

FINAL REPORT

Impacts of Climate Change on the Island Forests of Saskatchewan

Prepared for Prince Albert Model Forest

By Mark Johnson
Saskatchewan Research Council
Environment and Forestry

SRC Publication No. 12168-1E08

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Saskatchewan Research Council
125 – 15 Innovation Blvd.
Saskatoon, SK S7N 2X8
Tel: 306-933-7432
Fax: 306-933-7817

ACKNOWLEDGEMENTS

Funding for this project was provided by the Prince Albert Model Forest and Indian and Northern Affairs Canada. Many people assisted in providing information and data for this review. Staff of the Forest Service Branch of Saskatchewan Environment were particularly helpful. These included Shane Vermette, Wilf Goerwell, Fern Gruszka, Rory McIntosh, Dave Dorosh, Del Phillips, Phil Loseth, Vince Biamonte, Robert Moore, Dianne Allen, Bruce Walter, Steve Hyde, Jim Smith, Kim Clark, Dave Lindenias and Barry Otterson. Jeff Lettvenuk of GeoSpatial Consulting Inc. at the Saskatchewan Forest Centre was helpful in providing data with permission from Domtar Inc. Vicki Gauthier, Mark Doyle and John Doucette of Domtar Inc. kindly provided access to regeneration information on Domtar's FMA north of Prince Albert and answered many questions regarding this dataset. Others who provided information and replied to enquiries included Lane Gelhorn of Timberline Forest Inventory Consultants Ltd., Mark St. Arnaud, Alvin Anderson and Glen Padbury of the Saskatchewan Land Resource Centre (Agriculture and Agri-Food Canada), Al Balisky of Mistik Management Ltd., James Brandt of the Canadian Forest Service, Mike Demyen of Woodlands Campus (Saskatchewan Institute of Applied Science and Technology), Ron Burns of First Nations Island Forest Management Inc. and Roman Orynik of the Saskatchewan Forest Centre.

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CHAPTER I - THE HISTORY OF FOREST DISTURBANCE AND FOREST HEALTH IN THE ISLAND FORESTS

1. INTRODUCTION

1.1 Study area

The Island Forests represent the southernmost extreme of the boreal forest in central Saskatchewan. These forests occur on sandy deposits formed near the end of the last glacial period which, because of low agricultural suitability, have remained forested while the surrounding lands have been cleared and farmed. The Island Forests are centred on Prince Albert. The Nisbet Forest is largely to the west and south of Prince Albert, straddling the North Saskatchewan River, but portions extend east of the city. Fort à la Corne, the largest of the Island Forests, is mainly along the north side of the Saskatchewan River between Prince Albert and Nipawin. Two small Island Forests, Canwood and Torch River, are approximately 50 km west of Prince Albert and 20 km north of Nipawin, respectively. The Canwood Forest is close to the Nisbet Forest, while the Torch River Forest is close to the Fort à la Corne Forest. Most of the stands in the Island Forests are dominated by either jack pine (*Pinus banksiana*) or trembling aspen (*Populus tremuloides*). The location of the Island Forests is shown in Figure I-1.

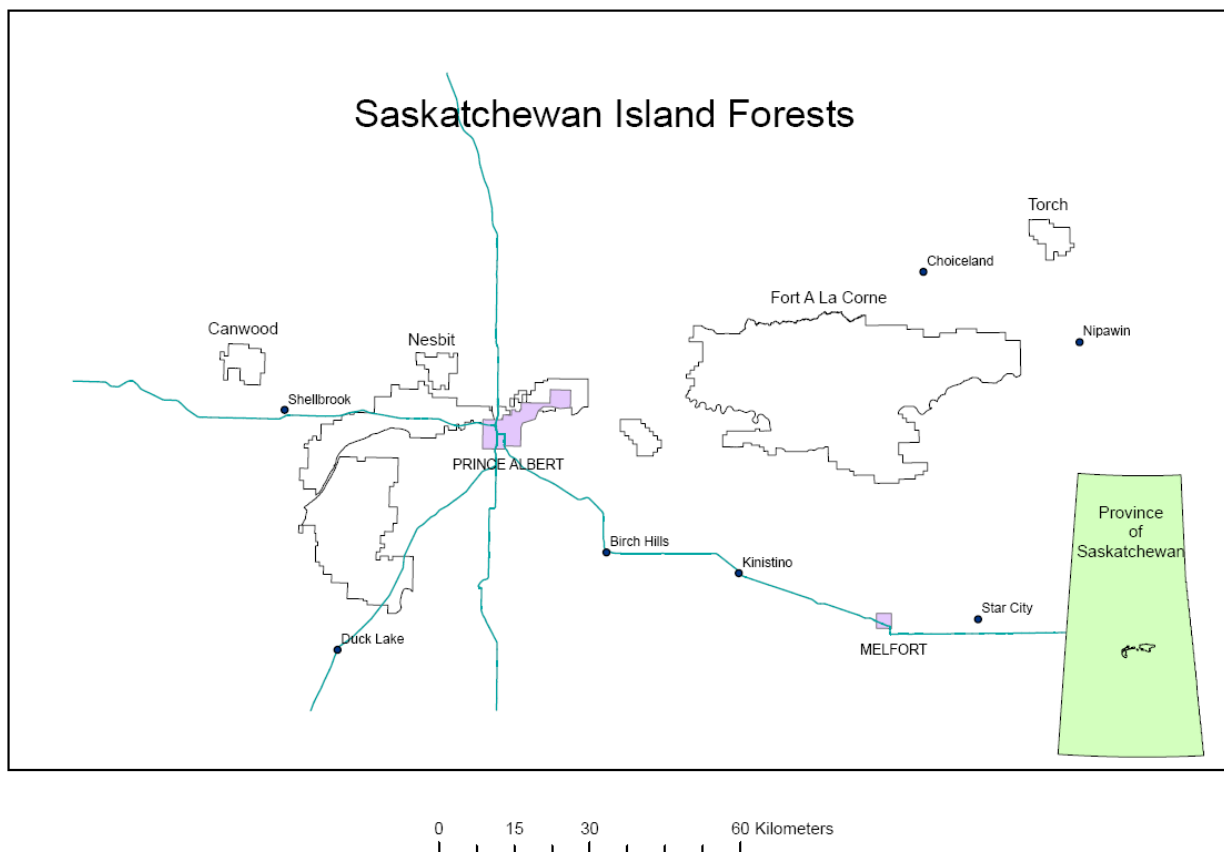


Figure I-1 Location of the Island Forests in central Saskatchewan

The transition from forest to grassland in this region is linked to climatic moisture balance, and the Island Forests are close to the threshold at which moisture becomes insufficient to support continuous forest vegetation. Hogg (1994) mapped a climate moisture index (CMI) for the prairie provinces, calculated as annual precipitation minus annual potential evapotranspiration. The zero value of this index coincides almost exactly with the southern boundary of the boreal forest across Alberta, Saskatchewan and Manitoba, indicating that positive values support forest while negative values support grassland/aspens parkland vegetation. Maps of average CMI presented by Hogg et al. (2007) showed that the Fort à la Corne Forest is roughly at a CMI of 5 cm, and the Nisbet Forest at -10 cm (Hogg 1994). This indicates that the Island Forests are climatically marginal for boreal forest, with the Nisbet Forest slightly drier than the Fort à la Corne Forest. The predominantly sandy soils in these forests allow rapid infiltration of rainwater, favouring deeper-rooted trees over shallow-rooted grasses, and allowing forest to develop in this marginal climate.

Hogg et al. (2007) mapped the most severe droughts of the past century. The Island Forests frequently experienced CMI values of -30 to -40 cm in drought years, compared to -20 cm in the main area of the boreal forest. The lower CMI values for the Island Forests indicate that they should show climate change earlier than the main boreal forest. Climate change modeling has shown that the warming predicted over the coming century will shift the grassland/forest threshold northward, making the area which is currently the southern edge of the forest more suitable for aspen parkland vegetation (Hogg and Hurdle 1995). Wolfe and Thorpe (2005) applied climate change scenarios to the Nisbet and Fort à la Corne Forests, and found that the climate in the 2050s could be similar to that presently found in grasslands of North Dakota.

These models imply a shift from forest to grassland in the Island Forests. Such a shift could be accelerated by major disturbance events such as wildfire and timber harvesting. Failure of tree regeneration following disturbance is a likely mechanism for the predicted change in vegetation zonation. However, there could also be mortality of mature trees, perhaps caused by interaction between drought and insect attack as has been shown for trembling aspen in the prairie provinces (Hogg et al. 2002, Frey et al. 2004). In the Island Forests, an important cause of mortality is parasitism by dwarf mistletoe (*Arceuthobium americanum*), which could be affected by variations in climate.

The Island Forests, close to urban centres and surrounded by agriculture, are the focus of an array of overlapping land uses, including timber harvesting, wildlife habitat, livestock grazing, outdoor recreation, gravel extraction, and diamond exploration. A shift from forest cover to grassland would drastically affect at least some of these uses, particularly timber harvesting. Moreover, the Island Forests may function as an “early warning system” for the impact of climate change on the larger boreal forest. Because they are at the dry southern margin of the boreal forest, they should be the first areas to change. The impacts of climate change on forest productivity and health is discussed in detail in Chapter II.

1.2 Forest management activities

The total area of the four provincial forests is approximately 226,423 hectares (ha) with a productive forest landbase of 195,356 ha. The sustainable timber harvest level for the Island Forests landbase has been determined by Saskatchewan Environment Forest Service (SEFS) to

be 84,100 m³ per year for the Fort a la Corne Forest and 61,700 m³ per year for the Nisbet Forest. The conifer harvest level within the Fort a la Corne forest has been estimated at 52,600 m³ per year and within Nisbet Forest it has been estimated at 20,200 m³ per year.

The total harvest allocation for the Island Forests is currently set by SEFS at 80,200 m³ of softwood and 26,200 m³ of hardwood annually, distributed between 18 permit holders and one Term Supply License holder. For each year of this Operating Plan in the Fort a la Corne Forest, softwood and hardwood harvest has been set at approximately 53,000 m³ and 17,000 m³, respectively. In the Nisbet Provincial Forest, the planned annual softwood harvest is approximately 21,200 m³ and the planned annual hardwood harvest is at 8,600 m³. In the Canwood Provincial Forest, the planned softwood harvest is approximately 2,000 m³ and 200 m³ for hardwood while in the Torch River Forest the annual harvest is 4,000 m³ and 400 m³.

There are 19 Independent Operators each with an annual Forest Product Permit and an additional fluctuating number of small operators with permits amounting individually to less than 500 m³ accessing timber within the Island Forests and operating under the regulatory framework detailed by the Forest Resources Management Act and Regulations (The Act and Regulations) of Saskatchewan.

Permit holders are required to operate in accordance with the conditions of approval attached to their permit. As detailed in The Forest Resources Management Regulations 9 Apr 1999 cF-19.1 Reg 1 s10. a Forest Product Permit may include the following conditions:

- The rate of harvest;
- The requirement to complete a scaling plan;
- The method and schedule for payment of dues and fees and, if applicable, any bonus to be paid pursuant to section 25 of the Act;
- The requirement to submit information relating to the licensee's forest operation and the sale, transfer or trade of forest products harvested;
- Any user agreements with another licensee respecting roads; and,
- Any other matters that the minister considers appropriate.

In 2003, the Minister of the Environment delegated to the Saskatchewan Forest Centre (SFC) the responsibility to administer a forest management trust fund. The fund was established and is maintained with Forest Management Fees paid by the Independent Operators for timber harvested from the Island Forests. The Trust Fund is used for the renewal, protection, development, and management of the timber resource.

The SFC's responsibilities identified in the Island Forests Management Agreement include the development of Annual Operating Plans (AOP) and other related forest management tasks for the Island Forests. To fulfill the requirements of the Act and this Agreement, these plans will include:

- Description of the volume of timber to be harvested and the location of harvest activities for each Independent Operator in the Island Forests;
- Description of the renewal activities to be carried out in the Island Forests that will be funded through the Trust Fund;

- Inclusion of a description and listing of the consultation activities conducted by or on behalf of SFC in preparation of the Draft AOP, including consultations with each Independent Operator.

The AOP will be prepared in accordance with:

- The Forest Resources Management Act and Regulations;
- Any Saskatchewan Forest Accord, any applicable Forest Management Plan, Ministerial Approval under The Environmental Assessment Act if required, and any Integrated Forest Land Use Plan, as amended from time to time;
- Any applicable standards in a Manual, as developed from time to time by the Minister;
- The terms of each Forest Product Permit issued to the Independent Operators; and
- The terms of the Island Forests Management Agreement.

The preparation and submission of these operating plans and projections for the period 2008 – 2012 is the primary step in the process of undertaking management activities for the Island Forests.

The SFC has used an open consultative planning process with the Independent Operators to meet the timber harvest commitments provided to the operators by SEFS while attempting to efficiently utilise the resource. The public consultation process developed and implemented in the preparation of this operating plan has enabled the public to become informed of management activities and to assist in the identification of values and concerns related to the area of operations. This consultation has been achieved through open houses held specific to this plan. Discussions with the operators, the public and with staff at SEFS have enabled the SFC to develop this plan with consideration and integration of non-timber values for the areas.

The 2007/08 Operating Plan for the Island Forests has been prepared with the intent of providing the planning information required to enable the operations of the Independent Operators to proceed within the requirements of The Forest Resources Management Act and Regulations. In lieu of a Forest Management Plan being in place for the Island Forests, this AOP was prepared with consideration of the objectives of Public Advisory Groups as reflected by the Integrated Forest Land Use Plan process being undertaken by SEFS for the Island Forests (Nisbet and Fort a la Corne Provincial Forest). The Integrated Forest Land Use Plans are available on-line from Saskatchewan Environment at: <http://www.environment.gov.sk.ca/>.

2. OBJECTIVES

The purpose of this portion of the study was to determine whether there is any evidence that the climate change impacts predicted for the Island Forests are already happening. Specific objectives were:

- to collect and analyze data on regeneration following wildfire and harvesting in the Island Forests, to determine whether there is any evidence of regeneration failure that can be related to climate change.

- to compare regeneration trends in the Island Forests to those in the main area of commercial forest, to determine whether regeneration failure is more likely in climatically marginal areas of the boreal forest.
- to collect and analyze data on dwarf mistletoe infestations, to determine whether there are any trends that can be related to climate change.

3. REGENERATION SURVEYS

3.1 Regeneration after timber harvesting in the Island Forests

An aerial regeneration survey of the Island Forests was conducted in 2005 by Timberline Forest Inventory Consultants Ltd. (2006). The report and data were provided by Saskatchewan Environment Forest Service Branch. The survey was mostly done in cutovers, although some of the data came from burns with silvicultural treatment (usually planting) and “open productive” land. Polygons of these types were viewed from a helicopter, and estimates were made of tree species density, height, leader length, condition, species composition, canopy pattern, competition, moisture regime, crown closure, and disturbance history. The data were used to assign map polygons to one of five categories:

1. SR - Sufficiently restocked
2. NSR - Not sufficiently restocked
3. US – Undersized softwood. The softwood trees had not attained the required height to be considered successful (e.g. jP 1.5 m tall)
4. UH – undersized hardwood. The hardwood trees had not attained the required height to be considered successful (e.g. tA 2.0 m)
5. SLG – Softwood leader growth. The softwoods did not meet the minimum leader growth (e.g. jP averaging 0.1 m leader growth over three years).

For the purpose of our data analysis, the US (undersized softwood), UH (undersized hardwood), and SLG (softwood leader growth) categories were lumped with the SR (sufficiently restocked) category rather than the NSR category. The US, UH, and SLG categories had sufficient numbers of trees per hectare to be considered sufficiently restocked, but were lacking only in height or rate of growth.

Most of the upland stands in the Island Forests have a jack pine component. This species is most abundant on the drier site types where regeneration failures are more likely to occur. Therefore, our analysis was limited to stands with at least 30% jack pine. This subset of data from the Timberline regeneration survey was used to search for trends in regeneration success/failure.

The regeneration survey recorded the disturbance history for each map polygon. Data were collected for three types of disturbance and subsequent treatment:

1. Cutover – these are areas which were cut and planted
2. Silviculture only – (Mainly old burns that were not salvage logged but were planted)
3. Open Productive – (Mainly old burns that had no recorded harvesting)

A summary of the amount of NSR land by disturbance/treatment regime is provided in Table I-1.

Table I-1 shows that burns which have been replanted (Silviculture Only type) have a lower percentage of NSR land than cutovers. However, there is a relatively small area of this type relative to cutovers. Burns which have not been planted (Open Productive type) have a similar percentage of NSR lands to cutovers which have been replanted. In the following analysis, only the data on cutovers are used.

Table I-1 Percentage of NSR land by disturbance type, for stands with a pine component in the four Island Forests

Disturbance type	Area (ha)		% NSR
	NSR	Total	
Cutover	3,317	21,056	16
Silviculture only	77	1,698	5
Open productive	294	1,948	15
Total	3,687	24,702	15

No age data were reported in the Timberline regeneration survey. In order to examine temporal trends, stand ages were estimated from recorded tree heights. Kabzems and Kirby (1956) gave table values for the relationship between height and age for jack pine on three site classes (Table I-2). These table values were represented by regression curves, by regressing log-transformed age on height (Table I-3).

Table I-2 Relationships between age and height for jack pine stands on poor, average, and good sites (Kabzems and Kirby 1956)

Age	Height (feet)		
	Poor Site	Average Site	Good Site
20	12	19	27
30	19	29	38
40	27	37	48
50	33	45	57
60	39	52	65
70	43	58	72
80	46	61	76
90	48	63	77
100	49	64	78

Table I-3 Regressions for age in relation to height of jack pine (based on Kabzems and Kirby 1956).

Site	Regression equation
Poor site	$\log_{10}(\text{Age}) = 0.0531 * \text{height in metres} + 1.117$
Average site	$\log_{10}(\text{Age}) = 0.0437 * \text{height in metres} + 1.048$
Good site	$\log_{10}(\text{Age}) = 0.038 * \text{height in metres} + 0.985$

In order to use these relationships, it was necessary to relate the Timberline regeneration data to the three site classes used by Kabzems and Kirby (1956). The only site information available in the regeneration data was moisture regime, with most of the pine stands assigned to very dry, dry, or moderately fresh moisture regimes. By comparing the vegetation descriptions for the three site types in Kabzems and Kirby (1956) with ecosite descriptions in Beckingham et al. (1996), it was determined that the “Poor Site” corresponds with very dry and dry moisture regimes, while the “Average Site” corresponds with moderately fresh moisture regimes. The “Good Site” values were used for the few polygons in the database with fresh or moister classes.

The appropriate regression equation was applied to the height data for the polygon to estimate its age. For trees shorter than shown in Table I-2, ages were interpolated from Figure 4 in Kabzems and Kirby (1956). Trees below 10 years of age were assigned an age of 5 years since the plotted graph did not extend below this age. Some stands had an older upper canopy layer as well as one or more younger subcanopy layers. Assuming the older canopy layers represent survivors of the last disturbance, the age since disturbance was estimated from the heights of the trees in the youngest layer.

Estimated ages since disturbance were combined into four ranges based on the chronology of droughts in the region. Hogg et al. (2007) mapped the most severe droughts of the past century. These are listed in Table I-4 for the Nisbet and Fort à la Corne Forests, where drought severity is represented by 10 cm increments of the climatic moisture index (CMI) for the individual year. The age ranges used in Table I-5 are bounded by approximate mid-points of large intervals between droughts.

Table I-4 Major droughts during the past century and their relative severity in the Nisbet and Fort à la Corne regions (after Hogg et al. 2007).

Major drought years	Climatic Moisture Index (cm)	
	Nisbet	Fort à la Corne
2001-2002	-40 to -50	-30 to -40
2000-2001	-20 to -30	-20 to -30
1987-1988	-30 to -50	-20 to -40
1979-1980	-20 to -30	-20 to -30
1963-1964	-30 to -40	-30 to -40
1960-1961	-30 to -40	-30 to -40
1940-1941	-30 to -40	-30 to -40
1936-1937	-30 to -40	-30 to -40
1918-1919	-30 to -40	-20 to -40

Regeneration survey results are related to age and moisture regime in Table I-5. These results show higher percentages of NSR in older stands. With the most severe droughts having occurred in recent years (Table I-4), we might expect there to be more NSR in stands originating more recently. However, the higher percentage of NSR in older stands may reflect lower replanting effort in earlier times.

Table I-5 Distribution of NSR lands on cutovers in the four Island Forests, by estimated year of origin and moisture regime.

Year of Origin	Moisture Regime	Area (ha)		% NSR
		NSR	Total	
1996-2005	Very Dry, Dry	149	2,280	7
	Moderately Fresh	800	3,578	22
	Fresh or moister		177	0
	Total	949	6,034	16
1976-1995	Very Dry, Dry	846	8,528	10
	Moderately Fresh	581	4,218	14
	Fresh or moister	18	86	21
	Total	1,445	12,832	11
1950-1975	Very Dry, Dry	492	1,004	49
	Moderately Fresh	113	549	21
	Fresh or moister		67	0
	Total	604	1,620	37
pre 1950	Very Dry, Dry	124	178	70
	Moderately Fresh	194	393	49
	Total	318	570	56
Grand Total		3,317	21,056	16

Moreover, mortality may continue within a stand with each new drought, with established trees still being susceptible. This may be particularly true in these southern forests where droughts are more severe than further north. Hogg et al. (2007) found elevated mortality of mature aspen in this region for several years following the 2001-2002 drought, and pine may be similarly affected. The increase in NSR lands on average sites in the youngest age range as compared to the next older age range may reflect the extremely severe drought of 2001-2002, which was the worst on record for this area (Hogg et al. 2007), and which immediately followed the previous year's less severe drought. At no other time were there consecutive years of drought. This may reflect a true increase in mortality rates as a result of recent severe droughts. However, on poor sites the percentage of NSR was slightly lower in the most recent time period.

Regeneration success was better (i.e. % NSR was lower) on Very Dry to Dry sites than on Moderately Fresh sites for the most recent two time periods. This result is surprising, because we might expect drought-caused mortality to be greater on drier sites. However, in the earlier two time periods, regeneration success was worst on Very Dry to Dry sites.

Table I-4 shows that the Nisbet Forest has had more severe droughts than the Fort à la Corne Forest. Data for the Nisbet Forest were examined to see whether trends were different than for the Island Forests as a whole. The small area of the Canwood Forest, which is just west of the Nisbet Forest, has been included in this dataset (Table I-6).

The percentage of NSR land was higher for the Nisbet Forest than for the Island Forests as a whole, in all time periods except for the second (1976 to 1995). The higher percentage of NSR land in 1996-2005 compared to 1976-1995 may be a reflection of the back-to-back drought years in 2001 and 2002. For the most recent time period, 32% of the cutover land in the Nisbet Forest is Not Sufficiently Restocked. The difference in percentage of NSR between Very Dry to Dry

sites and Moderately Fresh sites in the most recent time period is even stronger than for the Island Forests as a whole.

We were also interested in the relationship between regeneration and soil types. Digital soil databases for the region were acquired from the Saskatchewan Land Resource Centre. The data for the Fort à la Corne Forest have not yet been digitized and therefore are absent from the database, limiting the analysis to the Nisbet Forest. The soil databases were united with the databases from the regeneration survey. The soils and regeneration data sets were merged to obtain drainage or soil association information for the individual polygons of regeneration data, but also resulted in the creation of many new polygons. Resultant polygons of less than 1 ha in extent were excluded for analysis purposes.

Table I-6 Distribution of NSR lands on cutovers in the Nisbet and Canwood Forests, by estimated year of origin and moisture regime.

Year of Origin	Moisture Regime	Area (ha)		% NSR
		NSR	Total	
1996-2005	Very Dry, Dry	64	611	11
	Moderately Fresh	587	1349	43
	Fresh or moister		54	0
	Total	651	2014	32
1976-1995	Very Dry, Dry	163	4382	4
	Moderately Fresh	191	1891	10
	Fresh or moister		8	0
	Total	354	6282	6
1950-1975	Very Dry, Dry	65	78	84
	Moderately Fresh	47	142	33
	Total	112	220	51
pre 1950	Very Dry, Dry		15	0
	Moderately Fresh	82	99	83
	Total	82	115	72
Grand Total		1199	8630	14

Table I-7 shows regeneration results for the major soil types in the Nisbet Forest. Most soil polygons are a complex of two or more soil types. The dominant soil type was applied to the entire polygon for this analysis, since there was no mapping to indicate where the minor soil types within the polygon occur. Only soil types occupying 100 ha or more of the total survey area are included in this summary. The inclusion of Meadow Complex soils, with 242 ha with jack pine as one of the dominant species, suggests that the classification of soils and/or forest types by polygons is very approximate, since we would not expect substantial areas of pine on this gleysolic soil type.

Because Pine soils make up more than 80% of the area surveyed, they showed the same patterns as the totals for the Nisbet Forest in Table I-7: the percentage of NSR was high during three of the four time periods. The chernozemic or grassland soils (e.g. Edam and Nisbet) had surprisingly good regeneration in most time periods, with only a few hectares of NSR land.

These soils might be expected to have regeneration failures, since the soil profile indicates that they supported grassland in the past, but the data do not show this.

Table I-7 Areas and percentages of NSR lands on cutovers in the Nisbet Forest, by soil association and estimated year of origin.

Soil Association	Year of Origin	Area (ha)		% NSR
		NSR	Total	
Edam (Black Humic regosolic aeolian sands)	1996-2005		88	0
	1976-1995		720	0
	Total		808	0
Meadow complex (Gleysolic soils)	1976-1995		209	0
	Total		209	0
Nisbet (Dark Grey Chernozemic coarse sandy fluvial lacustrine)	1996-2005	7	24	30
	1976-1995	13	315	4
	1950-1975		3	0
	Total	21	342	6
Pine (Brunisolic coarse glaciofluvial)	1996-2005	628	1848	34
	1976-1995	338	4987	7
	1950-1975	112	217	51
	pre 1950	82	109	76
	Total	1160	7162	16

3.2 Regeneration following 1989 wildfires in the Island Forests

The North Cabin Fire in the dry spring of 1989 burned a large area (17,246 ha) of the Nisbet Forest (Hyde and Smith 1996). In the same spring, the Henderson Fire burned 11,189 ha in the Fort à la Corne Forest (Hyde and Smith 1996). Field observations suggested that pine regeneration was lower than would be expected for burns in jack pine forest. Because of these observations, ground surveys of regeneration were conducted in 1992 and 1993 by Saskatchewan Environment (Hyde and Smith 1996).

Surveys were stratified by drainage class and pre-burn forest cover type, and were limited to stands in which jack pine was an original component, excluding hardwood and spruce stands. Tree regeneration was counted in 2 m by 2 m plots. Results were expressed as percent stocking, i.e. the percentage of plots with at least one stem of jack pine or at least eight stems of trembling aspen. The percentage of plots with no stocking of any tree species was referred to as “empty stocking”. Drainage classes were grouped in the results to form two site types, one including very rapidly drained, very rapidly to rapidly drained, and rapidly drained sites, and the other including rapidly to well drained, well drained, well to moderately well drained, and moderately well drained sites. Only the average level of percent stocking for each site type and pre-burn cover type was given in the report (Hyde and Smith 1996). These results are summarized in Table I-8. In the S (Softwood), SH (Softwood-Hardwood), and HS (Hardwood-Softwood) species associations, Hyde and Smith (1996) presented stocking rates by crown closure and height class. These rates were averaged, weighting by the area in each type, to get the values in Table I-8.

Table I-8 Results of field regeneration surveys in the 1989 Henderson Burn (Fort à la Corne Forest) and the 1989 North Cabin Burn (Nisbet Forest), in relation to site type and pre-burn cover type.

Burn	Site Type*	Species Association			Cutover	Open Productive	All stands
		softwood- softwood (S)	hardwood- hardwood (SH)	hardwood- softwood (HS)			
AREA (ha)							
Henderson	RD	1,726	0	0		503	2,229
Henderson	WD	3,693	181	299	295		4,468
North Cabin	RD	5,742	66	71	736	276	6,891
North Cabin	WD	620	414	659			1,693
WEIGHTED AVERAGE PINE STOCKING (%)							
Henderson	RD	53				32	48
Henderson	WD	59	16	9	8		50
North Cabin	RD	24	3	14	19	1	22
North Cabin	WD	17	2	0			7
WEIGHTED AVERAGE ASPEN STOCKING (%)							
Henderson	RD	4				0	3
Henderson	WD	15	13	59	0		17
North Cabin	RD	16	59	43	7	18	15
North Cabin	WD	34	45	39			39
WEIGHTED AVERAGE EMPTY STOCKING (%)							
Henderson	RD	38				68	45
Henderson	WD	28	50	15	92		32
North Cabin	RD	50	17	38	73	66	52
North Cabin	WD	30	29	27			28

*Site Type:

RD = very rapidly drained, very rapidly to rapidly drained, rapidly drained

WD = rapidly to well drained, well drained, well to moderately well drained, moderately well drained

3.3 Domtar regeneration survey

One of the objectives of the study was to compare regeneration trends in the Island Forests with those further north in main body of the boreal forest. Because the Island Forests are climatically marginal for forest vegetation, it is expected that any trend towards climate-related regeneration failure should appear there first. To support such a hypothesis, it would be useful to show that regeneration failure was more likely to occur in the Island Forests than further north.

To provide data on the main boreal forest, a regeneration establishment survey of the Domtar FMA between Prince Albert and La Ronge was obtained from the Saskatchewan Forest Centre,

with permission from Domtar Inc. While this is a different type of survey from that available for the Island Forests, some comparisons with the island forest data may be possible. It may be particularly useful if definite dates for planting and assessment of establishment can be obtained.

Digital soil databases for this area were acquired from the Saskatchewan Land Resource Centre. The soil databases were united with the regeneration databases in a GIS system in order to assign soil attributes to the regeneration data.

Because we are waiting on definitions of some of the data fields in the Domtar data, analysis is still in progress and no results can be presented as yet.

4. DWARF MISTLETOE SURVEYS

Brandt et al. (1998) completed an aerial survey of the distribution of severe infestations of dwarf mistletoe in western Canada. Maps in this report show that the Saskatchewan Island Forests are highly infected. No quantitative data were collected in this study.

The survey of regeneration in cutovers in the Island Forests (Timberline Forest Inventory Consultants Inc. 2006) recorded incidences of mistletoe infection. As would be expected, infection rates increase with estimated stand age (Table I-9). Because stand ages were estimated from the height of the youngest tree layer, reported infections in the young age range may result from older infected trees being present in the stand.

Table I-9 Dwarf mistletoe infection rates in the Island Forests related to estimated year of origin for the stand.

Year of Origin	Area (ha)		Percent infected
	Mistletoe	Total	
1996-2005	54	6,233	1
1976-1995	1,053	15,590	7
1950-1975	547	2,138	26
pre 1950	374	740	50
Total	2,028	24,702	8

Brandt et al. (1998) indicated that mistletoe is more severe and widespread on the driest site types occupied by pine. The Timberline regeneration survey data do not show this pattern (Table I-10). The three most extensive moisture regimes with jack pine (very dry, dry and moderately fresh) have similar percentages of area infected. This implies that, if climate change shifts the moderately fresh sites to a drier state, this should not increase the percentage of infected forest. However, climate change may increase the total area of sites suitable for pine growth.

The occurrence of mistletoe in relation to soil type is shown in Table I-11. These data appear to show a correlation of mistletoe infection with soil types. Grassland soils (Edam, Nisbet, Whitesand) have little mistletoe infection. The main mistletoe infestations occur within the Pine soil association (Brunisol). This is a forest soil type. The grassland soil types may limit dwarf mistletoe development. However, since all forest stands having 30% pine or greater in one of the

tree layers were included in this analysis, it is possible that the percentage of aspen was higher on grassland than forest soils. This would need to be further explored.

Table I-10 Mistletoe infection rate related to site moisture regime.

Moisture regime	Area (ha)		Percent infected
	Mistletoe	Total	
Very Dry	13	178	7
Dry	929	12,860	7
Moderately Fresh	1,083	11,243	10
Fresh		128	0
Very Fresh		82	0
Moderately Moist		129	0
Moist	3	82	4
Total	2,028	24,702	8

Table I-11 Mistletoe infection in the Nisbet forest by soil association and estimated year of origin.

Soil Association	Year of Origin	Area (ha)		% infected
		Mistletoe	Total	
Edam (Black Humic regosolic Aeolian sands)	1996-2005		88	0
	1976-1995		736	0
	1950-1975	13	58	22
	pre 1950		8	0
	Total	13	890	1
Meadow Complex (Gleysolic soils)	1996-2005		14	0
	1976-1995		213	0
	1950-1975	5	5	100
	Total	5	231	2
Nisbet (Dark Grey Chernozemic coarse sandy fluvial-lacustrine)	1996-2005		24	0
	1976-1995		425	0
	1950-1975		84	0
	Total		533	0
Pine (Brunisolic coarse glaciofluvial)	1996-2005	37	1975	2
	1976-1995	464	6305	7
	1950-1975	104	262	40
	pre 1950	73	128	57
	Total	678	8670	8
Whitesand (Black Chernozemic coarse glaciofluvial)	1996-2005		1	0
	1976-1995		125	0
	pre 1950		3	0
	Total		129	0
Grand Total		708	10563	7

The species of dwarf mistletoe that infects the Island Forests (*Arceuthobium americanum*) is thought to have evolved in southwestern North America in lodgepole pine, and has only recently transferred to jack pine after glacial retreat and the subsequent meeting of ranges of the two species (Brandt et al. 2004). The southern limit of *A. americanum* is in California at 35°N. This suggests that temperatures in southern boreal Canada are unlikely to become too warm for survival of this species as a result of climate change.

The more northerly areas of the boreal forest are free of dwarf mistletoe. Germinative ability of overwintered seeds increased between -39 and -35°C (Brandt et al. 2004). Exposure of seeds from four northern Alberta populations to -38°C or colder for 96 hrs was almost always lethal (Brandt et al. 2004). In northern British Columbia where lodgepole pine were artificially infected with dwarf mistletoe and abnormally low temperatures were reached one winter (-38°C in December and -39°C in January), germination rates were extremely low and no branches were infected the following spring. These data suggest that climate change is likely to increase infection rates of dwarf mistletoe, because fewer winters will have temperatures severe enough to eliminate the year's cohort of mistletoe plants. In addition, dwarf mistletoe is likely to expand its range northward as winters ameliorate.

Figure I-2 shows the number of days at Prince Albert between 1900 and 2006 with minimum temperatures less than -38°C (data for 2000 and 2001 are missing). The number of days appears to have declined since 1998, with no days less than -38 in 2005.

Dwarf mistletoe completes its life cycle in fewer years on jack pine (5 years) as compared to lodgepole pine (7 years), possibly because lodgepole has had a longer evolutionary time to develop defences against mistletoe (Brandt 2006). Increased growing season length may result in more rapid development and spread of dwarf mistletoe. If more frequent droughts cause increased stress on pines, as has been reported for aspen in the region (Brandt et al. 2003, Hogg et al. 2005, Hogg et al. 2007), this factor alone or in combination with dwarf mistletoe infection is likely to result in increased losses in trees and individual tree productivity.

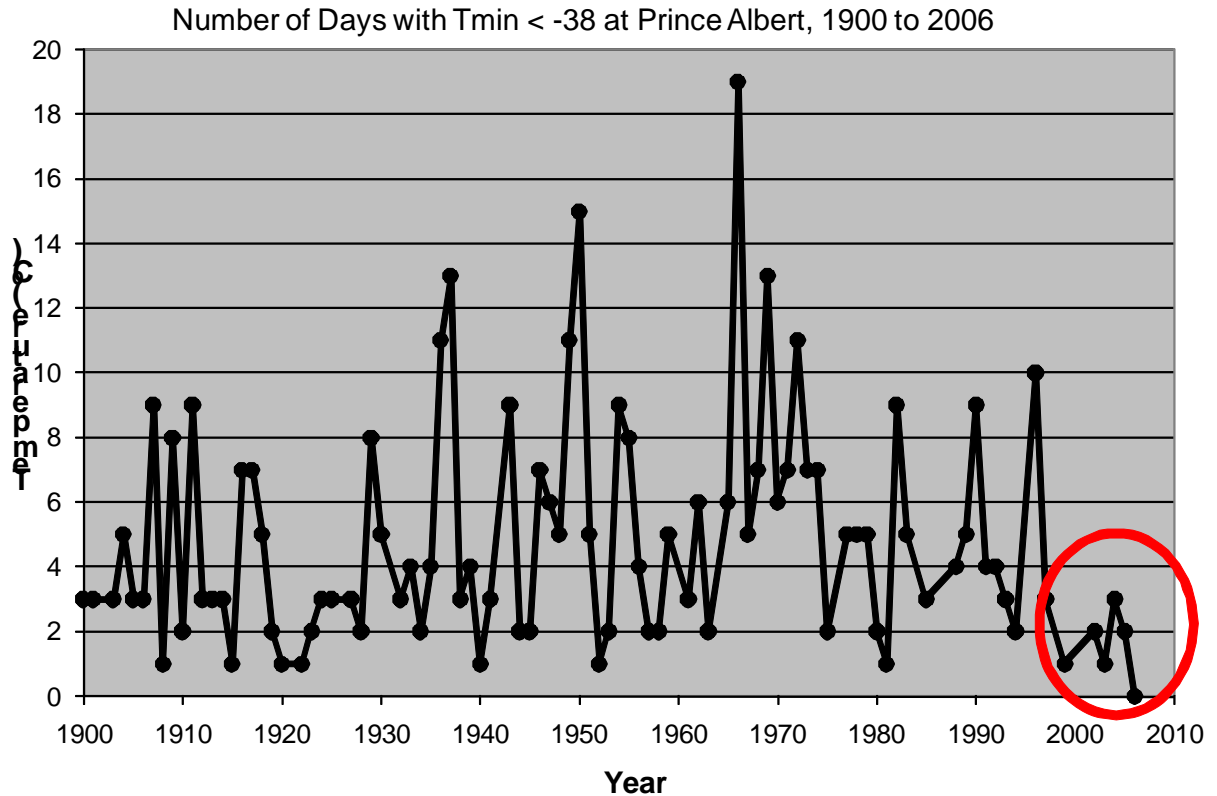


Figure I-2 Number of days at Prince Albert with minimum temperatures less than -38°C

5. CONCLUSIONS

As discussed in the introduction, the Island Forests of central Saskatchewan are climatically marginal for boreal forest, and climate change modeling suggest that forest in these areas may be converted to grassland over the coming century. One way in which this could occur is by failure of tree regeneration following disturbances such as fire and timber harvest.

Regeneration after the major 1989 wildfires in the Nisbet and Fort à la Corne Forests was surprisingly poor (Hyde and Smith 1996). On rapidly drained sites, which made up most of the North Cabin Burn in the Nisbet Forest, stocking was only 22% for pine regeneration and 15% for aspen regeneration. For the Henderson Burn in the Fort à la Corne Forest, where the climate is normally a little moister, pine stocking on rapidly and well drained sites was around 50%. Especially in the Nisbet Forest, regeneration was worse than would be expected for boreal wildfires in pine and aspen forests. Unfortunately, no data have been found on changes in post-fire regeneration rates with the climatic warming over the 20th Century.

Regeneration after cutovers in the Island Forests was also low (Timberline Forest Inventory Consultants Ltd. 2006). The age of cutovers was estimated from the tree heights recorded in the survey. For the most recent decade, 16% of the cutover land over all four Island Forests, and 32% of the cutover in the Nisbet Forest, is Not Sufficiently Restocked (NSR).

Estimation of ages of cutovers gives some indication of time trend. Regeneration is poorer, (i.e. higher percentage of NSR land) for older cutovers, which appears inconsistent with the hypothesis of regeneration failure with climatic warming. However, this trend could also reflect lower replanting effort in earlier years, so it is difficult to interpret in relation to climate change.

Unfortunately we are not yet able to report on how these results compare with regeneration after cutovers further north in the main body of the boreal forest.

If conversion from forest to grassland is predicted as a result of climate change, we might expect that the driest sites should be the first to show this conversion. The data on regeneration after the 1989 wildfires support this trend, with more “empty stocking” (i.e. plots with no tree regeneration) on “rapidly drained” sites than on “well drained” sites. However, the data on regeneration after cutovers show the opposite trend, at least for the most recent time periods, with less NSR land on “very dry to dry” sites than on “moderately fresh” sites. However, because different scales were used for rating moisture regime in these two datasets, caution should be used in comparing them.

In addition to regeneration failure, loss of forest in a warming climate could occur by mortality of mature trees. In the dry pine forests of the Island Forests, one of the main causes of mortality is infestation by dwarf mistletoe. Unfortunately, the data analyzed so far do not show whether this has changed over the past century of climatic warming. The cutover regeneration survey (Timberline Forest Industry Consultants Ltd. 2006) showed more mistletoe infection in older cutovers. However, because we expect infection to increase with tree age, this does not help us to identify any trend that can be attributed to climate change. With respect to site differences, we might expect more mistletoe infection on the driest sites, but data from the cutover regeneration survey do not show this trend. More analysis of mistletoe effects will be done when additional data are received.

CHAPTER II - THE IMPACTS OF CLIMATE CHANGE ON FOREST HEALTH AND PRODUCTIVITY IN THE ISLAND FORESTS

1. INTRODUCTION

Chapter I describes the current state of health and response to recent disturbance in the Island Forests near Prince Albert. Chapter 2 presents several analyses showing the projected impacts of future climate change on forest productivity, disturbance due to fires and insects, and the potential impacts of drought.

2. FUTURE CLIMATE AND DROUGHT

Figures II-1 and II-2 show the projected change in temperature between the 1950s and the 2050s according to two future scenarios that differ in the level of CO₂ emissions. These results are from the third generation of the Canadian Global Climate Model (CGCM3) used in the recent Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC 2007). The B1 scenario assumes a relatively low rate of emissions in the future based on the adoption of clean energy, with CO₂ levels reaching approximately 550 parts per million (ppm) by 2100 (approximately double that of preindustrial levels). The A1 scenario assumes a higher rate of emissions due to continued use of fossil fuels in which CO₂ levels reach 715 ppm by 2100.

Under the B1 scenario, temperatures in the Island Forests region increase by about 2.5 to 3.0 degrees by 2050 (Figure II-1), but under the A1 scenario temperatures increase by 3.0 to 3.5 degrees (Figure II-2). Projected future values of precipitation are much more uncertain but they are expected to increase between 10% and 30% for central Canada, occurring mostly in the winter and spring (IPCC 2007).

The effect of changing temperature and precipitation is not as important as how these factors will influence the likelihood of future drought. A recent example of the effects of drought in this region was seen in 2001-2002, in which the Climate Moisture Index was lower than at any time since the early 1900s (Table I-4, see also Hogg et al. 2007). Data from CGCM3 were used to project values of the CMI for the Island Forests for two time periods, 2046-2065 (hereafter 2050s) and 2081-2100 (2090s). Three emission scenarios were included in the analysis: A1 and B1 as discussed above and an extreme scenario (A2) in which CO₂ levels reach 850 ppm by 2100. Figure II-3 shows the results. The A2 scenario produces CMI values for the 2050s that are equivalent to those of the Swift Current region today, and values similar to those of Estevan for the 2090s. These results are due to both a large temperature increase and a reduction in precipitation in the A2 scenario. Given the assumption that values of CMI less than zero indicate areas where trees will not occur naturally (Hogg 1994), the Island Forest would be under severe drought stress in the future if this scenario were to actually occur. The A1 and B1 scenarios are not nearly as extreme, with the 2050 B1 showing an improvement in moisture availability due to a combination of a more moderate temperature increase and little change in precipitation.

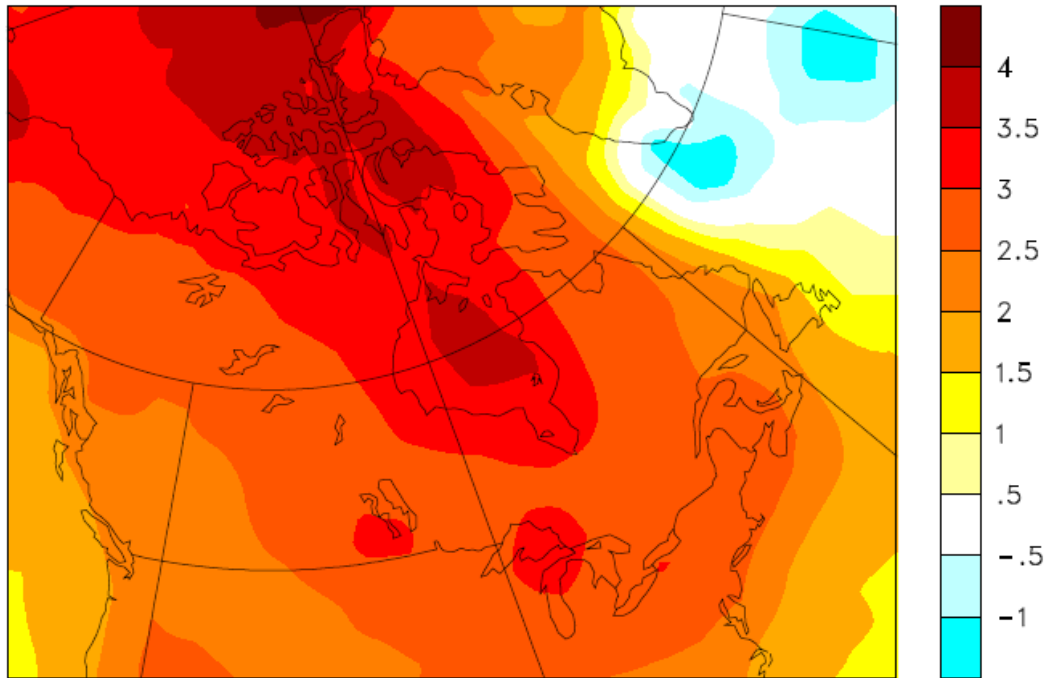


Figure II-1 Temperature change between 1950s and 2050s according to the B1 climate scenario

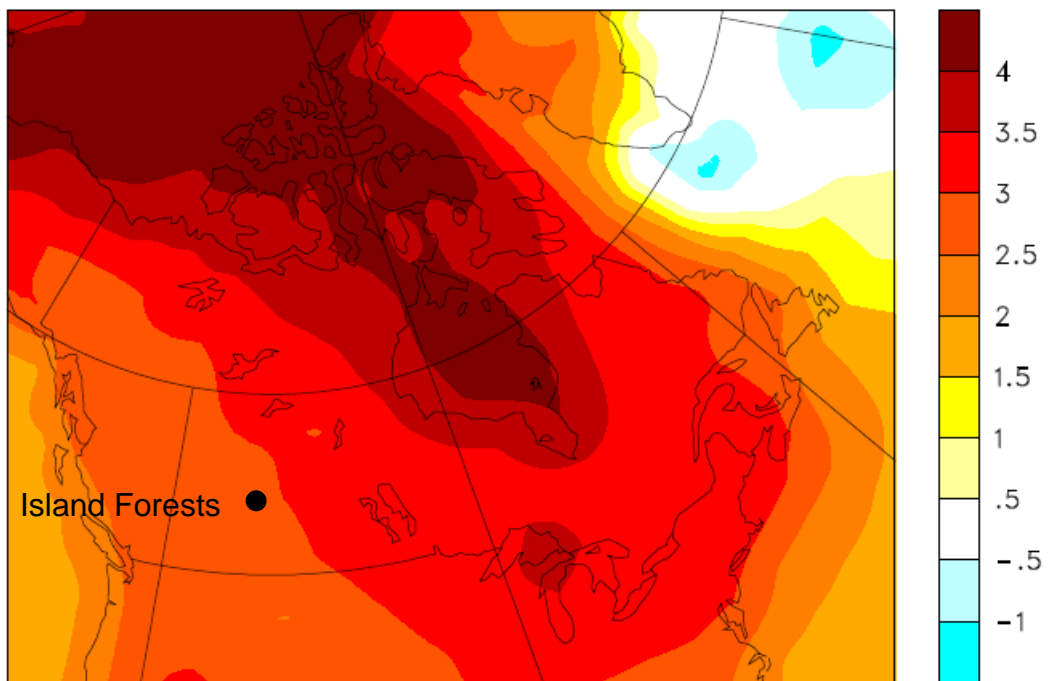


Figure II-2 Temperature change between 1950s and 2050s according to the A1 climate scenario

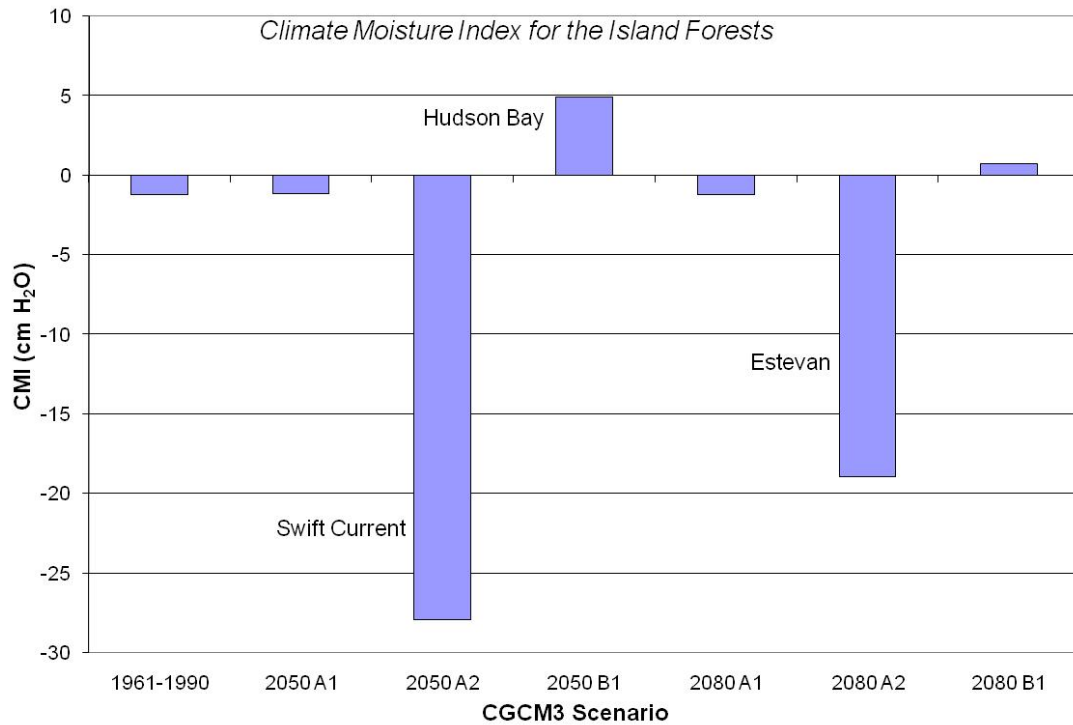


Figure II-3 Values of the Climate Moisture Index for the Island Forests area calculated for current and two future (2050s and 2090s) time periods and three emissions scenarios (A1, A2 and B1)

The CMI indicates the extent of moisture availability through a comparison of water inputs from precipitation and water loss due to evaporation and transpiration. An important additional factor that determines moisture availability for plant growth is the water holding capacity (WHC) of the soil, expressed as millimetres of water per metre of soil depth. The WHC is determined primarily by soil texture, i.e. the relative proportions of sand, silt and clay. As shown in Table II-1, more than 80% of the Island Forest area is made up of the Pine soil association which is largely sand. The WHC of sandy soils is considerably less than that of soils with higher amounts of silt or clay. This adds another aspect of drought vulnerability to the Island Forests landscape beyond that of climate alone. The likelihood of severe drought under future conditions raises the question of forest tree regeneration in the Island Forests. Regeneration failure is likely to become more common with more frequent droughts, with the eventual outcome that forest cover may disappear from these areas.

Table II-1 Water holding capacity of the most important soils in the Island Forest region
(Data from the National Land and Water Information Service 2007).

Soil Association	Texture	Area (ha)	WHC (mm/m)
Pine	Sand	83,929	45
LaCorne	Silty sand	18,590	100
Porcupine Plain	Sandy clay	7,231	140
Organic soils	Decomposed organic matter	6,800	300

3. FUTURE SCENARIOS OF FOREST HEALTH AND PRODUCTIVITY

3.1 Dwarf Mistletoe

As indicated in Chapter I, there is evidence that temperature plays a role in controlling the germination of dwarf mistletoe seeds, with temperatures less than -38°C the likely threshold (Brandt et al. 2004). There is also a suggestion that the number of days below this threshold has declined recently in the Island Forests region, as shown in Figure I-2. Data from the most recent Canadian Global Climate Model (CGCM3) were used to determine the expected number of days with minimum temperatures less than -38°C (cold days). Data from this model are available for two 20-year time periods, 2046-2065 and 2081-2100. Table II-2 shows the number of cold days from the CGCM3 model for the 1960-2000 time period (current) and for two future emission scenarios A1 (high emissions) and B1 (lower emissions). As compared to current values, the number of cold days declines dramatically in the future scenarios, particularly for later decades in the A1 scenario where warming is stronger due to higher emission levels.

Table II-2 Number of cold days as projected by the third-generation Canadian Global Climate Model for current and future decades under two emission scenarios (A1, higher emissions; B1, lower emissions). Model data are available for the time periods 1960-2000 (current), 2046-2065 and 2081-2100.

Decade	Days with Tmin < -38
1960	35
1970	87
1980	39
1990	41
A1	
2040	9
2050	5
2060	4
2080	1
2090	0
B1	
2040	9
2050	3
2060	3
2080	6
2090	4

Assuming that temperatures less than -38°C are important in controlling mistletoe infection, future temperatures will provide very little prevention.

Also important in determining mistletoe infection is the age of the forest. As shown in Table I-9, trees older than 50 years have a much increased likelihood of infection. Table II-3 shows the age-class distribution of jack pine in the Island Forests divided into young, immature and mature classes. Currently over 80% of the stands are more than 50 years old and by 2050 nearly all of the forest will be in the susceptible age class. Given the susceptibility to drought of the sandy soils in much of the Island Forests, and the advanced age of the forest, the vulnerability to mistletoe is already high and will likely increase substantially.

Table II-3 Age-class distribution of jack pine in the Island Forests.

Island Forest	Age Class (ha)		
	Mature (> 70 yr)	Immature (50-70 yr)	Young (< 50 yr)
Canwood	1,696	206	199
Fort A La Corne	13,506	11,243	8,670
Nesbit	17,886	2,789	2,306
Torch	2,576	492	121
Total	35,664	14,730	11,295
Percent of Total Area	58	24	18

3.2 Mountain Pine Beetle

The current outbreak of the mountain pine beetle (MPB, *Dendroctonus ponderosae*) in central British Columbia is well known. To date the outbreak has affected approximately 14 million ha and resulted in loss of over 500 million m^3 of pine volume. The outbreak is expected to peak by about 2014, by which time it will have killed an estimated 80% of all the pine in British Columbia (Taylor et al. 2006). Until recently the outbreak was restricted to lodgepole pine in British Columbia and the western fringes of Alberta. However, in June 2006 a large swarm of beetles was caught up in a strong westerly wind and transported from eastern British Columbia to central Alberta near Slave Lake (Alberta Sustainable Resource Development 2007). This area of Alberta is the zone in which the geographic range of lodgepole pine and jack pine overlap. The MPB has been shown experimentally to develop successful populations in jack pine, so there is every expectation that jack pine will prove to be a suitable host (Langor et al. 2006). The overlap in range between jack pine and lodgepole pine in north-central Alberta will provide the physical connection between the two host species, and recent experience has shown that large wind events can move large numbers of beetles several hundred kilometres. Therefore, physical spread will not present a problem.

As with dwarf mistletoe, temperatures of around -40°C in the early winter have been shown to limit the rate of beetle population growth. As shown above in Figure I-2, the frequency of cold days has declined recently and is likely to be much less in future decades (Table II-2). Physical access to jack pine and lack of temperature controls on the beetle's reproduction both suggest that a switch to jack pine east of British Columbia is likely.

An additional factor is the age of the forest. Work in BC has indicated that trees over 50 years are moderately susceptible and trees over 70 year are highly susceptible to MPB attack (Safranyik and Carroll 2006). Figure II-4 shows the age of the stands in the Island Forests. Areas shown in dark green are moderately susceptible, while areas in pink are highly susceptible. As indicated in Table II-3, over 80% of the area has trees over 50 years old and will be in the highly susceptible age class in the next few decades.

In summary, the age-class distribution, acceptability of host species, and physical proximity to current outbreaks all suggest that jack pine stands in the Island Forests are highly vulnerable to future mountain pine beetle attack.

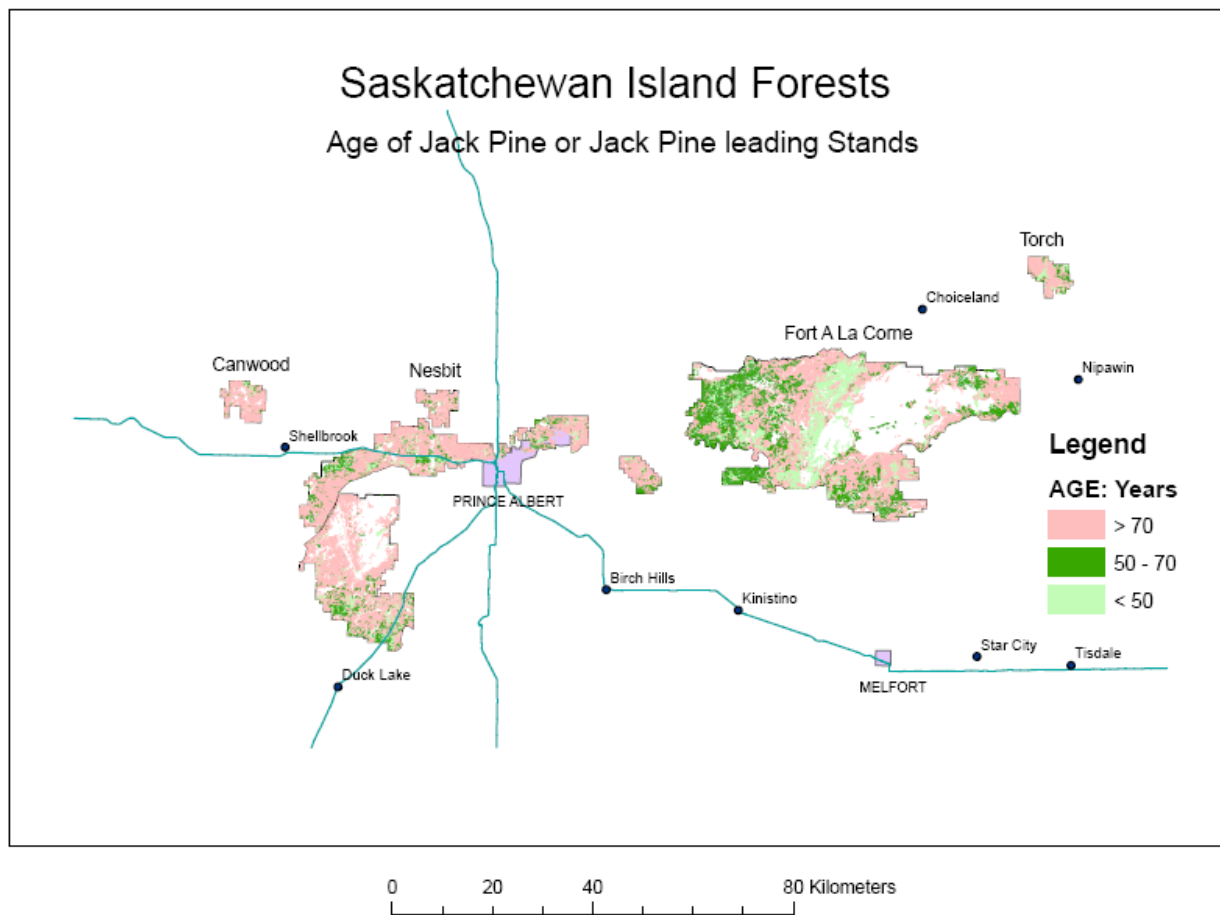


Figure II-4 Age of jack pine stands in the Island Forests.

3.3 Forest productivity

Forest productivity refers to tree growth that results in harvestable wood volume. The Saskatchewan forest inventory indicates current productivity levels for trees in the Island Forests expressed as Mean Annual Volume Increment (MAI) in m^3 per hectare per year ($m^3 ha^{-1} yr^{-1}$). Table II-4 shows current MAI values for jack pine and aspen, the two main species in the Island Forests.

Table II-4 Current Mean Annual Increment for aspen and jack pine in the Island Forests.

Species	Mean Annual Increment ($\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$)
Aspen	2.3
Jack Pine	2.0

We used a forest ecosystem simulation model (BIOME-BGC, Thornton et al. 2002) to generate estimates of forest productivity for future climate using output from CGCM3 as described above in the discussion of the Climate Moisture Index. Figure II-5 shows the change in forest productivity relative to current levels (average of 1960-2000). Forest productivity declines about 20% in the 2050s under the A2 scenario, corresponding to the decline in moisture availability as shown for the CMI in Figure II-3. For the other 2050 scenarios, productivity increases 10-20% under the A1 scenario and about 30% under the B1 scenario. For the 2080 scenarios, productivity remains about the same (A2) or increases between 20 and 35% (A1 and B1). Also note that the relative change in productivity is greater for jack pine than for aspen, indicating that jack pine may be favored under a future climate.

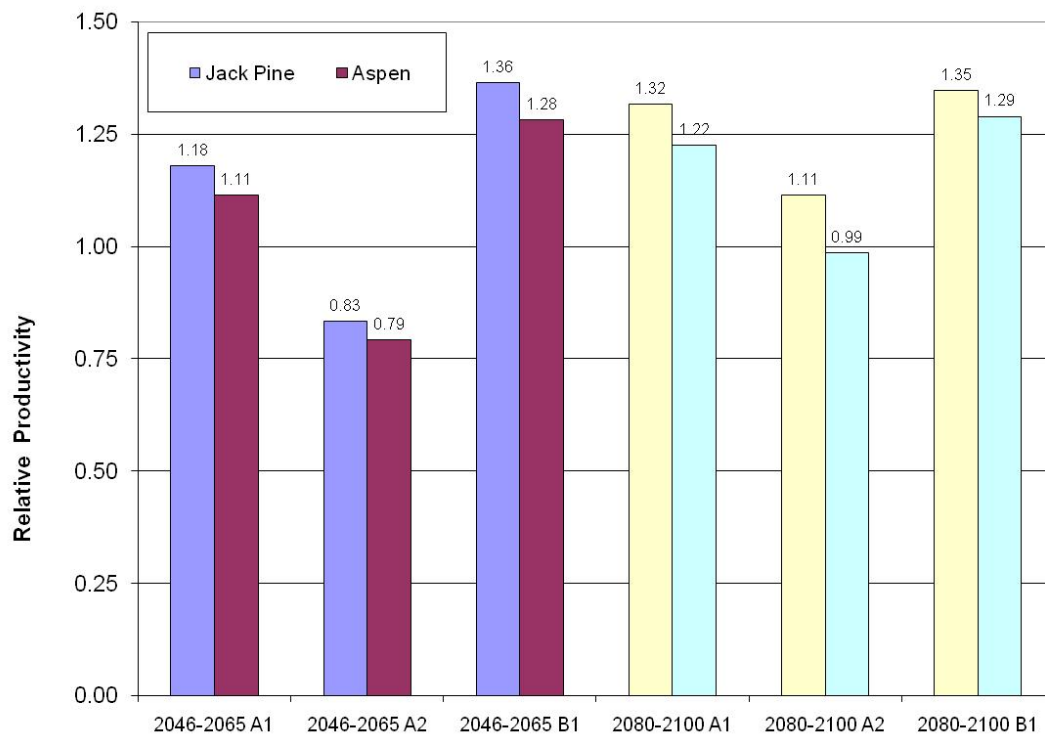


Figure II-5 Relative productivity of aspen and jack pine for the Island Forests as simulated by the ecosystem model BIOME-BGC.

The mechanisms for the changes in productivity are beginning to be understood. Many experiments have shown that, all else being equal, higher atmospheric CO₂ levels result in an increase in productivity. In a recent review, Norby et al. (2005) found that woody species in a wide range of environments experienced an increased in productivity of 23% under a doubling of CO₂, which is consistent with the results shown above. However, lack of available moisture

negatively affects growth even under higher CO₂ levels, as shown for the A2 scenario. This is consistent with results reported by Delucia et al. (1999) and Oren et al. (2001) for pine grown under elevated CO₂ levels in North Carolina. These authors also reported that lack of available nitrogen reduced the growth response to higher CO₂ levels, a factor potentially important in the Island Forests where the majority of the area is underlain by low-nutrient sandy soils (Table II-1). Finally, increased CO₂ levels result in increased water use efficiency and this may assist the trees in coping with drought effects under future climates (Long et al. 2004). The net effect of these factors will determine whether forest productivity increases or decreases in the future, and is likely to be highly specific to individual sites and species. However, compared to more productive areas in Saskatchewan's forests, growth is likely to be generally lower in the Island Forests in the future, and some portions of the area may not support forest cover in the future.

3.4 Forest fire behavior

Forest fire frequency and severity are expected to increase in Western Canada under future climate scenarios (Kafka et al. 2001, Flannigan et al. 2005). Kafka et al. (2001, hereafter Kafka) determined current and future potential fire behavior for the forested portion of Saskatchewan within the Boreal Plain Ecozone. They used weather station observations to determine current values of the Canadian Forest Fire Weather Index System (FWI, Van Wagner 1987). The FWI and its associated Fire Behavior Prediction System (FBP) provide a range of indices useful to fire suppression planning and tactics, including fuel moisture, rates of spread and estimates of fire area. Kafka interpolated these data across the landscape of central Saskatchewan using the Spatial Fire Management System (SFMS, Lee et al. 2002). This system enables the interpolation of FWI and FBP index values across large landscapes based on weather stations or other climate data distributed within or near the study area. After potential fire behavior was determined for the current climate, they recalculated FBP values for future climate scenarios using output from the first generation Canadian Regional Climate Model (CRCM 1, Caya and Laprise 1999). The CRCM 1 produced output for three 10-year time periods: 1975-1984 (used to compare model output to observed climate for the same time period), 2040-2049 (2040s) and 2080-2089 (2080s). The 1975-1984 data assume current levels of atmospheric CO₂ (1XCO₂). The 2040s correspond to the estimated time at which atmospheric CO₂ will have doubled (2XCO₂) and the 2080s the time at which CO₂ will have tripled (3XCO₂) (Caya and Laprise 1999). In this report we present data for the 1xCO₂ and 2xCO₂ scenarios.

Current and future values of the FBP data were interpolated across the landscape using SFMS. Maps were created showing current and future values of various FBP indices, with potential Head Fire Intensity chosen as the most useful. Head Fire Intensity (HFI) is a measure of heat release along the flaming front of a forest fire, and is a good measure of the difficulty of suppressing a fire (Hirsch et al. 1998). Head fire intensity values and associated fire behavior are given in Table II-5.

The FBP system identifies approximately 16 fuel types that differentiate forest stands based on characteristics important to fire behavior. These include tree form, size, fuel arrangement and continuity, and flammability of foliage (Forestry Canada Fire Danger Group 1992). The forest types identified in the provincial forest inventory were reclassified into the FBP fuel types in the by Kafka. The fuel type classification was then applied spatially to the forest inventory across the Island Forests landscape, yielding a map of fuel types based on the original forest inventory.

Table II-5 Fire behavior characteristics based on head fire intensity. Units are in kilowatts of heat released per meter of flaming fire front (from Kafka et al. 2001).

Head Fire Intensity Class (kW m ⁻¹)	General Fire Behavior Description
0 – 10	Smoldering or subsurface fires with little or no visible flame.
11 – 500	Slow moving surface fires with relatively low flame heights.
501 – 2,000	Moderately fast spreading fires with low and high flame heights. Isolated torching may occur if ladder fuels are present.
2,001 – 4,000	Fast spreading, high intensity surface fires or intermittent crown fires with short range spotting.
4,001 – 10,000	Very fast spreading intermittent crown fires with flames extending above the canopy and short to medium range spotting.
10,000 – 30,000	Continuous crown fires with extremely fast spread rates. Fire whirls, towering convection columns and medium to long range spotting possible.
30,000 – 100,000	Continuous crown fires with extremely fast spread rates and long range spotting. Conflagration or blow-up type fire behavior possible.

Table II-6 shows the HFI class by area across the Island Forests landscape for the current (1XCO₂) and future (2XCO₂) scenarios. Area in the lower classes either remains constant or declines except for the 2,000-4,000 kW m⁻¹ class. However, there is a nearly four-fold increase in the highest HFI class in which fire behavior is at its most extreme. Under these conditions fire severity (i.e. ecological impacts) will be very high and fire suppression will be very difficult if not impossible.

Table II-6 Island Forests landscape classified by Head Fire Intensity Class for 1XCO₂ and 2XCO₂ scenarios (data from Kafka et al. 2001).

Head Fire Intensity Class (kW m ⁻¹)	Area (ha)	
	1XCO ₂	2XCO ₂
0 – 10	2,001	0
11 – 500	68,150	68,144
501 – 2,000	31,145	0
2,001 – 4,000	8	31,151
4,001 – 10,000	23,018	4,211
10,000 – 30,000	89,836	87,903
30,000 – 100,000	8,532	29,280

Figures II-6 and II-7 show the spatial distribution of the HFI classes. The Fort à la Corne and Torch forests in particular will experience a large increase in area of forest stands occurring in the highest HFI classes, making fire impacts and fire suppression of concern in this area.

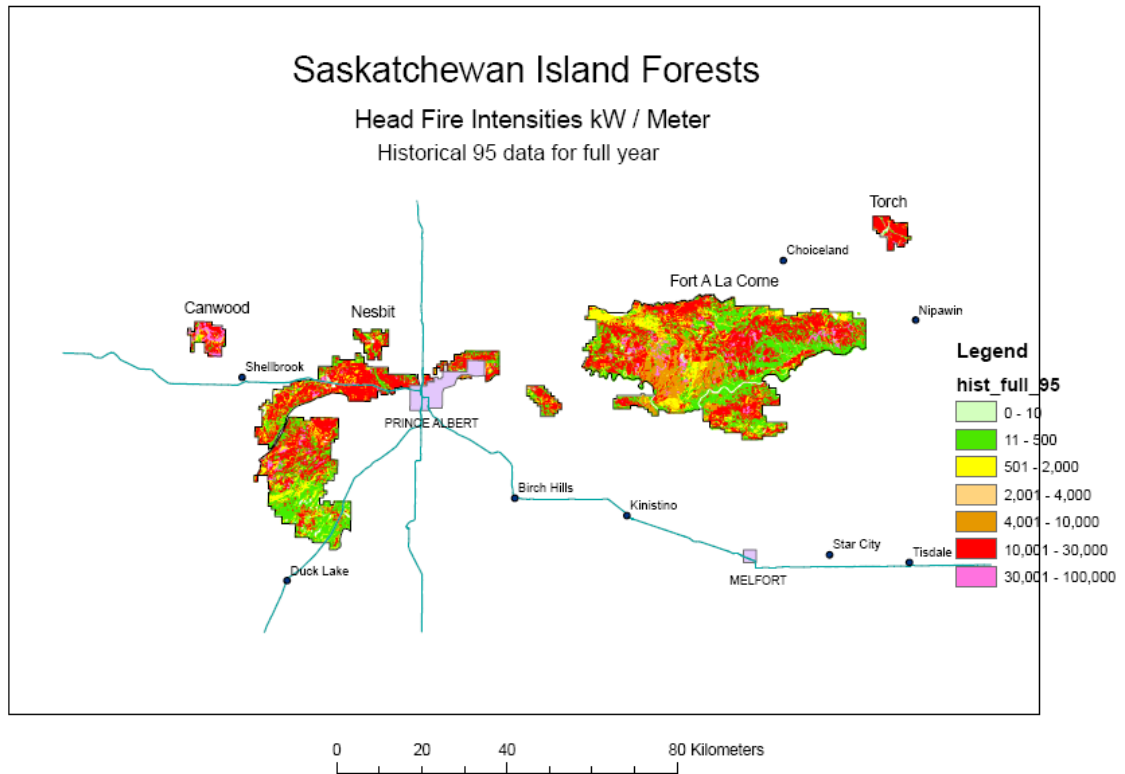


Figure II-6 Head Fire Intensity values for the Island Forests under the 1XCO₂ scenario (data from Kafka et al. 2001).

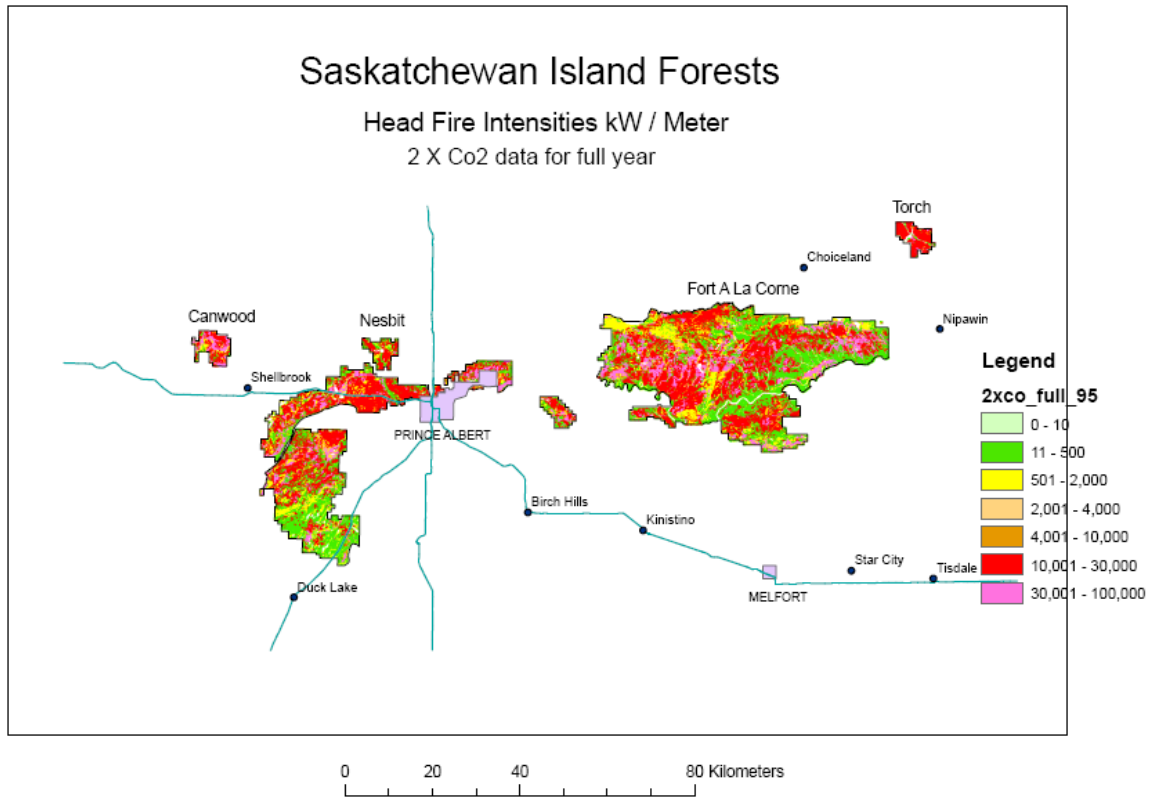


Figure II-7 Head Fire Intensity values for the Island Forests under the 2XCO₂ scenario (data from Kafka et al. 2001).

4. SUMMARY AND MANAGEMENT RECOMMENDATIONS

The foregoing analyses indicate that the Island Forests in central Saskatchewan may already be showing signs of climate change impacts, and are likely to be severely affected in the future. Particular sources of vulnerability include an aging forest, large areas affected by dwarf mistletoe, susceptibility to a future mountain pine beetle outbreak, a relatively large fire hazard and negative impacts on tree growth due to drought and low water-holding capacity soils.

The Island Forests are an excellent example of an area that should be considered as the “canary in the mine shaft”, where the impacts of climate change are likely to occur earlier than in the contiguous boreal forest to the north. This area could form part of a national “early warning” network of intensively monitored sites in which the signs of climate change will emerge first. It is also important to link sites in the Island Forests to existing monitoring programs. One example is the CIPHA study (Climate Impacts on the Productivity and Health of Aspen) currently being conducted by the Canadian Forest Service’s Northern Forestry Centre in Edmonton. While the CIPHA study is currently focused on aspen, additional sites could be added and the network expanded to monitor forest health and productivity in other forest types such as jack pine in the Island Forests area. Another opportunity is to link climate change monitoring to the existing Saskatchewan Forest Management Effects Monitoring Program. This network of permanent plots was established in the late 1990s to monitor the effects of forest management activities on

forest ecosystems. Currently there are 18 permanent plots in the Island Forests, and they could form the basis for continued monitoring of the Island Forests for climate change impacts.

It also needs to be emphasized that several current and planned developments will affect the Island Forests and will interact with the effects of climate change. Demand for recreation activities from growing urban populations, exploration and likely production of diamonds, other mining potential and continued forest harvesting will all have impacts on the Island Forest ecosystems. This area is important to the local forest industry, particularly to the First Nations involved in the First Nations Island Forests Management Inc. An integrated land management approach, as advocated by the Prince Albert Model Forest, is essential for managing the impacts of development in his area, particularly in light of some of the ecological vulnerabilities identified above.

Dealing directly with the vulnerabilities described above may also be possible. For example, dwarf mistletoe, older forest age classes and the potential for a MPB outbreak all add to the high fire hazard in the Island Forests. An approach to reducing fire hazard has been developed by the Canadian Forest Service and has shown success in several provinces including Saskatchewan. This is an approach known as FireSmart (Hirsch et al. 2001) and involves activities at both the local stand level and the landscape level. At the local level, the focus is on communities that occur in fire-prone forest environments. Surveys are conducted in the community that indicate sources of risk, e.g. tree canopies near houses, flammable roofing material, openings for embers beneath porches or decks, etc. These risk factors are quantified and suggestions made for reducing them. This program has been applied to several forest communities in Saskatchewan (e.g. Waskesiu, Candle Lake, etc.) and widely applied in Alberta. The benefits include both a reduced fire risk and an educated public that can assist others in reducing risk.

Another component of FireSmart is applied at the landscape level, and involves treating forest stands to reduce flammability and lower fire behavior. Examples include replacing coniferous stands with deciduous stands through timber harvesting in order to break up highly flammable contiguous stands; cleaning diseased and insect-killed trees; and targeting harvest operations at the most vulnerable older stands to increase diversity of age-classes. These activities may incur extra expense and will take several decades to have an impact, but the time to start considering these ideas is now before the risks increase. An additional advantage is that by reducing fire hazard at the landscape level, the risks for other impacts (insects, disease) are also reduced. Forest harvesting in the Island Forests could be scheduled to reduce the insect, disease and fire hazard as much as possible while still providing forest products.

Forest management also has the potential to help deal with some of these vulnerabilities. Immediate and aggressive regeneration of harvested (and possibly burned) stands will help ensure that forest cover is maintained. The First Nations Island Forest Management Inc. is well placed to take a leading role in ensuring prompt and successful regeneration in the Island Forests area. Selection of seed from drought-resistant individuals could also help maintain forest cover in the future. Experimental planting and monitoring of exotic species (e.g. red pine, ponderosa pine) may help identify species that will grow better under future conditions. Recent studies by Carr et al. (2004) and Thorpe et al. (2006) explore these alternatives in more detail.

In spite of these opportunities for reducing risk, the Island Forests may permanently lose forest cover in the future. Regeneration failure following fire or harvest is likely on some sites. This suggests that management planning needs to include the potential for a change to grassland in some locations so that this can be accommodated with a minimum of disruption.

CHAPTER III - REFERENCES

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