subject of much interest and often hotly debated. Our land, and the ways in which it is occupied and managed, is central in Canadian life. Contemporary land management practices, from a mainstream perspective, have evolved since the 16^{th} century when the French landed and began to settle the eastern regions of the country. The inhabitants of the land at that time had been living on the land and enjoying the bounty of flora and fauna available to them for thousands of years (Canadian Museum of Civilization, 2010; Carter, 1999, pg. 3; Ward, 1995, pg. 2). European contact with western Canada had occurred by the 17^{th} century (Carter, 1999, pg. 111) and by the 18^{th} century, hunters, trappers, voyageurs, and pioneers began to inhabit the western provinces of the Canadian prairie (Carter, 1999, pg. 49). The ensuing wave of colonization spread westward at a very rapid pace. Land was cleared, plows were hitched and the notion of progress coursed through the minds of many. "A new Eurocentric worldview was replacing the Aboriginal one. Land changed from community to commodity, from inhabited to owned" (Dormaar & Barsh, 2000).

Management of most of the land in the study area is largely in the hands of private landowners and as a result, most of the remaining woodlands in the area remain unprotected by law and vulnerable to deforestation. The 2006 Census of the province reported an increase in average farm size; there are presently over 49,000 farms in Alberta with a total area surpassing 21 million hectares (Statistics Canada, 2006). Farm cash receipts in Alberta rose 14% in 2012 to a record $12 billion, with both the reported revenues and annual increases being the highest of all the Canadian provinces (Alberta Agriculture and Rural Development, 2013). Furthermore, although private land management is dictated by various levels of government, there is no cohesive obligation to manage this land with a mind to future generations.

Management practices on public lands, governed by provincial authorities, stem from intentions of conservation and preservation. In 1995 the Government of Alberta implemented the *Special Places Program*, a commitment to expanding the network of parks and protected areas representing environmental diversity of natural regions in the province. Upon conclusion of the program in 2001, a total of 2 million hectares of protected land was added, through 13 expanded and 81 new sites (Alberta Tourism, Parks and Recreation, 2013a). In 2009 the ministry put forth a ten-year *Plan for Parks*, which was based on consultation with, among others, Aboriginal groups and engaging Aboriginal communities is identified among the first priority actions. However, the first 3 strategies of the *Plan for Parks* center on people, recreational use, and enhancement of facilities such as campgrounds; of the main priorities highlighted in the *Plan for Parks*, land conservation falls in fourth and last place (Alberta Tourism, Parks and Recreation, 2013b). Furthermore, I would emphasize that, through ministerial organization, management of parks falls under the same umbrella as Tourism and Recreation which also suggests that Mason's criticism of parks being considered 'luxury items' still holds true today (Mason, 1987, pg. 55).

The results of this study show that wooded retention in Moose Lake Provincial Park was the highest of the four land use units examined. However, the Provincial Park is protecting primarily coniferous forest. The Métis Settlement is protecting the deciduous forest stands to the greatest extent. The Métis land use unit is a heterogenous environment, similar to the Provincial Park in forest patch size index values. The First Nations land use unit was mostly unforested and more closely resembled the surrounding agro-environment, although there remains within it a relatively large patch of deciduous forest. Elizabeth Métis Settlement is the largest of the three delineated land use units, much larger than Moose Lake Provincial Park, and thus could feasibly offer the greatest surface area of protection of the Boreal Mixed-wood Forest in the study area.

The Provincial Park site housed two distinct forest types and thus had the highest richness levels for plant and lichen species. The forest type comprised of coarse sandy soils dominated by *P. banksiana* and foliose and fruticose lichen taxa growing in a low-litter environment was not found anywhere else in the study area. The forest type comprised of *Populus* sp. on soils with higher clay and silt content and a more abundant herbaceous understory was characteristic of the study area. The poplar dominated stands found within the land under Métis control most closely resembled those in the Provincial Park in essentially all aspects examined, including land cover classes, forest patch fragmentation metrics, and overall through the location of plots in the ordination figures. The plots we sampled in the First Nation site were found to be an intermediary between these two land uses and the agri-matrix, particularly with respect to the ordination results and fragmentation metrics, but the plots in the Reserve contributed more rare species to the regional pool than did those in the Settlement. The agricultural sites generally had the lowest values of forest cover and patch size and the most irregularly shaped forest fragments. Specifically, the two plots with the lowest core area and lowest species richness values were located in the Bonnyville area. None of the agricultural plots contributed rare lichen species and introduced species were prominent in the privately-owned agricultural land, further evidence of the habitat degradation stemming from land management regimes of the agricultural industry in this portion of the Central Boreal Mixed-wood of northern Alberta.

Scott denounces the impact of the free market and neo-colonialism, stating that "the entrenched doctrine of 'public' lands and resources competes with – and has historically overshadowed - Indigenous property systems and authority structures" (2004, pg. 17). Contemporary land *management* contrasts traditional aboriginal worldview and land *use*, "western science, including theory and literature related to forest ecosystem management, has been slow to recognize the complex and diverse values that Aboriginal people associate with their lands and resources." (Parlee, Berkes, & the Teetl'it Gwich'in Renewable Resources Council, 2005). In recognition of an intrinsic link to the natural world, a "special relationship with the land" (Russell, 2007, pg 8), both First Nations and Métis groups have been granted a constitutionally protected right to harvest for subsistence on their land. Aboriginal land use includes hunting, fishing, and the gathering of plants in order to meet nutritional, and medicinal needs, but also 'alternative' land uses, such as for spiritual and social needs, including community connectedness through activities such as berry picking **(**Parlee, Berkes, & the Teetl'it Gwich'in Renewable Resources Council, 2005).

Traditional aboriginal land-use does not equate with contemporary use of aboriginal land because of the implementation of the Reserve system and resulting fiduciary responsibilities of the crown and usufructuary rights of aboriginal peoples in Canada. For these reasons, care must be taken to avoid drawing simplistic conclusions about contemporary aboriginal land use or management regimes. Alberta is the only province or territory in Canada where Métis people have been granted the rights to their own land, designated differently than Reserve land for Status Indians. Although at a constitutional level, *aboriginal people* includes Indians, Métis, and Inuit, up until very recently, Métis legislation fell largely in the hands of the provincial government. This was due in part to a historic refusal on the part of the crown to recognize Métis people as "Indians". This uncertainty was removed on January 8, 2013 when the Federal Court of Canada recognized Métis and non-status Indians as "Indians" under section

91(24) of the Constitution Act, although the ruling does not encompass fiduciary responsibility of the Canadian government (Scoffield, 2013; Ma, 2013).

Despite changes to the *Indian Act*, legislative authority over Reserve land in Canada remains exclusively in the hands of AANDC. However, aboriginal self-governance does exist to a certain extent. Self-government agreements between AANDC and Aboriginal groups are negotiated on an individual basis and "address: the structure and accountability of Aboriginal governments, their law-making powers, financial arrangements and their responsibilities for providing programs and services to their members" (Aboriginal Affairs and Northern Development Canada, 2013a). Whether through the delivery of social programs or the construction of casinos, control of aboriginal lands is shifting away from the crown and increasingly aboriginal councils are managing their land and communities, and this is extending to economic development initiatives. Some notable examples include the Enoch and Cold Lake Indian Reserves in Alberta that have joint stakeholder casino development projects. Currently there are 15 First Nation-owned casinos in Canada, operating under varying provincial regimes. The economic benefits are shared with the provinces; in Alberta 30 percent of revenues go to the provincial government (Stueck, 2013). Ecotourism has also emerged as an industry for First Nations. The Cree Village Eco Lodge in northern Ontario was recently deemed one of the top 25 eco-lodges in the world by the National Geographic Society (Christ, 2013). Aboriginal cuisine, including locally raised, free range bison is on the menu and eco-tours by local guides are on the list of activities. Guests are willing to pay for such amenities; rooms start at $168 a night, meals and excursions are extra.

Limitations of the Study and Future Directions

In this study a limited number of plots from within each study site were sampled. Increased sampling effort would allow for more robust and elaborate statistical analyses. This is the first study to undertake a comparison of forest retention and plant and lichen diversity in First Nations land with other land uses in an agro-environment of the Boreal Mixed-wood in Canada and further analyses of different portions of these land use units or of other parks and protected areas, Métis Settlements, First Nations Reserves and agricultural communities may yield very similar or very divergent, but nonetheless interesting, results.

This research presents a snapshot of the current state of affairs of wooded ecosystems by land-use within the Boreal Mixed-wood of northeast Alberta, Canada. The quantitative and qualitative analyses presented herein are important for the preservation of our national heritage because they identify vulnerable areas, but also key land bases that are conserving ecosystem diversity. The results of this study clearly show that the aboriginal land examined herein is a valuable resource from the perspective of the retention of wooded ecosystems and the protection of regional diversity in the Central Boreal Mixed-wood of the Canadian landscape. In accordance with other studies, the agri-matrix I studied is characterized by small, relatively impoverished forest fragments. Through a more effective management regime that promotes variables highlighted in other fragmentation studies of the boreal mixed-wood, such as, patch size, shape, interior, and proximity and connectivity of forest stands, the patches that remain could be maintained as biodiversity hotspots in environments under intense development pressure for agriculture, timber harvesting, oil and gas exploration, urbanization and so on. This consideration could be extended to a multitude of ‘aboriginal lands’ defined as Reserves, Settlements or villages that together represent 617 First Nations in Canada (Aboriginal Affairs and Northern Development Canada, 2013b).

What this study also shows is that relatively little needs to be ‘done’, for example by way of large expenditures or overhauls, to maintain the ecological integrity of aboriginal lands, aside from leaving the land in its relatively undeveloped state and potentially incorporating sound ecological motives into future development plans, thus avoiding some of the mistakes of mainstream society in the last century. In fact this is already happening; the *Memorandum of Provisional Métis Title* set a precedent in this regard, by stipulating explicitly that “you cannot do anything to the land that does long term damage to it or other land in the Settlement area” (Bell, 1994, pg. 650). Globally this is occurring as well, consider the “Law of Mother Earth (*Ley de Derechos de la Madre Tierra*)” enacted by Bolivian President Evo Morales in 2012 (Eaton, 2012). The legislation, based on the indigenous Andean worldview of ‘Pachamama’ (Sacred Mother Earth), established 11 rights to nature including “rights to biodiversity, uncontaminated water and air, freedom from genetically modified crops and freedom from overdevelopment" (Buck, 2012). Increasingly, land use planning is a process of "marrying science with stakeholder engagement" (Weber, Krogmand, & Antoniuk, 2012) and resource development initiatives in Canada incorporate social-ecological indicators as well as the Traditional Ecological Knowledge of aboriginal peoples (Cheveau, Imbeau, Drapeau, & Belanger, 2008; Parlee, Geertsema, & Willier, 2012; Usher, 2000).

Sound land management practices protect not only the cultural heritage and traditional harvesting practices of Aboriginal people in Canada but the ecological integrity of our valuable natural resources for future generations of Canadians from all walks of life.

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APPENDIX I

Raw Surface Vegetation Data

Table A1-1: Mean percent cover of vascular and lichen species on 15 plots distributed across the 4 land use units. + denotes presence for all lichen species. P.P. = Provincial Park; F.N. = First Nation; M.S. = Métis Settlement; E.S. = European Settlement.

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Bonnyville E.S.			Beaverdam E.S.		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
TREES															
Betula papyrifera	1.8	1.5					5.5								
Picea glauca	3.2	1.8	17.4				15.9								
Picea mariana			2.3				1.9								
Pinus banksiana	44.8		9.1												
Populus balsamifera		5.7	2.0	15.2		0.1	24.5	5.5		6.2	36.0	53.6		4.8	
Populus tremuloides		37.4	17.0	38.6	65.4	57.7	18.7	62.7	83.0	7.2	16.0	14.6	77.6	4.3	71.5
Sambucus sp.											0.8				
SHRUBS															
Alnus crispa		0.2					4.5								
Alnus rugosa							45.5								
Amelanchier alnifolia	0.8	14.1	9.5	9.3	41.8	22.2	0.2	5.3	18.5	0.6	51.7	0.5	5.8	44.2	1.0
Cornus stolonifera		6.6		3.2		0.5	4.0			1.5		2.6	5.6	6.5	22.7
Corylus cornuta		11.2	0.6	1.2	2.2	0.5	3.3	19.8	2.0		0.1				
Prunus virginiana		16.3		15.3	19.0	34.0	0.5	11.5	17.6	0.4	2.3	0.8	2.2	3.8	
Ribes americanum							0.5					2.5		0.8	
Ribes glandulosum							0.3								
Ribes lacustre		1.7					0.2								
Ribes oxycanthoides		1.5	0.3	0.5		0.9	1.0					1.7	4.2	0.6	7.6
Ribes triste		4.6	0.5				3.8							0.4	
Rosa acicularis	0.6	8.3	11.5	25.4	8.0	12.2	6.2	21.7	9.9	0.9	9.3	2.3	8.4	6.8	26.7

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Rosa woodsii		0.1	0.2	5.7	0.5	6.0		5.5		2.5	5.4	0.5	7.0	1.8	0.3
Rubus idaeus		5.8		11.5	0.3	3.3	2.4	0.9	2.0	0.1	2.9	16.9	1.8	5.8	8.7
Salix bebbiana		1.9	1.1			0.2	7.4	23.5				0.4			
Salix candida								8.5							
Salix discolor		0.1		1.3			0.5		0.4				4.2		15.3
Salix glauca		2.7													
Salix maccalliana								1.8							
Salix planifolia			0.4												
Salix pyrifolia	0.2	0.2					1.2								
Salix scouleriana															8.1
Sheperdia canadensis		3.8	5.7							0.4		0.5			
Symphoricarpos albus		1.5	3.0	25.2	21.8	20.0	3.2	7.5	14.4	0.9	4.5	13.0	19.5	26.4	5.8
Vaccinium vitis-idaea	5.8														
Vaccinium myrtilloides	2.3														
Viburnum edule		1.0	0.9				6.5		3.5					1.4	0.2
FORBS															
Achillea millefolium			1.3	0.2	1.5	0.9	0.5	0.5	0.1	5.7		0.9	0.4	0.2	0.5
Achillea siberica				0.1		0.2	0.1	0.7				0.2	0.8		0.3
Actaea rubra		0.4	0.5	1.8	0.1	0.5	1.2		0.1			0.6	0.2	1.0	0.3
Agastache foeniculum				1.7	1.6	0.2			0.5	0.2				1.2	1.6
Agrimonia striata				1.0		0.4								2.8	
Anemone canadensis	0.3			0.5		0.5	0.2	2.0	0.1	9.6		0.2	3.0	0.2	1.3

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Antennaria microphylla											0.1				
Antennaria neglecta										0.1					
Apocynum androsaemifolium	0.5	1.1			1.3	3.1		3.6							
Aralia nudicaulis	0.5	15.2	4.1	11.8	33.7	4.5	43.6	8.1	15.5					2.2	6.6
Arceuthobium americanum	0.1														
Arctostaphylos uva-ursi	11.2		6.8												
Arenaria lateriflora				1.1	1.3	1.1	0.7	0.7	0.3			0.5	1.2	0.7	0.6
Aster ciliolatus		2.1	4.4	4.2	0.6	4.6	2.8	7.3	5.8			2.9	0.2	2.3	2.4
Aster conspicuus			2.5	1.1	11.2	0.1	1.6	9.5	1.0					0.8	
Aster laevis						0.5									
Aster puniceus	0.5	0.5	0.9		0.5	0.5	0.3	0.3	0.2			0.5		0.2	
Axyris amaranthoides											0.1				
Botricum virginianum							0.2					0.5			
Campanula rotundifolia	0.5					0.4									
Castilleja miniata								3.0							
Cirsium arvense										0.1			1.8	4.7	
Commandra umbellata	0.5		0.3		0.7	1.0									
Corydalis aurea											0.2				
Cornus canadensis		3.7	4.2				3.4	0.7	3.0					0.3	
Corallorhiza striata						0.2	0.5					15.9			
Corallorhiza maculata		0.5	0.5												
Delphinium glaucum			0.5												

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Disporum trachycarpum		0.2		0.9			1.5		0.2					0.3	
Epilobium angustifolium		0.7	0.8	0.2		0.5	4.0	5.7	1.4			6.4	0.6		1.9
Erigeron glabellus	0.2														
Erigeron philadelphicus					0.3					0.2			0.8		
Erysimum cheiranthoides														0.8	
Fragaria vesca		0.2		0.5			1.0								
Fragaria virginiana		1.7	3.5	4.0	0.5	2.7	2.6	6.8	0.9	1.7		4.8	1.6	1.3	0.8
Galium aparine												3.5			
Galeopsis tetrahit											1.1	0.1	0.2		0.6
Galium boreale		2.2	3.9	3.6	10.0	3.9	1.5	4.9	2.0	0.4	1.2	1.2	1.0	2.7	3.1
Galium triflorum		1.7		0.8		0.2	2.0		0.2		8.9		0.8	2.8	
Gentianella amarella						0.1		0.2							
Geum aleppicum				0.5		0.7								1.3	
Geum rivale				0.4			0.5					0.6		0.4	
Geum triflorum				0.3								0.1			
Habernaria viridis					0.5			0.1				0.3			
Halenia deflexa								2.0							
Heracleum lanatum				4.2		0.1	8.8					2.0	0.2	1.3	
Hieracium umbellatum						0.2									0.1
Lactuca tatarica				0.3	0.1	0.3									
Lathyrus ochroleucus		4.8	8.8	3.7	2.8	3.4	2.0	1.3	0.3	0.5		0.7	3.5	1.3	1.0
Lathyrus venosus		1.4	2.9	0.3	6.7	3.5	0.2	1.5	1.2			0.1	0.7		

Table A1-1 continued

Taxon	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Ledum groenlandicum	12.3														
Lilium philadelphicum					0.4	0.4		0.3	0.1			0.6			
Linnaea borealis		3.7	15.7				0.5	0.7							
Lonicera dioica		1.1	5.5	0.1	0.4	1.0	1.4	0.3	0.6	0.1		0.8		1.9	
Lonicera involucrata		5.7					4.6					4.7		2.0	
Maianthemum canadense	2.6	2.6	13.4	0.7	2.3	1.7	2.9	0.3	2.2					0.2	0.3
Medicago sativa										3.2			2.6		
Melampyrum lineare	0.8														
Melilotus alba						0.5							1.2		
Melilotus officinale													0.7		
Mentha arvensis												0.2			
Mertensia paniculata		1.6		3.5		1.3	4.2	0.7				1.1		1.2	
Mitella nuda		1.8				0.5	4.5					0.5			
Osmorhiza depauperata							1.3								
Petasites frigidus					0.1										
Petasites palmatus		2.8	0.2				3.5							0.2	
Petasites sagittatus												0.5	0.4		
Polygonum convolvus													0.8		
Polygala senega					0.2										
Polygonum sp.											0.1				
Potentilla anserina													0.2		
Potentilla arguta					0.2							0.1			

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Potentilla tridentata			0.1												
Pyrola asarifolia		2.3	2.3	1.0		0.6	0.3		1.0			0.2		0.8	
Pyrola elliptica			0.8			0.5						0.1			
Pyrola secunda		0.3	0.2	0.5			0.5		0.1			0.5			
Ranunculus abortivus														0.8	
Rubus pubescens		14.1	2.8	5.6	0.1		7.9	2.9	6.6			1.0		0.5	0.1
Sanicula marilandica				1.8	0.4	0.4						0.2		2.4	
Scutellaria galericulata												0.1			
Senecio pauperculus			0.1												
Silene pratensis											0.7			0.8	
Sisyrinchium montanum					0.5										
Smilacina stellata				0.8	2.7	1.9	0.5				0.2	3.3	1.8	2.7	0.6
Solidago canadensis				1.7	1.1	3.5	1.1	2.7	0.6	1.0		3.2	4.4	2.8	15.3
Solidago spathulata	0.4														
Sonchus arvenis													1.5	0.4	
Sorbus scopulina										0.1					
Stachys palustris				1.2		1.0	0.3		0.5			1.5		0.8	0.4
Stellaria media															0.1
Taraxacum officinale		0.3	0.1	0.9	1.3	1.5	0.6	0.7	0.4	48.0	0.1	1.2	3.2	3.3	0.8
Thalictrum dasycarpum		0.1		1.7	3.8	0.8								0.2	
Thalictrum sparsiflorum						0.6									0.3
Thalictrum venulosum			1.2	12.3	5.4	7.0			2.3		0.2	3.5	1.8	3.6	2.2

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Trientalis borealis		3.5	1.4				0.5								
Triflorum hybridum										1.0			0.2		0.4
Triflorum pratense						1.0				1.1			0.8		
Urtica dioica											1.8	15.1	0.8		
Vicia americana		0.5		3.1	3.1	2.0	0.1	3.7	0.4	8.0		0.8	3.8	0.8	0.8
Viola adunca			1.0		0.7	0.8		1.8	0.3			0.1	0.8		0.1
Viola canadensis				12.6	2.7	0.5	1.8		2.9		0.2		0.4	4.8	7.4
Viola neprophylla													0.8		
Viola renifolia		0.3	0.2		0.1										
Zizia aptera													0.8		
GRAMINOIDS															
Agropyron trachycaulum			0.5	0.2		2.3	0.3	2.4	0.3		0.2	0.7	7.8	3.3	4.2
Agropyron unilaterale						1.5	0.3		0.2					1.7	0.3
Bromus ciliatus						2.5		1.7						0.8	2.5
Bromus inermis ssp.inermis				6.6	3.7	0.5		0.5	0.3	4.2	23.4	4.9	31.5	15.8	19.0
Calamagrostis canadensis						1.5	1.0	4.9	2.8				0.5	0.5	4.7
Carex aenea					3.4									3.6	
Carex brunnescens						2.3		1.2							
Carex deweyana						0.5	0.6					0.6		0.7	
Carex limosa						1.0									
Carex nigromarginata		0.1													
Carex peckii		0.2					0.1								

Table A1-1 continued

Taxon	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Carex praegracilis		0.5													
Carex rossii		0.5													
Carex siccata	0.8				1.6	8.5		0.6							
Carex sp.	0.5	0.3	0.1	3.0	3.4				0.8				0.4		0.4
Carex utriculata						1.0									
Elymus innovatus						0.1	0.9	1.7	2.3						
Equisetum arvense		0.4					1.0							1.6	0.5
Equisetum fluviatile							1.4							0.3	
Equisetum pratense		2.0					0.5								0.3
Equisetum sp.		1.9	0.5												
Equisetum sylvaticum							0.4								
Hierchloe odorata														0.4	0.1
Juncus balticus						0.4									
Oryzopsis asperifolia		3.3	1.4		0.5				2.0						
Phleum pratense				0.2	0.5	0.3							0.8		
Poa palustris		0.1	0.2	2.6	6.4	6.9		0.2	0.5	14.8		9.4	2.5	11.8	0.8
Poa pratensis	0.6			0.1		1.2									
Poa sp.	0.4														
Schizachne purpurascens		0.3	4.0		0.4	0.4	0.3	1.0	0.6					0.8	
LICHENS															
Arthonia patellulata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Biatora vernalis	+	+	+	+	+	+	+		+		+	+	+	+	+

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Species	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Bryoria fuscenscens	+		+				+								
Bryoria lanestris	+	+	+				+								
Bryoria simplicior	+						+						+		
Bryoria sp.			+			+			+						
Buellia punctata		+	+	+	+	+	+		+	+	+	+	+	+	+
Caloplaca cerina		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Caloplaca holocarpa		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Candelaria concolor	+		+	+	+	+	+	+	+	+		+	+	+	+
Candelariella vitellina	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cetraria islandica	+			+	+										
Cladina mitis	+	+		+											
Cladina rangiferina	+		+												
Cladonia botrytes	+	+	+	+		+			+					+	
Cladonia cariosa		+	+	+											
Cladonia cenotea	+		+												
Cladonia coniocraea	+	+	+	+	+	+	+		+	+	+			+	
Cladonia crispata	+		+	+	+										
Cladonia cristatella	+	+	+												
Cladonia deformis		+													
Cladonia fimbriata	+		+	+	+	+	+		+						
Cladonia gracilis ssp.turbinata	+		+	+	+				+						

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Cladonia cervicornis ssp.verticillata	+		+												
Cladonia chlorophaea	+	+	+			+	+		+				+	+	
Cladonia cornuta ssp.cornuta	+		+			+			+						
Cladonia macilenta	+			+						+					
Cladonia multiformis	+		+												
Cladonia phyllophora	+	+	+	+	+	+	+		+	+	+		+	+	
Cladonia pyxidata	+	+	+	+	+	+									
Cladonia scabriuscula		+							+						
Cladonia squamosa				+											
Cladonia subulata	+	+		+											
Cladonia uncialis	+			+		+									
Evernia mesomorpha	+	+	+	+		+	+		+		+	+	+		+
Flavopunctelia flaventior	+		+	+		+	+	+	+		+		+	+	+
Hypogymnia enteromorpha	+														
Hypogymnia physodes	+	+	+		+	+	+		+			+			
Lecanora circumborealis	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Melanelia albertana	+	+	+	+			+					+			
Melanelia exasperatula		+				+	+								
Melanelia septentrionalis	+	+	+				+	+	+			+		+	
Melanelia sp.	+	+	+	+	+	+	+		+			+	+		+
Parmelia sulcata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Table A1-1 continued

Taxon	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Parmeliopsis ambigua		+	+	+	+		+					+			
Parmeliopsis hyperopta					+										
Peltigera aphthosa			+												
Peltigera canina			+			+	+			+					
Peltigera elisabethae	+														
Peltigera malacea	+														
Peltigera neckeri			+						+						
Peltigera neopolydactyla		+	+				+		+	+					
Peltigera praetextata				+				+	+						
Peltigera rufescens				+	+										
Phaeophyscia orbicularis		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Physcia adscendens	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Physcia aipolia	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Plastismatia glauca	+														
Ramalina dilacerata	+	+	+			+	+		+		+	+	+	+	+
Ramalina pollinaria	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Tuckermanopsis americana	+			+	+										
Usnea hirta	+	+	+	+	+	+	+	+		+		+	+	+	
Usnea lapponica	+	+	+	+	+		+								
Usnea scabrata	+		+				+								
Usnea sp.	+			+	+	+		+	+		+	+	+		+
Usnea subfloridana	+		+	+	+		+								

Table A1-1 continued

	Moose Lake P.P.			Kehewin F.N.			Elizabeth M.S.			Jessie Lake			Angling Lake		
Taxon	A	C	D	A	B	C	A	B	D	A	B	D	A	B	C
Vulpicida pinastri	+	+	+	+	+	+	+		+				+	+	
Xanthoria elegans								+			+			+	+
Xanthoria fallax		+	+	+	+	+	+	+	+	+	+	+	+	+	+
Xanthoria polycarpa	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

APPENDIX II

Rare Vascular Plant and Lichen Species

Table A2-1: Occurrence of vascular plant and lichen species unique to study site locations within the boreal mixed-wood of northeast Alberta, Canada. * denotes an introduced species.

Taxon	Common name	Lifeform
Provincial Park		
Pinus banksiana	Jack pine	tree
Salix planifolia	Flat-leaved willow	shrub
Vaccinium myrtilloides	Common blueberry	shrub
Vaccinium vitis-idaea	Bog cranberry	shrub
Arceuthobium americanum	Dwarf mistletoe	forb
Arctostaphylos uva-ursi	Kinnikinnick	forb
Corallorhiza maculata	Spotted coralroot	forb
Delphinium glaucum	Tall larkspur	forb
Erigeron glabellus	Smooth fleabane	forb
Ledum groenlandicum	Labrador tea	forb
Melampyrum lineare	Cow-wheat	forb
Potentilla tridentata	Three-toothed cinquefoil	forb
Senecio pauperculus	Balsam groundsel	forb
Solidago spathulata	Mountain goldenrod	forb
Carex nigromarginata	Black-edged sedge	graminoid
Carex praegracilis	Graceful sedge	graminoid
Carex rossii	Ross' sedge	graminoid
Cladina rangiferina	Grey reindeer lichen	lichen
Cladonia cenotea	Powdered funnel lichen	lichen
Cladonia cervicornis ssp.verticillata	Whorled ladder lichen	lichen
Cladonia cristatella	British soldiers lichen	lichen
Cladonia deformis	Deformed cup lichen	lichen
Cladonia multiformis	Sieve cup lichen	lichen
Hypogymnia enteromorpha	Tube lichen	lichen
Peltigera aphthosa	Freckle pelt	lichen
Peltigera elisabethae	Elizabeth's felt lichen	lichen
Peltigera malacea	Apple pelt	lichen
Plastismatia glauca	Ragged lichen	lichen
Métis Settlement		
Alnus rugosa	Speckled alder	shrub
Ribes glandulosum	Skunk currant	shrub
Salix candida	Hoary willow	shrub
Salix maccalliana	Maccall's willow	shrub
Castilleja miniata	Red paintbrush	forb
Halenia deflexa	Spurred gentian	forb
Osmorhiza depauperata	Spreading sweet-cicely	forb
Equisetum sylvaticum	Woodland horsetail	graminoid

Table A2-1 Cont'd.

Taxon	Common name	Lifeform
First Nation		
Aster laevis	Smooth aster	forb
Lactuca tatarica	Blue lettuce	forb
Petasites frigidus	Arctic coltsfoot	forb
Polygala senega	Seneca snakeroot	forb
Sisyrinchium montanum	Blue-eyed-grass	forb
Carex limosa	Mud sedge	graminoid
Carex utriculata	Beaked sedge	graminoid
Juncus balticus	Wire rush	graminoid
Cladonia squamosa	Cup lichen	lichen
Parmeliopsis hyperopta	Grey starburst	lichen
Peltigera rufescens	Felt pelt	lichen
Bonnyville area		
Sambucus sp.	Elderberry	tree
Sorbus scopulina	Western mountain ash	shrub
Axyris amaranthoides	Russian pigweed	forb*
Galium aparine	Cleavers	forb*
Antennaria microphylla	Small-leaved pussytoes	forb
Antennaria neglecta	Broad-leaved pussytoes	forb
Corydalis aurea	Golden corydalis	forb
Mentha arvensis	Wild mint	forb
Scutellaria galericulata	Marsh skullcap	forb
Beaverdam area		
Salix scouleriana	Scouler's willow	shrub
Erysimum cheiranthoides	Wormseed mustard	forb
Viola nephrophylla	Bog violet	forb
Zizia aptera	Heart-leaved alexanders	forb
Melilotus officinalis	Yellow sweet-clover	forb*
Polygonum convolvus	Wild buckwheat	forb*
Potentilla anserina	Silverweed	forb*
Ranunculus abortivus	Small-flowered buttercup	forb*
Sonchus arvenis	Perennial sow thistle	forb*
Stellaria media	Chickweed	forb*
Hierchloe odorata	Sweet grass	graminoid