Present and Future Focal Point Seed Zones for Jack Pine in Northwestern Region of Ontario

By

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MAJOR ADVISOR'S COMMENTS

ABSTRACT

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Key Words: adaptation, climate change, focal point seed zone, *seed to*, *seed from*, climate change scenario, genetic variation, jack pine, provenance, provenance test, seed source, seed transfer.

Jack pine (*Pinus banksiana* Lamb.) is among the most widespread and most ecologically and economically important species for planting and direct seeding in the Lake States and throughout much of the boreal forest of Canada. Focal point seed zones for northwestern Ontario jack pine were previously developed in the 1990's but are in need of revaluation and refinement based upon recent growth and mortality measurements and more current climate models. Updated focal point seed zones created for both present and predicted future climate conditions will provide forest managers with seed transfer guidelines that avoid maladaptation between seed sources and planting sites under a range of current and future climate conditions.

To update the existing focal point seed zones and develop future focal point seed zones of jack pine in northwestern Ontario, the newest version of the climate model OCM2 (1961-1990) was used to update the existing focal point seed zones, while four separate climate change models (CGCM1, CGCM2, HADCM3, CSIRO) were used to develop future focal point seed zones based on predicted future climate conditions. Data obtained from a freezing trial conducted by Davradou (1992), as well as data for additional growth and survival variables collected in recent years (1997, 2003 and 2004) were incorporated when compared with the previous focal point seed zone studies of jack pine in northcentral Ontario and northwestern regions of Ontario.

In total 23 and 47 biological variables including growth, phenological and freezing variables were determined for each seed source in these two study areas. Principal components analysis (PCA) was used to summarize the main components of variation patterns. The first two PC axes represented growth potential and phenology, respectively, for these two study areas. PCA axis factor scores for seed sources were regressed against current climatic variables. The significant regression equations were used to model the patterns of adaptive variation. Present and future focal point seed zones were produced through intersecting the two contour maps by GIS. Future focal point seed zones include where seed should go from a given location to best suit future climate conditions (*Seed To*) and where seed should come from now to be best adapted in the future to its planting location (*Seed From*).

Under these different predicted future climate models, by the middle of this century, seeds will transfer to the north or northeast to match the future climate conditions and seeds should come from areas lying to the south or southeast of the planting location to be best adapted to the future site. By the end of this century, the northward or northeastward shift gradually slows and seed zones will move back under some climate scenarios.

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INTRODUCTION

Jack pine (*Pinus banksiana* Lamb.) is a leading forest crop species in Ontario and collection of jack pine cones exceeds that of any other conifer species (OMNR 1991). Because of their most widespread distribution and economic value, jack pine and black spruce (*Picea mariana* (Mill) B.S.P.) account for more than 70% of the Ontario tree improvement effort and 80% of the current artificial regeneration efforts (OMNR1987).

Proper seed selection is the most important initial step in reforestation. Seed transfer guidelines are vital for species that exhibit patterns of adaptive variation, as the use of maladapted seed/stock may result in an increased risk of mortality or damage due to cold, drought, insects and disease (Anon. 1997). Matyas (1994) found that the southward transfer of more northerly jack pine provenances provided conditions close to optimum and increased height growth by approximately 20%. Thus, the optimal use of genetic resources depends on the plant material being well matched to the regeneration site. Seed zones must be developed based upon demonstrated patterns of adaptive variation on an individual species level.

In an earlier study, a method to produce 'site-specific focal point seed zones' was developed for jack pine based first on 64 seed sources sampled from northcentral Ontario (Parker 1992) and second on 102 seed sources from the northwestern Region of Ontario (Parker and van Niejenhuis 1996 a). This work was adapted into an Arc/View extension program and is currently utilized in northern Ontario (Rouillard 1999). The layout of these two sampled areas including test locations and provenances is shown in Figure 1.

Focal point seed zones for jack pine are in need of revaluation and subsequent refinement based on more recent growth and mortality measurements and recently updated versions of climate models. The results of two separate graduate theses by van Niejenhuis (1995) and Davradou (1992) were used to derive the original focal point seed zone models for jack pine in the northcentral area. The results of a Northern Ontario Development Agreement (NODA) funded project were used to develop the original focal point seed zone models for jack pine in the northwestern portion of Ontario (Parker and van Niejenhuis 1996 a). New data collected in 1997, 2003, and 2004 growing seasons were integrated with the earlier data to produce revised focal point seed zones for jack pine in 2005. These focal point seed zone were also updated with the second iteration of the Ontario Climate Model (OCM2) (Natural Resource Canada and Ontario Forest Research Institute).

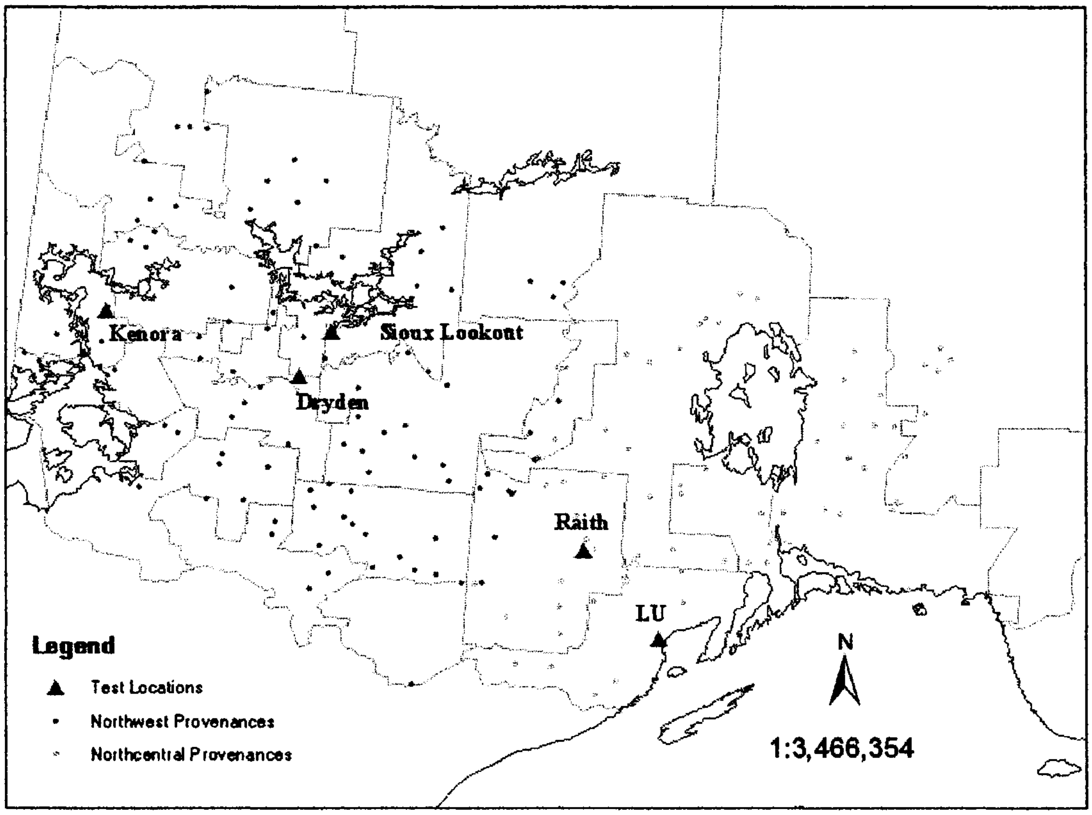


Figure 1. Jack pine seed source and field trial locations

Climate change will very likely lead to a change in habitats for boreal forest species in Canada. Many scientists believe that the effects of climate change will be serious and may pose a threat to sustainable forestry (Houghton 1997). Natural or artificial regeneration of forests with local seed sources will be become increasingly difficult if global warming occurs as predicted (Ledig and Kitzmiller 1992). Managers often make decisions based on their experience and intuition, but an intensified program of provenance testing is needed to provide accurate quantitative information for guiding seed transfer, especially, under a scenario of global warming. Improved forest management is increasingly viewed as an important means to counteract adversity resulting from global warming. Focal point seed zones modeled for future climates could provide information aiding in long-term seed selection decisions and may answer several questions: Are focal point seed zones for jack pine in study areas static or not? By the middle of this century, is a particular seed sources still suitable for this area? Where should sources be planted in order to be more suitable for the future climate condition? Where should seeds be taken from today to best match the future climate conditions of a given area? By the end of this century, how do the seed zones for jack pine in the study area change? Is there any difference among focal point seed zone models based on varying climate change scenarios?

To address these questions, the first objective of this study is to obtain reliable additional information on adaptive variation in jack pine and subsequently update focal point seed zones for jack pine in northwestern Ontario. Focal point seed zones should be dynamic in time as well as space, especially facing future climate change. The updated focal point seed zones will be used in the northwestern Ontario as the best available information for determining seed transfers for jack pine, which can help aid in reforestation decisions for forest managers under the present and future climate conditions.

Thus, the second objective is to develop future focal point seed zones for jack pine in the northwestern region of Ontario. Forest managers are concerned not only with short-term risk associated with planting trees, but also with long-term risk in maladaptation between seed sources and planting sites. These risks will be especially important where established plantations may not be intensively managed and the planted forest stands will be left to develop naturally. Rehfeldt *et al.* (1999) suggested that a major redistribution of tree species would happen in the future due to climate change. Focal point seed zones are based on climate data and will inevitably be altered by climate change. Focal point seed zone methodology uses models of adaptive variation to determine the necessary changes in seed zones and breeding zones resulting from global warming. Where seed should be transferred to from a given location to best-suit future climate conditions (*Seed To*), and where seed should come from now in order to be best adapted to its planting location (*Seed From*) in the future, are vital information when determining seed transfers under a scenario of global warming.

A final objective is to compare and explain future focal point seed zones in the study area based on various climate change scenarios. Because of uncertainties of projected climate models, it is necessary to develop focal point seed zones under varying future climate models. Seed zones necessary in developing a tree-improvement strategy for jack pine could be summarized by examining all focal point seed zones produced by the various models of future climate.

LITERATURE REVIEW

CLIMATE CHANGE

In the World

Climate change resulting from natural and human activities has become a pressing international concern. The climate is changing rapidly (Houghton *et al.*, 2001) and the scientific community accepts a consensus that the world is definitely warming (Bolin *et al.* 1986), with changes in average temperatures expected to be larger in northern areas than elsewhere (Houghton *et al.*, 2001). This warming is largely suggested to be a result of emissions of carbon dioxide and other greenhouse gases from human activities including industrial processes. These industrial processes include fossil fuel combustion, and changes in land use, such as deforestation (Bolin *et al.* 1986). The results reported in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Houghton *et al.* 2001) indicate an increase in global mean temperature ranging from 1.4 to 5.8°C for the end of the 21st century. Concurrently, it is expected on average that global mean precipitation will increase by about 2.4% per 1°C increase in temperature (IPCC 2001). These predictions may have real consequences for North America and the world with respect to agriculture, forestry, water sources, coastal areas and human populations *et al* (Caldwell 1979). As such, changes in precipitation patterns, increased risk of droughts and floods, threats to biodiversity and a number of potential challenges for public health may be expected in the coming century.

In Canada

Our current understanding based upon climate system science is that climate change is likely in Canada during the next century. In Canada, temperatures have increased by an average of 1.1°C (Environment Canada 1997), while the Great Lakes Basin has seen a 0.5 to 0.7°C rise (Smith *et al.* 1998) in the 21st century. Greater warming occurs during the winter and spring seasons. In Ontario, global circulation models (GCMs) based on a doubling of CO_2 predict an increase of mean annual temperature of 3-5°C with the largest temperature increases expected in the northwest and southern regions of the province in next century. The GCMs predict more complex changes in moisture patterns. Precipitation increases or decreases depending on the region and season. An increased frequency of extreme weather events is also likely to occur (Colombo *et al.* 1998; Parker *et al.* 2000). An approximate loss of about 5% to 10% in height growth is expected for a genetically adapted seed source if the average yearly temperature increases by 4°C (Schmidtling 1994). Since Ontario will be sensitive to climate change, it is important that policy- and decision-makers plan on adapting to the changes. Any actions undertaken today to cope with existing climate variability and extremes will reduce future vulnerabilities.

In Ontario, areas where forest tree species currently thrive may no longer provide the species' necessary temperature and moisture requirements (Papadopol 2000). Tree species will need to migrate in response to these environmental changes. Migration rates will differ for each tree species, likely resulting in the breakdown of current forest stand associations in the Boreal and Great Lakes-St. Lawrence Forest Regions. Maps showing simple northward shifts of major vegetation zones (e.g.

Hengeveld 1991) may not represent the changed composition of the future vegetation types; Ontario's northward shifted boreal forest of 2100 will not have the same species composition as it does today. This study aims at providing understanding to what extent focal point seed zones of jack pine in the northwest of Ontario will be affected by future climate changes, according to several climate change scenarios. Accurate predictions of future forest stand harvests will not be possible unless these impacts are accounted for.

Climate Change Applications

Climate change is expected to cause many changes in Canada's forests and very likely will lead to a change in the habitats of boreal forest species in Canada. The primary force determining the vegetation of a region is climate--in particular temperature, precipitation and seasonal variation. As such, if or when climate change occurs, it will bring major changes to Canada's forests. Even small changes in climate will affect plant growth and survival.

The distribution range of species will be reduced due to the higher temperatures and drought stress on growth. Failure to meet winter chilling requirements may also occur (Kimmins and Lavender 1987; McCreary *et al.* 1990). Higher temperatures may affect flowering and seed formation (Cannell 1987), reducing the ability of some species to regenerate at their southern margin or at low elevations. Higher temperatures will also favor insect pests because they will suffer less overwinter mortality and may also be able to complete more generations during the longer growing seasons. High temperature and drought stress will weaken trees and make them more vulnerable to insect attacks (Ledig and Kitzmiller 1992). Some types of species will decline because their populations are genetically adapted to the conditions under which they are now growing, not conditions 2.5°C warmer.

Climate change is also likely to affect pollination processes, alter the genetic structure of forest tree populations, and affect the genetic diversity of forest tree populations by modifying mechanisms of self-incompatibility, which could strongly affect both adaptedness and adaptability to further changes of forest tree populations (Giannini and Magnani 1994). Active interventions are needed in the Forest Management Planning process to circumvent these problems. To intervene and counter the possible destructive changes to native forests, foresters must understand about the range of adaptation within tree species. Intensified programs of provenance testing are needed to provide information for guiding seed transfer and forest restoration; however, much research relative to genetic and climate change issues have been carried out for many years.

Within species, populations may differ in their responses to various climatic variables, in the habitats that they are able to occupy, and in the breadth of habitats suitable for their survival and growth. Some studies have been completed by forest geneticists and tree breeders to analyze existing provenance tests, where population samples have been exposed to different environments. Matyas (1996) predicted how a tree will grow under warmer conditions. He accomplished this by measuring trees on northern and southern aspects. Suffling (1995) studied disturbance and vegetation zones using models and concluded that vegetation zones can shift northwards during global warming because of increased disturbance.

Rehfeldt *et al.* (1999) studied 118 populations of lodgepole pine (*Pinus contorta* Dougl. ex Loud.) in British Columbia. He developed population specific response functions driven by predicted climate variables and transfer functions that predict performance from the climatic distance over which populations were transferred. These functions can serve as guidelines for reforestation in a changing environment and explain the effects of climate change on adaptedness of populations. Rehfeldt suggested that a major redistribution of tree species and genotypes across the landscape may be needed to maintain forest productivity, health, and biodiversity should climate change scenarios be realized. Also, Rehfeldt *et al.* (2002) found that trees may grow far from their climate optimum and that the changing climate will increase survival and growth in a study of Scots pine (*pinus sylvestvis* L.) in a Eurasian provenance trial.

Based on response functions from a white spruce provenance trial, Cherry and Parker (2003) found optimal habitats for Ontario populations are expected to shift northward by approximately 2° latitude if the climate changes as expected. Using the same methodology, Parker *et al.* (2004) found optimal height growth tends to occur just north of the Canada/Minnesota border in western Ontario (48 to 49°) and in a zone from 45 to 47° N latitude in eastern Ontario for black spruce based on future climate warming predictions.

All of the above research is based on provenance trials, which provide valuable information on adaptation and responses to environmental change and are ideal for predicting and quantifying impacts of climate change at both species and population levels. Univariate climate model were used in these studies. Thus, limitations as result of uncertainties of climate models exist in the research. There is a need to consider combinations of climatic factors when predicting future habitats for forest tree species in Ontario.

Genetic Management under Climate Change

If global warming materializes as projected, natural or artificial regeneration of forests with local seed sources will become increasingly difficult (Ledig and Kitzmiller 1992). A forward-looking genetic management program for forest species is needed to respond to climate change. Tree species have limited ability to adapt genetically to new forest conditions. Local ecotypes may be threatened and genetic diversity may be reduced unless steps are taken to identify and conserve them. According to current climate change theory, there is pressure for a northward shift of species ranges (Houghton 1997) that will proceed with differing rates for various species (Peter 1990). Papadoopol (2000) stated that it was rational to establish new forests with species that might shift 300 to 600 km north of the limit of their current natural ranges. Reforestation strategies should emphasize conservation, diversification, and broader deployment of species, seed sources, and families given the uncertainties of predicted climate change (Ledig and Kitzmiller 1992). Non-local seed sources imported from further south or from lower elevations should be deployed in planting programs. Climate change will also require periodic updating of climate-based seed zones. The methodology of focal point seed zone (Parker 1992, 1996 a) allows the consideration of future climate condition. It provides important information to develop reforestation strategies that will utilize the best adapted seed source based on the predicted climatic condition.

Given the current uncertainty regarding regional shifts in climate, the planting of nursery stock representing widely adapted populations and diverse seed source mixtures has been recommended to increase the likelihood of regeneration success and long-term site adaptation (Ledig and Kitzmiller 1992). Breeding programs promoting genetic diversity, pest resistance, tolerance of environmental stresses, and increased growth with elevated CO_2 may be needed to ensure that species are adapted to the future environment (Namkoong 1984; Wang *et al.* 1995). The application of forest management responses to a changing climate will be needed to minimize the adverse impacts of climate change on Ontario's forests. Understanding and recognizing the potential effects of climate change on forests will allow resource managers to begin to modify forest management planning and policies to lessen negative impacts on the sustainability, biodiversity, health, and economic benefits of forest ecosystems. Accelerating research on adaptation, expanding the present program of progeny testing on a wider range of sites, and enlarging seed banks for gene conservation are directions for practice in tree improvement programs (Ledig and Kitzmiller 1992). Adaptation and mitigation strategies are needed to be innovative and preserve a degree of local flexibility under the climate change.

JACK PINE

Range and Ecology

Jack pine is an important commercial species of the boreal and cool temperate forests of North America east of the Rocky Mountains. Its geographic range extends from 42° to 65° N latitude, i.e., the Atlantic coast in Maine and Nova Scotia to the Mackenzie Valley in the Northwest Territories, and 65° to 130°W longitude from central Wisconsin to north central Quebec and northern Ontario (Critechfield and Little 1966). It includes broad ranges in latitude and climate (Yeatman 1966) and it forms an important constituent of the Great Lakes-St. Lawrence forest region (Rudolf 1958). The range of jack pine in North American is shown in Figure 2. The United States accounts for little boreal forest land area when compared with Canada.

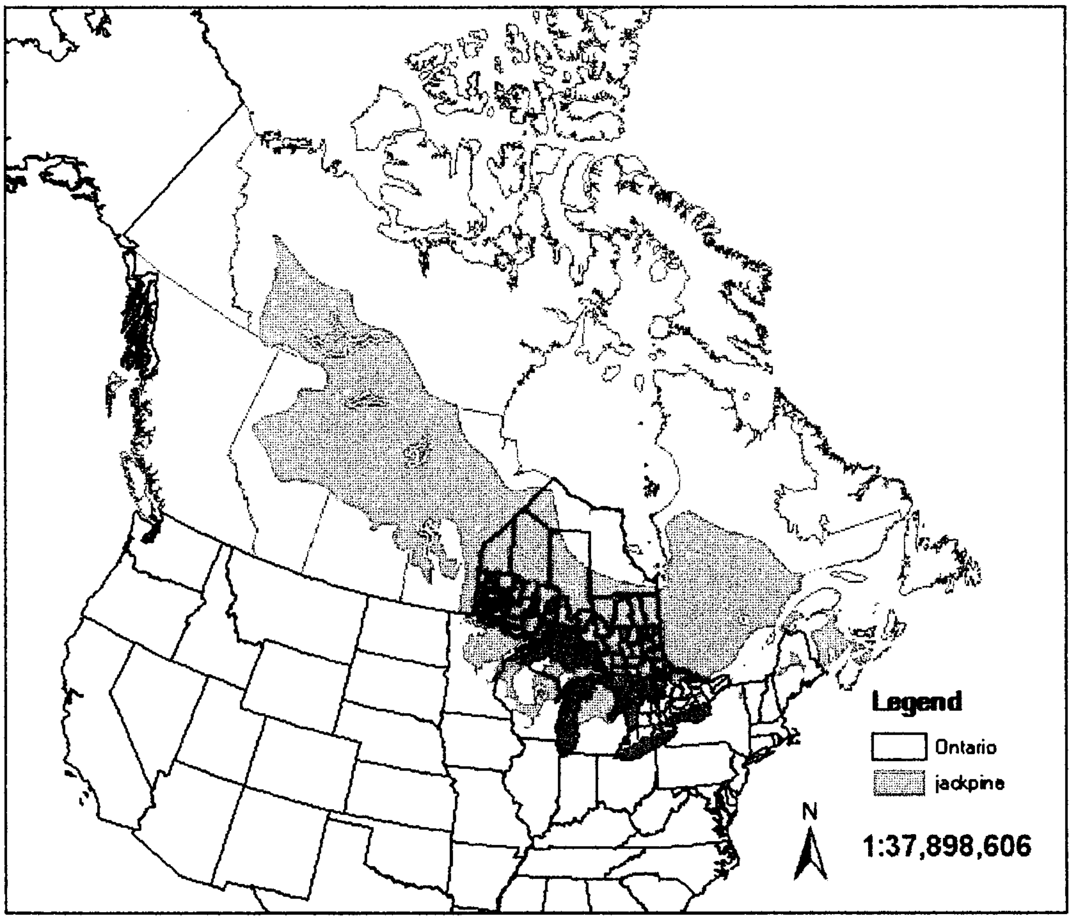


Figure 2. Range of jack pine in North America

Throughout its range in North America, jack pine utilizes a diverse range of habitat conditions. Mean annual temperatures vary from -5°C to 9.5°C, and mean minimum temperatures from -20°C to -45°C or lower. Precipitation varies between 13 to 58 cm and the growing season ranges from 60 to 170 days. Soils associated with jack pine stands are commonly sandy; however, loams, shallow soils over bedrock, and rarely organic soils may also be colonized by this species (Rudolph and Yeatman 1982).

Jack pine is the dominant or co-dominant species in eight recognized Forest Ecosystem Classification (FEC) Vegetation Types in northwestern Ontario (Sims *et al.* 1989). Common overstory associates include black spruce (*Picea mariana* (Mill.)B.S.P), trembling aspen (*Populus tremuloides* Michx.) and white birch (*Betula* *papyrifera* Marsh.). Often, jack pine stands have a predominant ericaceous shrub layer together with feather moss ground cover (Sims *et al.* 1990). Jack pine is an important forestry species in northern Ontario that is usually regenerated by direct seeding. Most of this seed will continue to come from seed collection and production areas located within designated seed zones.

Jack pine is among the most widespread and most ecologically and economically important species for planting and direct seeding in the Great Lakes States and throughout much of the boreal forest of Canada (OMNR 1991). By volume, jack pine is the second most important species harvested in Ontario. In addition to volume, the quality and characteristics of the wood of jack pine can also be greatly improved by modifying stem and branch form. In Ontario, jack pine and black spruce (*Picea mariana* (Mill) B.S.P.) are viewed as the top priority species because they receive more than 70% of the Ontario tree improvement effort (OMNR1987) and 80% of the current artificial regeneration efforts. This effort is being expended on these two species due to their significant level of genetic variation. Through genetic improvement and silvicultural management, the rotations of species can be shortened by more than 20% (Rudolph and Yeatman 1982).

Silvical and Genetic Traits

Jack pine is one of the province's most variable species. Stem and branch form as well as wood quality vary moderately (OMNR 1987). In most species, these traits are strongly heritable and can be easily manipulated through genetics. It is anticipated that substantial improvements in the stem and crown form could be made in the first generation. The growth rate is also variable but has only low to moderate heritability. Growth is a more important objective in later generations, when heritability can be increased by better control of test environment (OMNR 1987).

Genetic Variation

Provenance research in forestry deals with common garden plantations of wild populations of forest trees sampled randomly in certain parts of their distribution. Provenance trials with forest tree species have been established in many countries and have a long history (Zobel and Talbert 1984; Beuker *et al.* 1997). In the early 1960's, Holst (1967) started all-range jack pine sources covering Canada and the Lake States. The goal of provenance trials is to identify populations or areas of provenance which may provide reproduction material with the most desirable traits for a given region (Giertych 1997). In recent decades, provenance test is taking central role to assess and forecast effects of climate change (Davis *et.al* 2005). Observed variations in provenance tests may be interpreted as an adaptive response to changes in climate conditions (Maytas 1997). The necessary transfer of populations from the location of origin to the test site can be regarded as a simulation of environmental change and the response may be modeled; i.e., spatial (geographic) variation patterns may be interpreted as a simulation of responses to environmental change over time.

Considerable research has been directed at investigating jack pine's patterns of adaptive variation. These studies have included range-wide provenance tests to determine the broad patterns of geographic variation, and more restricted local provenance tests to determine the most desirable sources for artificial regeneration programs. Rudolph and Yeatman (1982) reported that local provenances were among the best performers in common garden field trials except in some particular cases. However, if environmental conditions have changed faster than the process of evolutionary adaptation, populations may not be optimally adapted to the new environment (Matyas 1990). Not all local sources performed best, usually those from milder climates performed better and sources transferred from south seem to surpass the local provenances in growth (Matyas and Yeatman 1992; Matyas 1996)

Patterns of variation in jack pine (by provenance tests) have been examined to be clinal with climatic and geographic and elevation gradient, although in some cases, with numerous irregularities (Schoenike and Brown 1963; Schoenike 1976; Yeatman 1966; Hyun 1979; Maley and Parker 1993; Davradou 1992; van Niejenhuis 1995 and Parker and van Niejenhuis 1996 a). King (1971) found eastern gall rust on 10 year old jack pine and incidence of white pine weevil were significantly different among seed sources. Ying (1991) reported that genetic resistance can be an effective tool in controlling white pine weevil. Characteristics that showed variation related to seed origin included growth and phenotypic variables. These variables include height growth, survival, bark thickness, tree form, winter injury, cold hardiness, pest resistance and cone and needle characteristics. Parker *et al.* (1996 b) reported that selection pressure corresponding to different FEC V-Type and S-Types have resulted in a detectable pattern of adaptive variation for jack pine in northern Ontario. Several allozyme studies have reported existence of genetic variability in ponderosa pine (*Pinus ponderosa* Laws.), lodgepole pine (*Pinus contorta* Dougl. *var latifolia*) and jack pine populations (O'Malley *et al.* 1979; Yeh and Layton 1979). Similar studies revealed that the levels of genetic variability were lower in jack pine compared to other pine species (Mosseler *et al.* 1991). Nkongolo and Gratton (2001) found 36.7% of the total molecular variance was related to provenance.

Cold hardiness and winter injury are a major concern when considering moving seed throughout the range of jack pine. Variations among jack pine seed sources in their ability to withstand winter injury were reported (Schantz-Hansen and

Jensen 1952, Yeatman 1976, Davradou 1992, and Parker and van Niejenhuis 1996 a). They concluded that winter hardiness is the critical factor in the survival and growth of planted jack pine in the boreal forest. Seed sources with long, warm growing seasons should not be moved to areas with severe winters and short growing seasons (Schantz-Hansen and Jensen 1952). The risk of winter injury and the increased susceptibility to disease as a result of increased stress may be expected when moving provenances north. Potential for early frost injury increases for trees displaying lammas growth (Rudolph and Yeatman 1982). Cold hardiness and associated physiological and morphological characteristics such as cessation of growth and date of bud set are provenance-related (Rudolph and Yeatman 1982). Foliage color change in jack pine in the fall of the year is also provenance-related (Rudolph 1980 and Davradou 1992). Hunt and van sickle (1984) also found genetic variation in jack pine with regard to susceptibility and resistance to certain diseases.

Schoenike (1976) concluded that all traits examined including crown, bark, wood, foliage and cones showed significant differences between populations of jack pine. The amount of variation associated with geographic location averaged 37 percent. Individual traits showed both continuous and irregular variation patterns across the range of the species. The most distinct clinal pattern was noted in an area from the Lake States to the Northwest. Schoenike (1976) also examined the correlations of individual traits with certain environment factors including: latitude, elevation, mean annual temperature, and mean annual precipitation. Most cases revealed low to moderate correlations. Higher correlations were seen for precipitation and bark thickness, precipitation and needle length, as well as latitude and needle volume.

Maley (1990) examined phenotypic variation in cone and needle characteristics of 64 jack pine seed sources in northwestern Ontario. A steep east-west cline at a longitude of 88.25° in the Nipigon area was found in this study. Patterns of variation demonstrated in the phenotypes of cones and needles appear to be a result of adaptation to local environment (Maley and Parker 1993).

Van Niejenhuis (1995) examined the adaptive variation of jack pine of 64 provenances in northcentral Ontario. The study measured eight growth variables and fourteen phenological variables in the greenhouse and at three common garden tests. These variables included elongation and cessation dates, duration of elongation, date of needle flush and foliage purpling. Variation expressed among seed sources was significant for all growth and many phenological variables. The pattern of variation in this portion of the range was clinal with numerous irregularities. The dependent variables were regressed against climate, spatial, soil and vegetative variables. The environment at seed source resulted in coefficients of determination as high as 0.57. July and average annual temperatures, heating degree days, frost dates, and soil and vegetation variables showed higher correlation with predictive models in this case (Van Niejenhuis 1995).

Parker and van Niejenhuis (1996 a), using common garden tests and a freezing trial of jack pine of 102 provenances in northwest of Ontario, found that 21 of 32 biological variables showed significant inter-provenance variation. Extreme minimum temperature and number of frost-free days were shown to be good predictors of this variation. In this study, the largest components of variation (28~30 percent) expressed among provenances were observed for the freezing trials. It was found that there is a gradual clinal trend from the southwest to the northeast. Northern sources flushed earlier while the southern sources flushed later.

SEED ZONE DELINEATION

Background

Transfer of plants to test locations with substantially different environments resulted in reduced adaptation to the new conditions (Matyas and Yeatman 1992). Specifically, material transferred beyond the range of adaptability for a species will demonstrate lower yield due to maladaptation. To define the range adaptability for a species, seed zone and seed transfer guidelines have been developed in all major forest regions (Lindgren and Ying 2000). A quantitative approach using regression coefficients to scale latitudinal transfer was first suggested by Morgenstern and Teich (1969). A conceptual model considering the performance of a seed source and the location or range of its deployment was developed using Cauchy function by Raymond and Lindgren (1990). Genetic differences among populations have been recognized as an important consideration when selecting appropriate sources of seed for artificial regeneration programs (Ledig and Kitzmiller 1992).

The use of seed zones is based on the assumption that the local population, which is the result of thousands of years of natural selection, is best adapted to the site (Rudolph and Yeatman. 1982). Although this hypothesis is still debated, some studies have been reported that some non-local seed sources outgrew local seed sources (Namkoong 1969; Mangold and Libby 1978; Matyas 1990, 1996; Matyas and Yeatman 1992, Rehfeldt 1999, 2002). The range of each species includes an array of environmental conditions. Within that range there are distinctive habitats for which certain trees within that species are better suited. Tree seed zones divide the range of a species into areas where the habitats are fairly similar. The size and shape of these zones varies depending upon the environment and the species. For species that have no or limited information on genetic variation and adaptability to non-native sites, there is a need for seed collection guidelines based on biological, climatological, and geographical criteria. Following the assumption that the local provenance is optimal, adaptive variation associated with the geographic origin of the parent tree can be obtained. Seed source variation in quantitative traits can be related to geoclimatic parameters at the location of seed sources and then can be modeled (Rehfeldt 1984).

Seed zone policy in Ontario was based on the assumption that areas of similar or nearly homogeneous climate will result in minimal inter-species variation (Anon. 1997). The strategy for reforestation efforts with boreal and other species has been to establish local seed zones and not to move seed or seedlings across zone boundaries. The existing seed zones of jack pine in northern Ontario correspond to boundaries taken from the Hills' (1959) site classification system and to administrative district boundaries has not been changed any more since the middle of the 1990's. These seed zones, represent a static pattern of polygons (OMNR 1987) based on the implicit assumption that until better information becomes available, seed collected from anywhere within a polygon is equally suited to reforest all areas within the polygon, but unsuited to reforest areas in adjacent or more distant polygons regardless of geographic proximity. This approach will not necessarily produce the best results since the approach is logically backwards. To produce a good seed zone each site should be considered individually in terms of locating potential seed sources with the appropriate matching adaptive characteristics.

Different Approaches for Seed Zone

Different approaches can model genetic variation in adaptive traits and guide seed sources transfer. Parker's (1992) focal point seed zone approach, which was built on Campbell (1974) and Rehfeldt (1984), is used in present study.

Campbell (1974, 1975, 1986)

Campbell (1974) initially laid the conceptual framework of modern-day seed zone delineation methodology. He developed an illustrative model as a basis for discussing seed transfer zone within a species-range, capable of providing stock adaptable to a particular plantation site. The model is based on the concept that synchronization of the development cycle of the tree with the seasonal cycle is the central problem of adaptation in high latitudes. Rate of damage was taken as a response variable to reflect poor synchronization, and the predictive variables chosen were (a) latitudinal and altitudinal 'transfer distances' (i.e. distances between the place of origin of a provenance and the trial site), and (b) 'plantation severity' (a measure of the severity of a plantation site based on the average response to damaging events of the populations tested). The prediction equation mainly emphasized the interaction between (b) and (a). Campbell (1975) first described the concept of risk assessment that was used in delineating seed transfer zones.

Campbell (1986) developed a guide for seed transfer in Douglas- fir for southwest Oregon by mapping genetic variation at the family level. Its aim was to estimate the proportion of seedlings that are maladapted to the plantation site when seeds are transferred. The main assumption of this approach is that local seed sources are best adapted to the planting site. According to this assumption, adaptive variation associated with the geographic origin of the parent tree can be separated from other genetic and environmental components of variation. The seed source variation in quantitative traits can be related to geoclimatic parameters at the location of the seed sources and can be modeled using the explanatory factors. When seed sources are transferred, a risk can be estimated and the greater the difference between the distributions of genotypes at the seed source origin and the plantation site, the greater the risk.

Rehfeldt (1984)

Rehfeldt (1984) developed a quantitative methodology for assessing geographic variation in Douglas - fir (*Pseudotsua menziesii* (Mrb.) Franco). It was used to develop seed transfer guidelines for various species in some areas of the western United States. In that study, Rehfeldt used three types of tests, a growth potential test done as a short-term field trial, a phenological test done in a greenhouse lasting one growing season, and a laboratory cold-hardiness test done in the month of September. Such data may be used to demonstrate patterns of adaptive variation that are useful in formulating seed zones. The results were used to establish least significant difference boundaries between sampled populations based on the results of ANOVA and regression against important environmental parameters. These differences are represented on a map as a generalized set of contour lines. These contours provide boundaries for movement of plant material; i.e., seed may be transferred within a contour interval, but not across another. The contours represented gradients of variation for the trait being modeled and spatially depict the regions in which populations were significantly different at the 80% level. Rehfeldt's approach was based on the actual patterns of adaptive variation present in each of the forest tree species targeted for regeneration.

These seed zone guidelines were based on the risk associated with moving seeds over a contour interval. Both Campbell's (1974, 1986) and Rehfeldt (1984) empirical method of seed zone were aiming at providing ecological basis for the development of guidelines dictating the movement of seed and plant material.

Although there is a debate that local sources are optimal, the advantage of Rehfeldt and Campbell's approaches are that information about genetic differentiation in growth and adaptive traits can quickly be obtained from provenance tests (growth potential), greenhouse trials (phenological variation) and laboratory experiments (freezing trial).

Raymond and Lindgren (1990)

A mathematical model was used to describe the relative performance of six different seed sources over a range of sites (Raymond and Lindgren 1990). In their study, latitude and elevation, along with performance measurements of seed sources at different planting sites, were used to develop a severity index. This severity index could be used to identify the optimal deployment of materials. Relative performance was the basis for delimiting seed zones or refining transfer rules. This approach relies on mathematical functions to model response of genotypes to environmental gradients. For practical application, this methodology requires extensive data from multiple provenance tests close to rotation age for each potential planting environment (Hamann *et al.* 2000). However, this information is rarely available (Ying 1997).

Focal Point Seed Zone (Parker 1992)

With modern computer methods, including multivariate statistical analysis and GIS techniques, there is a need to develop an operational method for identification of dynamic focal point seed zones. Parker (1992) developed site-specific seed zone delineation using GIS. By this method, an individual site to be reforested becomes the focal point and a unique seed zone is specially defined for each site as required. Instead of a region such as northern Ontario being divided into a checker-board pattern of polygons, the area may be divided into infinite number of zones, each corresponding to a single geographic point for which seed is required. The limits of each zone depend upon the desired level of similarity in adaptive traits. This was first time that GIS was used to define focal point seed zones based on adaptive variation in jack pine provenances located in northern Ontario. Parker's focal point seed zone methodology will be discussed in detail in the next section. Inspired by Campbell, Rehfeldt and Parkers' approaches to define seed zones, Hamann *et al.* (2000) used ordinary kriging to delineate seed zones. These methods examined variation in seed source performance and were modeled by a stochastic surface. The estimation surface variance was used to map seed zones. The advantage of this methodology is the ability to model heterogeneous surfaces, but it has uncertainty due to sampling and random genetic variation.

FOCAL POINT SEED ZONE METHODOLOGY

Background

Conventional seed zones are fixed geographic areas within which seed may be moved from a source to a reforestation site. Seed zones were originally defined to provide assurance that reforestation stock are adapted to a planting site by requiring that the seed was collected in the general area of the plantation. The philosophy underlying the development of the focal point seed zone was based on current opinion in Ontario that local seed sources are best for reforestation.

Interactive GIS Approach

Parker (1992) used geographic information systems (GIS) technology to delineate a unique seed zone for any site (the focal point) requiring seed for artificial regeneration based on a gencological trial of 64 seed sources in northcentral Ontario. Using the same methodology, Parker and van Niejenhuis (1996 a) developed focal point seed zones for jack pine using 102 seed sources in northwestern Ontario. The goal of the focal point method is to find the best matches between potential seed sources and a specific reforestation site. It is based upon similarities in adaptive variation-the patterns of genetic variation present in the natural forest that have evolved as a result of climate differences associated with changes of latitude, longitude, elevation, and other factors such as proximity to large bodies of water. While conventional seed zones are intended to represent a best compromise based primarily on spatial patterns, the establishment of fixed boundaries may not give the best adaptive match particularly when a reforestation site is found near a zone boundary. In contrast, the focal point seed zone approach converts our best knowledge of a species' adaptive variation into actual spatial data. This spatial data is then used to make best fit of seeds to planting sites.

Focal Point Seed Zone Methodology

Producing focal point seed zones requires a number of steps. The most important step is to develop mathematical models of adaptive variation for each species of interest (Parker 1992). These models are then used in conjunction with GIS technology to identify the zone of seed sources that best match a particular focal point reforestation site. Broadly speaking, these steps are as follows (Parker 1992):

"1. Provenance testing--Seed is collected from natural stands throughout the management area. Common-garden provenance tests are established, maintained, and measured to compare the growth of the seedlings from the sampled stands. Appropriate descriptors of tree growth are selected (e.g., measures such as height and diameter growth, and if available, other attributes such as frost hardiness and date of bud flush). These activities may occur over many decades.

2. Growth analysis--Measurements of the selected growth descriptors are analyzed to show differences among seed sources, to identify the principal components of variation, and to correlate these with climate variables. The objective is to establish the relationship between genetic variation in the species and climate differences.

3. Mapping--Once the mathematical models have been established, they are used to convert the observed adaptive variation into a spatial database in the form of high resolution geographic grids. GIS technology is then used to map the adaptive variation. For any point on the map (the focal point), it is possible to define a surrounding geographic area that falls within specified acceptable limits of similarity. The denser the shading on the map, the better the match in adaptive traits to the designated focal point."

The methodology developed in Parker (1992 and Parker and van Niejenhuis 1996 a) utilized Arc/GIS and Advanced Macro Language (AML) programming. The algorithm developed by Parker (1992) allowed an advanced user to operate this program independently. However, the advanced knowledge and technical support required by this program limited its use by forest managers. To address this problem, a series of seed zones were produced arbitrarily for every 12 minutes of latitude and 20 minutes of longitude by Parker *et al.* (1994). There is still a need to provide an interactive component that would allow the user to select specific regeneration or seed source sites to suit their specific needs.

To address this problem, Rouilliond (1999) developed FPSeedZ, an application extension for Arcview, based on Parker's research and methodology.

Arcview Extension (Rouilliond 1999)

Seed transfer guidelines are vital for species such as black spruce and jack pine that exhibit patterns of adaptive variation. If seed/stock is moved too far from its geographic origin it becomes more probable that it will be poorly adapted to the climatic conditions of the regeneration site. The use of maladapted seed/stock may result in an increased risk of mortality or damage due to cold, drought, insects and disease (Anon. 1997). Thus, the optimal use of genetic resources depends on the plant material being well adapted to the regeneration site.

FPSeedZ was designed to facilitate the transfer of knowledge from several years' research by Parker (1992, Parker *et al.* 1994, and Parker and van Niejenhuis 1996 a) to forest managers in a manner. It is simple to use and practical. It is expected that FPSeedZ will be used in the Northwestern region of Ontario as the best available information for determining seed transfers for black spruce and jack pine.

Current seed zone policy in Ontario is a climate-based approach that uses discretely mapped boundaries as guidelines for seed transfers. This approach uses the Ontario Climate Model to develop and refine seed zones that correspond with climatic gradients (Mackey *et al.* 1996). These guidelines are distributed in the form of a generalized seed zone map. The FPSeedZ approach improves upon this method in two general ways. Firstly, it is based upon both biological and climate data. This allows for species- specific determination of seed zones. Secondly, the seed zones are not static. Seed zones are determined based on the selection of a unique regeneration site. Current policy has made provisions for the use of programs such as FPSeedZ. It states that "when biological information is available, species specific seed transfer guidelines will take precedence over the generic climatically-based seed zones"(Anon. 1997). It is a user-friendly tool based on actual biological variation to guide seed transfer.

Methodology and Program Design

FPSeedZ utilizes biological data from four studies that were conducted in Northwestern Ontario. These studies examined the patterns of adaptive variation in jack pine and black spruce for the former north central and Northwestern regions of Ontario (Parker *et al.* 1994; van Niejenhuis and Parker 1996; Parker and van Niejenhuis 1996 a). Each of these studies employed the use of short-term common garden tests and greenhouse tests. The studies in the former northwestern region included additional freezing tests.

FPSeedZ was developed as an extension module for Arcview Geographic information systems. Along with the spatial analyst module, Arcview provides superior capabilities for modeling geographic and tabular data. Furthermore, the easy to use point and click graphical user interface and the powerful built in programming language (Avenue) provided an excellent media to translate Parker's research into a form that is intelligible and suited to the user's needs.

The methodology employed by FPSeedZ was developed and refined by Dr. Parker for several years (Parker 1992; Parker and van Niejenhuis 1996 a, 1996 b). FPSeedZ represents more updated version of this methodology including the use of the Ontario Climate Model (OCM1) and updated regression formulae.

Future Application

In addition to providing the best possible match of seed to planting site, the focal point approach has another important advantage over traditional seed zones. This advantage will be possible to specify a modified target climate and generate appropriately modified seed-suitability areas.

Rehfeldt *et al.* (1999) suggested that a major redistribution of tree species would happen in the future due to climate change. Focal point seed zones will inevitably change with the climate. FPSeedZ is dynamic instead of static. There is a need to update it with additional biological data (freezing variables and more recent growth variables), more accurate and reliable updated climate models and future climate scenarios and develop additional functions based on the FPSeedZ. Gene variation is a prerequisite for future evolution, in addition to a conservation objective related to the present adaptations. The concern about future adaptation, therefore, generates an urgent need to develop conservation programs that consider unique characteristics related to the long generation time of tree species. Climate change will undoubtedly affect current gene conservation strategies. Thus, a new focal point seed zone tool (Arcview extension) should provide the information need to determine where seed should be transferred from to best suit future climate conditions at a given location (*Seed To*) and where seed should come from now to be best adapted in the future to its planting location (*Seed From*).

In this way, forest managers will be able to predict where genetically improved seeds from today's orchards will perform best under tomorrow's predicted climates.

MATERIAL AND METHODS

STUDY AREA

This study area extends across a landbase of 23.2 million hectares. It spans roughly 3 degrees of latitude and 9 degrees of longitude, nearly covering the entire region of northwestern Ontario that lies south of the area of undertaking. Initially the study area was divided into two test regions representing the former North Central and Northwestern Regions. The location of this division was arbitrarily set at an approximate mid-point between the seed source locations for each respective study. The 91°W longitude line was determined by Yeatman (1966) to distinguish eastern and western zones. Sixty four and one hundred two jack pine provenances were used in the northcentral and northwestern regions of Ontario, respectively.

Northwestern Study Area

This work was part of NODA 4211 (Parker and van Niejenhuis 1996 a). This project included a greenhouse trial, field trials, and a freezing trial. The current study is based on the results of 1993 and 1994 (Parker and van Niejenhuis 1996 a), with new data collected from 1997, 2003 and 2004 growing seasons added.

STAND AND COLLECTIONS

Collections of jack pine cones were gathered in the summer of 1992 from the portion of northwest Ontario extending from a longitude of approximately 90°. The study area formed a rectangle of approximately 400 km east to west, and 350 km north to south. Within this area 102 jack pine stands of natural origin were selected. The locations of the seed sources and tests studied are shown in Figure 3. At each of the 102 collection sites, at least ten dominant jack pine trees with adequate numbers of seed cones in the upper crown were randomly selected. Each jack pine chosen was felled, measured, and aged, and cones that had matured the previous fall (1991) were collected. Stand and site descriptions, details of the collections, and descriptions of the growth trials of the 102 jack pine populations are provided in Appendix I (Parker and van Niejenhuis 1996 a).

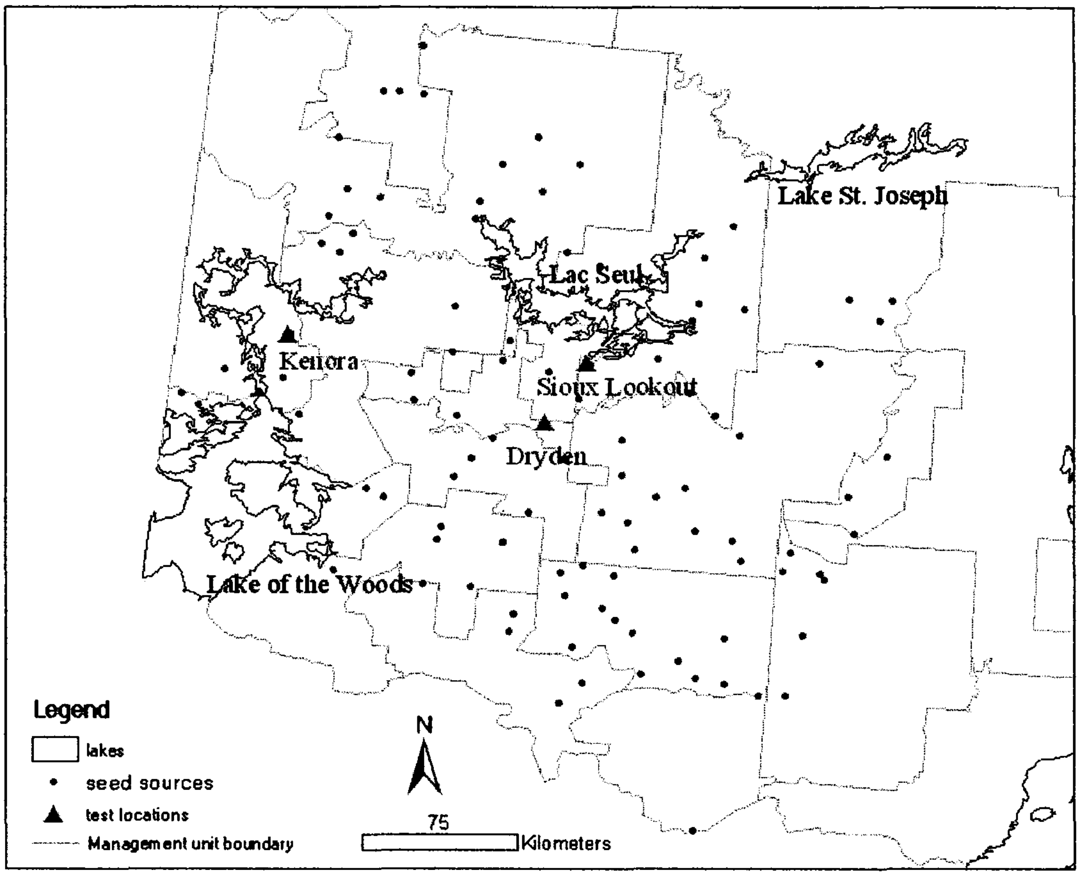


Figure 3. Locations of the 102 seed sources and three trial sites in northwest Ontario study area.

TEST ESTABLISHMENT

Cones from each jack pine at each site were individually processed for the extraction of seed, and equal numbers of seed per tree were bulked by site; cleaned seed was weighed and recorded for ten replicates of five seeds for each site.

Seedlings to be outplanted in the field and greenhouse trials were grown in leach tubes at the Lakehead University (Thunder Bay, Ontario) Greenhouse. Seeding of jack pine for the field trials was completed on April 8th1993; seeding for the greenhouse trial was completed on May 5th 1993.

In the summer of 1993, common garden tests, including seedlings of all 102 seed sources were established near the Fifth Creek Seed Orchard in the Kenora District (50°3'14"N, 94°23'30"W), at the Goodie Lake North Seed Orchard in the Sioux Lookout District (50°4'12"N, 92°21'23"W), and at the Dryden Tree Nursery (49°47'18"N, 92°36'7"W). Trial locations are referred to by the town or general area that they are located in. At each of these locations, field trials were planted. These consisted of three blocks of ten replicates per seed source arranged in a completely randomized design. A freezing trial of a single complete randomized block with 25 replicates from each seed source was established at the former Thunder Bay Forest Nursery (48°21'48"N, 89°23'57"W) to provide material for frost hardiness tests. As well, a Greenhouse trial consisting of a single, completely randomized block with 25 replications from each seed source was established at the Dryden Tree Nursery. These seedlings were transplanted from the leach tubes into 3-L pots. This stock was brought into a greenhouse in 1994 (additional information provided in Parker and van Niejenhuis 1996a).

DATA COLLECTION

Seedlings heights of jack pine were measured (1993 and 1994) at one forestry nursery, three field trials and one greenhouse trial. Tree heights were measured with height poles and diameter was measured at breast height using diameter tapes. Missing or dead trees were noted. Tree height increments were also measured at all trials but the Thunder Bay Forest Nursery. A total of 14 height variables were measured during 1993 and 1994. Seedling heights were remeasured in 1997 and 2003 and diameter was measured in 2003 at the Thunder Bay Forest Nursery trial. Seedling heights were remeasured in fall of 1997 and 2004 and diameters were measured in the fall of 2004 at the Sioux Lookout and Kenora trials. Survival counts were also determined at Sioux Lookout and Kenora trials in 1997 and 2004, and for Thunder Bay Forest Nursery in 1997 and 2003. Six survival variables were used in further analysis. Thus, a total of 23 growth variables and six survival variables were measured in this study.

Phenological data, including elongation initiation date, elongation cessation date, and duration of elongation in days were estimated. The needle flushing date was recorded for each seedling at all trials but Thunder Bay Forest Nursery. A total of 12 phenological variables were recorded in this study. The shoot elongation measurements were fitted to a growth equation described by Rehfeldt and Wykoff (1981):

$$Y = \frac{1}{1 + be^{(-rX + c/X)}}$$

$$\ln(\frac{1}{Y} - 1) = \ln(b) - rX + c(\frac{1}{X})$$

Where: Y is the proportion of the total elongation observed by day X, and ln(b), r, and c are regression coefficients. A multiple linear regression algorithm was written following the methods of Sokal and Rohlf (1981) to calculate the regression coefficients and coefficients of multiple determinations (R-square) and to plot the growth curves. Regression of the elongation data for each seedling allowed estimates for the time of elongation initiation and the time of elongation cessation. Growth duration was then calculated as the difference between these two estimated dates.

FREEZING TEST

Three comparative freezing damage trials were conducted in the fall of 1994. Current year needles were collected and bulked from ten seedlings of each seed source. Nine replicates of 20 needles from each seed source were placed in labelled bags. These included three controls, three of a first treatment temperature, and three of a second treatment temperature. These were cooled at a rate of 2°C per hour in a programmed chest freezer and maintained for 2.5 hours at treatment temperatures varying from -8°C on the earliest date of 15 September to -38°C on the last date of October 12th 1994. Percent damage was assessed relative to control samples maintained at 5°C. In this manner comparative freezing damage data were obtained for the 102 sources for six different freezing treatments (Parker and van Niejenhuis 1996 a).

Overall, 23 growth variables, 12 phenological variables, 6 survival, and 6 freezing variables, totalling 47 biological variables were collected in this study (Table 1).

Table 1. Definition, code and unit of measured biological variables

Test	Variable	Code	Unit
Greenhouse			
	GH94 needle flush date	GH94FLSH	days
	GH94 elongation start date	GH94STRT	days
	GH94 elongation stop date	GH94STOP	days
	GH94 increment of leader growth	GH94INCR	mm
	GH93 height	GH93HT	mm
	GH94 height	GH94HT	mm
Dryden			
	DR94 needle flush date	DR94FLSH	days
	DR94 elongation start date	DR94STRT	days
	DR94 elongation stop date	DR94STOP	days
	DR94 increment of leader growth	DRINCR	mm
	DR93 height	DR93HT	mm
	DR94 height	DR94HT	mm
Kenora			
	KE94 needle flush date	KE94FLSH	days
	KE94 elongation start date	KE94STRT	days
	KE94 elongation stop date	KE94STOP	days
	KE94 increment of leader growth	KE94INCR	mm
	KE93 height	KE93HT	mm
	KE94 height	KE94HT	mm
	*KE97 height	KE97HT	mm
	*KE97 survival	KE97SURV	%
	*KE04 height	KE04HT	mm
	*KE04 survival	KE04SURV	%
	*KE04 diameter	KE04DIAM	mm
Sioux Lookout			
	SL94 needle flush date	SL94FLSH	days
	SL94 elongation start date	SL94STRT	days
	SL94 elongation stop date	SL94STOP	days
	SL94 increment of leader growth	SL94INCR	mm
	SL93 height	SL93HT	mm
	SL94 height	SL94HT	mm
	*SL97 height	SL97HT	mm
	*SL97 survival	SL97SURV	%
	*SL04 height	SL04HT	mm
	*SL04 survival	SL04SURV	%
	*SL04 diameter	SL04DIAM	mm
Thunder Bay Forest Nursery			
	TB93 height	TB93HT	mm
	TB94 height	TB94HT	mm
	*TB97 height	TB97HT	mm
	*TB97 survival	TB97SURV	%
	*TB03 height	TB03HT	mm
	*TB03 survival	TB03SURV	%
	*TB03 diameter	TB03DIAM	mm
Freezing Trials			
	Frz1 Temp2 (-8^{0}C on 15 September)	FRZ1T2	%
	Frz1 Temp3 (-14^{0}C on 15 September)	FRZ1T3	%
	Frz2 Temp2 (-18^{0}C on 28 September)	FRZ2T2	%
	Frz2 Temp3 (-25^{0}C on 28 September)	FRZ2T3	%
	Frz3 Temp2 (-28^{0}C on 12 October)	FRZ3T2	%
	Frz3 Temp3 (-38^{0}C on 12 October)	FRZ3T3	%

Note: Flush, start and stop date: number of days starting on 1 May.

Freezing data: percent damage relative to control samples. Survival: percent of alive

* Results are not previously published

Climate Data and Future Climate Change Scenarios

Ontario Climate Model data for the period 1961 to 1990 OCM2 (with 1 km resolution) were obtained from Natural Resource Canada and Ontario Forest Research Institute. The future climate scenarios considered in this study were the CGCM1 obtained from Canadian Institute for Climate Studies, University of Victoria (www.cics.uvic.ca/scenarios/other/interpgrid/normals40.zip) for the period 2040-2069 in the form of Canada-wide grids with 15 km resolution, HadCM3 Climate Change Experiments (Hadley Centre, U.K.), CGCM2 (Canadian Global Coupled Model 2nd version, Canada) and CSIRO (Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia). The other three future climate scenarios (projected for 1990-2100) were provided by David T. Price, Edmonton, Natural Resource Canada. Thirty six climatic variables were selected including monthly average maximum temperature, monthly average minimum temperature and monthly average precipitation for both current and future climate models.

HadCM3, developed in 1998, is a coupled atmosphere-ocean general circulation model (AOGCM) developed at the Hadley Centre and described by Gordon *et al.* (2000) and Pope *et al.* (2000). Unlike earlier AOGCMs at the Hadley Centre and elsewhere (including HadCM2), HadCM3 does not need flux adjustment (additional "artificial" heat and freshwater fluxes at the ocean surface) to produce a good simulation. The higher ocean resolution of HadCM3 is a major factor in this. CGCM2 has been used to produce ensemble climate change projections using the older IS92a forcing scenario, as well as the newer IPCC SRES A2 and B2 scenarios. Compared with CGCM1, CGCM2 has the ability of a climate model to reproduce the present-day mean climate and its historical variation adds confidence to projections

(Flato and Hibler 1992). Using climate model simulations, CSIRO has estimated future changes in Australian temperature, rainfall and evaporation. The estimates take into account uncertainties associated with the range of future global warming and the range of regional climate model responses (Whetton 2001).

More current emission scenarios A2 and B2 were applied in present study. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in high population growth. Its scenario envisions population growth to 15 billion by the year 2100 and rather slow economic and technological development (IPCC 2001). The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability (IPCC 2001). Its scenario envisions slower population growth (10.4 billion by 2100) with a more rapidly evolving economy and more emphasis on environmental protection. It therefore produces lower emissions and less future warming (IPCC 2001).

An Arc/Info (Environment Systems Research Institute 2000) AML program, written by Dr. Parker, was used to extract climatic data for each of seed sources. A three-dimensional trend surface was generated for each of 36 variables, and a unique value for each variable was generated for the 102 seed sources in northwestern Ontario and each of 64 seed sources in northcentral Ontario. The summary of geographical variables and climate variables (for 1961-1990) for 102 seed sources is listed in Table 2.

Table 2. Geographic and climatic variables with study area ranges, units and codes for 102 seed sources in northwestern Ontario

Variable	**Mean**	**Std Dev**	**Range Max**	**Range Min**	**Unit**	**Code**
Longitude	92.5	1.2	95.1	90.3	decimal degre	long
Latitude	49.7	0.7	51.4	48.1	decimal degre	lat
Elevation	423	72	649	180	m	elv
January mean monthly maximum temperature	-13.0	1.1	-9.9	-15.0	°C	janmaxt
February mean monthly maximum temperature	-8.7	1.0	-5.9	-10.6	°C	febmaxt
March mean monthly maximum temperature	-0.9	0.7	0.7	-2.3	°C	marmaxt
April mean monthly maximum temperature	8.3	0.9	10.1	6.7	°C	aprmaxt
May mean monthly maximum temperature	16.6	0.8	18.2	15.2	°C	maymaxt
June mean monthly maximum temperature	21.3	0.4	22.2	20.4	°C	junmaxt
July mean monthly maximum temperature	24.5	0.5	25.5	23.4	°C	julmaxt
August mean monthly maximum temperature	22.5	0.6	23.7	21.2	°C	augmaxt
September mean monthly maximum temperature	15.9	0.7	17.3	14.7	°C	septmaxt
Octomber mean monthly maximum temperature	8.8	0.8	10.3	7.3	°C	octmaxt
November mean monthly maximum temperature	-1.3	0.8	0.8	-2.9	°C	novmaxt
December mean monthly maximum temperature	-10.0	1.1	-7.0	-12.2	°C	decmaxt
January mean monthly minimum temperature	-24.4	1.0	-23.0	-26.8	°C	janmint
February mean monthly minimum temperature	-21.6	1.1	-19.9	-24.5	°C	febmint
March mean monthly minimum temperature	-13.9	1.2	-12.0	-17.0	°C	marmint
April mean monthly minimum temperature	-4.2	0.9	-2.8	-6.5	°C	aprmint
May mean monthly minimum temperature	3.4	0.8	4.4	1.4	°C	maymint
June mean monthly minimum temperature	9.1	0.7	9.9	7.3	°C	junmint
July mean monthly minimum temperature	12.5	0.6	13.2	10.7	°C	julmint
August mean monthly minimum temperature	10.9	0.7	11.7	8.6	°C	augmint
September mean monthly minimum temperature	5.6	0.6	6.3	4.1	°C	septmint
Octomber mean monthly minimum temperature	0.3	0.4	0.8	-0.9	°C	octmint
November mean monthly minimum temperature	-8.9	0.6	-7.9	-10.6	°C	novmint
December mean monthly minimum temperature	-20.0	0.9	-18.1	-22.2	°C	decmint
January mean monthly precipitation	33.5	4.0	43.7	26.8	mm	janprec
February mean monthly precipitation	26.3	4.8	37.5	18.8	mm	febprec
March mean monthly precipitation	34.8	2.9	42.2	27.6	mm	marprec
April mean monthly precipitation	40.1	4.5	55.9	32.6	mm	aprprec
May mean monthly precipitation	64.6	6.8	77.5	52.3	mm	mayprec
June mean monthly precipitation	98.4	5.6	112.1	87.4	mm	junprec
July mean monthly precipitation	94.4	4.4	101.5	84.0	mm	julprec
August mean monthly precipitation	90.2	4.3	97.6	78.7	mm	augprec
September mean monthly precipitation	83.4	7.0	96.7	63.4	mm	septprec
Octomber mean monthly precipitation	60.4	8.3	77.5	42.5	mm	octprec
November mean monthly precipitation	40.5	4.2	51.3	32.1	mm	novprec
December mean monthly precipitation	33.9	4.9	47.5	25.5	mm	decprec

Five integrations scenarios (i.e., HADCM3A2, HADCM3B2, CGCM2A2, CGCM2B2 and CSIROB2), together with CGCM1 (2040-2069), were used in the present study to predict how the climate change may affect focal point seed zone models. Focal point seed zones were evaluated for the projections by the middle of this century (2050) and by the end of this century (2099) for HADCM3, CGCM2 and CSIRO scenarios.

Note that the available general circulation models were expressed as monthly climate variable ratios (or differences) derived from respective scenarios, subsetted for Ontario. Scenarios showing differences in monthly temperature and ratios of monthly precipitation, rather than actual climate values, were needed to compare focal point seed zones between each of the three temporal points: present day (1990), mid-century (2050), and end-of-century (2099). A base-line scenario representing current climate conditions, data on 1960-1990 from Dr. Dan McKenney, was used to extract data for these scenarios. A C- language algorithm was written for this purpose by Dr. Parker. These scenarios were on a 7.5 km grid resolution of monthly mean temperature and monthly average precipitation. From the extracted data, a trend was observed that the extent of predicted future warm was CSIRO > CGCM2 > GGCM1 > HADCM3; also, scenario A2 predicted warmer conditions than B2 in the future.

Scenario Tools (http://www.cics.uvic.ca/scenarios/plots/select.cgi) was run to get the detailed descriptions on these five different scenarios from an intuitional aspect. The results of this procedure are presented in Table 3. Figures 4 and 5 show temperature and precipitation trends between the years of 2050 and 2080 (the best estimates we could get) for the point 50° N latitude 89° W longitude. Based on CGCM2A2, temperature is predicted to increase by 2.7°C and 4.8°C, while precipitation is predicted to decrease by 3% and decrease by 1% for 2050 and 2080, respectively; based on GCM2B2, the temperature increase is predicted to be 2.3°C and 3.2°C and the precipitation decrease by 8% for 2050 and keep the same as current precipitation for 2080; based on HADCM3A2, the temperature increase is predicted to be 2.7°C and 5.1°C and the precipitation increase by 15% and 9.0% for 2050 and 2080; based on HADCM3B2, the temperature increase is predicted to be 2.6°C and 3.6°C and the precipitation increase by 10% and increase by 15%, respectively; based on CSIROB2, the temperature increase is predicted to be 3.9 and 5.7°C and the precipitation decrease by 1% and increase of 6% for 2050 and 2080, respectively.

Table 3. Climate change projected to 2050 and 2080 based on 1961-1990 climate model at 49.5°C N, 92.5°C W

Scenario	TC (°C) 2050	TC (°C) 2080	PC (%) 2050	PC (%) 2080
HADCM3A2	2.7	5.1	15.0	9.0
HADCM3B2	2.6	3.6	10.0	15.0
GCGM2A2	2.7	4.8	-3.0	-1.0
CGCM2B2	2.3	3.2	-8.0	0.0
CSIROB2	3.9	5.7	6.0	-1.0

Source: calculated by scenario tools (Canadian Institute for Climate Studies, University of Victoria)
TC: Temperature Change; PC: Precipitation Change

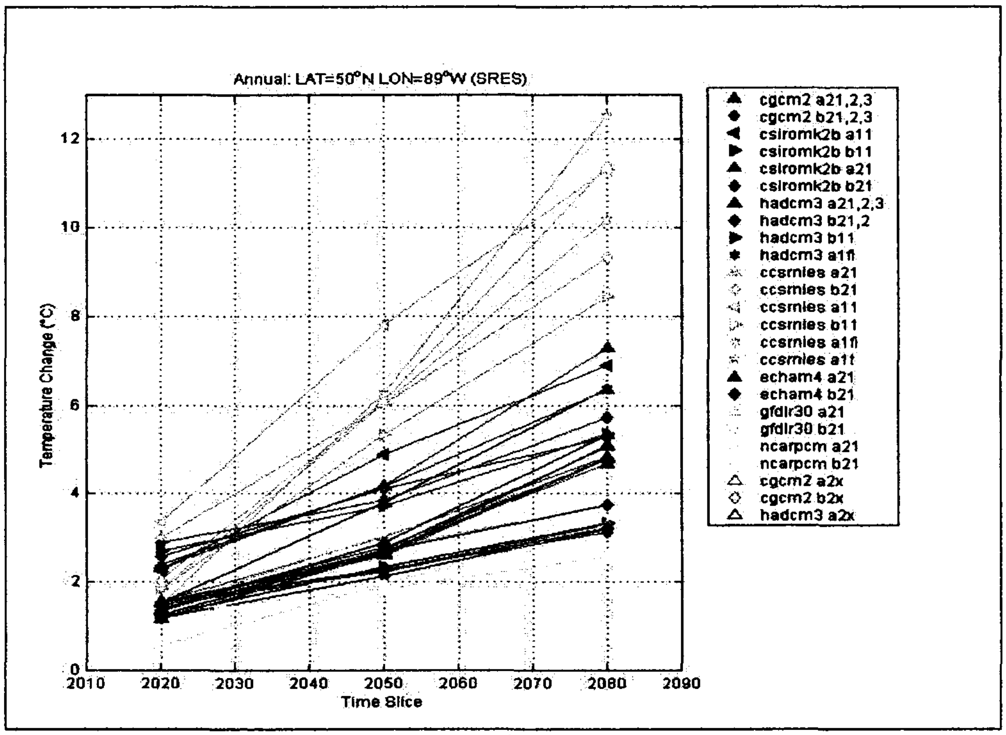


Figure 4. Temperature prediction based on 1961-1990 climate model (source: Scenario Tools Canadian Institute for Climate Studies)

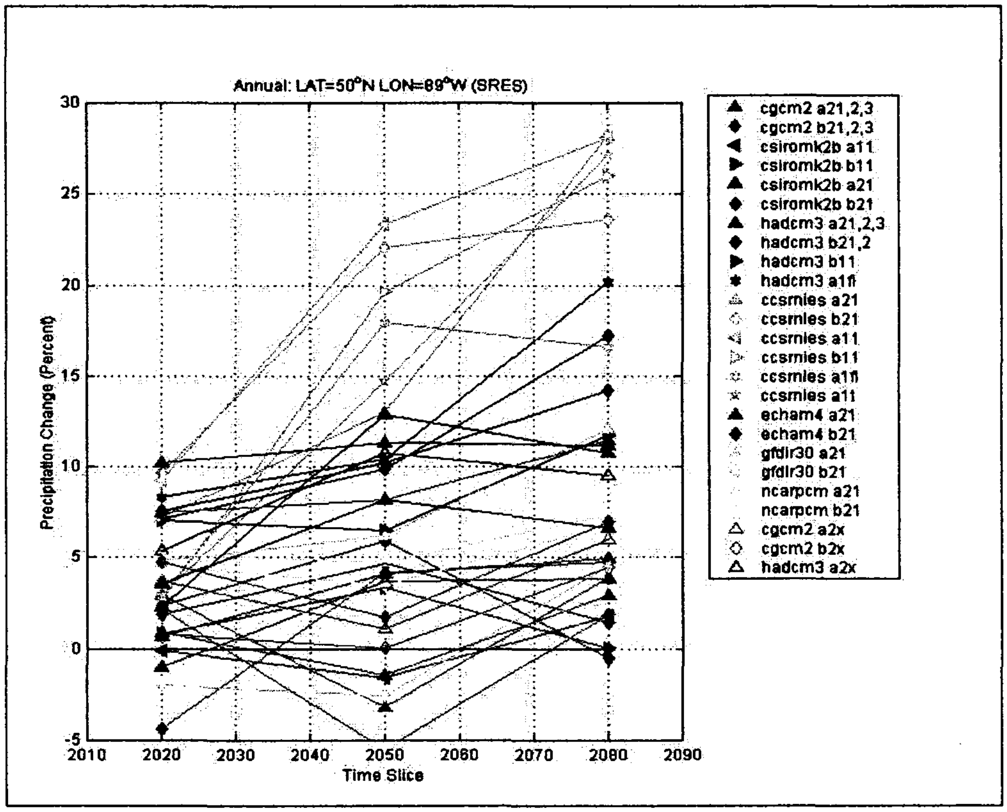


Figure 5. Precipitation predicted based on 1961-1990 climate model (Source: Scenario Tools Canadian Institute for Climate Studies)

Northcentral Ontario Study Area

The following two studies describe van Niejenhuis' morphological and phenological results (1995) and Davradou's freezing test (1992) from northcentral Ontario, which were used to derive the original focal point seed zone models for jack pine in the northcentral area.

TEST ESTABLISHIMENT

This study area is located in the province of Ontario, to the north and west of Lake Superior, and to the east and west of Lake Nipigon. All populations from which seed was collected are located between the longitudes of 86°47' and 90°54'. To the east of Lake Nipigon, the most southerly collection was near Terrace Bay at a latitude of 48°47'. The most southerly western collection was at a latitude of 48°05'. The most northerly collection site lies north of Lake Nipigon at 50°27'.

Throughout the study area, 64 jack pine stands were selected from which cones were collected during the summer of 1987. The locations of the 64 collection sites are illustrated in Figure 6. Detailed location information for each provenance is presented in Appendix II (van Niejenhuis 1995).

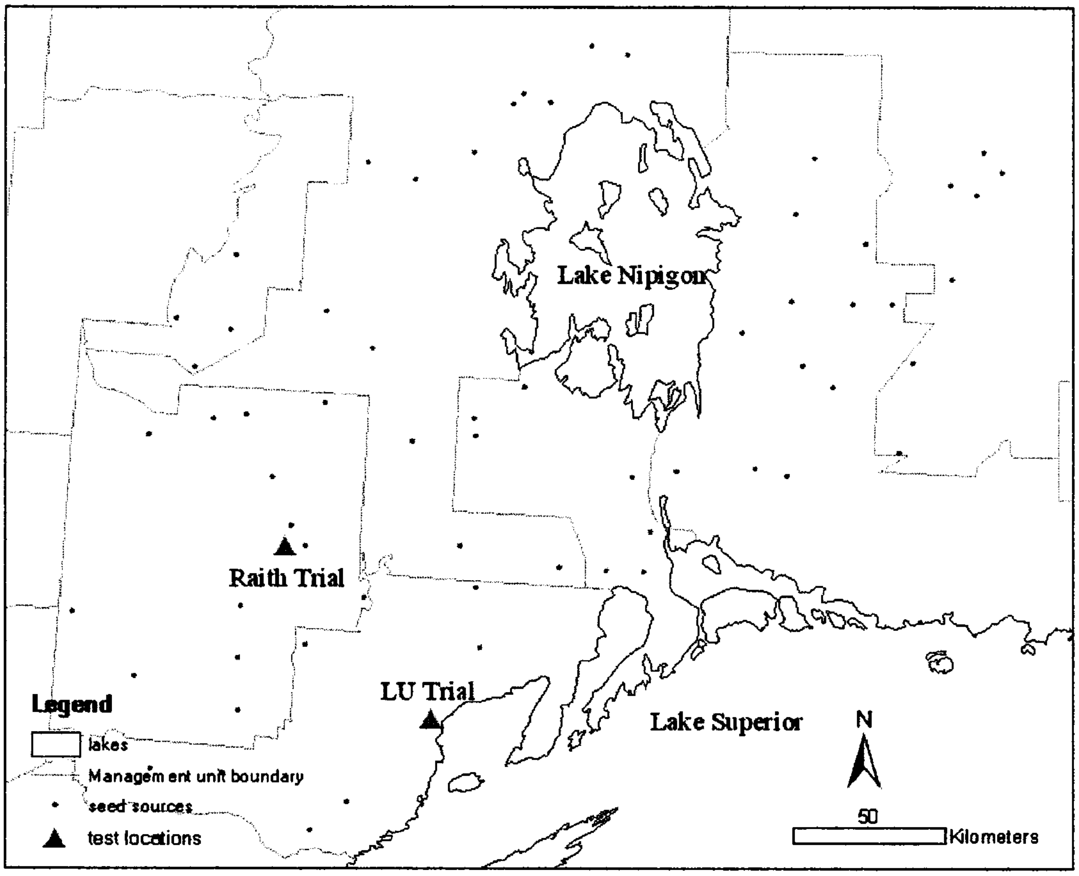


Figure 6. Location of the 64 seed sources and two trial sites in the northcentral region of Ontario.

At each site, ten healthy, cone-bearing trees separated by at least 20 m were selected for cone collection. A minimum of 10 cones were collected from each tree, and height and age of each sampled tree were recorded and averaged for each stand. From the cones of the 10 trees at each collection site, seed was extracted and bulked. Stock for the field and greenhouse trials was grown at the Lakehead University greenhouse in the winter of 1987-1988 for transplanting to three common garden tests in the spring of 1988.

The LU field test site was cleared and tilled. The Raith test site was extremely stressed. The LU greenhouse test was established in 3-L pots. Both of the field designs consisted of three blocks, each containing 10 seedlings from each seed source planted randomly at 0.5 m spacing. The greenhouse test contained 640 seedlings (10 from each seed source), also arranged in a completely random design.

DATA COLLECTION

Growth variables included year 1, 2, and 3 heights (1988, 1989 and 1990) at LU and Raith trials, and year 1 heights (in 1989) at the greenhouse trial, for a total of eight variables. Repeated measures of the terminal shoot throughout the period of elongation in the second growing year (1989) allowed for the derivation of phenological variables. For each seedling in each test, initiation, cessation, and duration of terminal shoot elongation were derived using multiple linear regression techniques described by Rehfeldt and Wykoff (1981), for an additional nine variables. Needle flushing date (i.e., the date the first needle emerged from a fascicle on the terminal shoot) for each seedling was recorded during the second (1989) growing season, for an additional three variables (additional information provided in van Niejenhuis 1995).

FREEZING TEST

Seven comparative freezing damage trials were conducted over three years (Davradou 1992). Information obtained from these trials is shown in Table 4. At each date needles were removed and bulked from the current growth from ten seedlings representing each seed source. Twelve replicates of each of 10 needles each from each seed source were placed in small labelled plastic bags and stored in a refrigerator at 5°C. Three test temperatures and a 5°C control were used for all freezing tests. Three replicates per seed source were used for each of the four temperature treatments. Needles collected in September 1988 were cooled in a freezer at 2°C per hour to each of three temperatures (-8, -13 and -18) and maintained for 1 hour. See Table 2 for 1989 and 1990 results. Freezing injury was evaluated visually. Tissue discoloration was used as criterion for rating injury. For each provenance, the proportion of needles exhibiting injury was recorded at each test temperature at each sampling date. Percent damage was assessed relative to control samples maintained at 5°C. In this fashion, comparative freezing damage data were obtained for the 64 sources for 21 freezing treatments. Only nine freezing treatments were used in subsequent analysis due to the other 12 exhibiting high percentages of samples with either too much (100%) or too little (0%) damage, which gave no useful information and introduced noise variables. The freezing data were transformed by arcsine (additional detailed information provided in Davradou 1992). All biological and freezing variables measured at each of the tests are presented in Table 5.

Table 4. Temperatures and durations of the freezing trials. (From Davradou 1992)

Date of Trials	Temperatures / Druations		
	TreatmentI(T1)	Treatment II(T2)	TreatmentIII(T3)
09/28/1988 (D1)	- 8°C 1 hour	- 8°C 1 hour	- 18°C 1 hour
09/01/1989 (D2)	- 6°C 1 hour	- 6°C 1 hour	- 18°C 1 hour
09/09/1989 (D3)	- 9°C 1 hour	- 9°C 1 hour	- 19°C 1 hour
09/19/1989 (D4)	- 9oC 1 hour	- 9°C 1 hour	- 18°C 1 hour
07/21/1990 (D5)	- 2°C 1 hour	- 2°C 1 hour	- 6°C 1 hour
08/06/1990 (D6)	- 1°C 1 hour	- 1°C 1 hour	- 6°C 1 hour
09/23/1990 (D7)	- 2°C 1 hour	- 2°C 1 hour	- 6°C 1 hour

Table 5. Variables definition, code and measurement unit for northcentral Ontario

Test	Variables	Code	Measurement unit
Greenhouse	1988 Height Growth	GH88	millimeter
	1989 Height Growth	GH89	millimeter
	Elongation Initiation	GHIN	Date
	Elongation Cessation	GHCS	Date
	Elongation Duration	GHDR	Date
	Needle Flushing	GHNF	Date
	Purpling	GHR	% Purpling (Arcsine)
LU Field trial	1988 Height Growth	LU88	millimeter
	1989 Height Growth	LU89	millimeter
	Elongation Initiation	LUIN	Date
	Elongation Cessation	LUCS	Date
	Elongation Duration	LUDR	Date
	Needle Flushing	LUNF	Date
	Purpling	LUR	% Purpling (Arcsine)
Raith Field trial	1988 Height Growth	R88	millimeter
	1989 Height Growth	R89	millimeter
	1990 Height Growth	R90	millimeter
	Elongation Initiation	RIN	Date
	Elongation Cessation	RCS	Date
	Elongation Duration	RDR	Date
	Needle Flushing	RNF	Date
	Survival	RSU	numbers of living tree
Freezing Trial	Freezing treatment 1	D1T1	09/28/88 -8℃ 1 hour(%damage)
	Freezing treatment 2	D1T2	09/28/88 -13℃ 1 hour(%damage)
	Freezing treatment 3	D1T3	09/28/88 -18℃ 1 hour(%damage)
	Freezing treatment 4	D2T1	09/01/89 -6℃ 3 hour(%damage)
	Freezing treatment 5	D3T1	09/09/89 -9℃ 1.5 hour(%damage)
	Freezing treatment 6	D4T1	09/01/89 -9℃ 2 hour(%damage)
	Freezing treatment 7	D5T2	07/21/90 -3℃ 2.5 hour(%damage)
	Freezing treatment 8	D7T2	09/23/90 -5℃ 5 hour(%damage)
	Freezing treatment 9	D7T3	09/23/90 -6℃ 6 hour(%damage)

CLIMATE DATA

The same climate models and methodology for northwestern Ontario area were used in this northcentral Ontario study area (see climate data and climate change scenarios section in northwestern area). The summary of the climate interpolated by GIS and geographical variables for the 64 jack pine seed sources are listed in Table 6.

Table 6. Geographic and climatic variables with study area ranges, units and code for 64 seed sources in north central Ontario

Variable	Mean	Std Dev	Range Max	Range Min	Unit	Code
Longitude	88.9	1.2	90.9	86.8	decimal degree	long
Latitude	49.4	0.6	50.5	48.1	decimal degree	lat
Elevation	1290	254	1700	650	m	elv
January mean monthly maximum temperature	-12.5	1.3	-9.3	-14.5	^{0}C	janmaxt
February mean monthly maximum temperature	-8.5	1.1	-6.0	-10.3	^{0}C	febmaxt
March mean monthly maximum temperature	-1.5	0.7	0.1	-2.6	^{0}C	marmaxt
April mean monthly maximum temperature	7.1	0.8	9.0	5.8	^{0}C	aprmaxt
May mean monthly maximum temperature	15.3	0.9	17.2	12.5	^{0}C	maymaxt
June mean monthly maximum temperature	20.1	0.9	21.2	16.2	^{0}C	junmaxt
July mean monthly maximum temperature	23.5	0.9	24.7	19.1	^{0}C	julmaxt
August mean monthly maximum temperature	21.5	0.8	22.7	18.8	^{0}C	augmaxt
September mean monthly maximum temperature	15.2	0.7	16.5	13.8	^{0}C	septmaxt
Octomber mean monthly maximum temperature	8.5	0.7	10.0	7.5	^{0}C	octmaxt
November mean monthly maximum temperature	-0.8	0.9	1.1	-2.1	^{0}C	novmaxt
December mean monthly maximum temperature	-9.0	1.1	-6.3	-10.9	^{0}C	decmaxt
January mean monthly minimum temperature	-25.9	1.7	-21.1	-28.6	^{0}C	janmint
February mean monthly minimum temperature	-23.5	1.8	-19.5	-26.8	^{0}C	febmint
March mean monthly minimum temperature	-16.4	1.7	-12.9	-19.5	^{0}C	marmint
April mean monthly minimum temperature	-6.5	0.9	-4.6	-8.4	^{0}C	aprmint
May mean monthly minimum temperature	1.0	0.5	2.0	0.0	^{0}C	maymint
June mean monthly minimum temperature	6.3	0.5	7.6	5.4	^{0}C	junmint
July mean monthly minimum temperature	9.9	0.6	11.3	8.9	^{0}C	julmint
August mean monthly minimum temperature	8.4	0.5	9.6	7.4	^{0}C	augmint
September mean monthly minimum temperature	3.8	0.6	5.6	2.7	^{0}C	septmint
Octomber mean monthly minimum temperature	-0.9	0.5	0.8	-1.9	^{0}C	octmint
November mean monthly minimum temperature	-9.7	1.2	-6.5	-11.7	^{0}C	novmint
December mean monthly minimum temperature	-20.4	1.5	-16.1	-23.2	^{0}C	decmint
January mean monthly precipitation	42.5	7.2	65.2	32.7	mm	janprec
February mean monthly precipitation	32.5	3.1	41.5	26.9	mm	febprec
March mean monthly precipitation	42.4	5.0	55.9	32.7	mm	marprec
April mean monthly precipitation	43.6	3.3	53.1	37.7	mm	aprprec
May mean monthly precipitation	70.1	5.0	77.8	60.3	mm	mayprec
June mean monthly precipitation	89.9	5.4	103.2	78.6	mm	junprec
July mean monthly precipitation	95.2	6.0	104.0	81.8	mm	julprec
August mean monthly precipitation	90.8	3.7	98.5	83.2	mm	augprec
September mean monthly precipitation	90.7	7.5	110.5	75.3	mm	septprec
Octomber mean monthly precipitation	73.5	5.7	88.2	66.3	mm	octprec
November mean monthly precipitation	58.0	7.5	73.2	46.2	mm	novprec
December mean monthly precipitation	47.0	8.5	66.3	36.8	mm	decprec

DATA ANALYSIS

The same methodology for data analysis was used in both the northcentral area and the northwestern regions of the Ontario study area.

To obtain more reliable adaptive variation information on jack pine, additional data was added to the earlier jack pine data sets of 1988, 1989, 1990 for northcentral area (van Niejenhuis 1995 for biological data and Davradou 1992 for freezing data) and 1993 and 1994 for the northwestern Ontario area (Parker and van Niejenhuis 1996 a). Additional new data collected during the course of 1997, 2003 and 2004 were combined with previous data for use in the present study.

Univariate Analysis

Each of the measured biological variables was analyzed by ANOVA to determine the amount of variation expressed among seed sources. For the greenhouse trial and freezing tests, each of which consisted of only one block, one-way ANOVAs were run, and the coefficients of intraclass correlation were calculated (Sokal and Rohlf 1981) to determine the extent of differentiation among the seed sources. The model used was:

$$Y_{ij}=\mu+ A_i + \varepsilon_{ij}$$

Where: Y_{ij} = measured variable value of replication j of seed sources i;

μ = the overall mean;

A_i = the random effect of seed source i;

i = the number of seed sources (i =1- 64 for northcentral Ontario and 1-102 for northwestern Ontario);

j = replicates per seed sources (j = 1 to 25 replicates per seed source);

ε_{ij} = the random effect of replication j of provenance i.

Similarly, for the field trials, two-way ANOVAs were run and the results were presented as percents of variation attributable to seed sources, blocks and seed source x block interactions. The model used was:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{jk} + \varepsilon_{ijk}$$

Where: Y_{ijk} = measured variable value of replication k of seed sources i at block j;

μ = the overall mean;

A_i = the random effect of the j^{th} provenance;

B_j = the random effect of the i^{th} block;

$(AB)_{jk}$ = the interaction effect in the subgroup representing the i^{th} seed source and the j^{th} block;

i = the number of seed sources (i =1- 64 for northcentral Ontario and 1-102 for northwestern Ontario);

j = the number of blocks (j = 1, 2, 3);

k = replicates for each seed source in each block (k = 1 to 10 replicates per seed source);

ε_{ijk} = the random effect of replication k of block j of provenance i.

ANOVAs on the new data gathered for both study areas were used in the present study. Only means values of previously analyzed variables were used in the subsequent analysis.

SAS 8.01 (SAS Institute 2000) GLM procedure was run primarily to obtain provenance overall means and block means. The GLM procedure in SAS was also used to calculate Least Significant Difference (LSDs) among provenances. Variables that showed significant at $p < 0.05$ were retained for further analysis. PROC VARCOMP and the Restricted Maximum Likelihood method (REML) were used to calculate the components of variance (SAS Institute 2000). Intralass correlation coefficients (I.C.C) convey meaning about the level of adaptive variation expressed at each of the measured tests, by indicating what fraction of the observed variation is expressed among provenances.

I.C.C formula is as follows:

$$\left(\frac{\sigma^2 provenance}{\sigma^2 provenance+\sigma^2 error}\right)x100\%$$

Variance components were obtained for growth variables, phenological variables, survival and freezing variables to calculate Intraclass Correlation Coefficients

Multivariate Analysis

All growth and freezing variables which showed significant inter-provenance adaptive variation were run by simple regression and multiple regression against the three geographical and 36 climate variables. The 36 climate variables were monthly average maximum temperature, monthly average minimum temperature and monthly average precipitation for each month of the year. This step was done by regression procedure (SAS Institute 2000) with the maximum r^2 method. Biological variables with both $p < 0.05$ level of significant among seed sources and significant regressions against the climatic data at $p < 0.05$ level were included in further steps in the focal point seed zone procedure (Parker and Van Niejenhuis 1996 a). Only variables expressing adaptive variation are useful for determining seed zones. These two steps ensured that variables retained in the future PCA have strong correlation between the components of adaptive variation and the local climate of the seed source. In the northcentral region, 20 of out of 29 measured variables were retained i.e. five growth, one survival, nine phonological and five freezing variables; 30 out of 45 measured variables were retained, i.e., 21 growth, three survival, six phenological and three freezing variables in the northwestern Ontario area.

Seed source mean values for the 21 in northcentral variables and 30 northwestern variables were analyzed using principal components analysis (PCA) to summarize the main components of variation in the data set. New summary variables consisting of principal component scores were calculated for each main axis of variation. These PCA summary variables were reproduced graphically as contour maps by GIS to show patterns of geographic variation. Additional multiple linear regressions were run for the PCA scores against climatic data for the 64 and 102 seed sources using the regression procedure in SAS (SAS Institute 2000). Preliminary regressions were run using a backwards stepwise procedure with a probability at the 5% level. Thirty six climatic variables were used in this step (Table 1 and Table 5). To avoid overfit regressions, variables with tolerances considerably less than 0.1 or t values less than 2.0 were eliminated (Wilkinson *et al.* 1992) and the regressions were rerun. These simplified regressions were used to model the main PCA axes. Scores predicted by the regressions were calculated for each of the 64 and 102 seed sources. The predicted scores were then graphically reproduced as contour maps by GIS to summarize the modeled pattern of geographic variation.

Focal Point Seed Zone

Three algorithm ArcGIS (Arc/Info) AML programs written by Dr. Parker were run to generate present and future focal point seed zones. Future focal point seed zones include *Seed To* and *Seed From* based on different climate change scenarios. It was determined by intersection of the regression-based first two PCA grids in each case. Zones of simultaneous similarity represented a minimum level of adaptive similarity on both modeled PCA axes. A series of focal point seed zone maps based on current and future climate conditions was illustrated in the present study for both areas. Two types of future climate focal point seed zone maps were prepared: best adaptive match for the future seed source (*Seed From*) and best future location for seed taken from focal point (*Seed To*).

RESULTS: Northwestern Ontario

SINGLE VARIABLE ANALYSES

Select results obtained from the ANOVA for variables measured in 1993 and 1994 in Northern Ontario Development Agreement (NODA) funded project (Parker and van Niejenhuis 1996 a) were used in the present study. Only the means of these variables were analyzed in the subsequent analysis.

Greenhouse Trial

One-way ANOVA tests revealed that provenance was a significant source of variation for all the variables in the greenhouse trial, except the elongation stop date variable in 1994. The portion of the total variance attributed to seed source ranged from 4.98% for seedling height increment during the course 1993 and 1994 up to 21.02% for the 1993 height (Parker and Niejenhuis 1996 a).

Field Trials

In the four field tests, one-way ANOVA tests of all the biological variables revealed that significant differences existed between provenances for the majority variables at the $p < 0.05$ level. Variables that did not show significant differences were 1994 elongation start date at the Dryden and Kenora tests, 1994 elongation stop date at Dryden, Kenora and Sioux Lookout tests (Parker and Niejenhuis 1996 a). For growth variables, 1997 height, 2004 height and 2004 diameter at Kenora and Sioux Lookout tests were not significant at $p< 0.05$ level, but the height variables showed some differentiation. The six freezing variables were all significant at $p< 0.05$ level.

All variables and significance levels are shown in Table 7. Provenance mean values for all variables are included in Appendix III (variables measured in 1993 and 1994 and freezing variables were obtained from Parker and Niejenhuis (1996 a).

All the variables except for the 1994 cessation of elongation date at the Greenhouse trial, the start of elongation at the Dryden, Kenora, Sioux Lookout tests, 1997 height at the Kenora test and 2004 diameter at Kenora and Sioux Lookout tests explained some level of genetic variation between provenances. Those variables showing zero or very little genetic variance were excluded from further analysis (Parker and Niejenhuis 1996 a).

Provenance differentiation was evident in all trials. Specifically, this trend was clearer during the course of the first several growing seasons than in the later. I.C.C values were used here to explain the extent of differentiation between provenances. The largest components of variation expressed among provenances were found for the freezing trial, which accounted for 19.6-37.9 percent. Generally, I.C.C values were higher for seedling height variables than those of phenological variables. More variation was explained among seed sources for height and needle flush dates in the Greenhouse due to the well controlled environment. The level of differentiation between provenances showed by seedling height growth was very little (0.1 and 1.17%) for the 1997 seedling height for Kenora and Sioux Lookout trials. These values were greater (5.13 and 5.58%) in 2004, although they were not significant at the $p<0.05$ level, which was not expected. Perhaps, there was an unfavourable environment during that growing season. The level of differentiation showed by survival for these two trials was 4.91 and 9.48%, respectively; survival was significant at $p = 0.05$ level for Sioux Lookout trial and at the $p < 0.2$ level for the Kenora trial. Diameter measured in the 2004 growing season indicated little or no differentiation among seed sources (3.9 and 0%). Perhaps the stem density was part of the cause. For the Thunder Bay Forest Nursery trial, it was not the same situation; the level of differentiation among provenances indicated by seedling height growth increased with time except for the first growing season when the first year seedling height explained the largest differentiation (7.44%).

Table 7 showed that the percentages of variation expressed by blocks in the three blocked test designs were very low or moderate, ranging from 0 to 5.96. Block x provenance interaction term generally was very low, ranging from 0 to 2.08 of the total variation. This component of variation was not considered in the focal point seed zone method.

Table 7. Means, standard deviations, and percentages of variation expressed among 102 seed sources of jack pine.

Variables	Mean[a]	SD[a]	Provenace(%)	Block(%)	Interaction(%)
Greenhouse					
Gh94 flush date[b]	6.78	1.41	17.05	-	-
GH94 start date	5.3	4.79	8.05	-	-
GH94 stop date	79.43	12.01	0 ns[c]	-	-
Gh94 increment (cm)	3.3	1.4	4.98		
GH93 height (cm)	10.24	1.61	21.02	-	-
GH94 height (cm)	18.86	3.3	12.74	-	-
Dryden					
DR94 flush date	23.81	2.05	14.54	2.49	1.52
DR94 start date	14.58	3.95	0.35ns	2.39	0.00
DR94 stop date	78.25	14.01	0.70 ns	1.78	0.00
DR94 increment (cm)	5.58	2.68	5.58	1.66	0.65
DR93 height (cm)	13.11	2.36	12.2	1.25	0.53
DR94 height (cm)	21.15	3.72	10.67	3.64	0.66
Kenora					
KE94 flush date	28.35	3.04	3.36	5.96	0.38
KE94 start date	13.1	4.03	0.47ns	0.25	0.00
KE94 stop date	71.72	20.58	0.12ns	0.09	0.00
KE94 increment (cm)	3.35	1.96	4.9	0.11	0.21
KE93 height (cm)	12.88	2.31	6.29	0.24	2.08
KE94 height (cm)	17.83	3.51	9.42	1.57	0.3
*KE97 surv (%)	95.3	0.68	0.4	5.43	0.00
*KE97 height (cm)	67.67	6.74	0.1ns	2.12	1.01
*KE04 surv (%)	74.8	1.43	4.91	0.00	0.00
*KE04 height (cm)	318.38	36.64	5.13ns	0.00	0.00
*KE04 diam (cm)	24.31	3.09	3.85ns	0.56	0.19
Sioux Lookout					
SL94 flush date	28.53	2.47	6.04	2.71	0.00
SL94 start date	17.75	2.99	0.75	0.52	0.96
SL94 stop date	74.85	17.37	0.21ns	0.00	1.12
SL94 increment (cm)	3.73	2.37	3.38	5.58	0.00
SL93 height (cm)	12.23	2.23	6.45	2.19	0.98
SL94 height (cm)	18.23	3.95	6.82	5.46	0.18
*SL97surv (%)	88.6	1.08	1.63	1.78	0.00
*SL97height (cm)	62	7.7	1.17ns	2.37	1.05
*SL04surv (%)	82.9	1.26	9.48	0.00	0.00
*SL04 height (cm)	257.73	23.6	5.58ns	0.34	0.00
*SL04 diam (cm)	17.24	2.61	0ns	0.65	0.19
Thunder Bay Forest Nursery					
TB93 height (cm)	12.23	2.42	7.44	-	-
TB94 height (cm)	24.62	6.27	3.87	-	-
*TB97 height (cm)	147.64	29.21	5.41	-	-
*TB03 height (cm)	487.7	57.54	5.57	-	-
*TB03 diam (cm)	3.36	0.87	4.69	-	-
Freezing trials					
Frz1 Temp2[d]	4.81[e]	2.33	32.24	-	-
Frz1 Temp3	11.38	7.42	26.53	-	-
Frez2 Temp2	14.92	3.82	36.44	-	-
Frez2 Temp3	17.72	5.29	19.62	-	-
Frez3 Temp2	9.62	1.48	37.88	-	-
Frez3 Temp3	10.74	2.18	35.75	-	-

[a] based on 102 seed source values

[b] Number of days starting on May 1st. [c] Not significant (a = 0.05).

[d] Freezing trial dates and temperatures: Frz1 Temp2 was -8 on 15 Sept; Frz1 Temp3 was -14 on 15 Sept; Frz2 Temp2 was -18 on 28 Sept; Frz2 Temp3 was -25 on 28 Sept; Frz3 Temp2 was -28 on 12 Oct; Frz3 Temp3 was -38 on 12 Oct.

[e] percent damage relative to control samples.

* Unpublished data

Examination of the seed source means revealed that the five earliest needle flush dates in 1994 were obtained for sources 73, 76, 8, 7, 74 at the Greenhouse trial, 7, 70, 72, 6, 74 at the Dryden trial, 73, 72, 71, 8, 92 at the Kenora trial and 7, 77, 93, 5, 80 at the Sioux Lookout trial. Seed sources 70, 71, 72, 73, 74, 76 and 80 originated in the north portion of the study area. Sources 70, 76, 80 were located around the north of Lac Seul. Sources 6, 7, and 8 originated from the eastern of portion of the study area, while sources 43 and 101 originated from the south of study area. Source 72 was the earliest to needle flush, while source 21 was the latest to flush needles for both the Greenhouse and Dryden trials.

Source 98 showed the tallest seedling height in Kenora trial by 1993 and 1994. Source 29 was the second tallest seedling height for 1993 which is located near the Kenora trial. Source 98 originated from the middle potion of the study area, southern of the Kenora test location. By 1997, the tallest seedlings originated from source 101, averaging 75.8 cm after 5 years. The top 5 seedlings heights were obtained for sources 101, 28, 9, 38 and 34 for 2004 in the Kenora trial, averaging 358.7, 358.5, 356.8, 356.2 and 354.7 cm after 12 years. Source 96 showed the biggest survival (90%) and source 5 showed the lowest survival (50%) at the Kenora trial after 12 years (2004).

SIMPLE REGRESSION ANALYSIS

Results were obtained from the simple linear regressions (start = 1 and stop = 1) run on each biological variable against three geographic and 36 climatic variables. The bigger the r^2 value, the better the relationship between biological variables and geographic and climatic variables is explained.

There were nine dependent variable regressions found to be non- significant at the $p < 0.05$ level. These variables were 1994 elongation start date for Greenhouse trial, 1994 elongation start date, 1997 height and 2004 height for the Kenora test, 1994 elongation stop date, 2004 diameter for the Sioux Lookout trial, FRZ1T2, FRZ1T2 and FRZ2T1 for the freezing trial. All dependent variable regressions were significant at the $p < 0.05$ level for the Thunder Bay Nursery trial. Coefficients of determination (r^2) ranged from 3% for Kenora 1994 elongation stop date and Thunder Bay Nursery 1997 survival, up to 60% for the Greenhouse 1994 needle flush date. Flushing dates had relatively high r^2 values, ranging from 60% for the Greenhouse 1994 down to 23% for Kenora 1994, compared with the other height and phenological variables. Surprisingly, geography and climate explained none of or only low levels of the variation among seed sources in the freezing trials.

In the retained variables (variables with not significant at the $p < 0.05$ level were excluded), latitude was the most often selected (eight times) to explain differences in the biological variables. Photoperiod differences due to latitude are considered one of the main factors influencing the initiation of winter hardening in trees (Weiser 1970). Average November monthly minimum temperature was found 6 times to be related to the biological variables. Average September monthly maximum temperature was selected 5 times, and March maximum temperature was selected 3 times. Overall, the temperature variables produced higher r^2 values than the precipitation variables.

Both best r-square selection simple linear (start = 1 and stop = 4) and backwards stepwise multiple linear regression analyses were run for all the variables in each test against three geographic and 36 climatic variables. The coefficient of determination (r^2) and the independent climatic variables are provided in Table 8 for all regressions that were significant at the $p < 0.05$ level.

Flushing dates had the highest r^2 values. Spring maximum temperature played an important role in determining needle flushing date variables. Simple linear regressions accounted for as much as 60 percent of the variation and multiple regressions accounted for up to 65 percent. Latitude is a good predictor for growth variables; it was selected nine times by height growth variables, the variation ranging from 6 percent to 28 percent. The survival variables were closely related to spring and fall maximum temperatures. Freezing trial variables showed unexpected results in that they showed large variation between seed sources while low or no levels of variation were explained by climate. Climate was significant in explaining variation between provenances for only 3 of the 6 phenological variables, with r^2 ranging from 1 percent up to 5 percent. Even multiple regressions accounted for only 11 to 15 of the percent variation.

Simple regression results are similar to those from a Parker and van Niejenhuis study (1996a) which found that r^2 values for flushing dates were the highest, ranging from 25 percent to 59 percent, and freezing variables showed low or no level of variation explained by climate in their study. Mean maximum daily temperature in July, mean annual temperature and heating degree days are important variables in determining needle flushing date in that study. Mean maximum daily temperature in July is the most selected (18 times) in that study, with r^2 values ranging 4 for DR94 start date to 59 percent for DR94 flush date.

Table 8. Results of simple linear and backwards stepwise multiple linear regression against 3 geographic and 36 climate variables

	Simple regression		Multiple regression	
Dependent variable	Climate variable	R^2	Climte variable	Max R^2
GH94FLSH	marmaxt	0.6		
	septmaxt	0.59	marmaxt	0.65
	aprmaxt	0.59	aprprec	
	maymaxt	0.58		
GH94STRT	marmint	0.35		
	augmaxt	0.34	novmint	
	aprmint	0.34	marprec	0.42
	junmaxt	0.33	augprec	
GH94INCR	janmaxt	0.13		
	marmaxt	0.13		
	febmaxt	0.13	janmaxt	0.13
	lat	0.13		
GH93HT	marmaxt	0.12		
	marmaxt	0.11	maymaxt	
	febmaxt	0.11	decmint	0.397
	lat	0.11	marprec	
GH94HT	janmaxt	0.16	aprmaxt	
	marmaxt	0.16	janprec	
	febmaxt	0.15	febprec	0.41
	maymaxt	0.15	novprec	
DR94FLSH	maymaxt	0.51		
	aprmaxt	0.5	maymaxt	
	marmaxt	0.5	julmaxt	0.56
	janprec	0.49		
DR94STRT	julmaxt	0.068		
	augmaxt	0.066	julmaxt	
	julmaxt	0.064	elv	0.09
	maymaxt	0.06		
DR94STOP	junprec	0.05	janmaxt	
	maymint	0.04	septmaxt	
	octmint	0.039	janmint	0.12
	aprmint	0.037	maymint	
DR94INCR	lat	0.28		
	decmaxt	0.24		
	novmaxt	0.23	lat	0.28
	febmaxt	0.22		
DR93HT	lat	0.17	long	
	octmaxt	0.17	elv	
	novmint	0.15	junmaxt	0.3
	novmaxt	0.15	aprprec	
DR94HT	loat	0.24		
	octmaxt	0.24	lat	0.29
	novmaxt	0.23	aprprec	
	marmaxt	0.22		

Table 8. Results of simple linear and backwards stepwise multiple linear regression against 3 geographic and 36 climatc variables (cont'd)

	Simple regression		Multiple regression	
Dependent variable	Climate variable	R^2	Climte variable	Max R^2
KE94FLSH	maymaxt	0.23	maymaxt	0.23
	junmaxt	0.23		
	aprmaxt	0.21		
	julmaxt	0.2		
KE94STOP	aprmaxt	0.046	marmint	0.14
	maymaxt	0.045	julprec	
	augmaxt	0.045	septprec	
	aprmint	0.044		
KE94INCR	lat	0.11	maymaxt	0.59
	decmaxt	0.1	septprec	
	septprec	0.1		
	octprec	0.09		
KE93HT	novmint	0.1	decmint	0.2
	decmint	0.08	janprec	
	octmaxt	0.074	aprprec	
	lat	0.073		
KE94HT	novmint	0.114	octmint	0.21
	octmaxt	0.113	novmint	
	marmaxt	0.11	aprprec	
	aprmaxt	0.1		
KE97SURV	elv	0.044	elv	0.0438
	septmaxt	0.037		
	marmaxt	0.037		
	aprmaxt	0.036		
KE04SURV	septmaxt	0.11	septmaxt	0.11
	augmaxt	0.1		
	julmaxt	0.1		
	aprmaxt	0.1		
SL94FLSH	novmint	0.352	octmaxt	0.39
	maymaxt	0.346	junprec	
	junmaxt	0.344		
	junprec	0.343		
SL94STRT	septprec	0.054	septprec	0.054
	octprec	0.052		
	long	0.046		
	decprec	0.042		
SL94INCR	septprec	0.14	septprec	0.14
	octprec	0.12		
	mayprec	0.098		
	long	0.087		
SL93HT	novprec	0.327	long	0.452
	mayprec	0.26	marprec	
	marmaxt	0.22		
	aprmaxt	0.2		
	maymaxt	0.18		
SL94HT	lat	0.09	junmint	0.26
	novmint	0.08	septmint	
	novmaxt	0.074	decmint	
	marmaxt	0.071		

Table 8. Results of simple linear and backwards stepwise multiple linear regression against 3 geographic and 36 climate variables (cont'd)

	Simple regression		Multiple regression	
Dependent variable	Climate variable	R^2	Climte variable	Max R^2
SL97SURV	septmaxt	0.13		
	octmaxt	0.127	septmaxt	
	novmaxt	0.11	junprec	0.21
	marmaxt	0.11		
SL97HT	lat	0.064		
	novmint	0.061		
	novmaxt	0.059	na	na
	marmaxt	0.059		
SL04SURV	septmaxt	0.077		
	marmaxt	0.074	elv	
	aprmaxt	0.071	augmaxt	0.11
	octmaxt	0.061		
SL04HT	novmint	0.069		
	octmint	0.056	long	
	junmaxt	0.052	novmint	0.14
	maymint	0.044	aprprec	
TB93HT	octmaxt	0.069		
	lat	0.062	lat	
	junmaxt	0.053	janmaxt	0.19
	novmint	0.051	mayprec	
TB94HT	novmint	0.238	julymint	
	marmaxt	0.197	octmint	0.34
	janmaxt	0.194	novmint	
	decmint	0.191	aprprec	
TB97HT	novmint	0.27		
	marmaxt	0.261	octmint	
	janmaxt	0.26	novmint	0.34
	decmint	0.254	decprec	
TB03SURV	lat	0.054		
	septprec	0.052	elv	0.09
	novmint	0.052	novmint	
	decmaxt	0.05		
TB03HT	decmint	0.149		
	novmint	0.144	octmint	
	marmint	0.132	novmint	0.19
	janmaxt	0.132	decprec	
TB03DIAM	janmaxt	0.33		
	marmaxt	0.32	janmaxt	
	febmaxt	0.33	aprprec	0.36
	octmaxt	0.31		
FRZ2T2	aprprec	0.049		
	junmint	0.044	julmint	
	julmint	0.043	febprec	0.11
	maymint	0.028	marprec	
FRZ3T1	septmaxt	0.148		
	marmaxt	0.147		
	aprmaxt	0.146	septmaxt	0.15
	janmaxt	0.141		
FRZ3T2	marmint	0.137		
	aprmaxt	0.134	marmint	0.14
	maymaxt	0.131		
	decmint	0.129		

Note: all variables are significant at $p < 0.05$ level.

MULTIVARIATE ANALYSIS

Variable Correlations

Many of the variables examined in this study were highly correlated. The Pearson correlation matrix based on the mean values for those measured variables in Sioux Lookout and Kenora trials is presented in Tables 9 and 10. Positive correlations were consistently displayed between growth variables. Generally, survival variables were negatively correlated with needle flush date. Specifically, 2004 survival in both trials had a significant negative correlation at the $p<0.05$ level with coefficients of -0.39 and -0.28, respectively. Growth variables were positively correlated with other growth variables within each trial. All the growth variables but 1997 height in Kenora were negatively correlated with date of elongation start, meaning that seed sources whose seedlings initiated elongation earlier were taller, on average. At the Sioux Lookout trial, the correlation between height variables and needle flush variables decreased with time, ranging from 0.316 for height at 1993 down to 0.058 for height at 2004.

Table 9. Pearson's correlation matrix of the variables measured in the Sioux Lookout trial based on provenance means

	SL94FLSH	SL94STRT	SL94STOP	SL94INCR	SL93HT	SL94HT	SL97SURV	SL97HT	SL04SURV	SL04HT	SL04DIAM
SL94FLSH											
SL94STRT	-0.082										
SL94STOP	0.035	-0.084									
SL94INCR	0.101	**-0.275**	**-0.301**								
SL93HT	**0.316**	-0.107	0.183	**0.272**							
SL94HT	**0.232**	**-0.199**	0.072	[illegible]	[illegible]						
SL97SURV	**-0.278**	0.014	0.089	-0.179	-0.065	-0.054					
SL97HT	0.174	-0.098	-0.120	[illegible]	**0.275**	[illegible]	**-0.166**				
SL04SURV	[illegible]	0.058	0.044	-0.090	-0.105	-0.041	[illegible]	-0.012			
SL04HT	0.058	-0.074	-0.053	[illegible]	0.145	**0.291**	-0.083	[illegible]	0.079		
SL04DIAM	**-0.192**	0.019	-0.086	**0.299**	**0.212**	**0.284**	-0.070	[illegible]	0.113	[illegible]	

Note: Bold means significant at the p< 0.05 level, values in grey shading mean significant at the p < 0.01 level

Table 10. Pearson's correlation matrix of the variables measured in the Kenora trial based on provenance means

	KE94FLSH	KE94STRT	KE94STOP	KE94INCR	KE93HT	KE94HT	KE97SURV	KE97HT	KE04SURV	KE04HT	KE04DIAM
KE94FLSH											
KE94STRT	0.058										
KE94STOP	-0.039	-0.029									
KE94INCR	**-0.223**	-0.088	-0.119								
KE93HT	0.085	-0.037	[illegible]	[illegible]							
KE94HT	0.022	-0.044	**-0.234**	[illegible]	[illegible]						
KE97SURV	-0.095	-0.152	**0.226**	**-0.202**	-0.005	-0.033					
KE97HT	[illegible]	0.029	-0.012	[illegible]	[illegible]	[illegible]	-0.102				
KE04SURV	[illegible]	0.028	**0.213**	0.113	-0.143	-0.075	[illegible]	[illegible]			
KE04HT	-0.004	-0.034	-0.079	**0.268**	0.191	**0.266**	-0.054	[illegible]	-0.080		
KE04DIAM	0.036	-0.002	-0.001	**0.194**	0.087	0.143	-0.179	[illegible]	-0.033	[illegible]	

Note: Bold means significant at the p< 0.05 level, values in grey shading mean significant at the P < 0.01

RESULTS OF PRINCIPAL COMPONENT ANALYSIS

The results of principal components analysis of the 30 retained variables are shown in Table 11. Eigenvalues, the percentage of total variation attributed to each component and the associated component loadings are presented for first three principal component axes. The first three PC axes accounted for 31%, 10% and 7% of total variation respectively. The other PC axes showed low eigenvalues (less than 2) and contributed little to the explained variation; thus, they were not considered for the multiple regressions against climatic variables in the further analysis. In eigenvector one, all the variable loadings were positive except Kenora 2004 survival, Sioux Lookout 1997 and 2004 survival and Sioux Lookout 1994 elongation start date. Component loadings ranged from values of 0 for the FRZ2T2 to 0.26 for the TB94HT and GH94FLSH. Loadings for phenological variables were intermediate. The high loading values for the height growth variables, in conjunction with the uniformly positive signs for almost all the variables, indicated that the first axis mainly represents growth potential (i.e., seed source with the greatest potential for growth generally had the highest growth at each trial). Except for the Sioux Lookout elongation start date variable, the loadings for phenological variables were positive which indicted that the sources having the greatest growth potential flushed later and started and stopped elongation later. Positive signs for the freezing variables suggested that seed sources with the greatest growth potential suffered the greatest frost damage.

The second component displayed high loadings for the survival variables from 0.27 down to 0.12; the loadings for all the phenological variables, two of the three freezing variables and the Greenhouse variables were negative, while the loadings for the height growth variables were positive for field trials. The biological significance of second axis is less obvious for the biological significance than in the first one. The mixed signs for the loadings indicates that the second axis is generally a descriptor of phenological characteristics; i.e. the bigger the positive value, the later the needles flush and the smaller survival potential. Signs changed for flush variables and freezing variables, but did not change for height variables at the three field trials and the Thunder Bay nursery trial. This implies that the earlier flushing sources with higher height growth potential generally showed a reduction in height growth at the field trials but not at the Greenhouse. Less cold-hardy sources had higher survival potential, higher growth potential, flushed earlier, and started elongation earlier.

The third component was dominated by performance at the greenhouse trial, with strong loadings from greenhouse height growth variables. The third component had an eigenvalue of 2.22, and accounted for 7 percent of the total variance. The biological significance of this axis is not obvious. The other 27 axes are not shown, as their contribution to the total variance is only 52 percent.

Table 11. Principal components analysis results for 30 growth, phenological and freezing characters

Principal Components			
PCA axis	1	2	3
Eigenvalues	9.27	3.10	2.22
Difference	6.17	0.88	0.45
Percent variation	0.31	0.10	0.07
Cumulative variation	0.31	0.41	0.49
Variables*	Components Loadings		
GH94FLSH	0.26	-0.21	0.03
GH94STRT	0.16	-0.21	-0.11
GH94INCR	0.16	-0.21	0.25
GH93HT	0.15	-0.15	0.26
GH94HT	0.19	-0.21	0.26
DR94FLSH	0.23	-0.22	-0.07
DR94INCR	0.17	0.03	0.35
DR93HT	0.23	0.13	-0.31
DR94HT	0.23	0.03	-0.04
KE94FLSH	0.13	-0.30	-0.25
KE94INCR	0.16	0.21	0.30
KE93HT	0.22	0.22	-0.20
KE94HT	0.23	0.25	-0.11
KE04SURV	-0.05	0.12	0.16
SL94FLSH	0.21	-0.19	-0.11
SL94STRT	-0.06	-0.15	-0.05
SL94INCR	0.16	0.19	0.34
SL93HT	0.21	0.25	-0.19
SL94HT	0.22	0.27	-0.06
SL97SURV	-0.10	0.23	-0.02
SL97HT	0.16	0.09	0.20
SL04SURV	-0.09	0.27	0.02
TB93HT	0.19	0.16	-0.22
TB94HT	0.26	0.13	-0.01
TB97HT	0.25	-0.01	0.11
TB03HT	0.18	0.01	-0.03
TB03DIAM	0.23	-0.03	0.10
FRZ2T2	0.00	0.01	-0.01
FRZ3T1	0.11	-0.21	-0.22
FRZ3T2	0.11	-0.16	-0.07

FLSH: Number of days starting on May 1st.
INCR: Increment of height
STRT: Number of days starting on May 1st.
FRZ: Percent damage relative to control samples (Freezing trial dates and temperatures).

The results of the correlation between the first three PCA axes against the 36 climatic variables are shown in Table 12. All but nine correlations were significant; non-significant correlation values were obtained for monthly minimum temperature in July, August and monthly precipitation from January to April, July, August and December. In other words all 12 correlations of maximum temperature with the first PCA were significant, showing high positive correlation coefficients ranging from 0.68 down to 0.56. Of the five correlations of precipitation variables against the first PC axis, all but November precipitation (-0.27) were positive. This result indicated that the higher the maximum and minimum temperature, the higher growth potential was. For the November precipitation, the opposite was true. These results demonstrate the high level of intercorrelation of the climatic variables and the large component of adaptive variation expressed by the first PCA axis. All the monthly maximum and minimum temperature values except the July minimum temperature are significant against the second PCA axis correlations. These correlations are negative, indicating that needle flush and elongation occur earlier when the values of these climate variables are higher. Precipitation variables except June precipitation (-0.4), had positive correlations with phenology (second PCA axis). This means that needle flush occurs earlier and survival potential is higher when precipitation values are higher. For the first two PCA axes, the strongest correlations generally occurred between monthly maximum temperatures, although very strong correlations were also found with the first axis for November and December minimum temperature. No significant correlation was found for maximum temperature. All the precipitation variables except November were found to have significant correlation with this axis.

Table 12. Correlation of PCA Axes 1, 2 and 3 factor scores with 36 climatic variables

Climate variable	Component		
	prin1	prin2	prin3
janmaxt	**0.669**	**-0.325**	0.039
febmaxt	**0.665**	**-0.311**	0.043
marmaxt	**0.679**	**-0.350**	0.008
aprmaxt	**0.625**	**-0.428**	-0.093
maymaxt	**0.634**	**-0.412**	-0.114
junmaxt	**0.624**	**-0.403**	-0.141
julmaxt	**0.577**	**-0.419**	-0.137
augmaxt	**0.562**	**-0.435**	-0.132
septmaxt	**0.646**	**-0.397**	-0.075
octmaxt	**0.671**	**-0.296**	-0.001
novmaxt	**0.659**	**-0.284**	0.041
decmaxt	**0.615**	**-0.219**	0.097
janmint	**0.480**	**-0.342**	-0.098
febmint	**0.512**	**-0.363**	-0.119
marmint	**0.527**	**-0.392**	-0.127
aprmint	**0.472**	**-0.404**	-0.170
maymint	**0.372**	**-0.315**	**-0.209**
junmint	**0.200**	**-0.202**	**-0.211**
julmint	0.108	-0.157	**-0.201**
augmint	0.114	**-0.217**	**-0.195**
septmint	**0.220**	**-0.293**	-0.194
octmint	**0.440**	**-0.321**	-0.170
novmint	**0.652**	**-0.296**	-0.065
decmint	**0.627**	**-0.322**	-0.009
janprec	-0.091	**0.315**	**0.219**
febprec	-0.030	**0.343**	**0.221**
marprec	-0.066	**0.287**	**0.241**
aprprec	0.176	-0.154	**0.211**
mayprec	**0.343**	0.001	**0.226**
junprec	**0.550**	**-0.396**	-0.024
julprec	0.070	0.106	**0.254**
augprec	-0.140	**0.202**	**0.260**
septprec	**0.281**	0.162	**0.255**
octprec	**0.338**	0.017	**0.253**
novprec	**-0.273**	**0.210**	0.155
decprec	0.023	**0.227**	**0.239**

Note: values in bold are significant at the $p < 0.05$ level.

MULTIPLE REGRESSION ANALYSIS

Backward stepwise multiple linear regression analysis was used to examine the relationship between the PCA summary variables, dependent variables and climate variables (independent variables).

Results of multiple regression analysis among the first three PCA axes and the 36 climatic variables are presented in Table 13. Regression of the first PCA axis against December maximum temperature, November minimum temperature and April precipitation had an r^2 value of 0.55. Sources with high December maximum temperature, high November minimum temperature and low amounts of April precipitation were predicted to have higher growth potential. Seed sources with the highest positive scores on the first PCA axis had December maximum temperature of approximately -10°C, and November minimum temperature of -9°C and April precipitation of about 35 mm, while sources with the lowest scores had December maximum temperature of approximately -12°C, November minimum temperature of -10°C and April precipitation of about 42 mm.

Regression of the second axis against August maximum temperature, November minimum temperature and June precipitation had an r^2 value of 0.237. Sources from areas with low August maximum temperatures coupled with colder November minimum temperatures and lower amounts of June precipitation were predicted to needles flush earlier and lower survival potential. Seed sources with highest scores on this axis to the southwest of study area had August maximum temperature 24.1°C, -10.3°C in November minimum temperature and 89.2 mm June precipitation, while sources in the north (lower scores) had maximum temperatures of 23°C in August, November minimum temperature of -8.3 °C and 108 mm June precipitation. Regression of the third PC axis against climatic variables was only explained (significant at $p<0.05$ level) by August precipitation with an r^2 of 0.06.

Table 13. Results of regression of PCA axes against climatic variables for 102 jack pine seed sources in northwest Ontario.

Dependent Variables	Independent variable	Coeffeicent	t value	Tolerance	Significance
	constant	13.70			
PCA 1	decmaxt	0.51	5.15	0.35	0.00
$R^2 = 0.55$	novmint	0.62	4.16	0.55	0.00
	aprprec	-0.08	-3.71	0.55	0.00
	constant	31.00	3.75		
PCA 2	augmaxt	-0.83	-3.13	0.30	0.00
$R^2 = 0.237$	novmint	0.68	2.22	0.22	0.029
	junprec	-0.06	-2.13	0.28	0.034
PCA 3	constant	-5.44			
$R^2 = 0.06$	augprec	0.06	2.69	1.00	0.01

Factor scores were predicted by GIS based on the regression equations developed using the climatic variables. The new factor scores reflect the adaptive variation explained by these models. Figures 7 and 8 graphically summarize the geographic pattern of variation predicted by the first two multiple regressions in Table 13. The trend surface diagram produced by the set of scores predicted for the first component is seen in Figure 7. Figure 7 can be interpreted as the pattern of adaptive variation in terms of growth potential in northwest Ontario. Generally, sources with greater growth potential, corresponding to higher positive scores on the first axis, were from the southwest portion of the sampled area. Sources with reduced growth potential were found in the north portion. Clinal variation with latitude is shown. Figure 8 shows the pattern of adaptive variation in terms of phenological characteristics and survival. Sources with the lower scores, indicating earlier needles flush and higher survival potential were from the south-western portion of study area.

Extreme positive scores were predicted for the north-eastern portion of the sampled area. The sources in close proximity to Lake of the Woods also showed early needles flush and greater survival potential. The pattern of variation based on the second axis PCA scores follows a gently longitudinal trend. The map produced by the third PC factor scores is not shown here due to its more complex geographic pattern and the lower coefficient of determination ($r^2 = 0.06$) against the climatic variable.

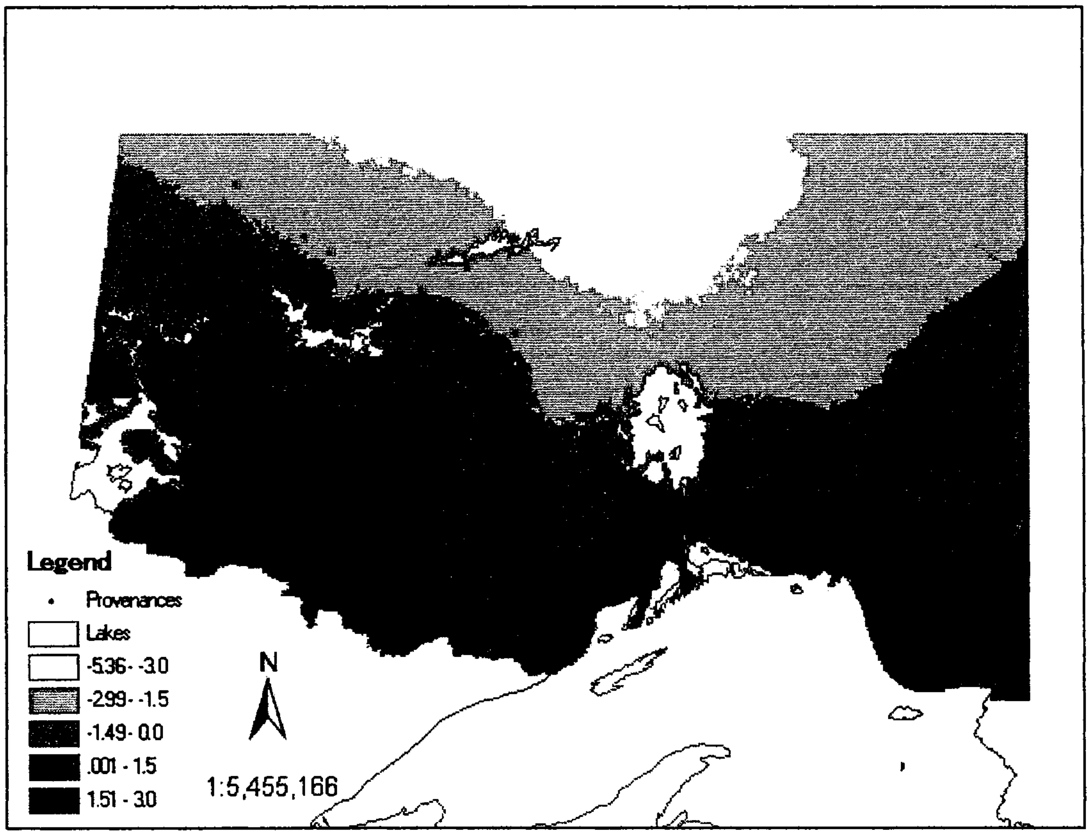


Figure 7. Predicted factor scores from the PC1 regression model based on OCM2

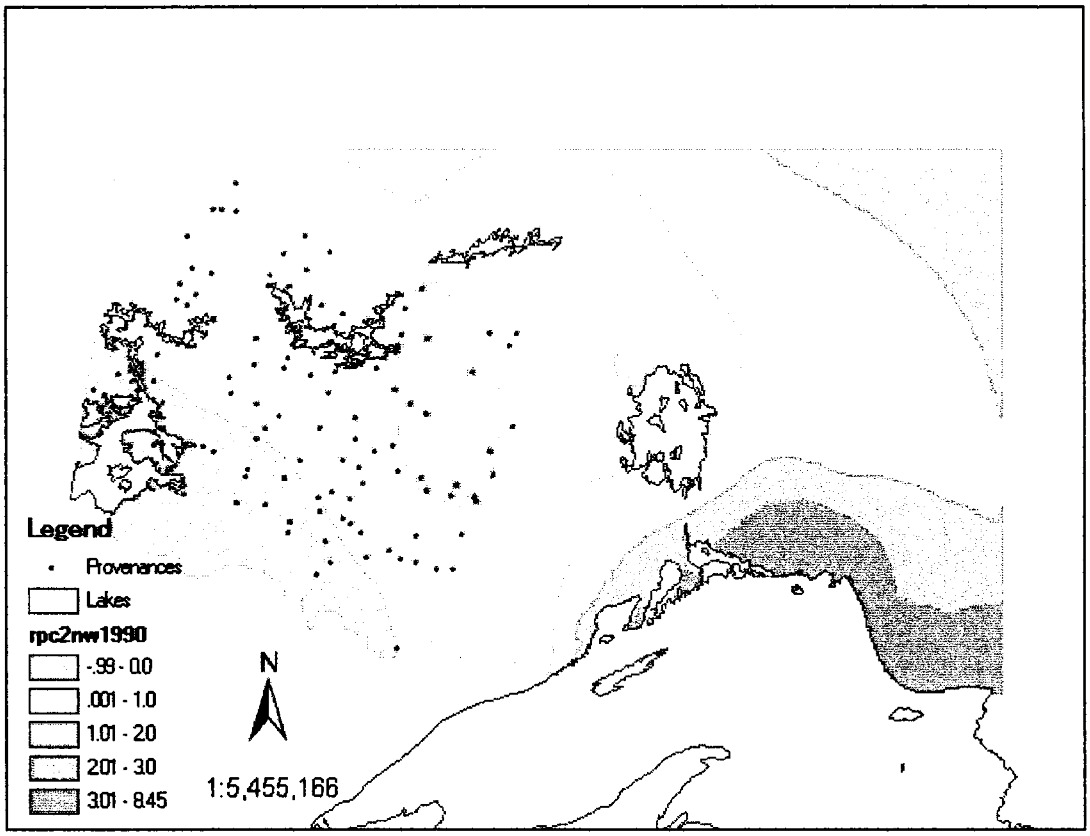


Figure 8. Predicted factor scores from the PC2 regression model based on OCM2

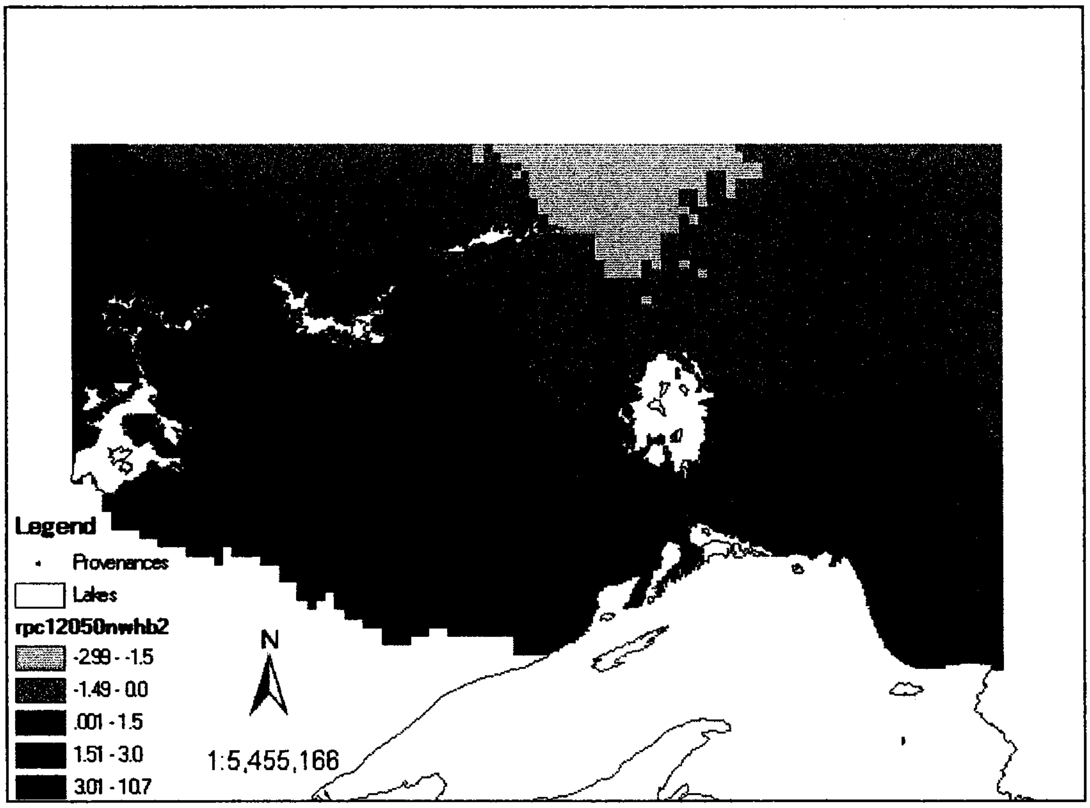


Figure 9. Predicted factor scores from the PC1 regression model based on HADCM3B2 projected for 2050

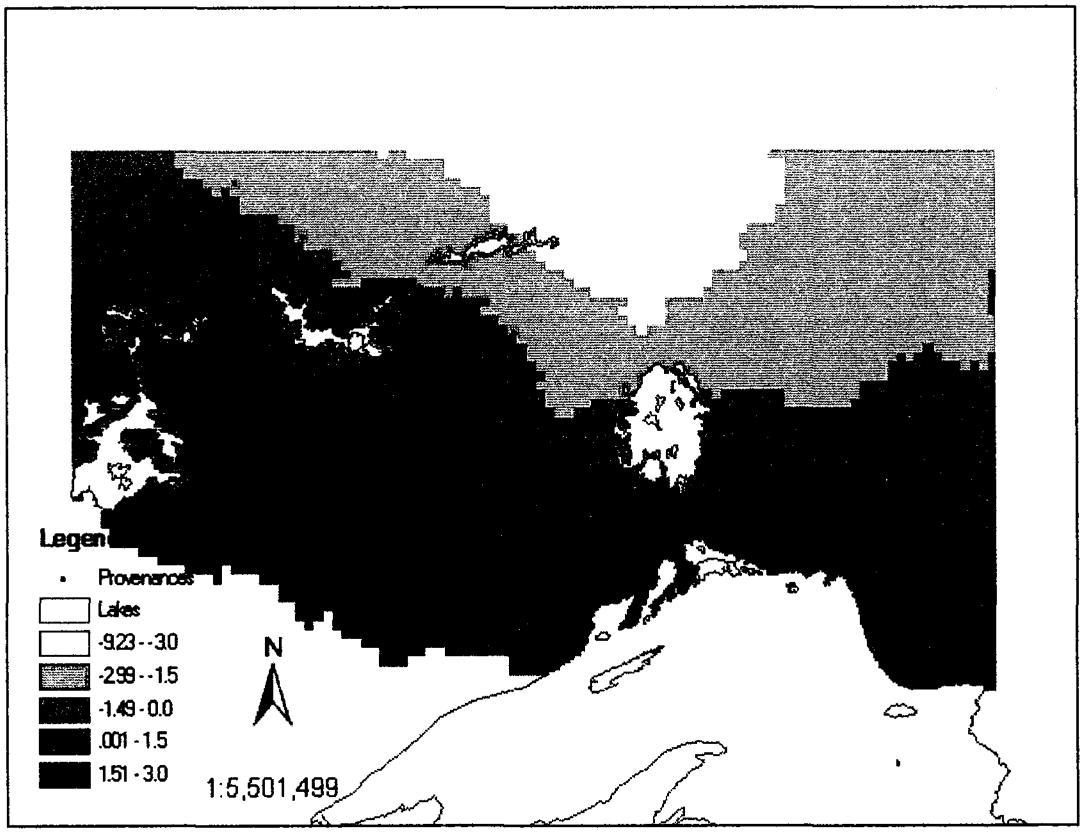


Figure 10. Predicted factor scores from the PC1 regression model based on HADCM3B2 projected for 2099

Figures 9 and 10 show the pattern of adaptive variation of growth potential based on HADCM3B2 projected for 2050 and 2099. They demonstrate similar trends as Figure 7, which is based on OCM2. By 2050, the color ramp moves to the more northern portion of the study area, which means sources from this area will have higher growth potential in the future in the sampled area than those in the current conditions (Fig.7). By 2099, the northward shift is not very obvious compared with the map projected to 2050, but Figure 9 still shows higher growth potential when compared with Figure 7. Figures 11 and 12, based on CGCM2A2, show a moderately different growth potential trend (predicted for 2050 and 2099) when compared with Figure 7. The growth potential decreases from the southwest to the northeast portion of this map by 2050 in Figure 11. Figure 12 shows a different pattern of growth potential based on GCCM2A2 for 2099. All sampled area show low growth potential with the lowest growth potential in a small area in the south and a bigger area in the north of the sampled area (Fig. 12). Figures 13-14 and 15-16, show predicted factor scores from PC2 regression models based on HADCM3B2 and CGCM2A2, respectively. These figures show the cline of adaptive variation of phenology and survival characteristics. Compared with Fig. 8, by 2050, sources from the west portion of the sampled area will show earlier needle flush and lower survival potential (Fig. 13). By 2099, the longitudinal trend is not as evident, with early needle flush and low survival potential moving to the east portion of the study area (Fig. 14). The total sampled area shows the earlier needle flush and lower survival potential by 2050 based on CGCM2A2 (Fig. 15). By 2099, sources with lower survival potential and earlier needle flush will come from the west portion of the sampled area compared with Fig. 8. Compared with Fig.13 and 14, Figures 15 and 16, based on CGCM2A2, show earlier needle flush and lower survival potential.

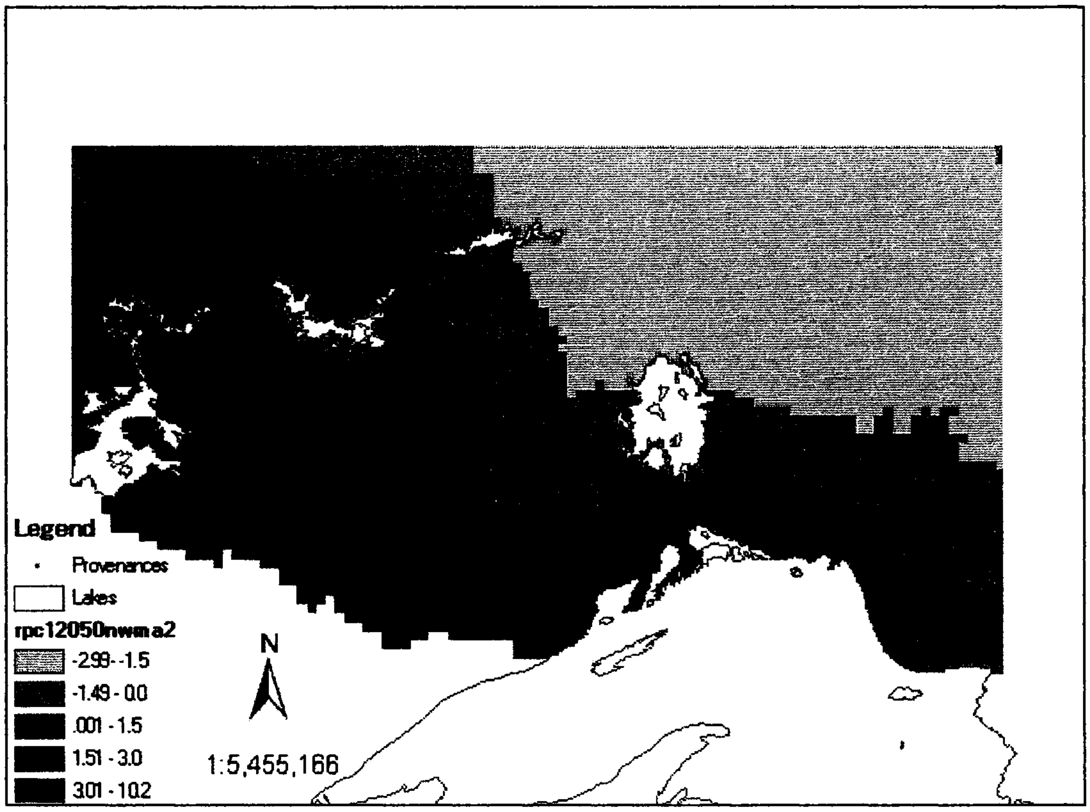


Figure 11. Predicted factor scores from the PC1 regression model based on CGCM2A2 projected for 2050

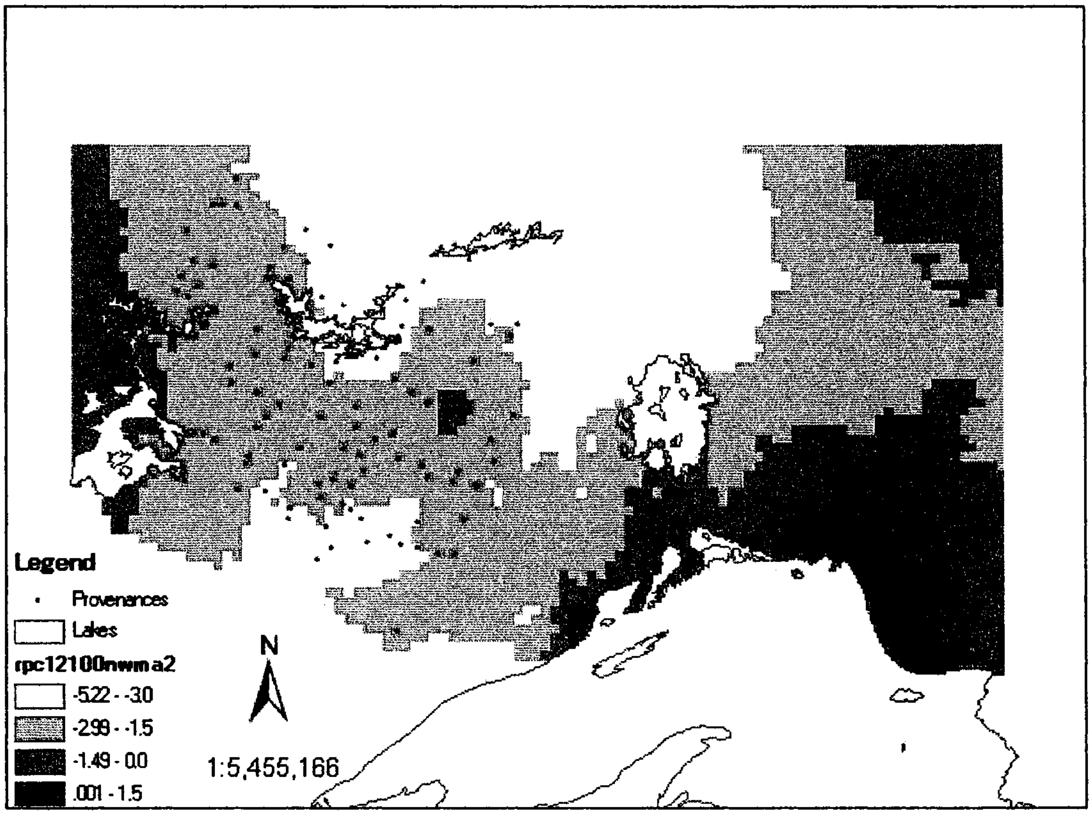


Figure 12. Predicted factor scores from the PC1 regression model based on CGCM2A2 projected for 2100

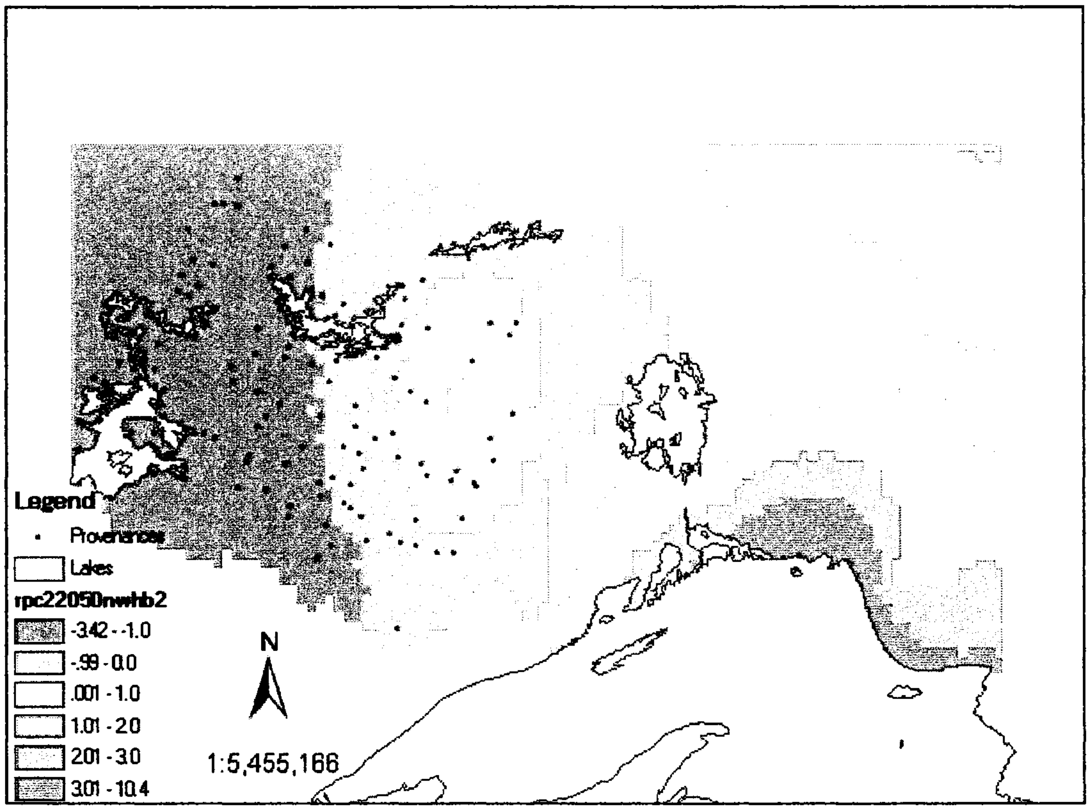


Figure 13. Predicted factor scores from the PC2 regression model based on HADCM3B2 projected for 2050

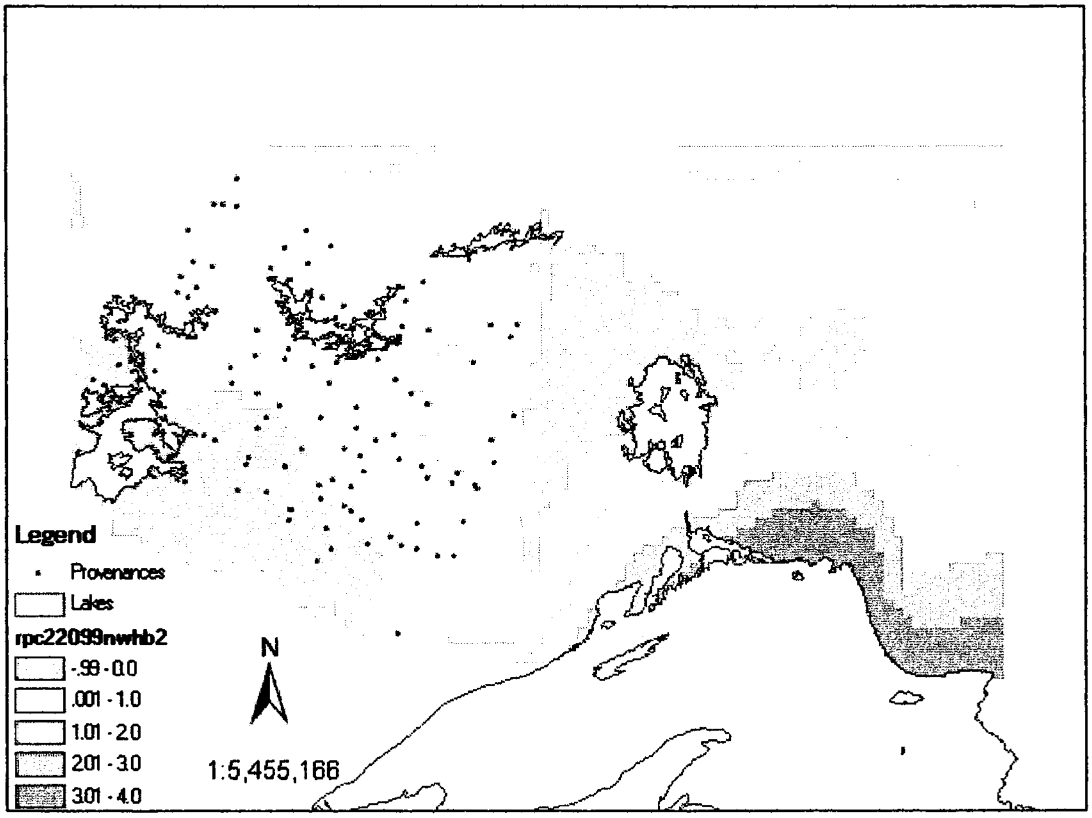


Figure 14. Predicted factor scores from the PC2 regression model based on HADCM3B2 projected for 2099

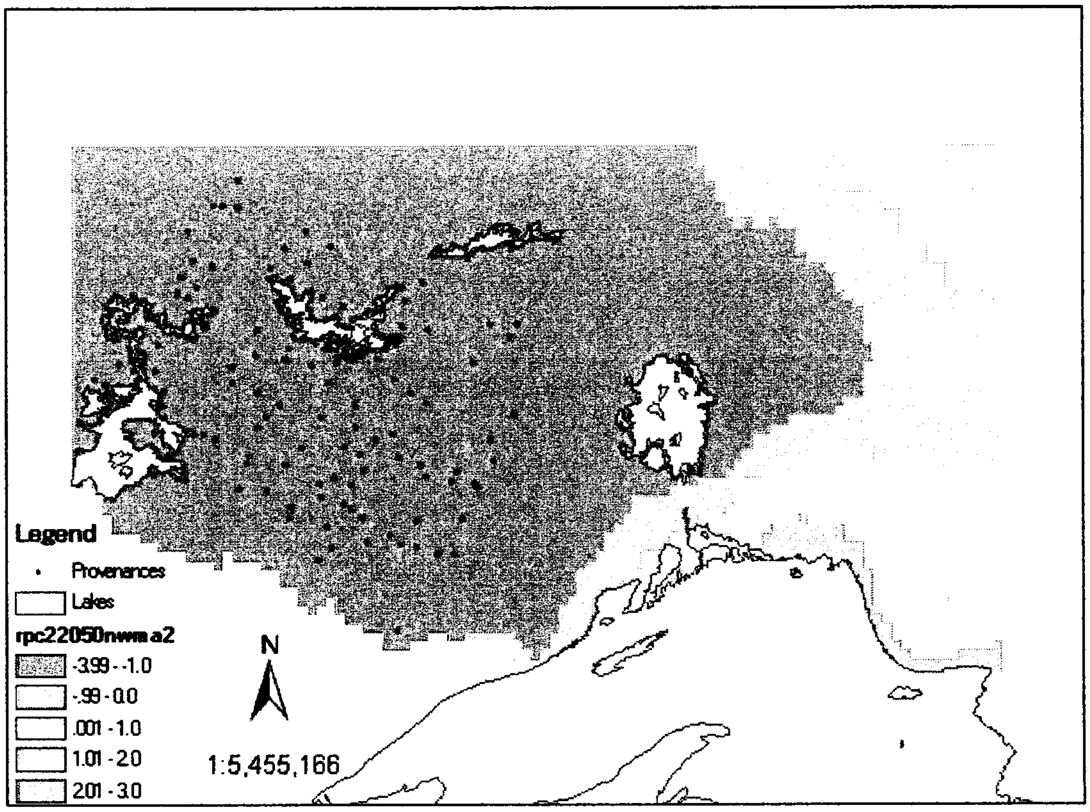


Figure 15. Predicted factor scores from the PC2 regression model based on CGCM2A2 projected for 2050

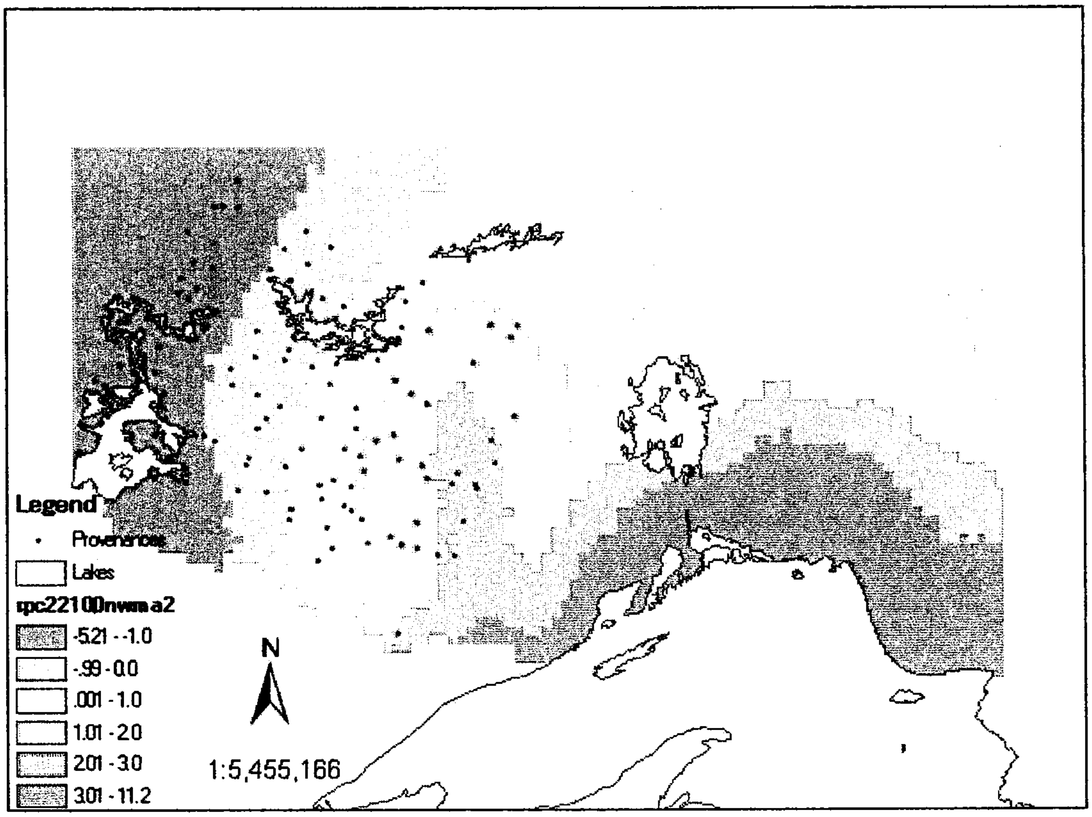


Figure 16. Predicted factor scores from the PC2 regression model based on CGCM2A2 projected for 2100

FOCAL POINT SEED ZONES

The r^2 values obtained from regressions for PC1 and PC2 axis against climate variables are 55 and 24 percent. The first two PCA axes account for 31 and 10 percent, respectively, of the variation among seed sources (total of 41%) and were used to generate focal point seed zones in the northwestern Ontario area. In these maps, the focal point is represented by a red star; the three different shades of green represent areas within 1-3 standard deviations from the focal point. The darker the color, the greater the similarity. No shading indicates that the area is outside the range of 3 standard deviations around the focal point, suggesting that these areas are not recommended for seed transfer.

A series of focal point seed zones based on focal point (49.5°N, 92.5°W) are presented here based on current climate condition (OCM2) and future climate conditions (CGCM1, HADCM3A2, HADCM3B2, CGCM2A2, CGCM2B2 and CSIROB2). Another series of seed zones is shown in Appendix V.

Figures 17 through 33 show both present and future focal point seed zones. Future focal point seed zones include where seed should come from now to be best matched in the future to its planting location (*Seed From*), and where seed should go from a given location to best match future climate conditions (*Seed To*) based on the six climate change scenarios projected for the middle of this century (2050) and the end of this century (2099). Figure 17 shows a seed zone based on a focal point from the central portion of the study area in northwestern Ontario (49.5°N, 92.5°W). It shows suitable areas across almost all of the range, except in a band occurring from the most northwest to most northeast portion of the study area. This figure represents a band of adaptive similarity ranging from the northwest to southeast. The major trend is determined by the first PCA axis.

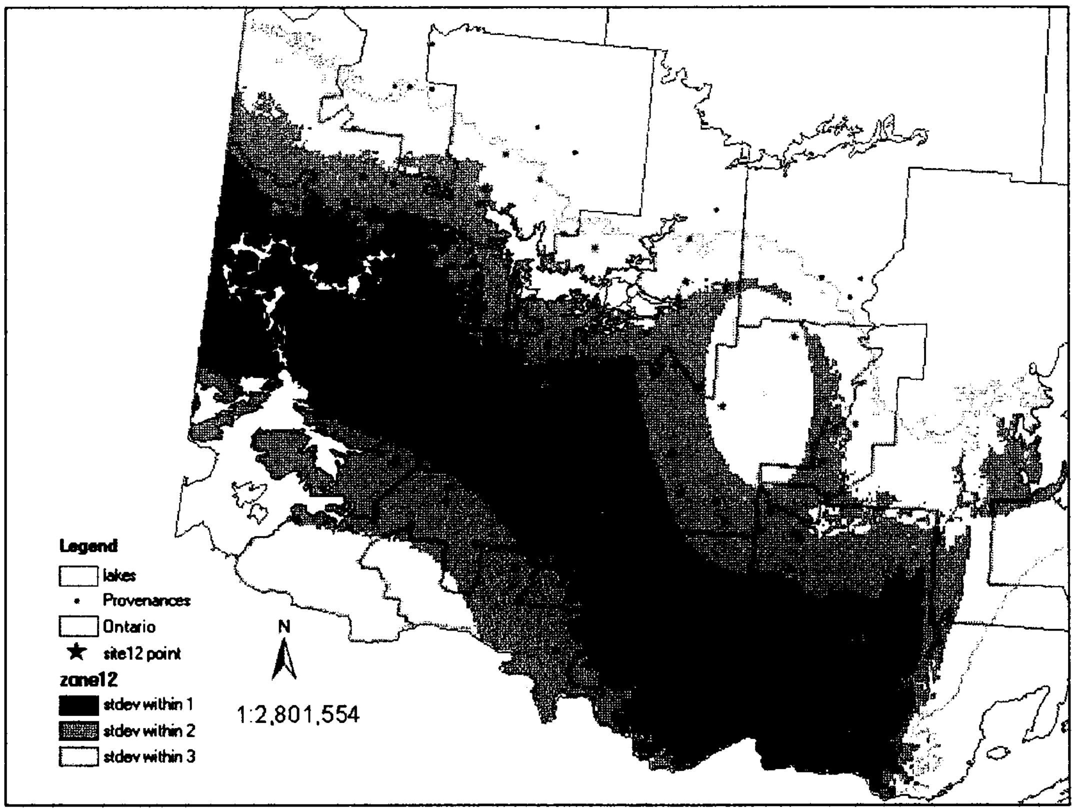


Figure 17. Focal point seed zones at coordinate 49.5°N, 92.5°W based on OCM2

Focal point seed zone methodology allows for use of predicted future climate models to show anticipated changes in seed zones resulting from climate change. Figures 18 though 33 show *Seed To* and *Seed From* based on different climate change models projected for the middle (2050) and the end (2099) of this century. Taking the same focal point (49.5°N, 92.5°W) as an example, *Seed To* and *Seed From* based on CGCM1 projected for 2040-2069 are shown in Figures 18 and 28. By 2069, seed sources from this focal point should be transferred to the north and northeast portion of the range in order to be best matched future climate condition (Fig. 18). An area between Lac Seul and Lake ST. Jonsoph demonstrates the greatest suitability (within 1 standard deviation of the focal point); the east part of Lake Woods in this range is not suitable for this location by 2069. When examining the entire Ontario area, another area, northeast of Lake Nipigon, shows the most suitable potential site for seed sources to be used at this focal location. Shifting the concept, by 2069, seed sources should come from the south and southwest portion of the study area to best match the future condition (Fig. 28). No dark green area remains is left in this seed zone, which means that by 2069 the most suitable seed sources (within 1standard deviation of the focal point) for this focal site have disappeared from northwestern Ontario area.

Figures 19 though 27 show where seed should transfer to from a given location (the selected focal point), to best match the future climate conditions. Figures 19, 21, 23, 25, 26 and 27 show the future focal point seed zones (*Seed To*) for the middle of this century (2050) based on future climate models HADCM3A2, HADCM3B2, CGCM2A2, CGCM2B2 and CSIROB2. An evident trend is that all seed zones for the current climate condition shift northward or north-eastward to best match the climate conditions predicted for the middle of this century (2050). Figure 19 generally represents a band of seed zones based on HADCM3A2 by 2050 ranging from the northwest to the southeast, and then to the eastern portion of the study area, extending through Lake Nipigon. Figure 21, based on HADCM3B2, shows a different seed zone which winds in a dragon-like fashion west and east, with a large suitable area in Quebec. The west and south portions of this study area are not suitable sites for seed sources obtained from the focal point by 2050.This differs from the seed zones that are based on HADCM3A2. Figures 23 and 25 show *Seed To* based on future climate models CGCM2A2 and CGCM2B2, respectively, projected for 2050. Two bands formed this seed zone; one ranges from the north to the southeast and the other starts from the south of Lake Nipigon and continues into Quebec (Fig. 23). The difference between these two maps lies in that Fig. 23 shows a shift of the northern band eastward, and the most suitable areas (within 1standard deviation) have appeared.

Figure 27 shows a *Seed To* based on CSIROB2 projected for 2050. Compared with other seed zones for 2050 based on different climate scenarios, Fig. 27 shows little suitable area for the seed sources from this focal point; the north band, especially, is reduced to a tiny area along the west shore of James Bay.

By the end of this century, how do these seed zones change based on different climate scenarios? Future focal point seed zones based on HADCM3A2 projected for 2050 and 2099 show similar trends (Fig. 19 and Fig. 20), although seed zones for 2099 (Fig. 20) expands within the study area by 2099 and shrinks in the east near Lake Nipigon. A similar trend is seen in Figures 21 and 22 based on the HADCM3B2. Fig. 22 shows more suitable area in northwestern Ontario, but Quebec is no longer suitable by 2099. By the end of this century, no area in Ontario is suitable for planting of seed sources from the focal point based on CGCM2B2 (Fig. 26) and CSIROB2 (not shown).

Figures 28 through 33 show the future focal point seed zones (*Seed From*) based on these different future climate models. Fig. 28 through 31 all show seed sources should come from the southwest today, to best match the future climate condition at the focal point site. Fig. 29 and 30 show very similar zones based on HADCM3A2 projected for 2050 and 2099. Figure 30 (for 2099) shows more suitable area (within 2 Std. dev. from focal point) for planting. *Seed From* maps based on HADCM3B2 for 2050 and 2099 are shown in Fig. 31 and 32, respectively. Figure 32 shows larger suitable areas when compared with Fig. 31, which means that by the end of this century, there are more seed sources from this zone that match the future climate conditions for this focal point. Under CGCM2A2, no seed sources are suitable for the focal point in the sampled area in order to match the climate condition in 2050. Seed sources should come from the north portion of the sampled area to best match the 2099 condition for the focal point (Fig. 33), which contrasts sharply with recommendations based on other climate change scenarios. Examination of the seed zones based on the other future climate scenarios indicates that, by the end of this century, no more seed sources from this study area are suitable for the focal point based on the CGCM2A2, CGCM2B2 and CSIROB2; especially for CGCM2B2, even by the middle of this century, no seed sources from sampled area are suitable for this focal point.

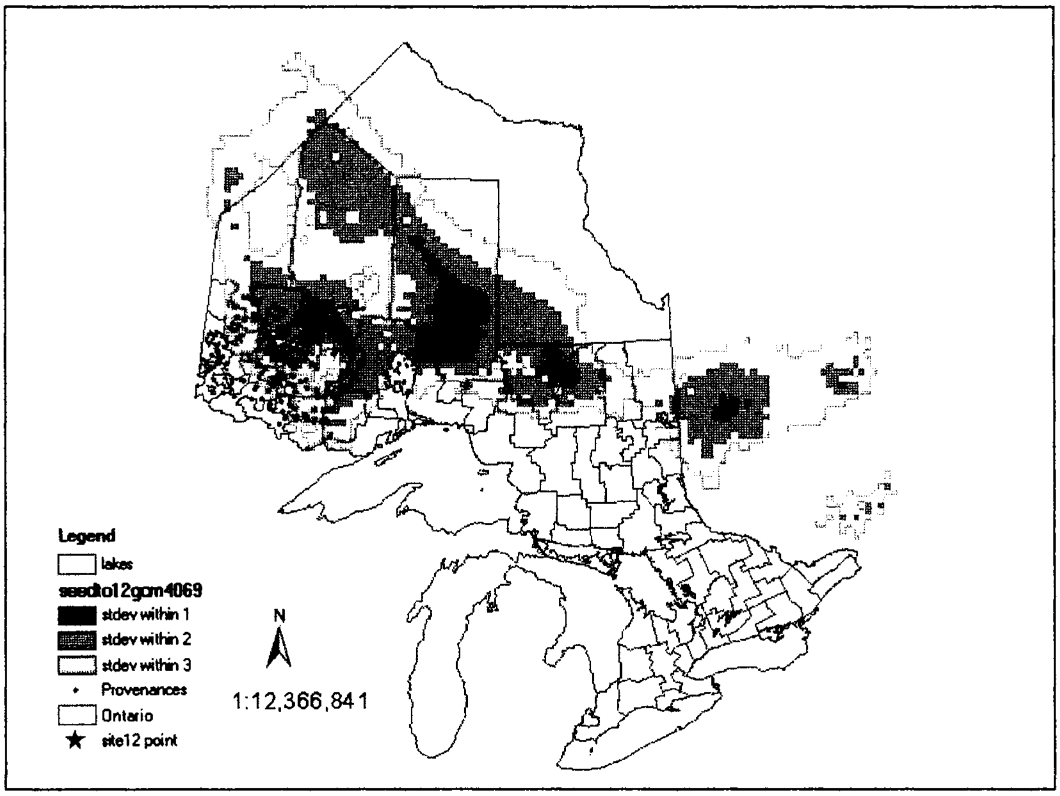


Figure 18. Best '*Seed To*' transfer zone in 2069 for seed from point 49.5°N, 92.5°W based on CGCM1

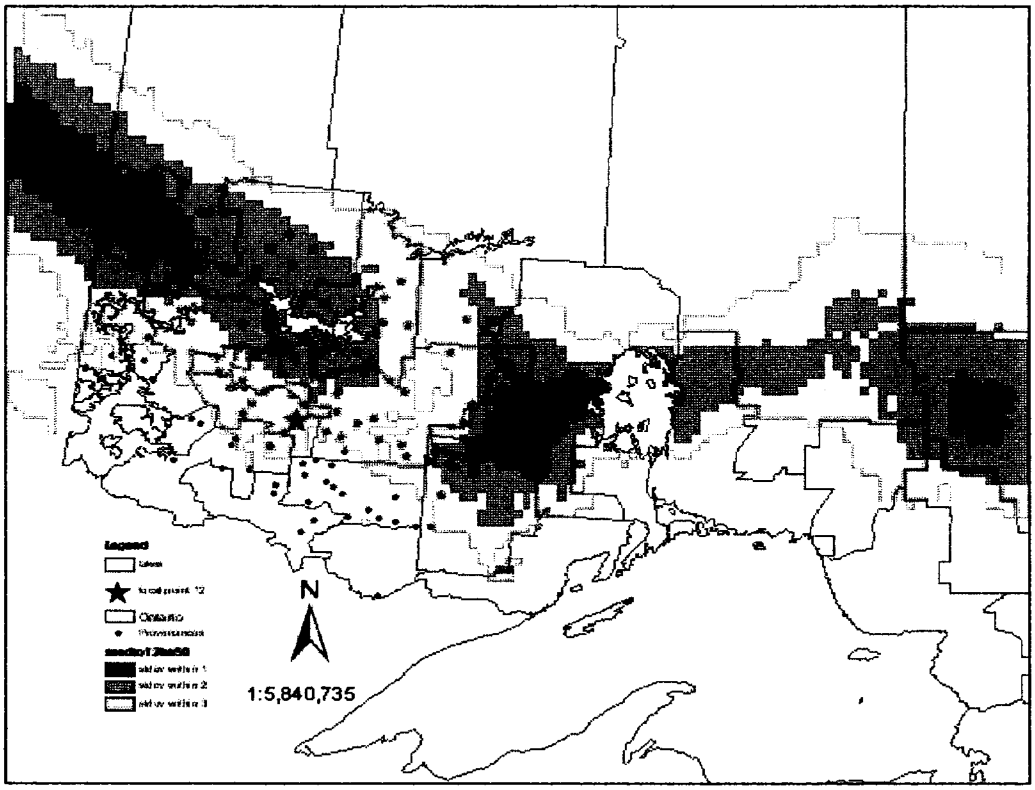


Figure 19. Best '*Seed To*' transfer zone in 2050 for seed from point 49.5°N, 92.5°W based on HADCM3A2

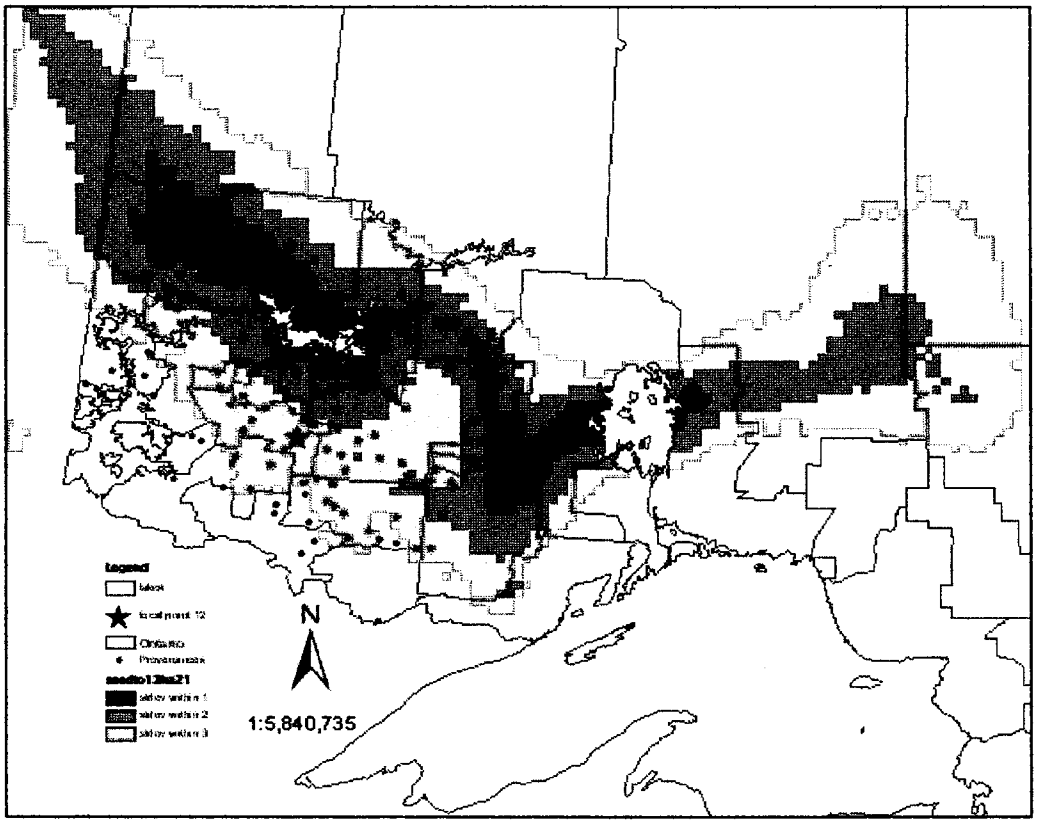


Figure 20. Best '*Seed To*' transfer zone in 2099 for seed from point 49.5°N, 92.5°W based on HADCM3A2

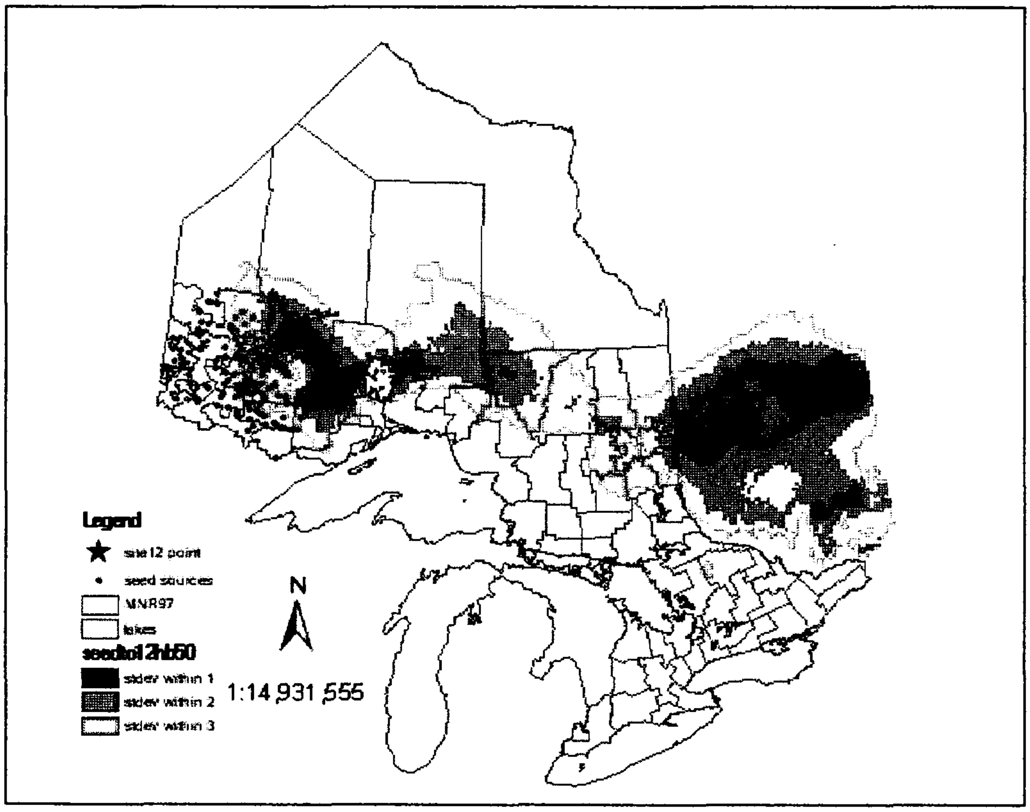


Figure 21. Best '*Seed To*' transfer zone in 2050 for seed from point 49.5°N, 92.5°W based on HADCM3B2

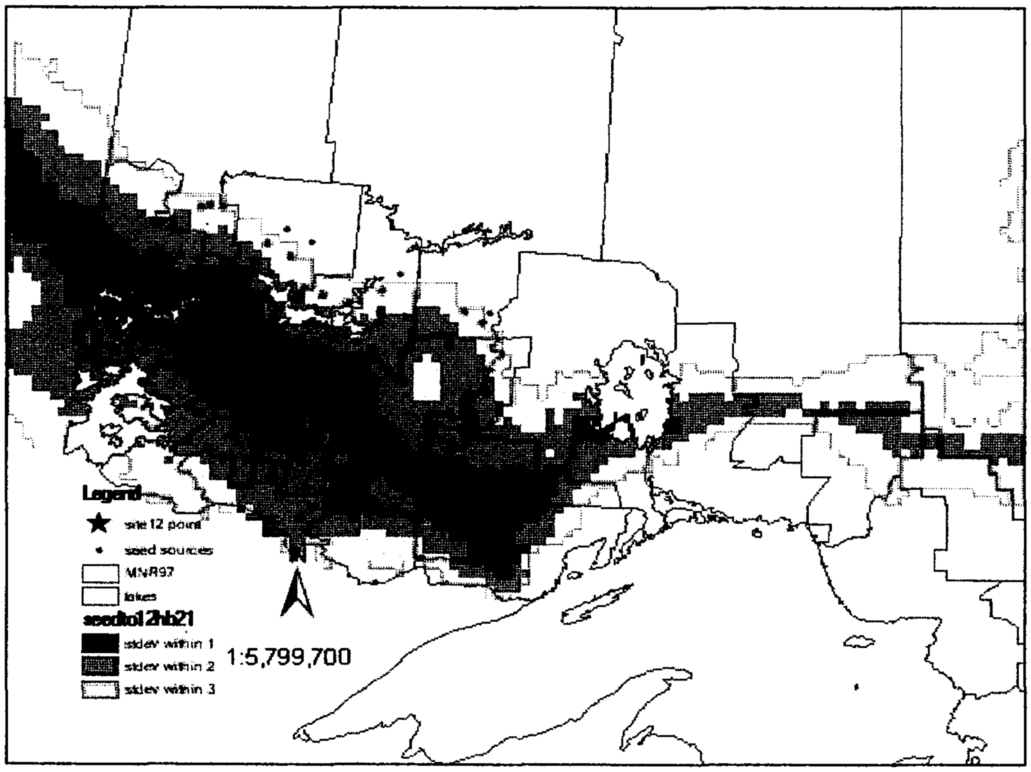


Figure 22. Best '*Seed To*' transfer zone in 2099 for seed from point 49.5°N, 92.5°W based on HADCM3B2

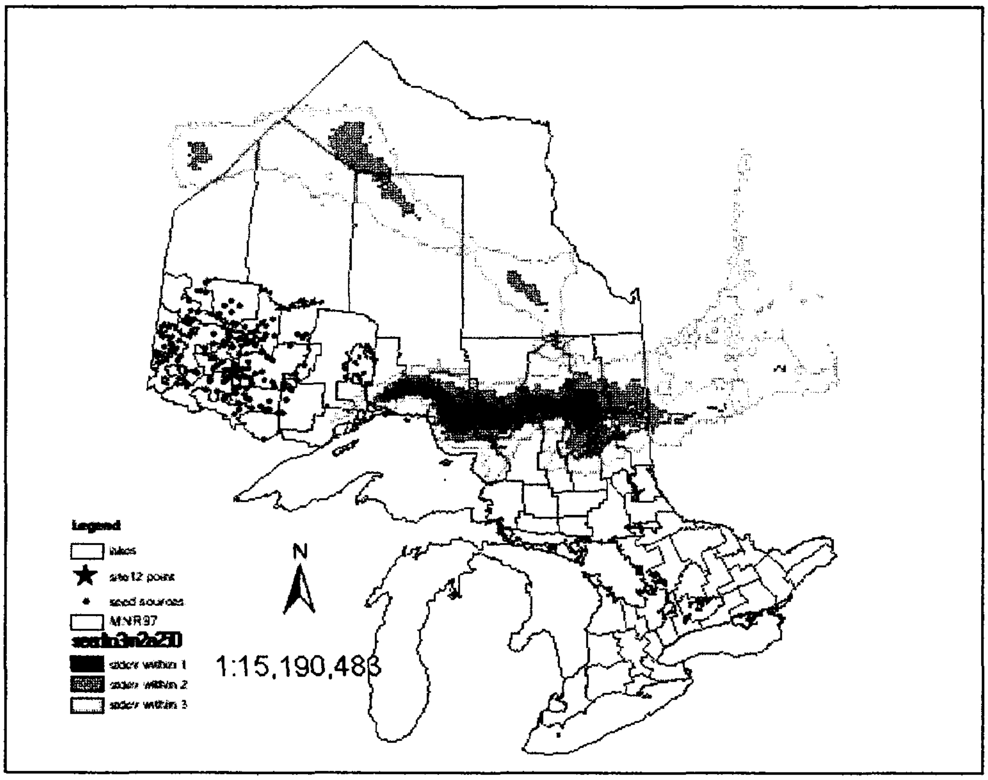


Figure 23. Best '*Seed To*' transfer zone in 2050 for seed from point 49.5°N, 92.5°W based on CGCM2A2

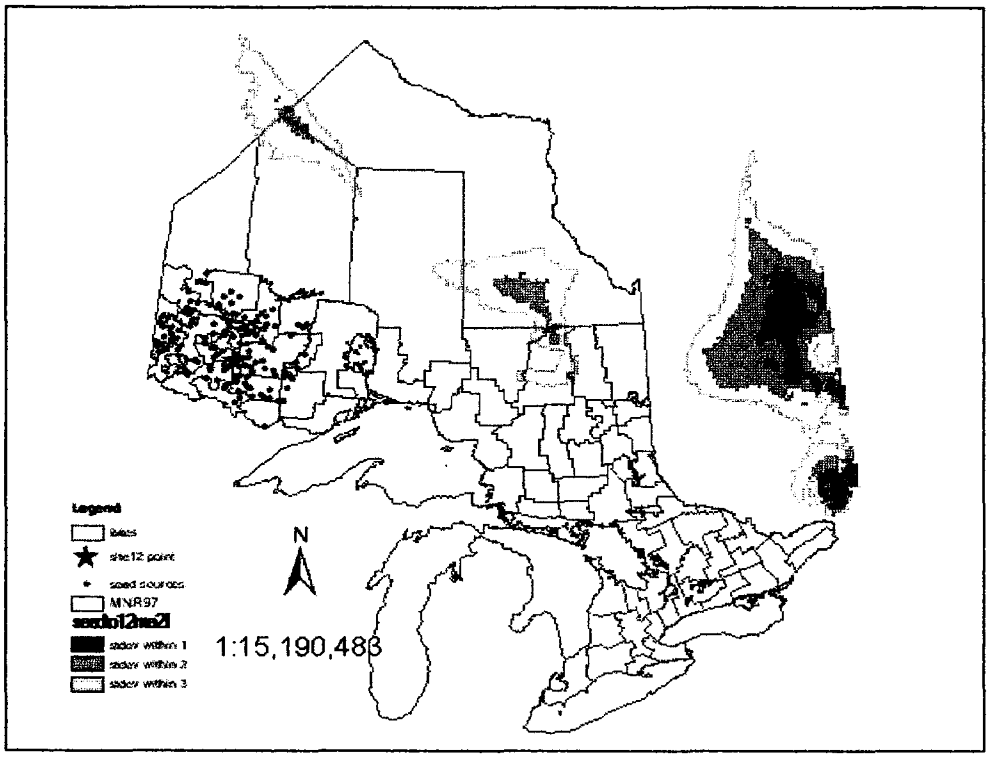


Figure 24. Best '*Seed To*' transfer zone in 2099 for seed from point 49.5°N, 92.5°W based on CGCM2A2

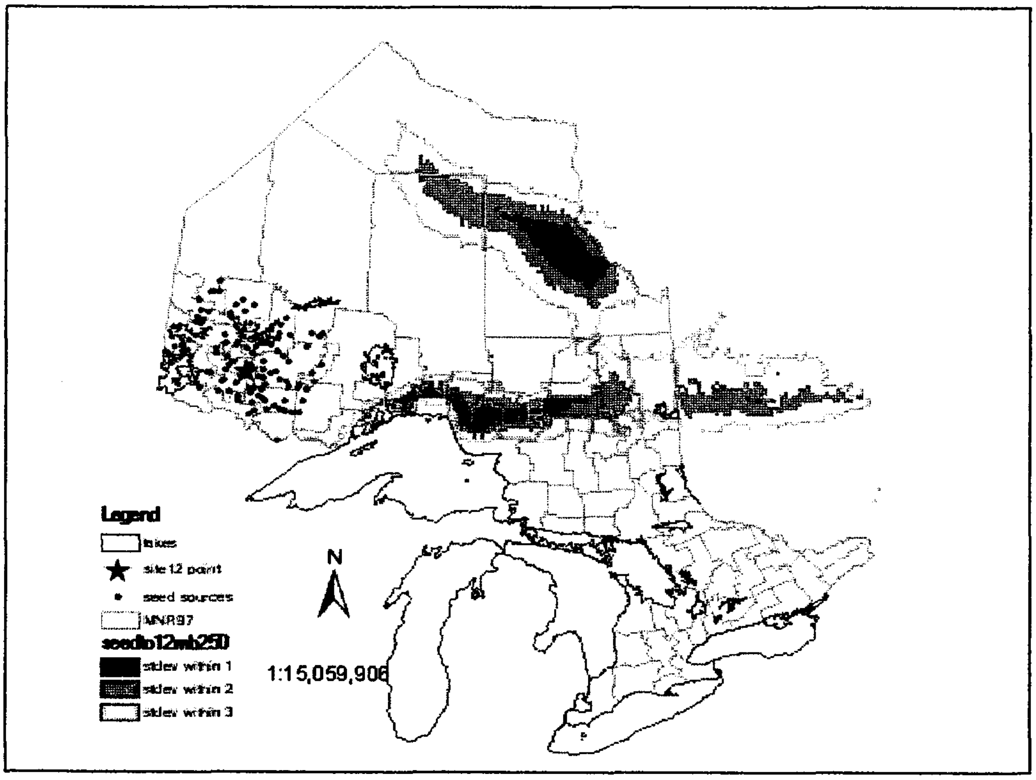


Figure 25. Best '*Seed To*' transfer zone in 2050 for seed from point 49.5°N, 92.5°W based on CGCM2B2

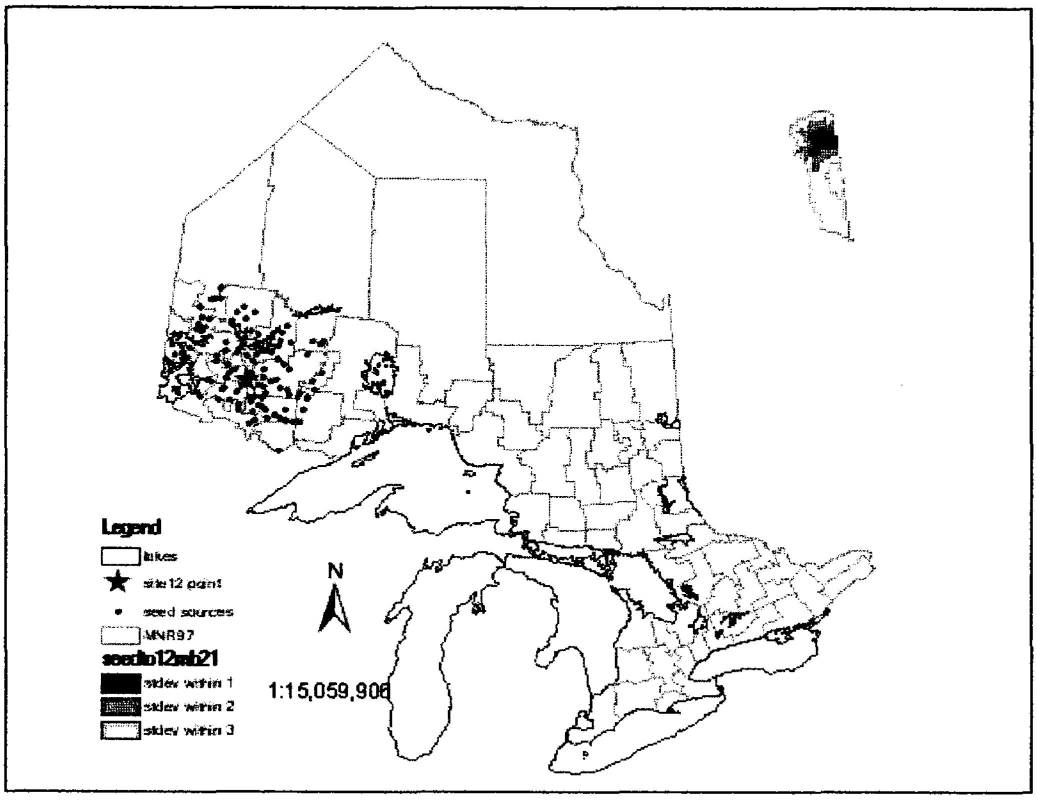


Figure 26. Best '*Seed To*' transfer zone in 2099 for seed from point 49.5°N, 92.5°W based on CGCM2B2

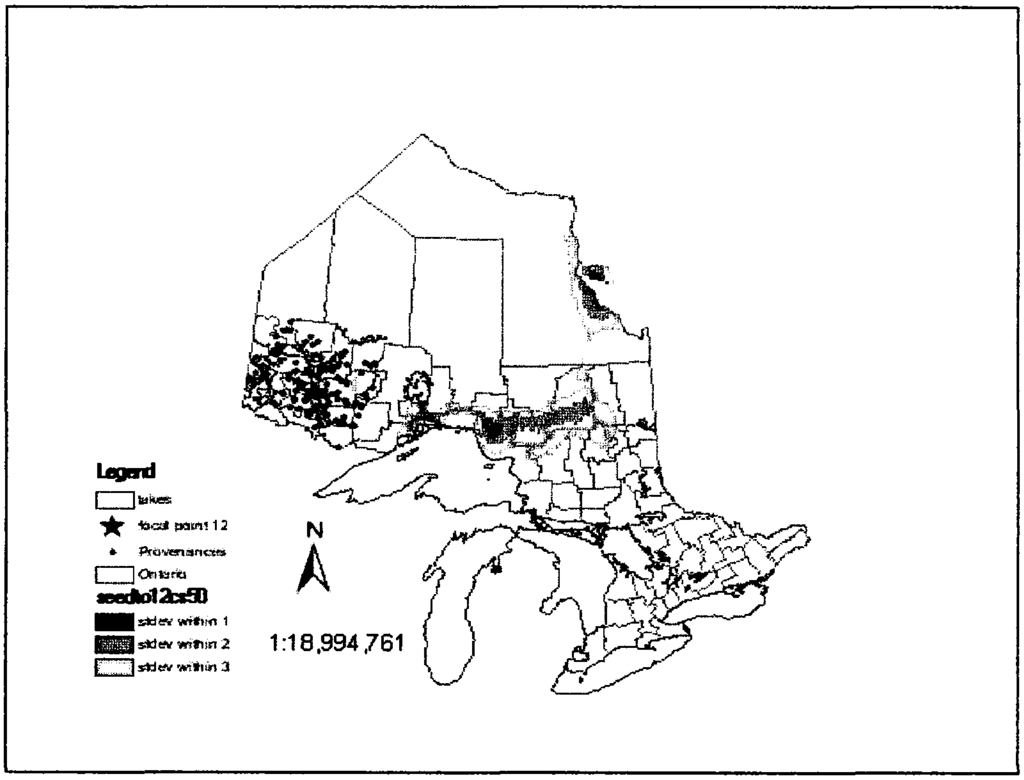


Figure 27. Best '*Seed To*' transfer zone in 2050 for seed from point 49.5°N, 92.5°W based on CSIROB2

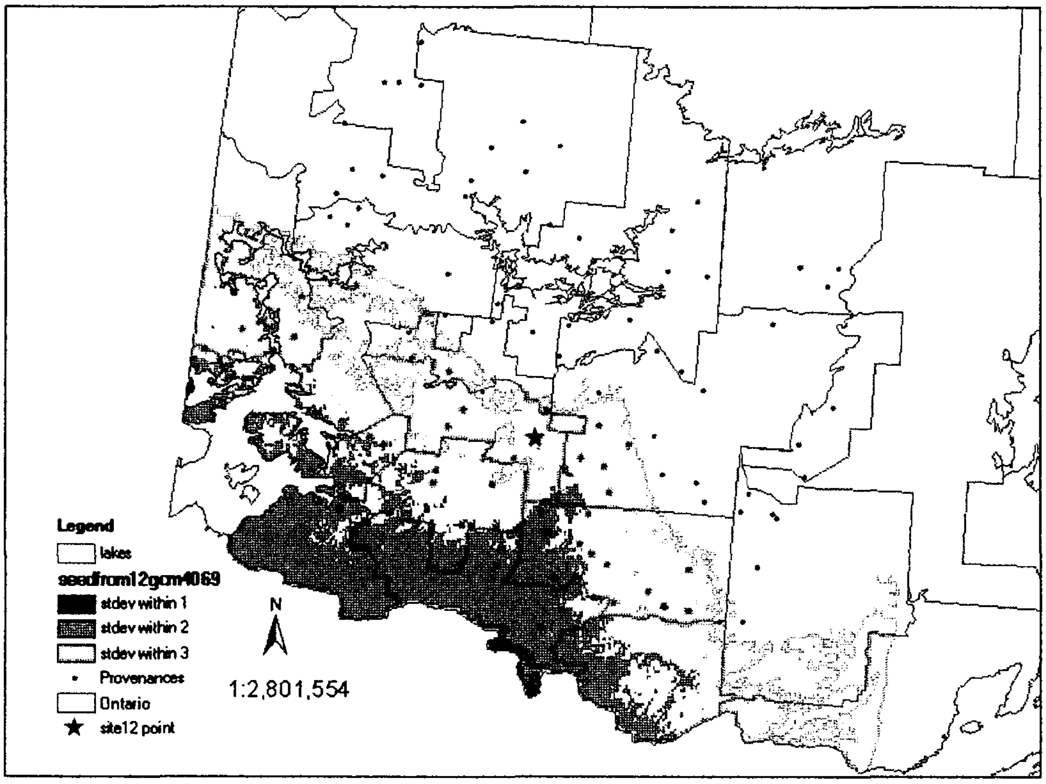


Figure 28. Best '*Seed From*' transfer zone in 2069 to best match climate of point 49.5°N, 92.5°W based on CGCM1

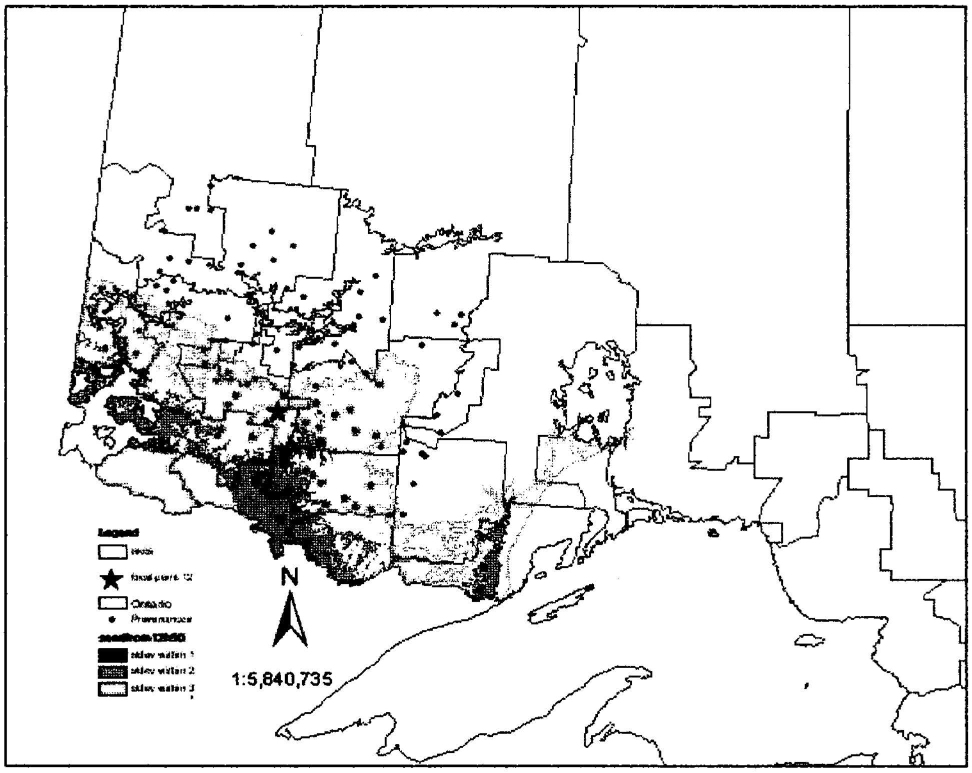


Figure 29. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2050 based on HADCM3A2

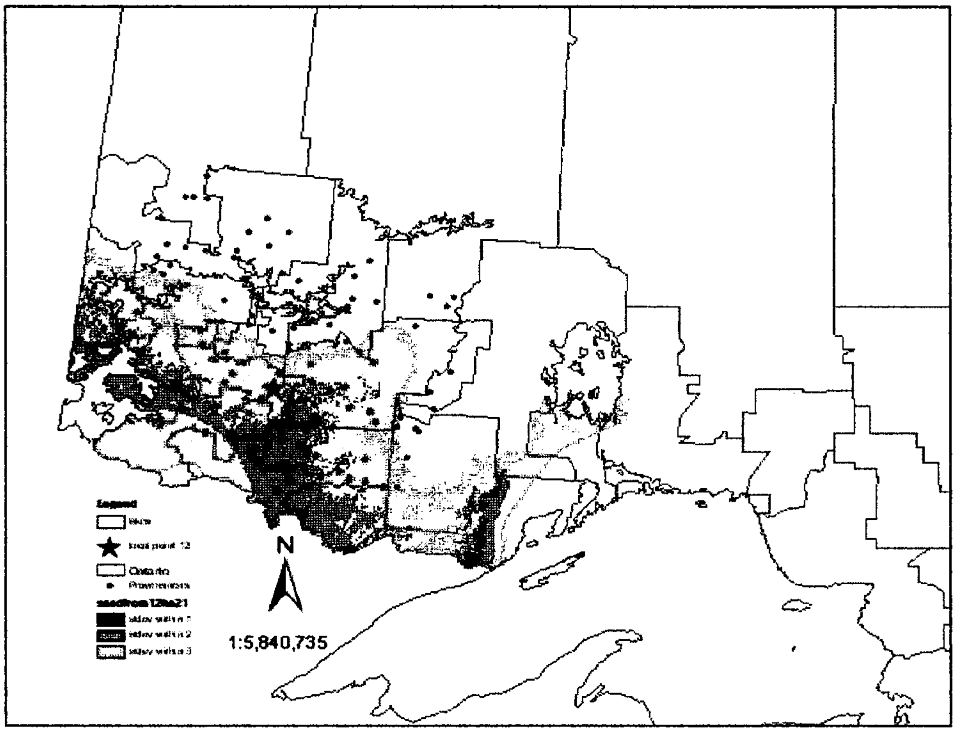


Figure 30. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2099 based on HADCM3A2

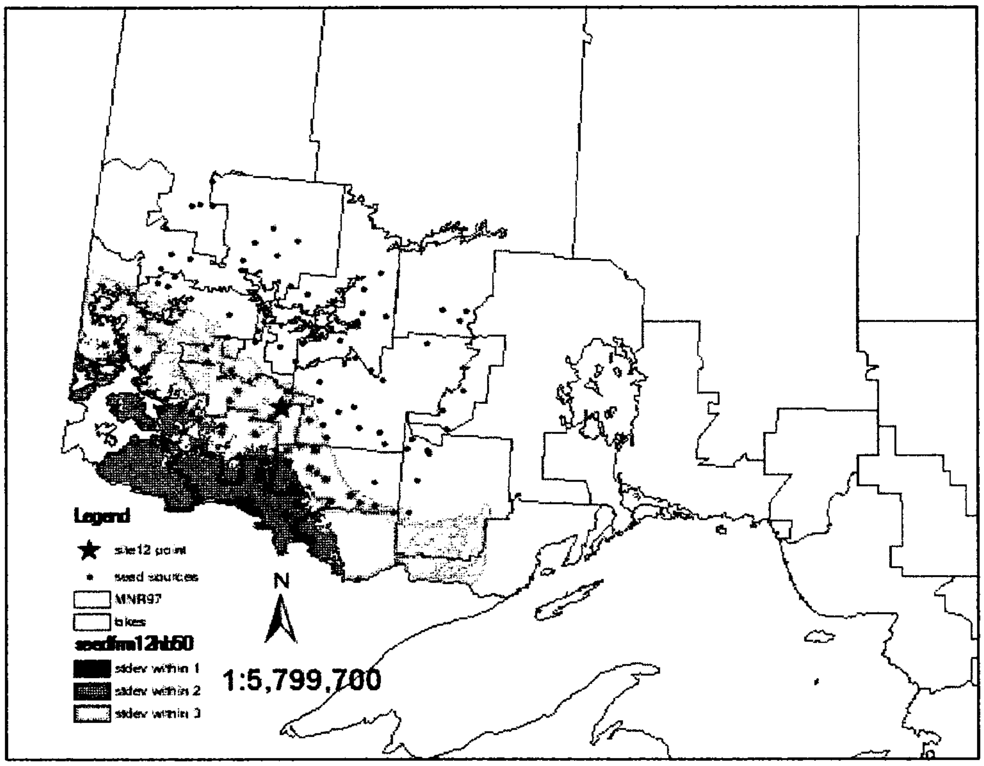


Figure 31. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2050 based on HADCM3B2

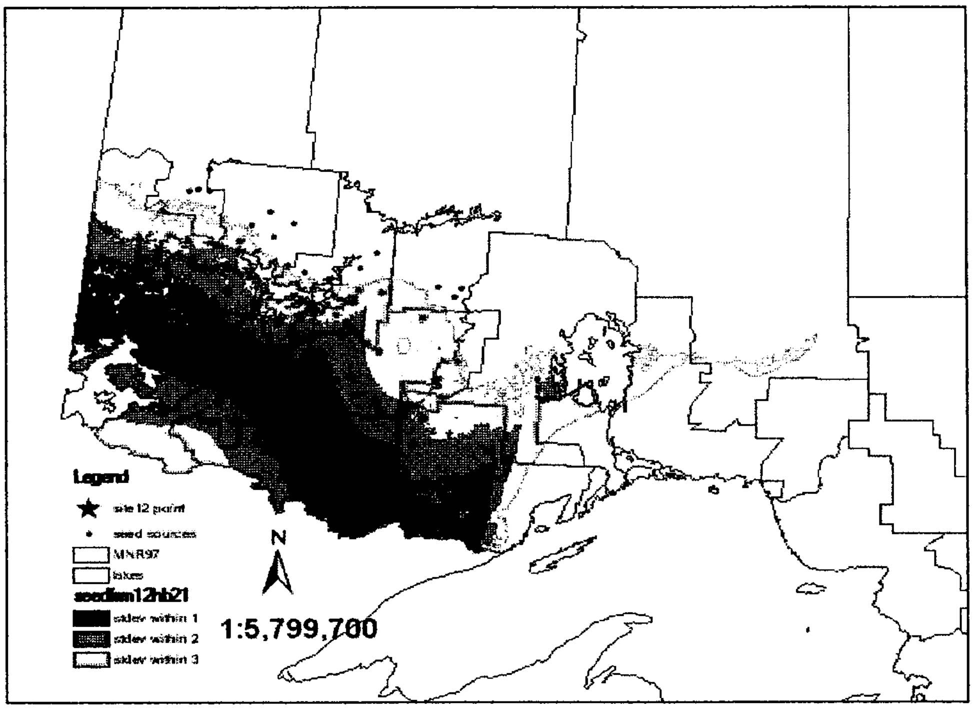


Figure 32. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2099 based on HADCM3B2

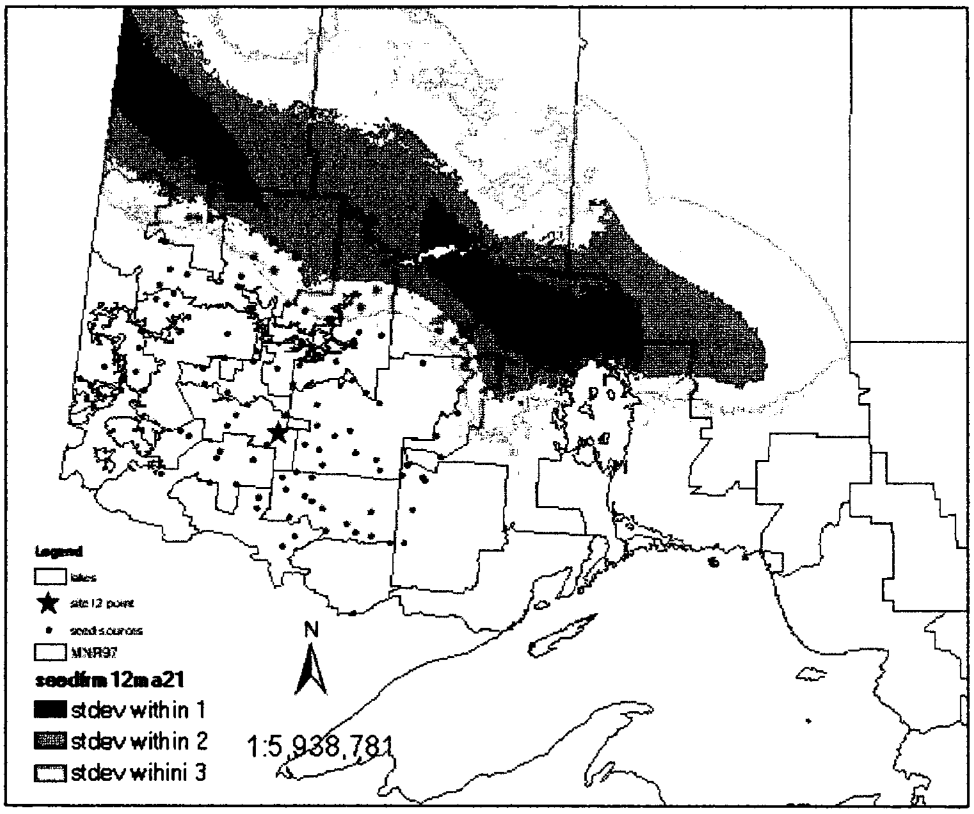


Figure 33. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2099 based on CGCM2A2

RESULTS : Northcentral Ontario

SINGLE VARIABLE ANALYSIS

Analysis of Variance

Select of the ANOVA results for variables measured in 1988, through 1990 as presented by van Niejenhuis (1995) were used in the present study. However, only the means of these variables were used in the subsequent analysis. In addition, the original data of Davradou's (1992) freezing trial was added to the current study. The results of the freezing trial were not used in the original version of the focal point seed zone models.

Significant difference in seedling growth was observed between the three tests. Seedlings grown at the Lakehead University Nursery trial showed the greatest height with the longest growing season, while seedlings at the Raith forestry trial had the shortest growing season and poorer growth than those grown at the other two trials.

Provenance differentiation was evident at the Greenhouse trial, although six out of 29 measured variables were not significantly different at the $p<0.05$ level. In general, the variation in seedling height among provenances was greater than the variation expressed by phenological variables. Freezing variables explained the largest variation among provenances ranging from 51.8 percent at D1T1 down to 2.5 percent at D1T3 (Table 7). The interaction between block and provenance in field trials generally accounted for none or a very small fraction of the total variation. This component was not included in the Table 14.

Table 14. Portion of the total variance expressed among 64 seed sources and measurement units

Variable	Mean[a]	SD[a]	I.C.C[b]	Unit	Variable	Mean	STD DEV	I.C.C	Unit
GH88	95.1	36.8	24.7**	mm					
GH89	100.6	32.4	15.4**	mm	R90	279.6	133.9	16.7**	mm
GHIN[c]	26.9	1.6	0.8ns[d]	days	RIN	23.2	5.2	1.4ns	days
GHCS	81	11.2	3.0ns	days	RCS	74.9	11.4	5.3**	days
GHDR	54.1	11.3	2.8**	days	RDR	51.8	12.5	4.7**	days
GHNF	30.4	1.9	15.5**	days	RNF	33.4	6.6	4.6**	days
LU88	101.6	40.7	25.6**	mm	**D1T1**	42.2	12.9	51.8**	days
LU89	330.7	104.9	30.0**	mm	**D1T2**	54.2	13.1	37.6**	%
LU90	768.1	197.7	19.6**	mm	**D1T3**	79.1	12.4	2.5**	%
LUIN	13.3	0.7	5.4**	days	**D2T2**	97.1	8.1	37.2ns	%
LUCS	87.8	13.2	4.0**	days	**D3T1**	96.2	13	10.1ns	%
LUDR	74.6	13.2	4.2**	days	**D4T1**	96.6	10.8	13.4*	%
LUNF	27.7	3.6	4.4**	days	**D5T2**	30.6	40.5	21.4*	%
R88	66.1	33.9	13.1**	mm	**D7T2**	13.7	14.8	11.1ns	%
R89	151.9	76.8	18.4**	mm	**D7T3**	43.2	32.3	42.6**	%

[a] Based on the 64 provenance values

[b] The intraclass correlation coefficient ($r=S_A^2/(S_A^2+S^2)*100$)

[c] Number of days (starting on May 1st)

[d] Not significant ($a > 0.05$)

* Significant at the $p< 0.05$ level; ** Significant at the $p < 0.01$ level

Note: the I.C.C results of variables in bold has not been published previously.

A contour map depicting survival at the Raith trial was constructed to show the gradual changes in adaptive variation throughout the seed collection area (Figure 34). There are obvious lake effects on the survival at the Raith trial with poorer survival around Lake Nipigon and west of the Lake Superior shore, except in the northern portion. Seed sources from the Raith trial location showed good survival potential compared with seed sources from the Lakehead University trial location. At the northwest and southwest corners of the sampled area, the contour map shows a latitudinal trend; as latitude increases, the survival decreases in the northwest portion, but the reverse is true for the southwest portion of sampled area.

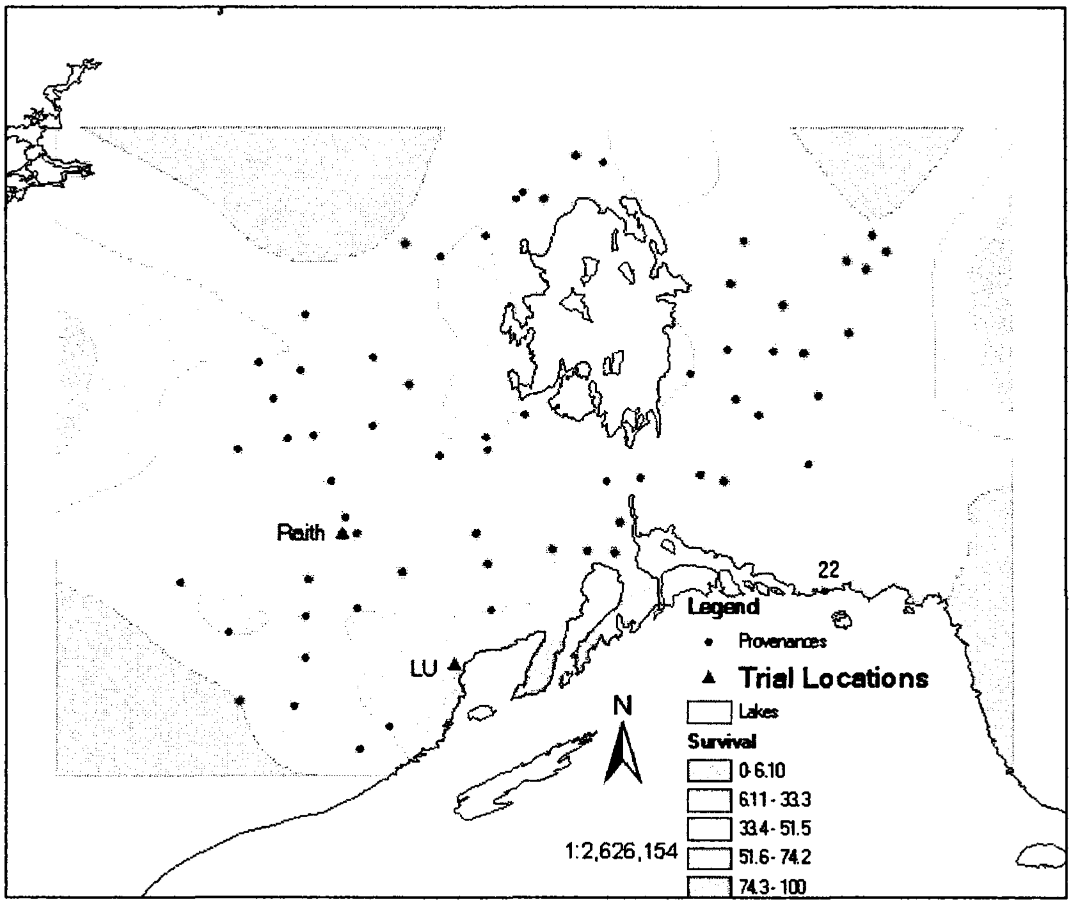


Figure 34. Contour map for survival at the Raith trial in northcentral Ontario

SIMPLE REGRESSION ANALYSIS

Simple regression analysis was used to examine the relationships between measured variables and geographic and climatic predictor variables. Simple linear and backwards stepwise multiple linear regression and analyses were run for all test variables against the 36 climatic variables with the best R^2 method of SAS. The results are shown in Table 15. Climate and geographic values for each provenance are shown in Appendix II and Appendix VII. Four measured variables were found to be non-significant at the $p < 0.05$ level including 3 height variables from the Raith trial and one freezing variable, D1T2. R^2 values for retained variables ranged from 2.8 percent for Raith 1988 height against November precipitation to 43.1 percent for the date of needle flush at the Lakehead University Field trail against April maximum temperature. Date of needle flush was best explained by the climatic variables compared with other measured variables. Measured LU field trial variables showed the most significant relationships to climatic variables; i.e. they had bigger R^2 values compared with other trials. Maximum temperature at the beginning of growing season best explained measured variables at this trial. April and June maximum temperature and July and August minimum temperature were significant in this trial.

The results of the simple regression analysis are presented in Table 15. April maximum temperature was the most frequently retained variable (5 times) to explain differences within the measured variables; November precipitation was included 2 times at $p< 0.05$ level of significant. Overall, temperature-related variables produced the highest R^2 values and were included 14 times; compare with variables related to precipitation (6 times), longitude (1 time), or elevation (1 time).

Table 15. Results of simple linear regression against 3 geographic and 36 climate variables

Depdent variable	Climate vabriable	Constant	Coefficient	MaxR^2	Sig
Greenhouse					
GH88	augmaxt	-92.4	8.67	0.10	0.021
GH89	aprprec	13.8	1.99	0.18	0.002
GHIN	janprec	27.7	-0.02	0.05	**0.117**
GHCS	octmaxt	102.7	-2.56	0.19	0.001
GHDR	octmaxt	74.6	-2.42	0.17	0.002
GHNF	mayprec	25.4	0.07	0.16	0.004
GHR	octmaxt	133.9	-9.4	0.24	0.000
LU Field Trial					
LU88	maymaxt	-89.2	12.3	0.27	0.000
LU89	aprmaxt	-22.4	49.3	0.35	0.000
LU90	aprmaxt	195.1	80.35	0.41	0.000
LUIN	julmint	15.0	-0.17	0.18	0.002
LUCS	junmaxt	43.8	2.17	0.31	0.000
LUDR	junmaxt	27.8	2.31	0.35	0.000
LUNF	aprmaxt	21.3	0.91	0.50	0.000
LUR	aprmaxt	99.3	-8.19	0.35	0.000
Raith trial					
R88	augmint	25.1	4.79	0.03	**0.196**
R89	novprec	96.5	1.1	0.06	**0.078**
R90	novprec	181.5	1.95	0.07	**0.051**
RIN	maymint	22.5	1.03	0.10	0.020
RCS	novprec	64.8	0.16	0.10	0.020
RDR	novprec	39.6	0.19	0.11	0.019
RNF	aprmaxt	22.8	1.54	0.34	0.000
RSU	long	421.9	-4.2	0.21	0.001
Freezing trial					
D1T1	junmint	78.0	-5.64	0.10	0.020
D1T2	decpric	44.3	0.23	0.04	**0.140**
D1T3	octmint	85.4	6.21	0.12	0.014
D2T1	long	-43.6	1.59	0.31	0.000
D3T1	septprec	30.0	0.19	0.04	**0.139**
D4T1	long	232.5	-1.51	0.12	0.010
D5T2	mayprec	244.9	-2.88	0.23	0.000
D7T2	decprec	3.6	0.9	0.19	0.001
D7T3	novprec	-25.5	1.23	0.14	0.007

Note: Bold represents not significant at the $p < 0.05$. They will be excluded from the subsequent analysis.

MULTIVARIATE ANALYSIS

Principal Components Analysis

Principal components analysis (PCA) was used to examine the patterns of variation displayed in this study because many of the variables measured in these trials were highly correlated. Variables that showed a significant portion of the total variance attributable to seed sources and with significant regression against climate variables at the $p < 0.05$ level were included in the PCA. Because the elongation duration was calculated from the date of elongation initiation and date of elongation cessation, only two of these three variables were included in the PCA. The provenance means of five height variables, nine phenological variables, survival at the Raith trail and five freezing variables (transformed using arcsine transformation), a total of 20 variables were included in the PCA .

Table 16 shows the results of the principal components analysis conducted on the 20 variables retained. Eigenvalues, the percentage of total variation attributed to each component, and the associated eigenvectors are shown for the first three principal component axes. The first three PC axes together account for 50.8 percent of the total variation.

The first component, with an eigenvalue of 5.498 and accounting for 27.5 percent of the variance, had high positive loadings for all height growth variables. The highest positive loadings corresponded to Lakehead University greenhouse heights for all three years (0.36-0.40). Negative loadings were displayed for variables LU purpling, LU elongation initiation, greenhouse purpling and survival at Raith trial; two freezing variables also had negative signs. The signs of these loadings, together with the high coefficients for the height growth variables, indicate that the first axis is generally a descriptor of growth potential; i.e., seed sources with the greatest potential for growth generally had the highest growth.

The second component accounted for 15 percent of the total variation. Two of the five freezing variables, Needle flush, elongation cessation, and survival variables at the Raith trial each made strong positive contributions to the second axis with respective component loadings of 0.299, 0.125, 0.494, 0.461, and 0.458. All of the needle flush variables demonstrated negative component loadings. This axis appears to reflect the phenological and cold-hardiness potential. The opposite polarity of the variable loadings implies a negative correlation between hardiness; i.e. more frost hardy sources with flush later in the season.

The third axis accounted for 8 percent of the total variation. Three of the six freezing variables had high positive eigenvector loadings, ranging from D5T2 at 0.29 to D4T1 at 0.43. Needle flush for the greenhouse trial showed the highest negative loadings, which indicates increased cold-hardiness occurs with later needle flush. The interpretation for this PC is more difficult than that of the first PC.

The remaining 17 PCs, cumulatively accounted for about 49 percent of the total variation. Individually, they each accounted for less than 10 percent of the total variation among traits. Generalized trends in the pattern of variable loadings were less evident for those axes and, therefore, these PCs will not be discussed further.

Table 16. Results of principal components analysis of 20 growth, phenological and freezing variables for 64 jack pine seed sources in north central Ontario.

	Component		
PCA axis	1	2	3
Eigenvalue	5.498	2.970	1.695
Percent Variation	0.275	0.149	0.085
Cumulative	0.275	0.423	0.508
Variables*	**Component Loadings**		
GH88	0.273	0.021	-0.109
GH89	0.241	0.156	0.359
GHNF	0.140	-0.144	-0.524
GHR	-0.200	-0.033	-0.028
LU88	0.359	0.000	-0.023
LU89	0.402	0.053	0.100
LU90	0.397	-0.019	0.083
LUIN	-0.240	-0.043	0.107
LUCS	0.230	-0.186	-0.225
LUNF	0.231	-0.109	0.099
LUR	-0.341	-0.049	-0.227
RDR	0.073	0.494	-0.133
RCS	0.104	0.461	-0.125
RNF	0.132	-0.339	0.077
RSU	-0.067	0.458	-0.055
D1T1	0.048	0.076	-0.091
D1T3	0.084	-0.084	0.349
D4T1	-0.144	0.035	0.430
D5T2	-0.103	0.125	0.291
D7T3	0.035	0.299	-0.038

*See variables definition in method and Materials section Table 5.

Multiple Regression Analysis

The PCA factor scores for the 64 provenances were regressed against the climatic variables using backwards stepwise multiple linear regression. To avoid overfit regressions, variables with tolerances considerably less than 0.1 or t values less than absolute 2.0 were eliminated (Wilkinson *et al.* 1992). Significant regression equations were generated for the first three sets of factor scores, with coefficients of determination (r^2) ranging from 0.315 to 0.55. PC1 was fit to a model including April maximum temperature, October maximum temperature, June minimum temperature and October precipitation (Table 17). These results suggest that spring, summer and fall temperature as well as fall precipitation are good indictors of growth potential. Climatic predictor variables retained in the second equation included only March precipitation and November precipitation. This result suggests that spring and late fall precipitation variables are important indicators of phenology. The best fitting model for the third axis contained December maximum temperature, February Precipitation and June precipitation, with r^2 at 0.39. All predicative variables in each of the models had significant difference at the $p < 0.05$ level.

Spatially explicit models of adaptive variation were generated by GIS based on the regression equations developed using the climatic variables. The trend surface diagram produced by the set of scores predicted for the first component is seen in Figure 35. Generally, sources with greater growth potential, corresponding to higher positive scores on the first axis were from the southwest portion of the sampled area. There was an area with higher factor scores on the north-eastern shore of Lake Superior, probably due to lake effects. Sources with reduced growth potential were found in the northeast portion of the study area. Clinal variation exists corresponding to elevation and altitude. The growth potential had a negative correlation with elevation and a negative correlation with altitude in this area.

The pattern of variation based on second-axis PCA scores generally follows a longitudinal trend (Figure 36), showing reduced survival and earlier flush when moving from the east to the west. Sources with higher positive scores, indicating later needle flush and higher survival potential, were from the eastern portion of the study area, especially to the east of Lake Nipigon. Also sources 31, 33, 34, 48, 51, and 64 from the southwest portion of the study area showed higher survival. The extreme negative score was predicted for the western portion of sampled area. Figure 37 shows more a complex geographic pattern and can be interpreted as showing the pattern of adaptive variation in terms of cold-hardness and corresponding to the greenhouse needle flush. This map shows a longitudinal trend indicating more cold hardiness along lines of longitude. A latitudinal trend is found from the southeast portion of the sampled area. It shows reduced hardiness and with the increasing latitude in this area.

Table 17. Results of regression of PCA axes against climatic variables for 64 jack pine seed sources in northern center Ontario.

Dependent Variable	Independent Varibles	Coeficent	t value	Tolerance	Significance
	constant	-9.13			
PCA 1	aprmaxt	1.56	4.53	0.12	0.00
R^2 = 0.55	octmaxt	-1.07	-2.41	0.10	0.02
	junmint	0.63	2.66	0.51	0.01
	octprec	0.04	2.04	0.55	0.047
PCA 2	constant	-0.88			
R^2 = 0.315	marprec	-0.08	-3.32	0.82	0.017
	novprec	0.08	4.59	0.82	0.00
PCA 3	constant	1.11	0.36		
R^2 = 0.39	decmaxt	0.50	3.83	0.50	0.00
	febprec	-1.34	-2.54	0.43	0.01
	junprec	0.09	3.47	0.73	0.00

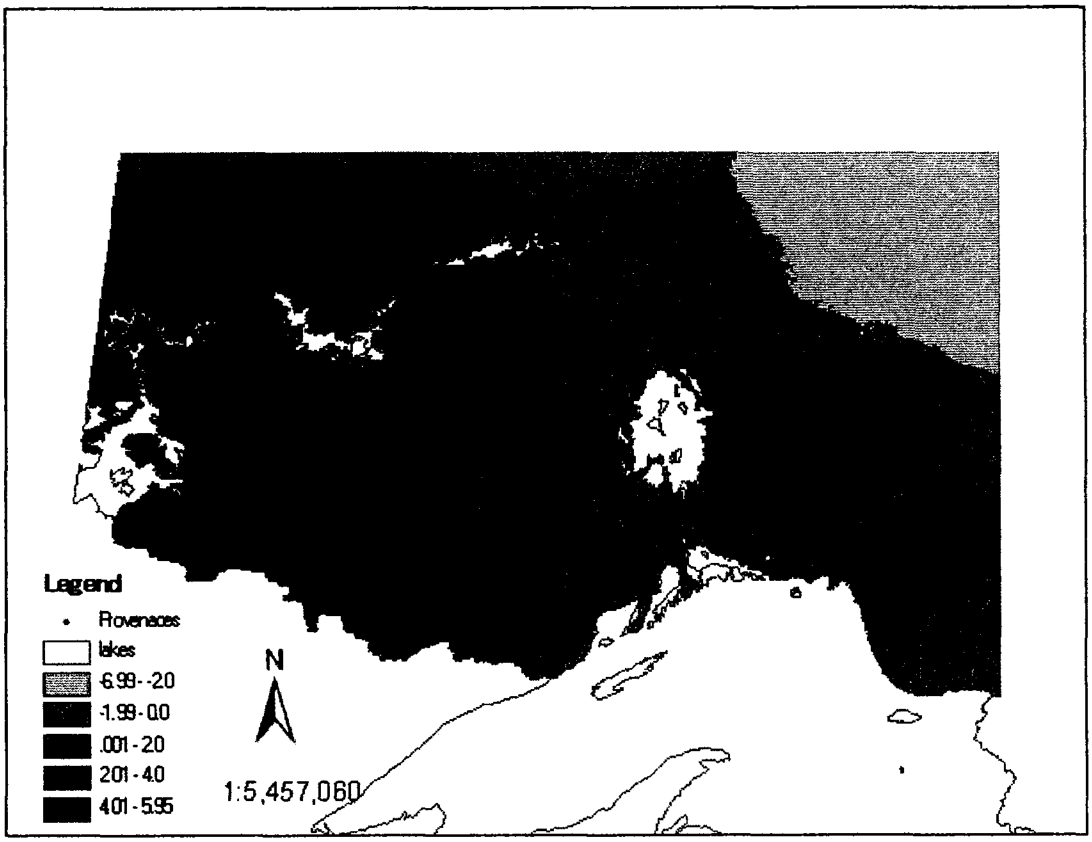


Figure 35. Predicted factor scores from the PC1 regression model based on OCM2

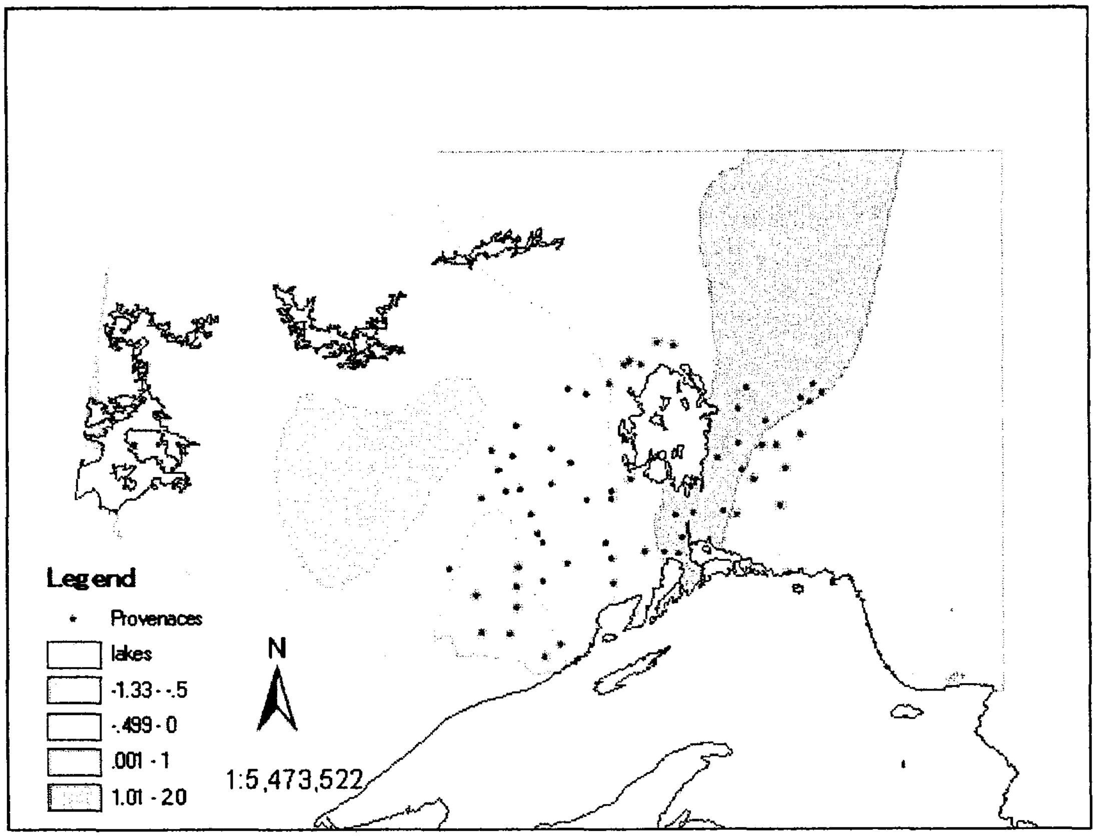


Figure 36. Predicted factor scores from the PC2 regression model based on OCM2

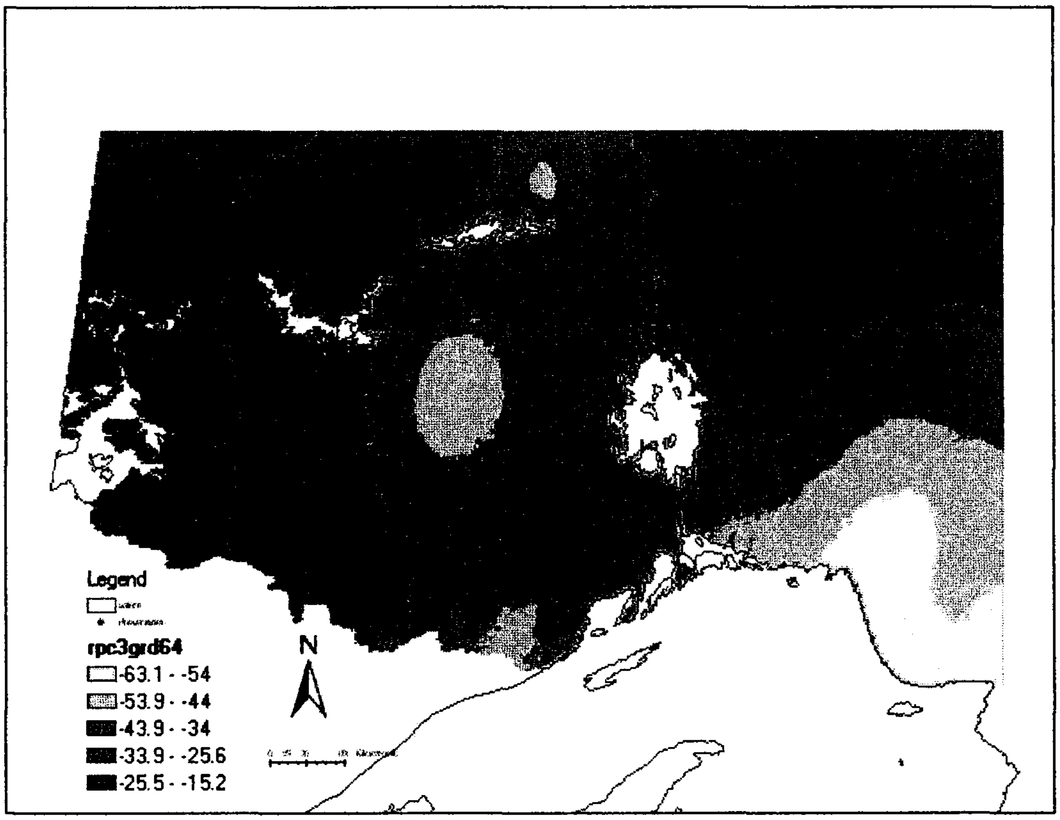


Figure 37. Predicted factor scores from the PC3 regression model based on OCM2

Figures 38 through 42 (showing a longitudinal trend) are GIS-generated contour maps that graphically summarize the geographic pattern of variation expressed among the 64 seed sources (PC1) based on the same regression models as Figure 35. However, they were expressed by future climate models CGCM1 (2040-2069), HADCM3A2 and HADCM3B2 projected for 2050 and 2099. When compared with Figure 35, they look coarser due to the future climate models' resolutions being 15 km and 7.5 km rather than 1 km for OCM2. In this study area, the growth potential decreases from southwest to the northeast region. The patterns of these figures look similar to that predicted by OCM2. The two pairs of figures (39, 40) and (41, 42) show the growth potential based on HADCM3A2 and HADCM3B2 projected for 2050 and 2099. They predict higher growth potential in the sampled area than Fig. 35, which was based on OCM2 (1990). This result indicates that seed sources from this area have greater growth potential in the future. Contour maps that present growth potential prediction for 2099 show higher growth potential compared with those predicted for 2050 based on both HADCM3A2 and HADCM3B2 models. Contour maps predicted by HADCM3A2 and HADCM3B2 demonstrate similar trends in predicted growth potential within the study area (Fig. 39, 41 and 40, 42).

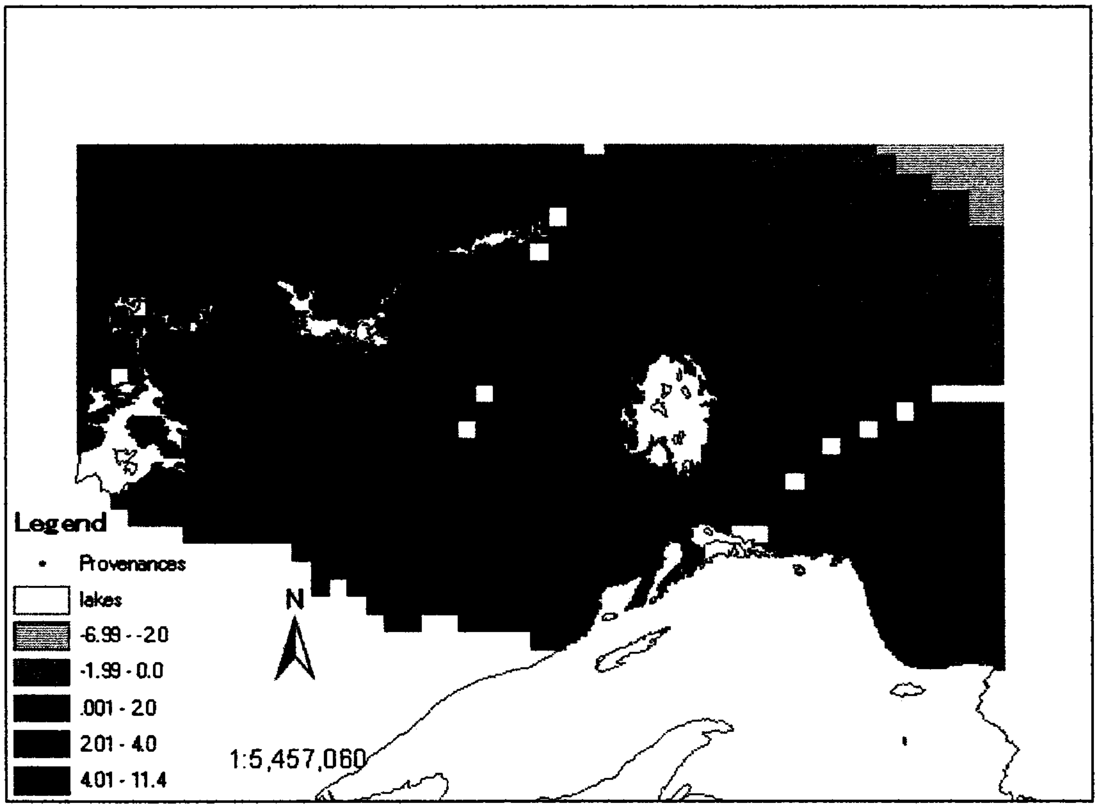


Figure 38. Predicted factor scores from the PC1 regression model based on CGCM1 (2040-2069)

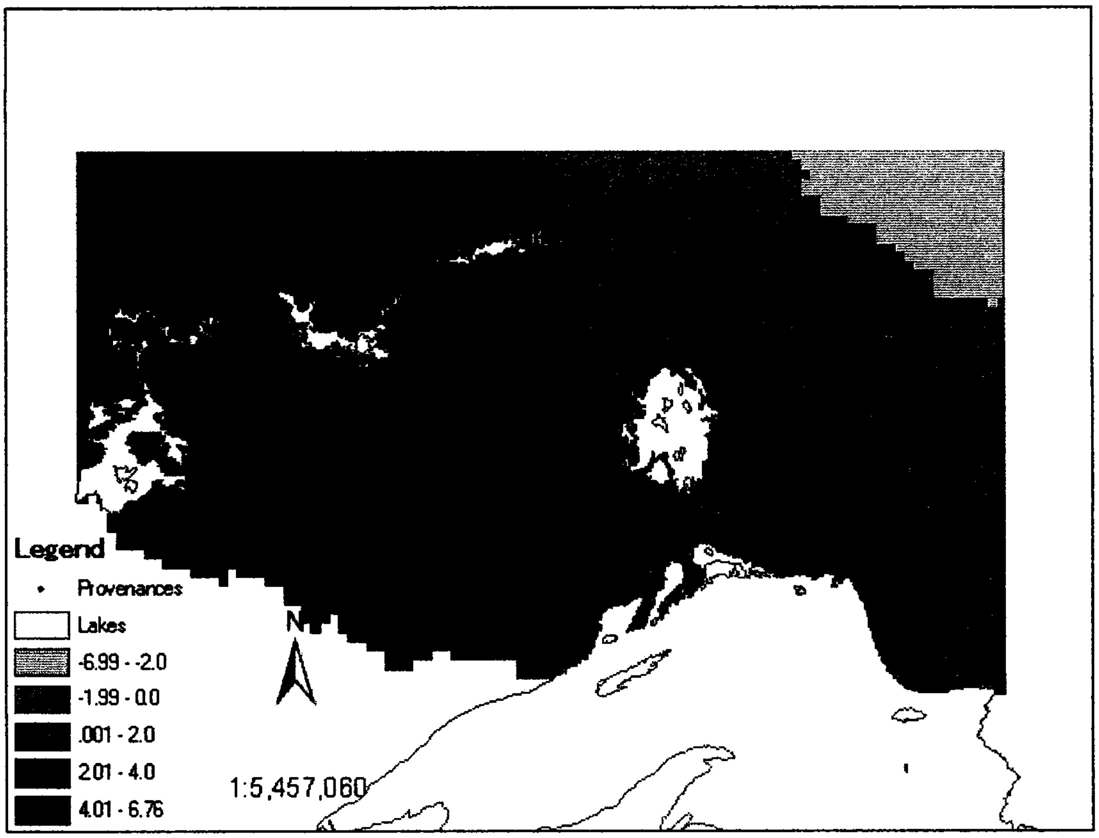


Figure 39. Predicted factor scores from the PC1 regression model based on HADCM3A2 (2050)

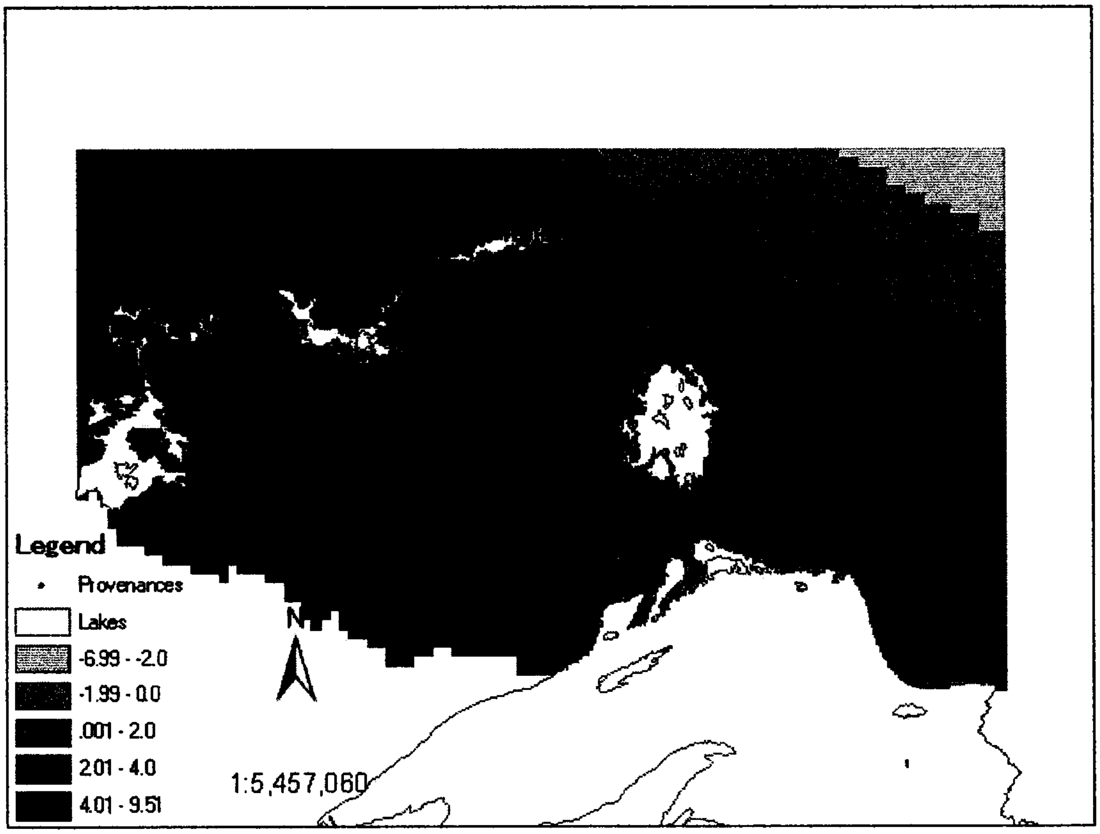


Figure 40. Predicted factor scores from the PC1 regression model based on HADCM3A2 (2099)

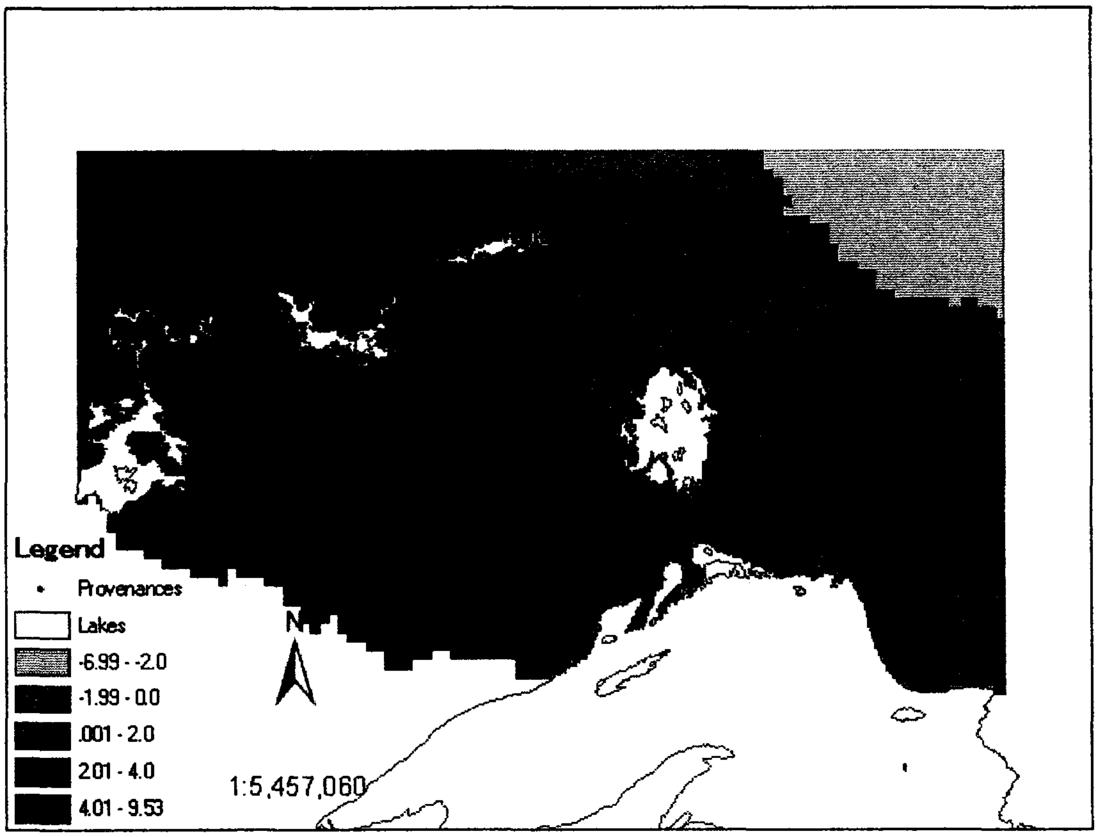


Figure 41. Predicted factor scores from the PC1 regression model based on HADCM3B2 (2050)

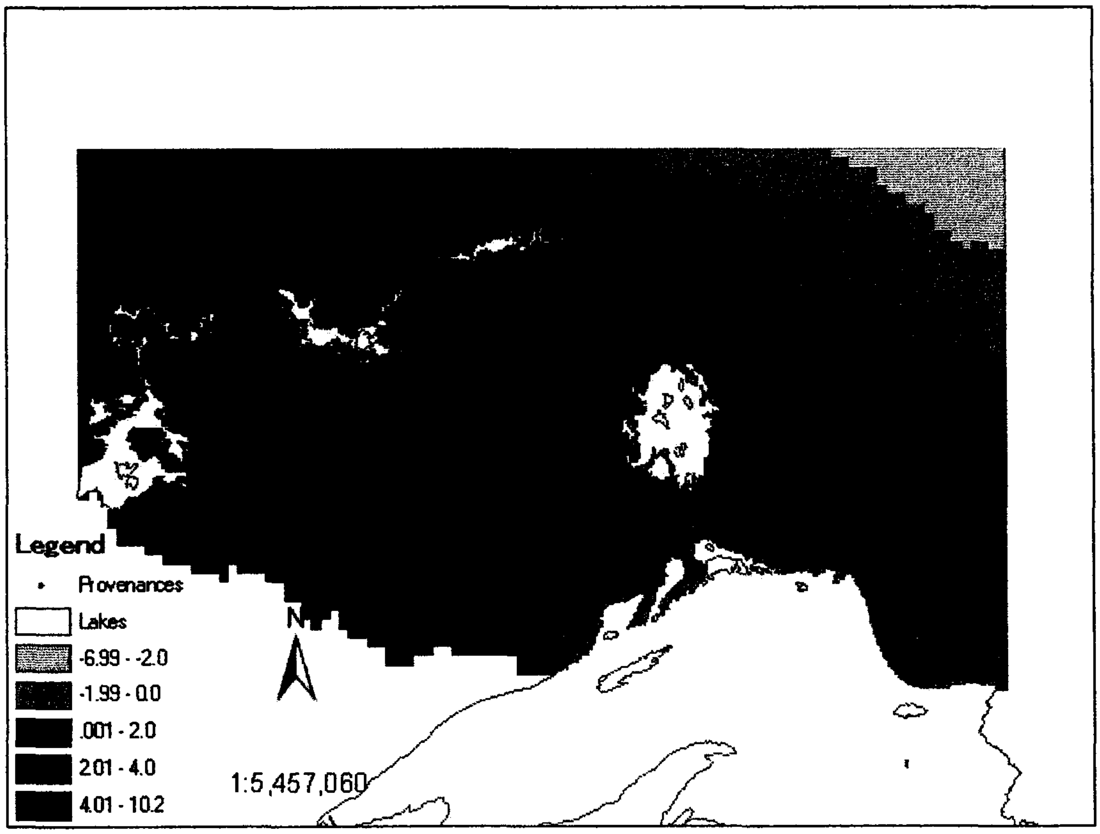


Figure 42. Predicted factor scores from the PC1 regression model based on HADCM3B2 (2099)

Figures 43 through 47 illustrate the pattern of variation based on the second PCA axis under future climate models and demonstrate a similar longitudinal trend as Figure 36. As longitude decreases, needle flush occurs later, the duration of the growing season is reduced, and the survival potential decreases.

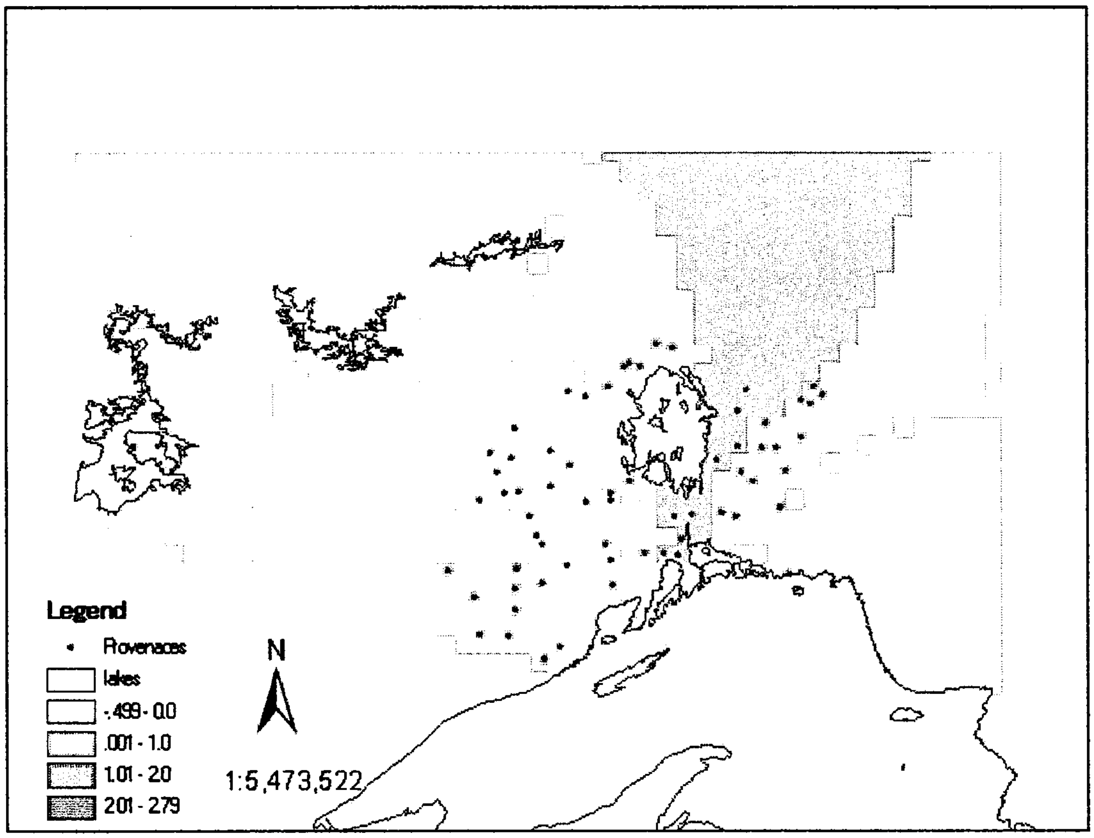


Figure 43. Predicted factor scores from the PC2 regression model based on CGCM1 (2040-2069)

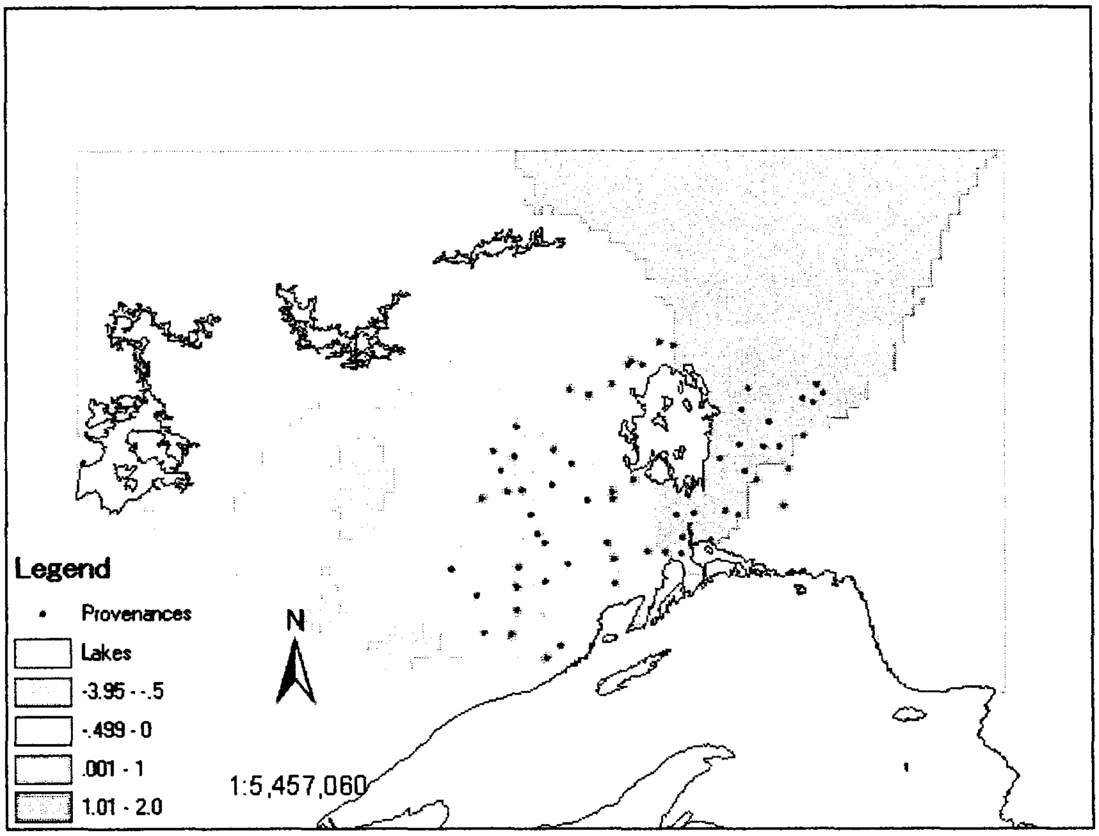


Figure 44. Predicted factor scores from the PC2 regression model based on HADCM3A2 (2050)

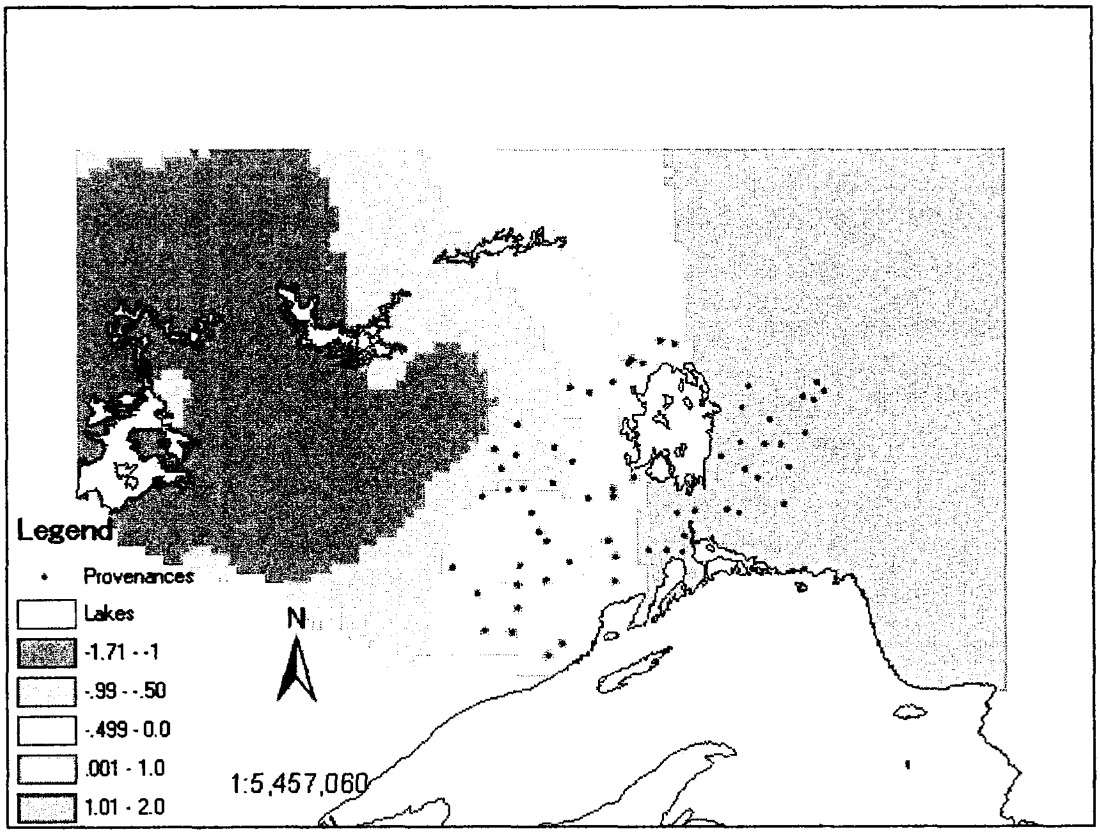


Figure 45. Predicted factor scores from the PC2 regression model based on HADCM3A2 (2099)

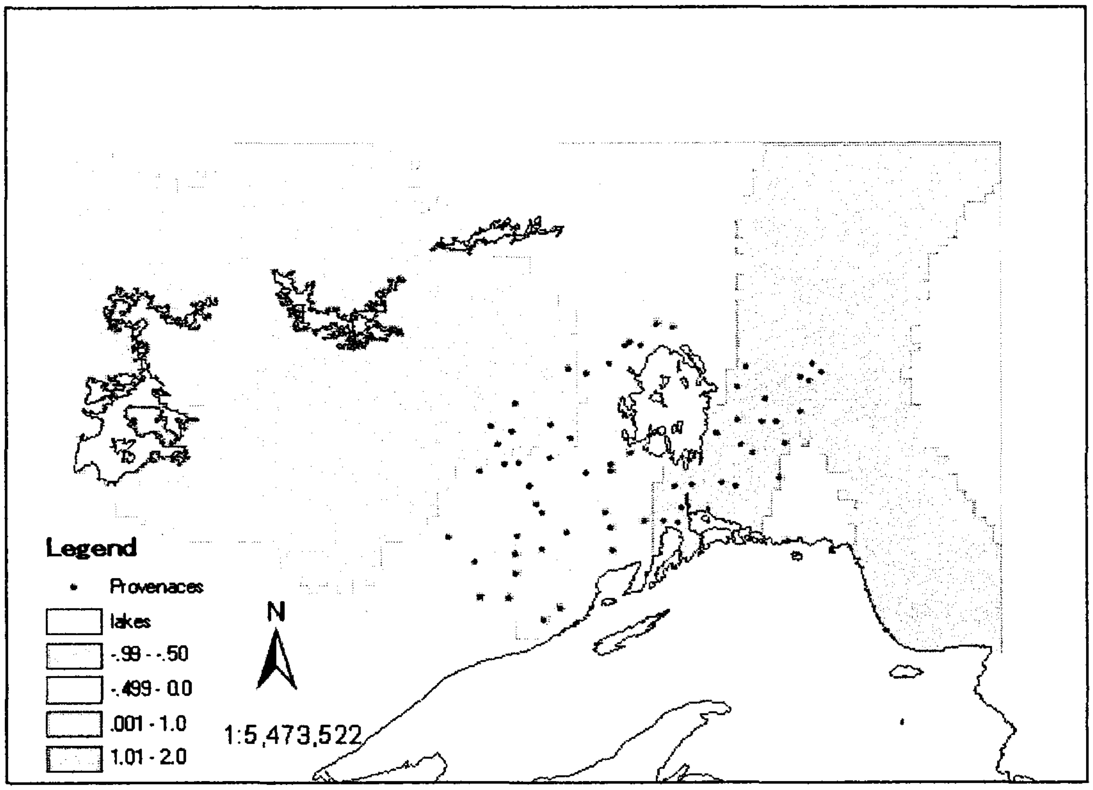


Figure 46. Predicted factor scores from the PC2 regression model based on HADCM3B2 (2050)

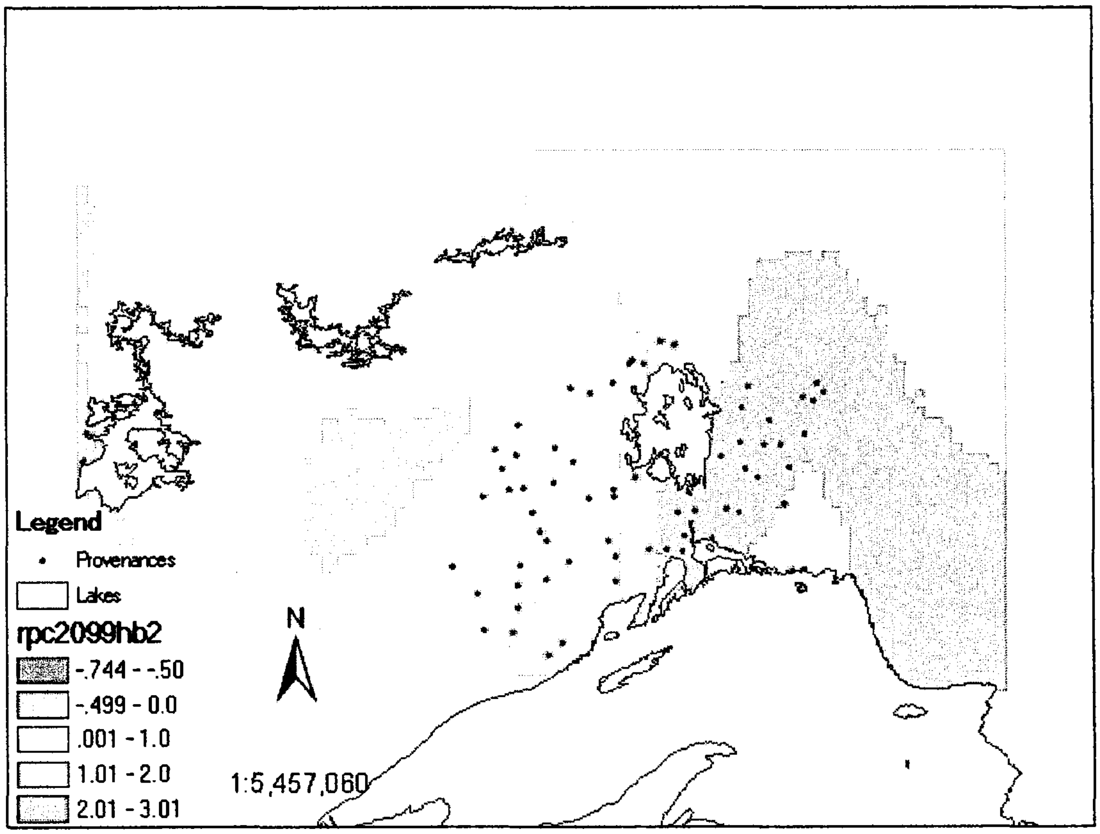


Figure 47. Predicted factor scores from the PC2 regression model based on HADCM3B2 (2099)

Focal Point Seed Zones

In the northcentral Ontario study area the first two axes, totalling 42.3 percent of the variation, were used to generate focal point seed zones. There are two reasons that the third axis was not included in generating focal point seed zones: first, this principal component accounts for only 8 percent of the total variation with a smaller eigenvalue (1.7); secondly, to make comparisons between focal point seed zones produced by the climate model OCM1, two PCs were used in that case (Parker 1996a). In both cases, these two axes were considered equal for the calculation of focal point seed zones due to their independence.

In the following figures (48 through 66) the focal point is represented by a red star. The darkest shade of green is used to depict areas with a climate that lies within 1 standard deviation of that of the focal point. The intermediate shade of green is used to represent areas within 2 standard deviations and the lightest shade of green is used to represent areas within 3 standard deviations. Non-shaded areas represented areas that are outside the range of 3 standard deviations from the focal point and, therefore, are not recommended for seed transfer.

A focal point (48.5°N, 90.5°W) from the southwest of the sampled area was selected to demonstrate present and future focal point seed zones. Seed zones based on current climate condition (1990) and the future climate conditions (2040-2069, 2050 and 2099) based on different climate change scenario models are shown in Figures 48 through 66. Future focal point seed zones include where seed should go from a given location to best suit future climate conditions (*Seed To*) and where seed should come from now to be best adapted in the future to its planting location (*Seed From*). A further series of seed zones based another focal point (50.1°N, 87.9°W) from the east of Lake Nipigon based on these climate change scenarios is provided in Appendix VIII.

The area around Lake Nipigon, excluding the northern shore, shows suitable planting sites for seed originating from the focal point. It can also be said that seed sources from the aforementioned area are suitable to be planted at the focal point, although the southwest area of the map shows the best match (standard deviation within 1 from focal point). Areas to the west of the Lake Superior shore show the lightest green.

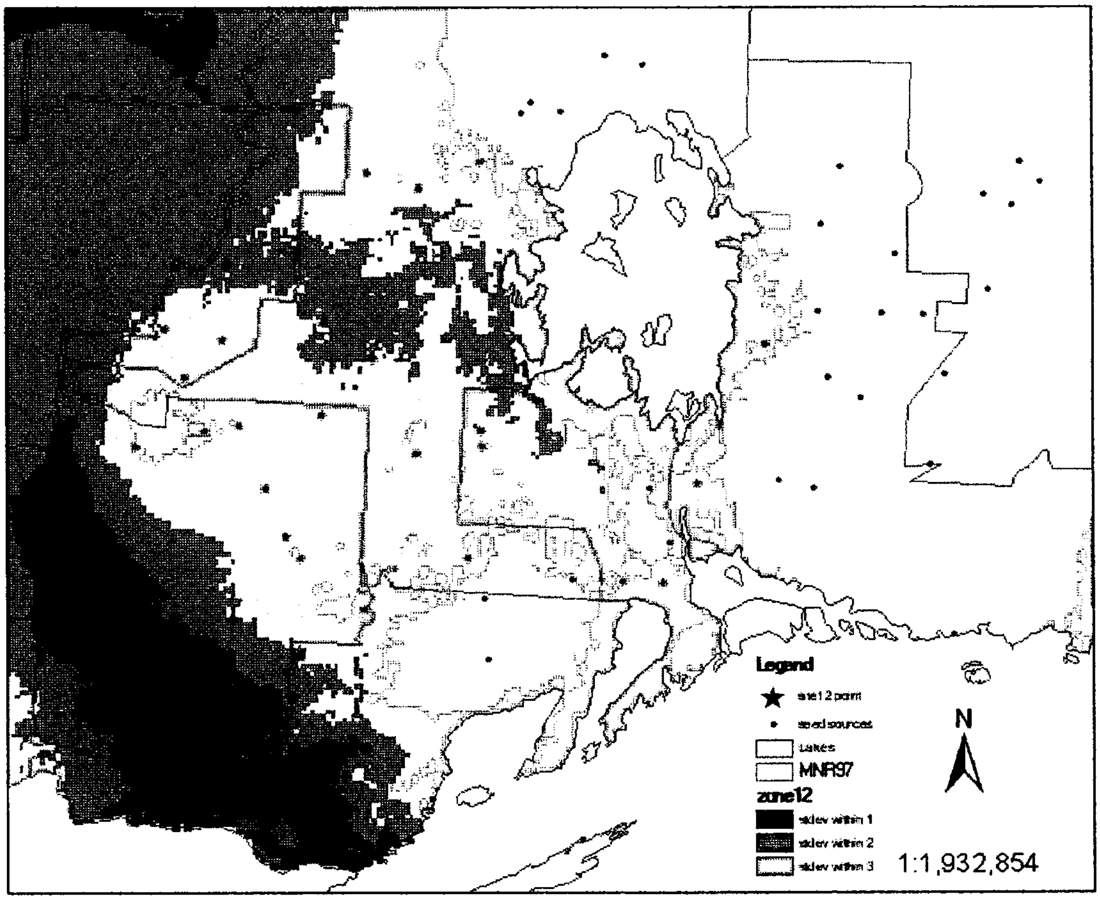


Figure 48. Focal point seed zones at coordinate 48.5°N, 90.5°W based on OCM2

By 2069, seed obtained from the focal point is no longer suitable for the original area; the seed is best adapted to the north and northeast portions of the study area under future climate conditions (Figure 49). Figure 50 shows where seeds should come from today, to best match the focal point climate by 2069 according to CGCM1. No seed sources in the northwest study area are predicted to be well adapted to the focal point; instead sources should come from the southwest of the Lake of the Woods.

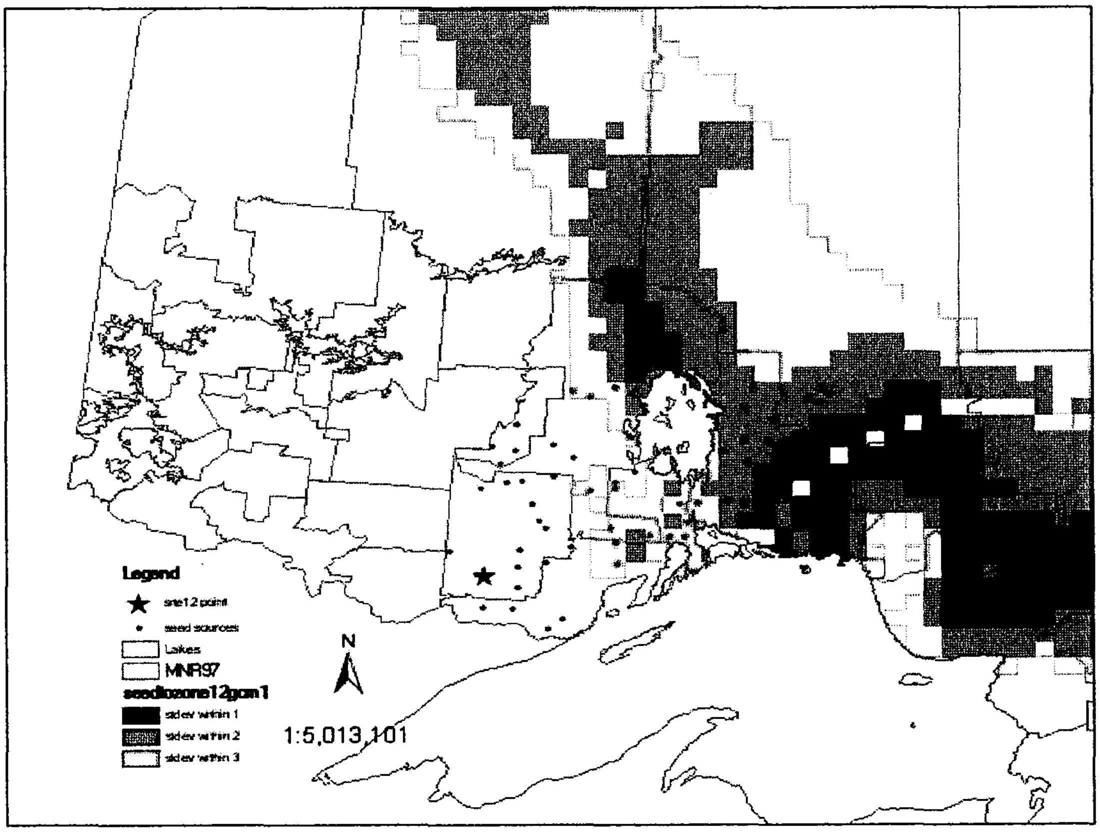


Figure 49. Best '*Seed To*' transfer zone in 2069 for seed from point 48.5°N, 90.5°W based on CGCM1

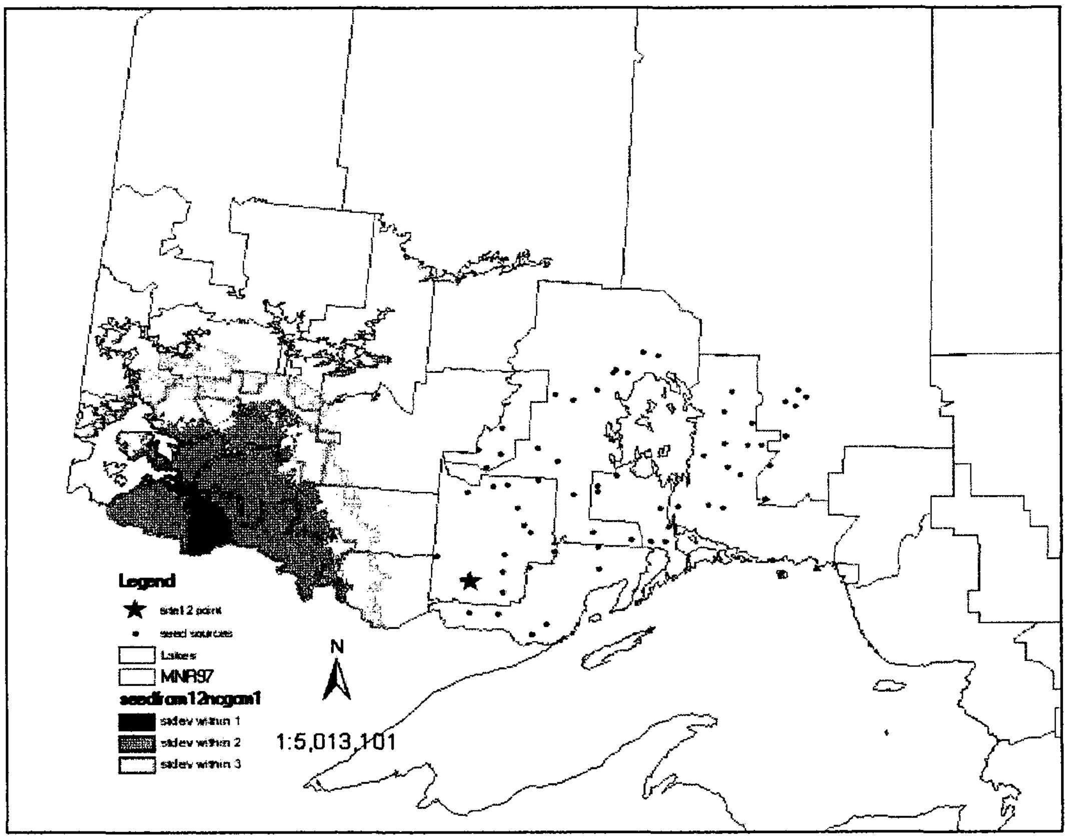


Figure 50. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2069 based on CGCM1

Examination of the relationship between elevation and future focal point seed zones reveals a trend. With the projected climate warming in the future, seeds will go where the climate is somewhat milder; i.e. at higher elevation. To best match the future climate, seeds should come from a relatively low elevation area today.

The pairs of figures (51 and 52), (53 and 54), (55 and 56), (57 and 58), and (59 and 60) show future focal point seed zones (*Seed To*) for 2050 and 2099 based on future climate models HADCM3A2, HADCM3B2, GCCM2A2, CGCM2B2, and CSIROB2, respectively. A general trend is that all these future seed zones will shift northward or north-eastward to best match the future climate conditions compared with the current focal point seed zone based on OCM2 (1990). Seed zones extend to the northwest of the study area. Comparing these seed zones, Figures 51 and 52 have similar shape, showing the suitable future areas for seed sources originating from the focal point. By the end of this century, Fig.52 shows that the most southern portion of the study area is not suitable for planting. The green area moves from the northwest to the east by 2099 when compared with the seed zone by 2050. Fig. 53 and 54 based on HADCM3B2 show a similar trend to Fig. 51 and 52. There is very little or no best suitable area (standard deviation from the focal point within 1) identified in Fig. 53 projected for 2050; however, best suitable area in the projection for 2099 (Fig. 54). Referring to the CGCM2A2 model projected for the year 2050, seed sources originating from the focal point are suitable to be planted almost anywhere within the study area but a small area to the southwest (Figure 55). By 2099, future seed zones for this point move north and the most suitable *Seed To* area for the source has decreased (Figure 56). The study area appears to be divided by Lake Nipigon and the eastern portion is not suitable for planting. The most suitable *Seed To* area is found to the southeast of Lac Seul. Figures 57 and 58 show very different *Seed To* maps based on CGCM2B2 compared with those based on CGCM2A2. By 2050 and 2099, neither the northcentral nor northwestern Ontario study regions provide suitable planting locations for seed sources originating from the focal point. Suitable sources move northwards and appear in a band. Figures 57 and 58 are very similar except that the most suitable *Seed T*o area moves from the northwest portion to the northeast portion of the suitable transfer band between 2050 and 2099. Suitable sources move more north and appear in a band shape. Fig. 57 and 58 are very similar except the most suitable area for transfer is from northwest to northeast by the end of this century. Figure 59 shows a *Seed To* map based on CSIROB2 projected for 2050 which is outside of the study area; a suitable band stretches from the northwest to the northeast in the Hudson Bay area. By 2099, two separate seed zones are identified; one suitable area is found within the study area (northcentral Ontario) north of the focal point, while the other is found far northeast of the sampled area (Fig.60).

Figures 61 through 66 show the future focal point seed zones (*Seed From*) based on the different future climate models. They all show that seed sources should come from southwest and west of the sampled area (within this area) today, to best match the future climate condition at the focal point site. Seed sources that match the climate condition at the focal site are also found outside of the northwestern Ontario study area. Figures 61 and 62 show very similar *Seed From* zones based on HADCM3A2 projected for 2050 and 2099. Figure 62 (for 2099) shows the most *Seed From* suitable area (within 1standard deviation of the focal point) decreases in the sampled area. *Seed From* based on HADCM3B2 for 2050 and 2099 are shown in Figures 63 and 64, respectively. No regions within 1 standard deviation of the focal point are identified in Figure 64. This is not the case for Figures 65 and 66, which are based on CGCM2A2 projected for 2050 and 2099, respectively. No most *Seed From* suitable area is found in Fig. 65. While by 2099, areas most suitable for the focal point have appeared (Fig. 66). By the middle and end of this century, no seed sources from the study area elsewhere in Ontario are suitable for planting at the focal point based on the CGCM2B2 and CSIROB2 climate models.

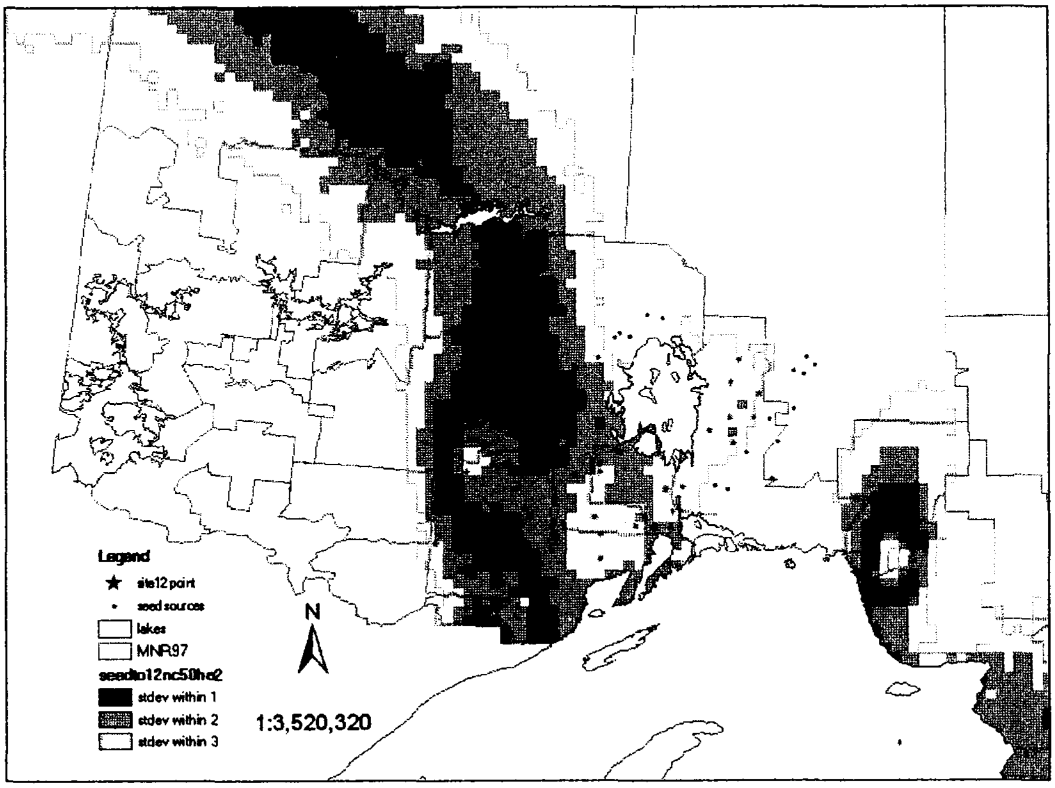


Figure 51. Best '*Seed To*' transfer zone in 2050 for seed from point 48.5°N, 90.5°W based on HADCM3A2

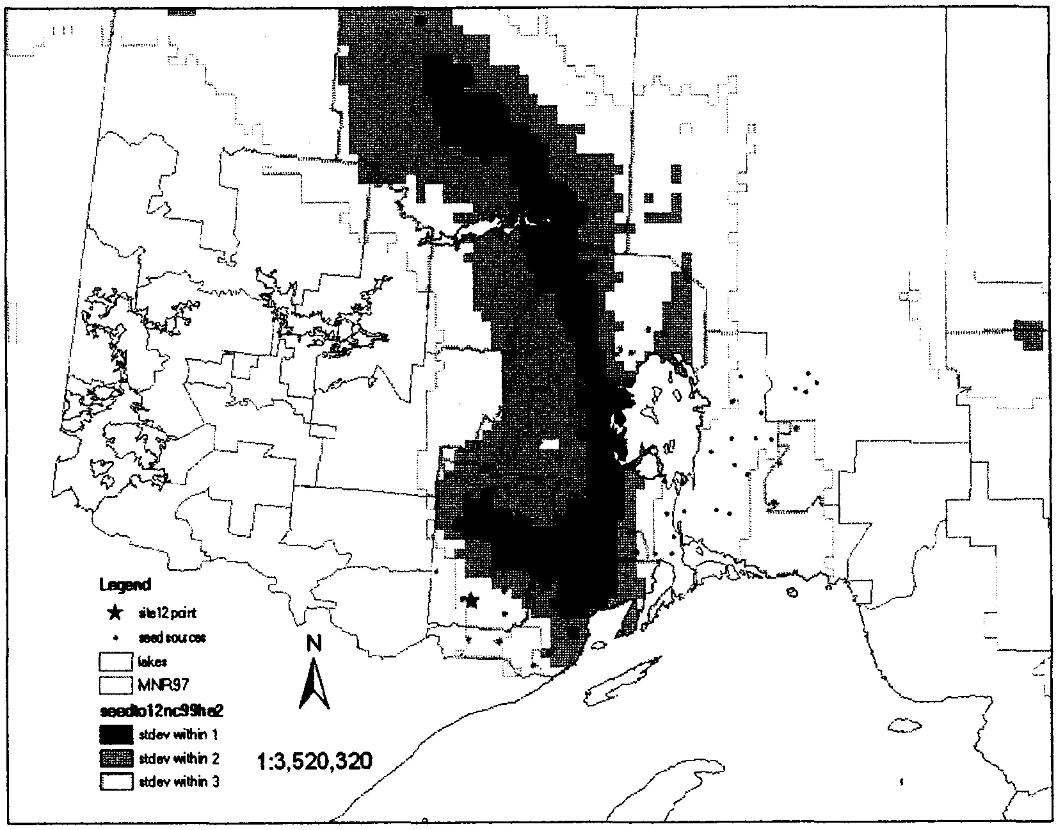


Figure 52. Best '*Seed To*' transfer zone in 2099 for seed from point 48.5°N, 90.5°W based on HADCM3A2

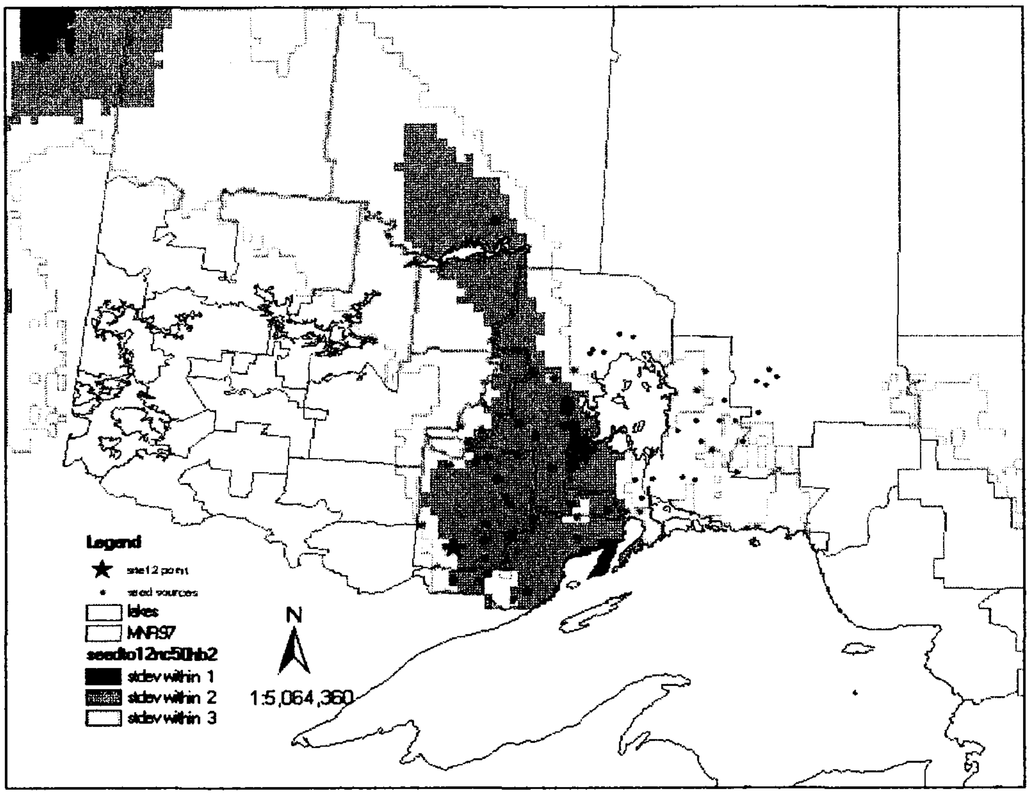


Figure 53. Best '*Seed To*' transfer zone in 2050 for seed from point 48.5°N, 90.5°W based on HADCM3B2

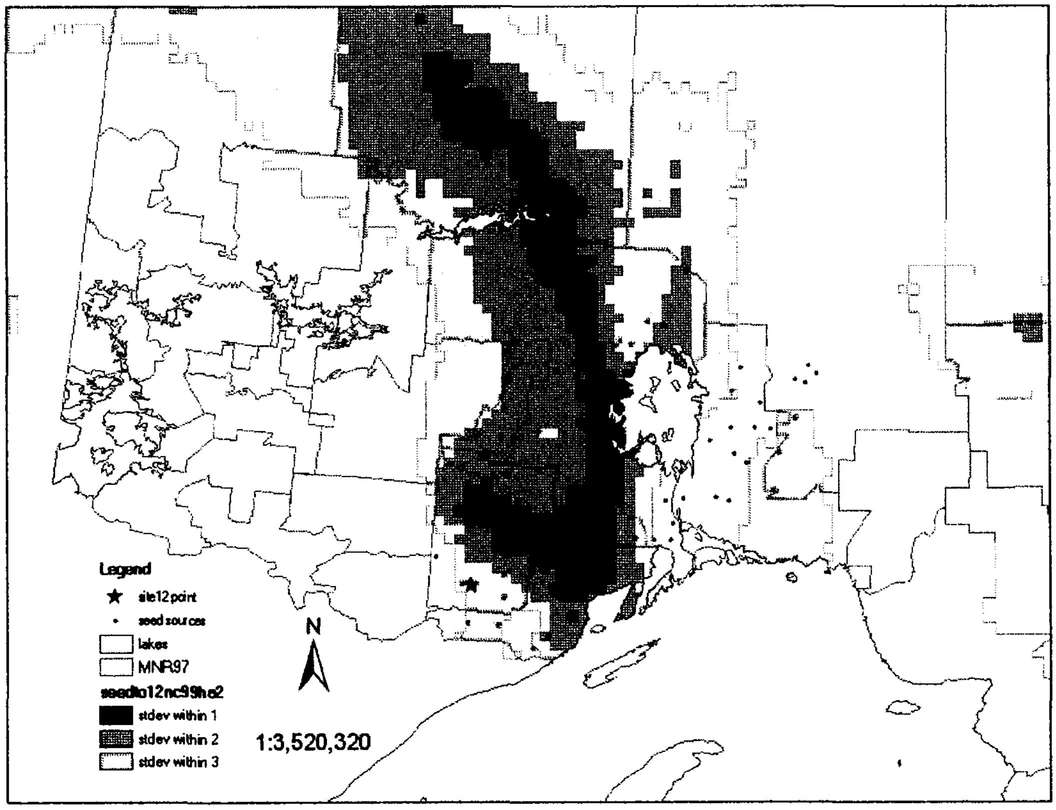


Figure 54. Best '*Seed To*' transfer zone in 2099 for seed from point 48.5°N, 90.5°W based on HADCM3B2

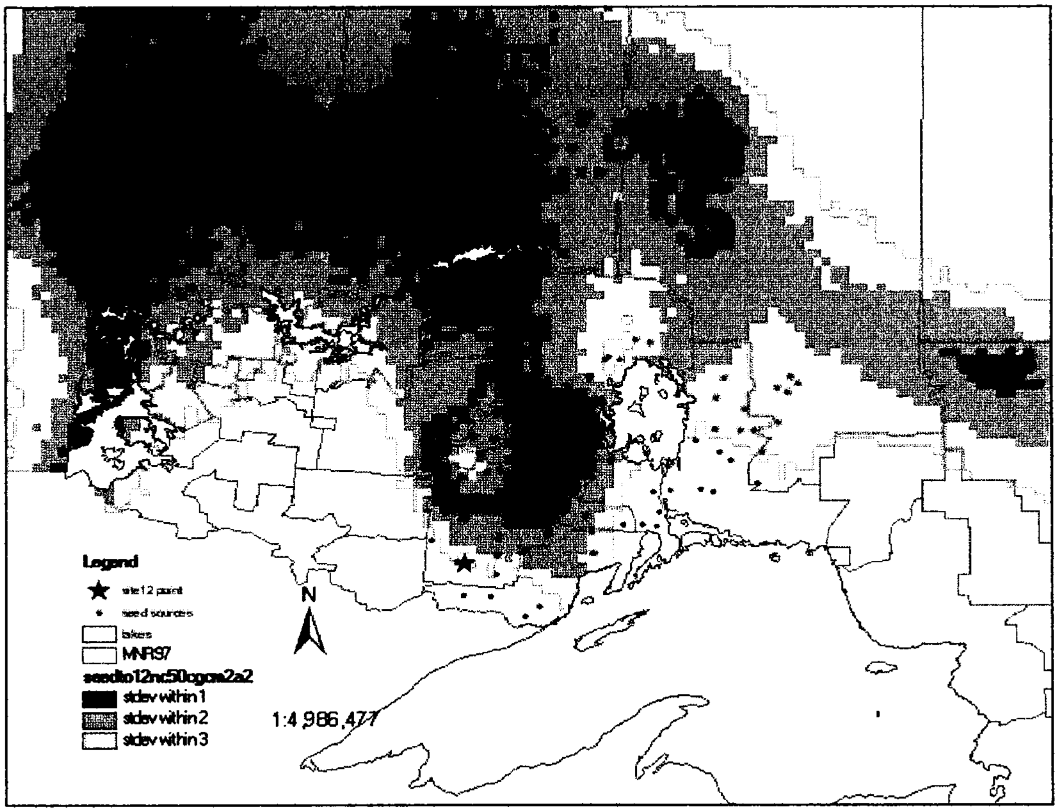


Figure 55. Best '*Seed To*' transfer zone in 2050 for seed from point 48.5°N, 90.5°W based on CGCM2A2

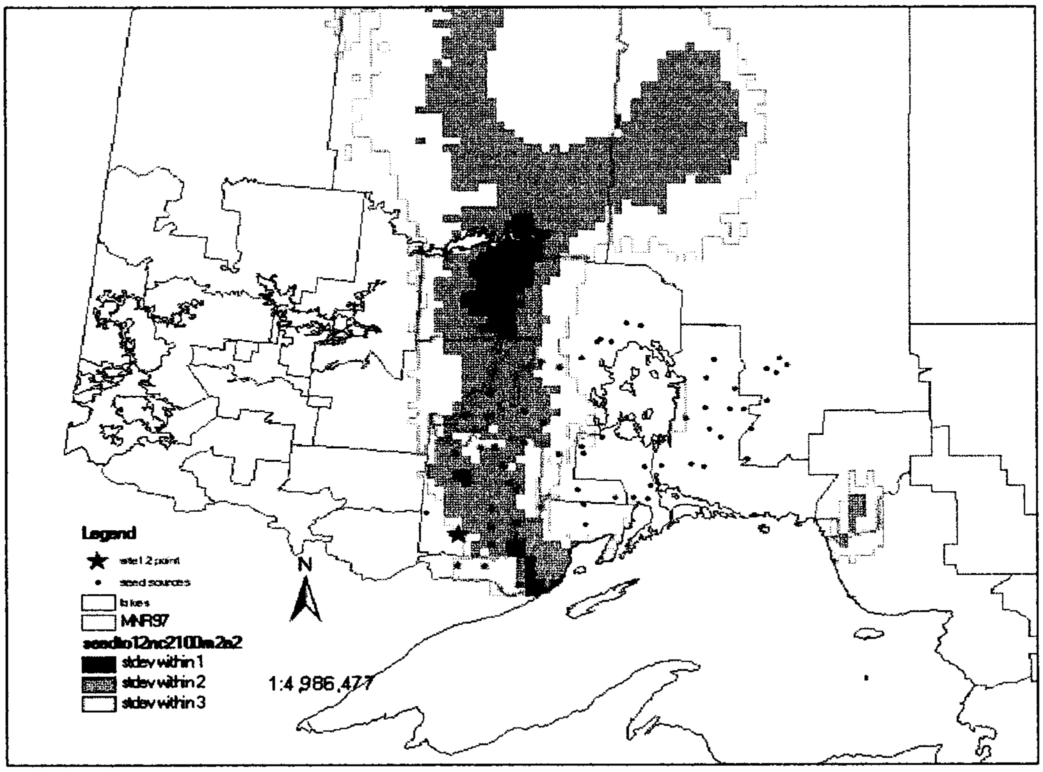


Figure 56. Best '*Seed To*' transfer zone in 2099 for seed from point 48.5°N, 90.5°W based on CGCM2A2

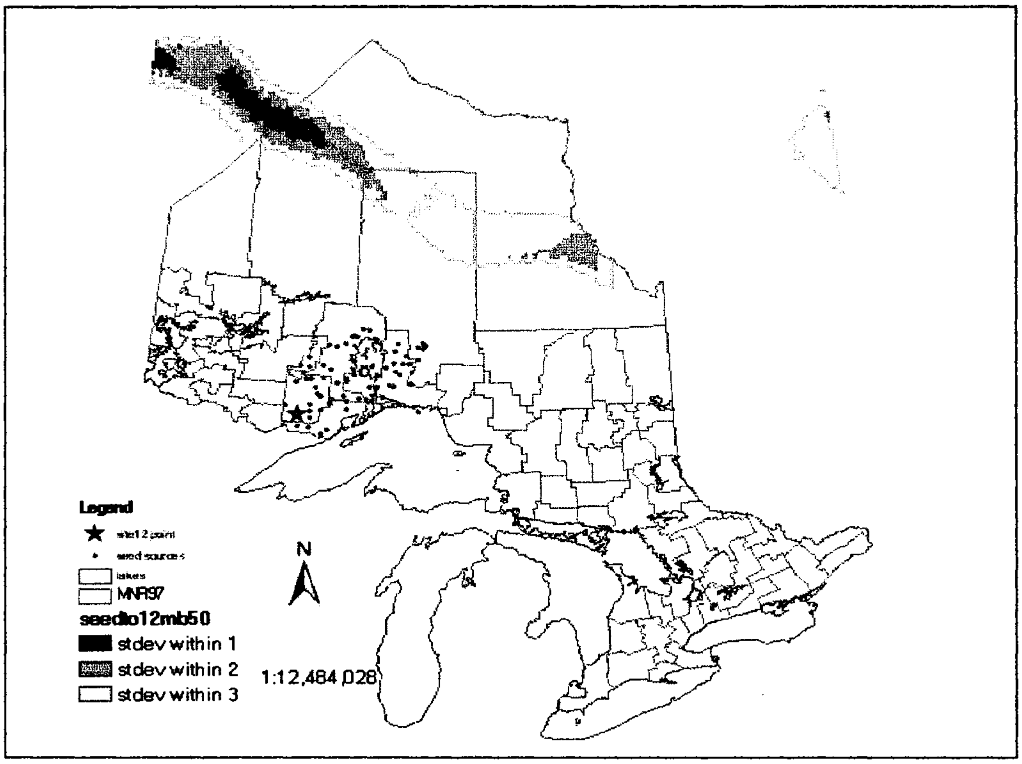


Figure 57. Best '*Seed To*' transfer zone in 2050 for seed from point 48.5°N, 90.5°W based on CGCM2B2

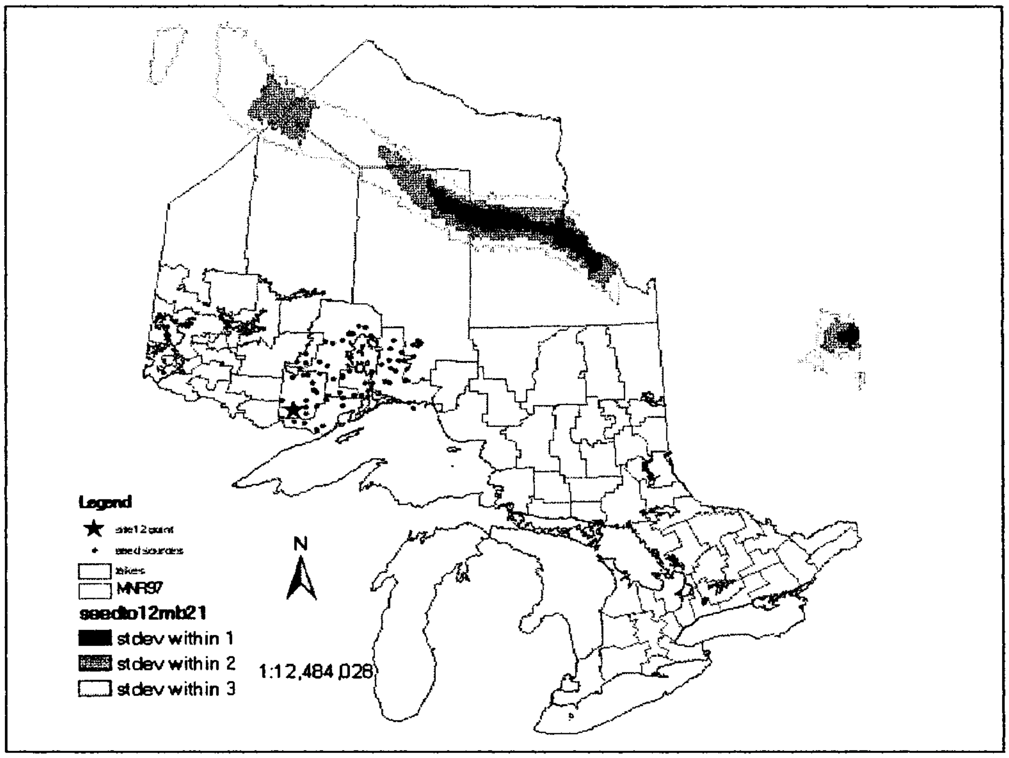


Figure 58. Best '*Seed To*' transfer zone in 2099 for seed from point 48.5°N, 90.5°W based on CGCM2B2

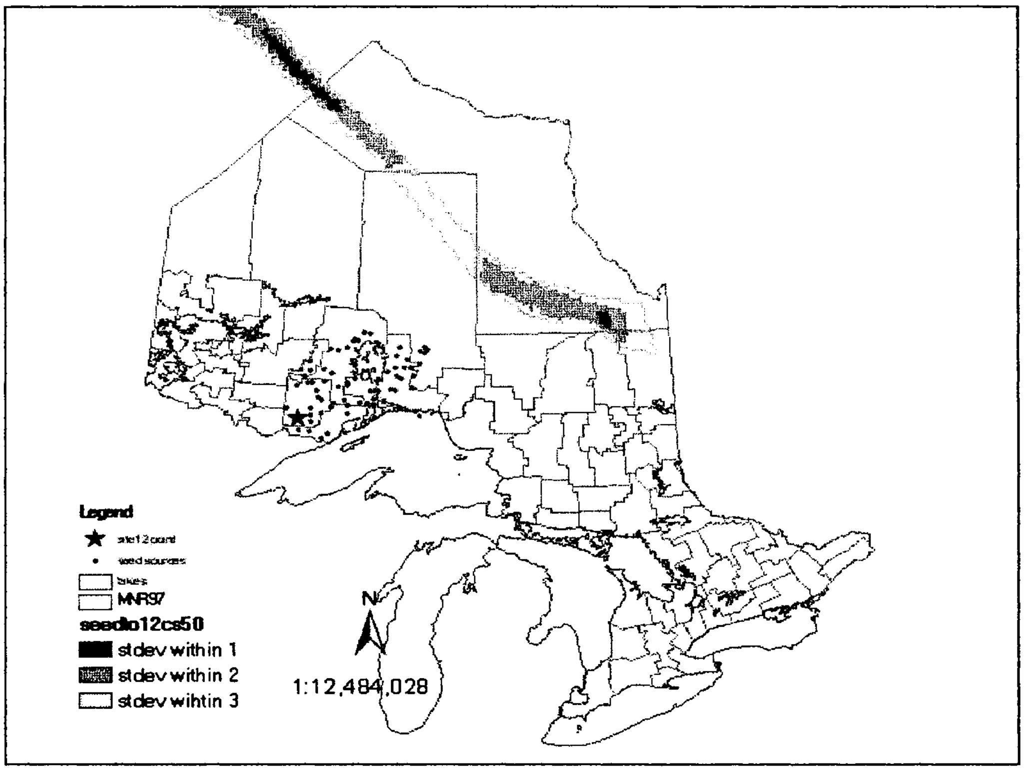


Figure 59. Best '*Seed To*' transfer zone in 2050 for seed from point 48.5°N, 90.5°W based on CSIROB2

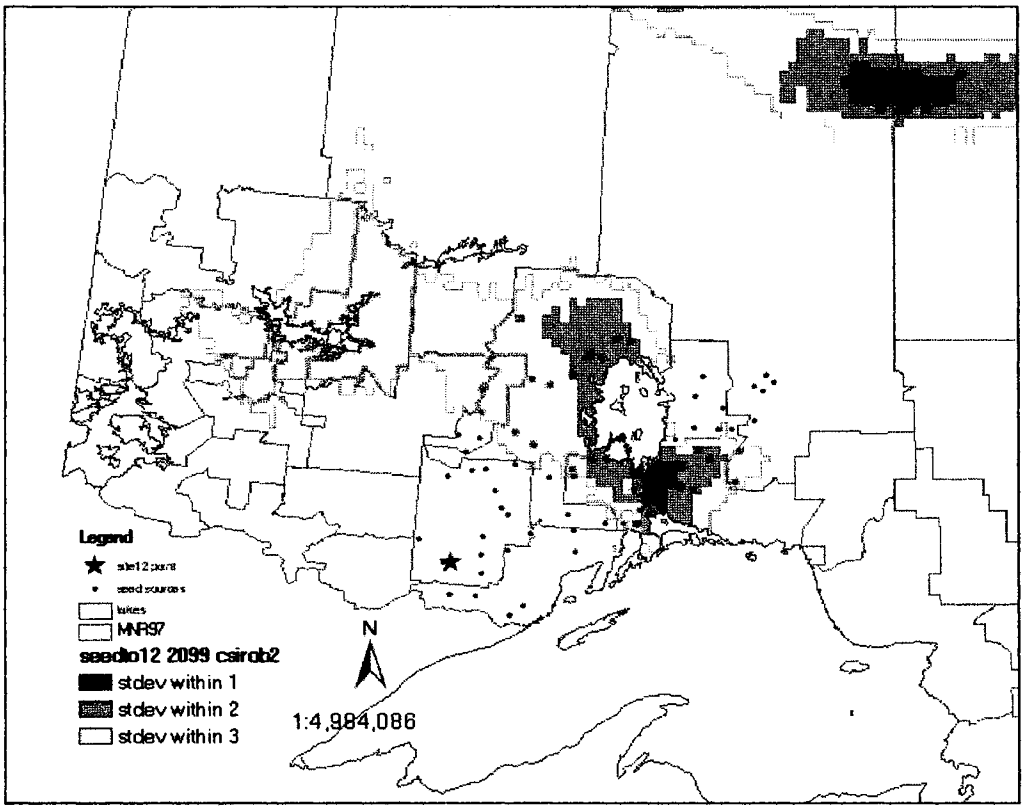


Figure 60. Best '*Seed To*' transfer zone in 2099 for seed from point 48.5°N, 90.5°W based on CSIROB2

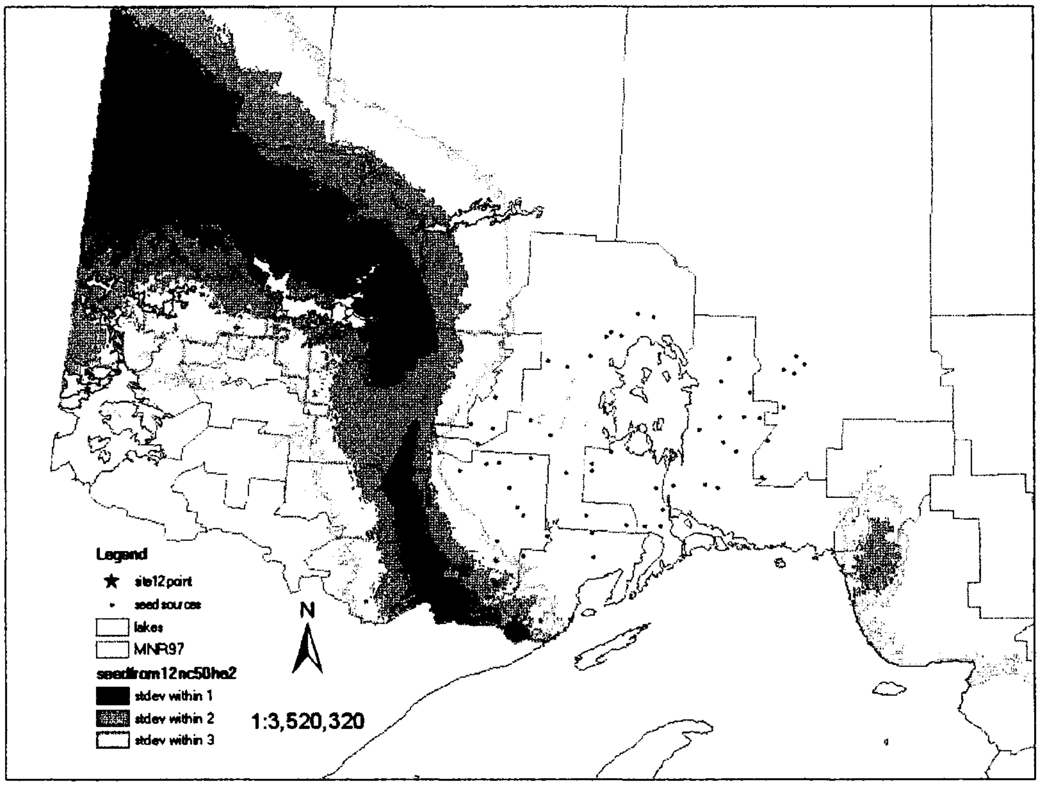


Figure 61. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2050 based on HADCM3A2

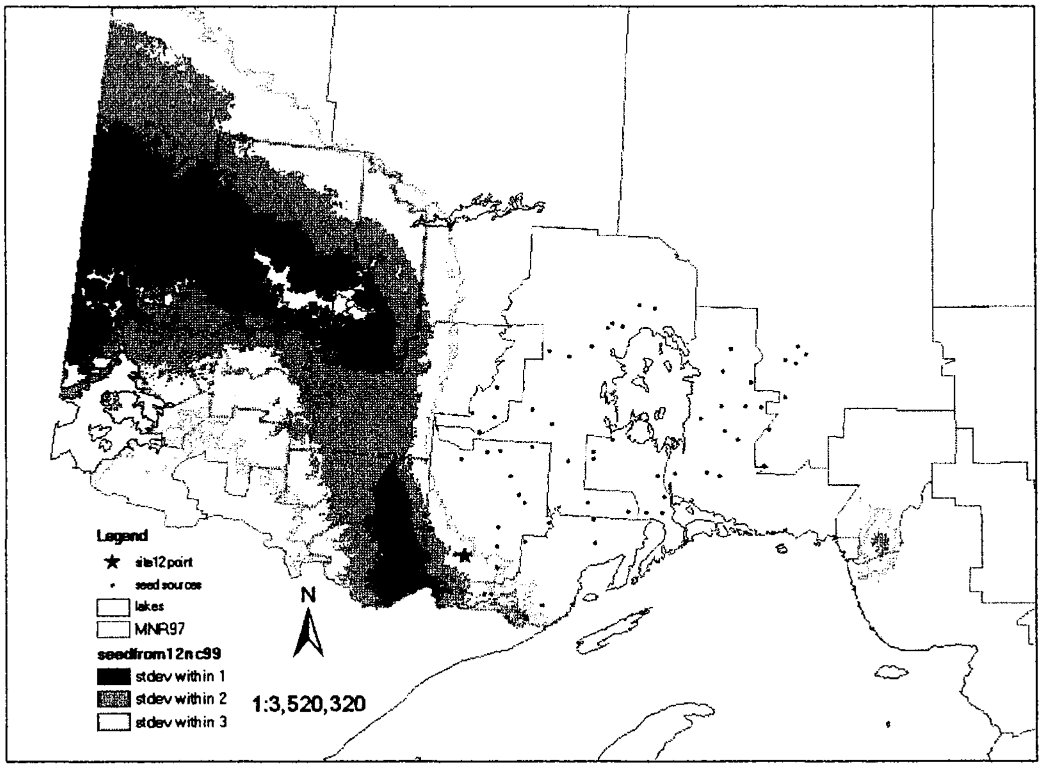


Figure 62. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2099 based on HADCM3A2

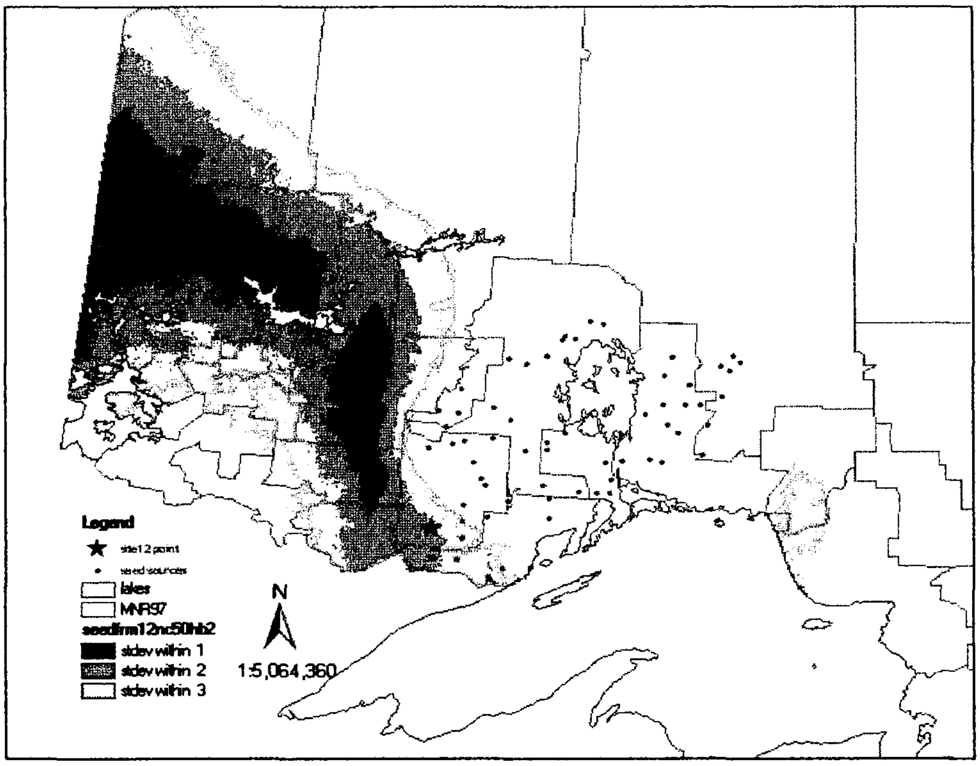


Figure 63. Best '*Seed From*' transfer zone in 2050 to best match climate of point 49.5°N, 92.5°W based on HADCM3B2

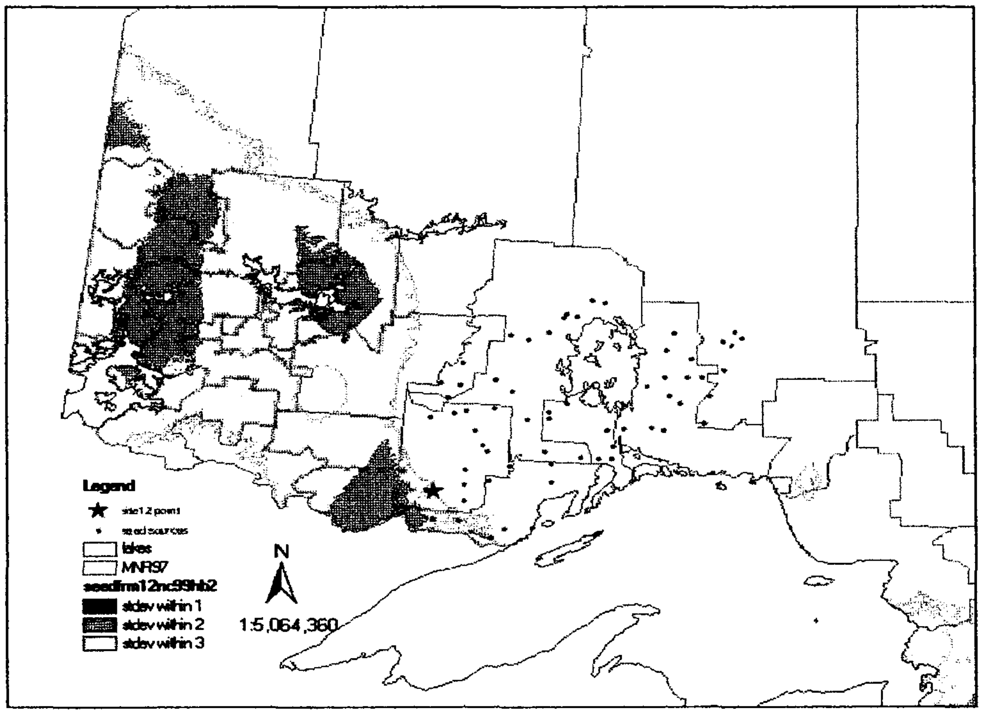


Figure 64. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2099 based on HADCM3B2

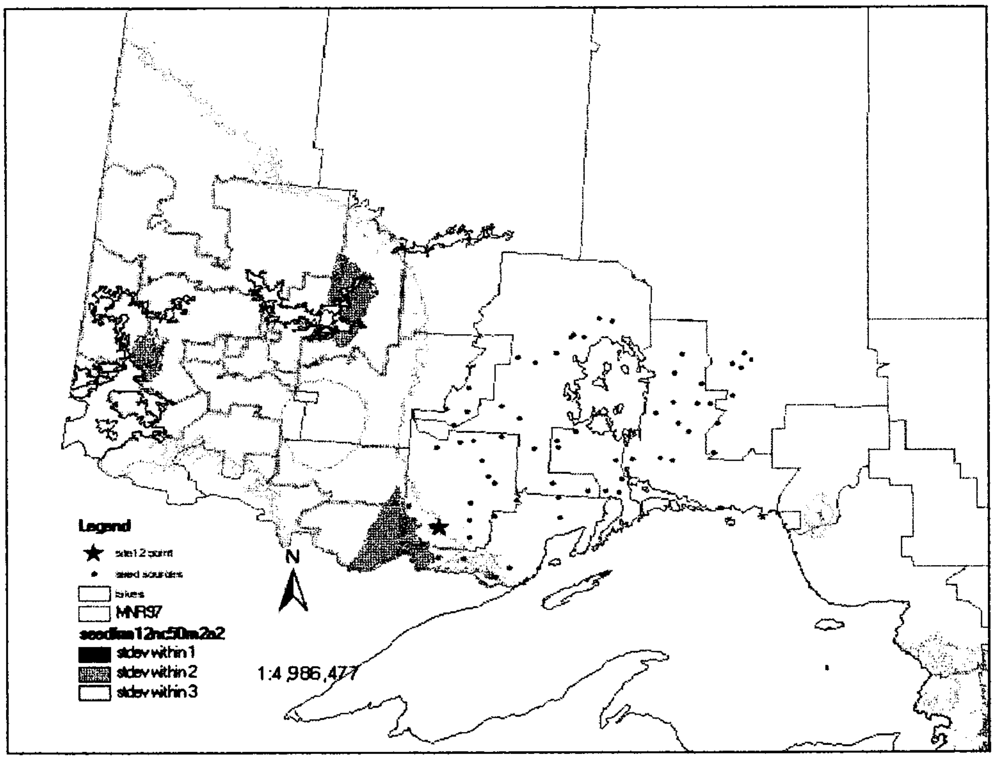


Figure 65. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2050 based on CGCM2A2

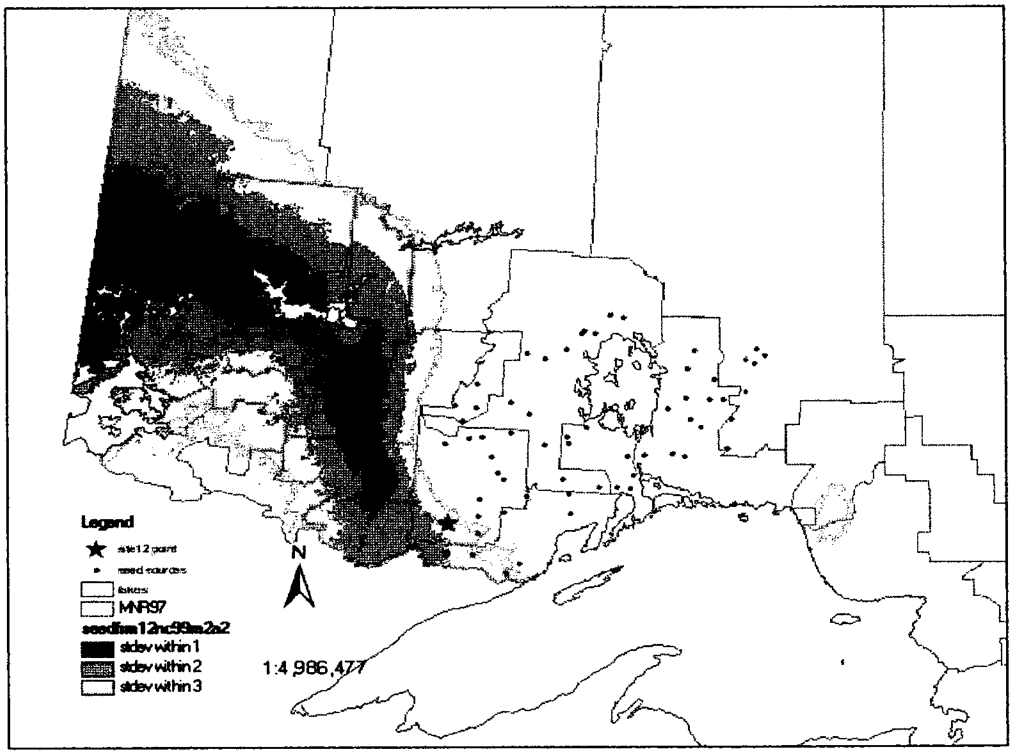


Figure 66. Best '*Seed From*' transfer zone to best match climate of point 49.5°N, 92.5°W in 2099 based on CGCM2A2

DISCUSSION

ADAPTIVE VARIATION OF JACK PINE

Part of the results on an ANOVA (variables measured in 1988, 1989 and 1990) presented by van Niejenhuis (1995), Davradou's (1992) freezing variables and variables (measured in 1993 and 1994) in a Northern Ontario Development Agreement (NODA) funded project (Parker and van Niejenhuis 1996 a) were used in the current study.

The results of the present study are consistent with those of many studies dealing with adaptive variation of jack pine determined by provenance tests. These studies have shown clinal patterns in many measured traits including height, diameter, survival, cone and needle traits, cold hardiness, lammas growth, insects, diseases, form and many phenological variables (Arend *et al.* 1961; Batzer 1962; Schoenike and Brown 1963; Rudolph 1964; Yeatman 1966; Matyas and Yeatman 1992; Morris and Parker, 1992; Hyun 1979; Maley 1993; Davradou 1992; van Niejenhuis 1995; Parker and van Niejenhuis 1996 a; Matyas 1996).

In a study of range-wide jack pine provenance tests in Ontario, Maytas and Yeatman (1992) regressed height and survival traits against precipitation, latitude and heat sum. They found that seed sources transferred moderately northward would result in superior growth potential or at least equal performance to local provenances. The results of that study gave the proof for the possible superiority in growth potential of northward shifted populations over the local ones. In their study, they used ecological distance, a measure of environment change for the transferred sources, to describe limitations of safe transfer distance for jack pine. From a practical viewpoint, this ecological distance graph can be viewed as seed transfer guidelines, although it has limitations. As such, only height and survival were used to model the effects of limited transfer, limited ecological factors and method of mortality analysis (seed sources displaying less than 50% survival were regarded as complete failures) etc. Standard deviations from focal point were used in focal point seed zone methodology to show best adapted areas for reforestation. The findings of the present study will give forest managers a more reliable, more accurate and more operational tool when making seed selection.

Many measured growth, phenological and freezing variables explained significant variation among provenances in the current study. One-way ANOVA showed an unexpected result; i.e., height and diameter differences at 11 years measured in 2004 at Kenora and Sioux Lookout trials were not significant among seed sources. This is somewhat surprising given that the finding of Alm *et al.* (1966) that highly significant differences among jack pine seed sources were found in height and diameter growth after 9 years in the University of Minnesota Cloquet Forestry Center in Carlton County, Minnesota. Also, King (1966) reported that 10-year height growth of trees showed a significant difference among provenances. Matyas and Yeatman (1992) found height and survival at year 15 showed great differences. Perhaps the seedlings suffered competition in moisture and light due to the narrow stem density (0.5 m spacing) or some other environmental factors in the present study area. The trend today is to plant at spacing wider than the traditional 2 m in northern Ontario (Morris and Parker 1992). Perhaps, competition for moisture tends to regulate form as a factor superimposed upon competition for light and space (Morris and Parker 1992). Height traits were significantly different among seed sources in their young age (van Niejenhuis 1995; Parker *et al.* 1996a). This environment stress may have become stronger over time. It is possible that height and diameter differences could not show up under this circumstance in spite of genetic variation among seed sources. In other words, the effects of interaction between genotype and environment might have overshadowed genetic influence on phenotype of seedlings in this case. This effect may have resulted from the seedlings suffering extreme weather conditions.

Overall, the freezing variables explained more variation among seed sources than the other growth variables and phenological variables. The height growth variables expressed more variance than phenological variables and diameter variables. In addition to variation among provenances, among family variation may result from block effects, environmental effects and within provenance differences. In the current study, I did not deal with family variation within seed sources, a possible source of experimental error that might exist.

Testing families over a similarly broad range of environments and artificial screening for adaptive traits will ensure the maintenance of well-adapted, genetically improved populations composed of adaptational generalist rather than specialist elements (Balduman 1999). Beaulieu *et al.* (2004) reported that, although the proportion of variation due to families within provenances for black spruce was smaller than that due to provenances, it was significant for most of the growth traits. Mullin *et al.* (1995) also found that for most of the growth traits, family-within-provenance variance components explained a significant proportion of the total variation in a black spruce study.

Cold Hardiness

Cold hardiness, as an important criterion, was first considered when seed selection was made for reforestation in the boreal climates of Canada (Yeatman and Holst 1972, Rudolph and Yeatman 1982). Cold hardiness traits in the current study in the northcentral study area showed significant differences among seed sources. Seed sources (22, 31, 32, 33 and 34) from the north shore of Lake Superior showed less frost hardiness. In the northwestern study area, an obvious Lake Superior shore effect was found; seed sources from this area showed greater growth potential (Fig.7). Perhaps the southern location, lower elevation and water body produce a warmer environment for jack pine. But this was not the case for the northcentral study area. This phenomenon might give some indications that it is necessary to separate these two study areas. The greater the cold hardiness similarity between seed source and reforestation site, the less the risk of winter injury and susceptibility to disease. For both the previous study and the current study in the northwestern Ontario study area, cold hardiness traits were found to be significantly different among seed sources.

Examination of the relationship between cold hardiness and parent tree environment (longitude, latitude and elevation) in study areas found that there was a positive correlation against latitude with coefficient 0.25 and 0.20 in northcentral and northwestern Ontario study areas, respectively. Comparing the predicted factor scores from PC2 regression models in both study areas, a trend was found (Fig. 8 and Fig. 36) that showed needles flush later with increasing latitude; this trend was more obvious (Fig. 36) in the northcentral Ontario area. There was a negative relationship with elevation (Pearson correlation coefficient -0.325) in the northcentral study area, and a positive but not significant relationship (0.08) in the northwestern Ontario study area. This result was not consistent with Jonsson *et al.* (1980) who indicated that trees of northern origin or from high elevations developed frost hardiness earlier than those of southern origin and from low elevations. Balduman *et al.* (1999) reported that movement of material up 600 m in elevation would result in a 10 % increase in fall cold damage. Differentiation within the study area seed sources was arbitrary in the current study, perhaps partly due to the lakes effect. Especially, Lake Nipigon in the northcentral study area somehow counteracts cold hardiness.

COMPARISONS BETWEEN FORMER AND CURRENT STUDIES

Differences of multiple regression equations for PCA axis 1 and 2 between the earlier and the current studies of jack pine in the same study area were illustrated in Table18. In the northcentral area, the first PCA axis, reflecting growth potential of seed sources, was predicted by 3 temperature variables and one precipitation variable. In contrast, three precipitation variables and one temperature variables were retained in the former study (Parker and van Niejenhuis 1996 a). The second PCA axis reflecting phenology was predicted by two precipitation variables in the current study, while two temperature variables and two precipitation variables were retained in the former study reflecting susceptibility to drought or environmental stress. The same methodology was used in the former and current study with the inclusion of additional freezing trials (Davradou 1992) in the current study. In the northwestern Ontario area, both PC1 axes and PC2 axes were predicted by two temperature and one precipitation variables in the current study. But in the former study, precipitation variables accounted more in the first two PC axes. More biological variables and more updated climate models are used in the current study.

Comparisons of the regressions of PCA axes against climatic variables for jack pine data in the present study and the former northcentral and northwestern Ontario (Parker *et al.* 1994, Parker and Van Niejenhuis 1996 a) show differences in many ways (Table 18). Different climate models were used in these studies. Climate data for the period 1951-1980 (OCM1) was used in the former study, while OCM2 for the period 1961-1990 was used in this present study. In the former northcentral study, the first two axes accounted for 33 and 21.5 percent of the total variation with r^2 value of 0.52 and 0.38, respectively. While in this present study, the first two axes accounted for 27.5% and 14.5% of the total variation with r^2 value of 0.55 and 0.32, respectively. The first axis in present study has the higher r^2 value of 0.55 (growth potential) compared with 0.52, while with lower r^2 value of 0.32 was found for the second axis compared with 0.38 in the former study. The higher r^2 value suggests more confidence in the focal point seed zones generated by this axis. Only two precipitation variables were used to represent the second axis (representing phenology). Precipitation models have more uncertainties when used to predict seed source climate. The first two axes are weighted equally; maybe this action results in weakness of methodology of focal point seed zones.

Table 18. Comparison of multiple regressions equations for PCA Axes 1 and 2 between the former and current study

Study Region		PC axis	Variation	Climate Variables	R^2
North Central	Former(1994)	PC1	33%	March minimum temperature May precipitation July precipitation Prec4 MnT3	0.52
		PC2	21.5%	March mimimum temperature December minimum temperature October precipitation Prec4 MnT	0.38
	Current(2004)	PC1	27.5%	April maximum temperature October maximum temperature Jun minimum temperature October precipitation	0.55
		PC2	14.5%	March precipitation November precipitation	0.32
Northwesten	Former(1996)	PC1	37.8%	July maximum temperature average April precipitation July precipitation	0.665
		PC2	17.3%	March precipitation GrowStr	0.35
	Current(2004)	PC1	31%	December maximum temperature November minimum temperature April precipitation	0.55
		PC2	10%	August maximum temperature November minimum temperature June precipitation	0.24

Note:
Prec4: average precipitation (mm) for 6 weeks from the start of the growing season;
MnT: mean annual temperature; MnT: mean temperature for the entire growing season;
GrowStr: start of growing season (last day of 5 consecutive days when mean daily temperature > 5°C)

In the northwestern Ontario study, the first two axes accounted for 31 and 10 percent of the total variation compared with the 37.8 and 17.3 percent in the former study. The decreased amount variation in the first two axes accounted for in the present study may result from more environment variation over time and additional biological variables used: 30 principal components, compared with 21 in the former study. The r^2 values of 0.55 and 0.24 for the first two axes in present study compared to 0.665 and 0.35 in the former study, respectively. In the present study, only 36 monthly climate variables were available both for OCM2 and future climate scenarios. But an additional 29 climate variables included in OCM1 were used in the former study including start of growing season, mean annual temperature, entire growing season and average precipitation. The decreased r^2 values for the first two axes in the present study compared with the former study might partly result in the differences between these two climate models.

FOCAL POINT SEED ZONES OF JACK PINE

In terms of differentiation of populations based on clinal variation, focal point seed zones have been developed for black spruce and jack pine in northwestern Ontario (Parker 1992, Parker *et al.* 1994 and Parker and van Niejenhuis 1996 a) and for white spruce across the Ontario province (Parker and Lesser 2004). Focal point seed zones are based on the actual patterns of adaptive variation present in each forest tree species targeted for regeneration. Numerous growth, phenological and freezing damage variables are used to delineate seed zones. They represent true patterns of adaptive variation within a species based on regression models of summarized biological variables against climate.

Present Focal Point Seed Zones

The results of a Northern Ontario Development Agreement (NODA) funded project were used to develop the original focal point seed zone models for jack pine in the northwestern portion of Ontario (Parker and van Niejenhuis 1996 a). OCM1

(1951-1980 average climate girds) was used in the early study, and 29 climate variables, e.g. start of growing season, mean annual temperature, entire growing season and average precipitation etc, were included in OCM1. In present research on these focal point seed zones, an updated second iteration of the Ontario Climate Model (OCM2) (1961-1990 average climate grids) was adopted. New data collected in 1997, 2003 and 2004 growing seasons, were integrated with the earlier data to produce revised focal point seed zones for jack pine in 2005. Thirty six monthly climate variables are available both for OCM2 and future climate scenarios used in the present studies. A focal point seed zone model is selected to show the differences between the current and former study based on focal point 49.5°N 92.5°W. Certain differences of focal point seed zones exist between two studies (Fig. 17 and Fig. 67).

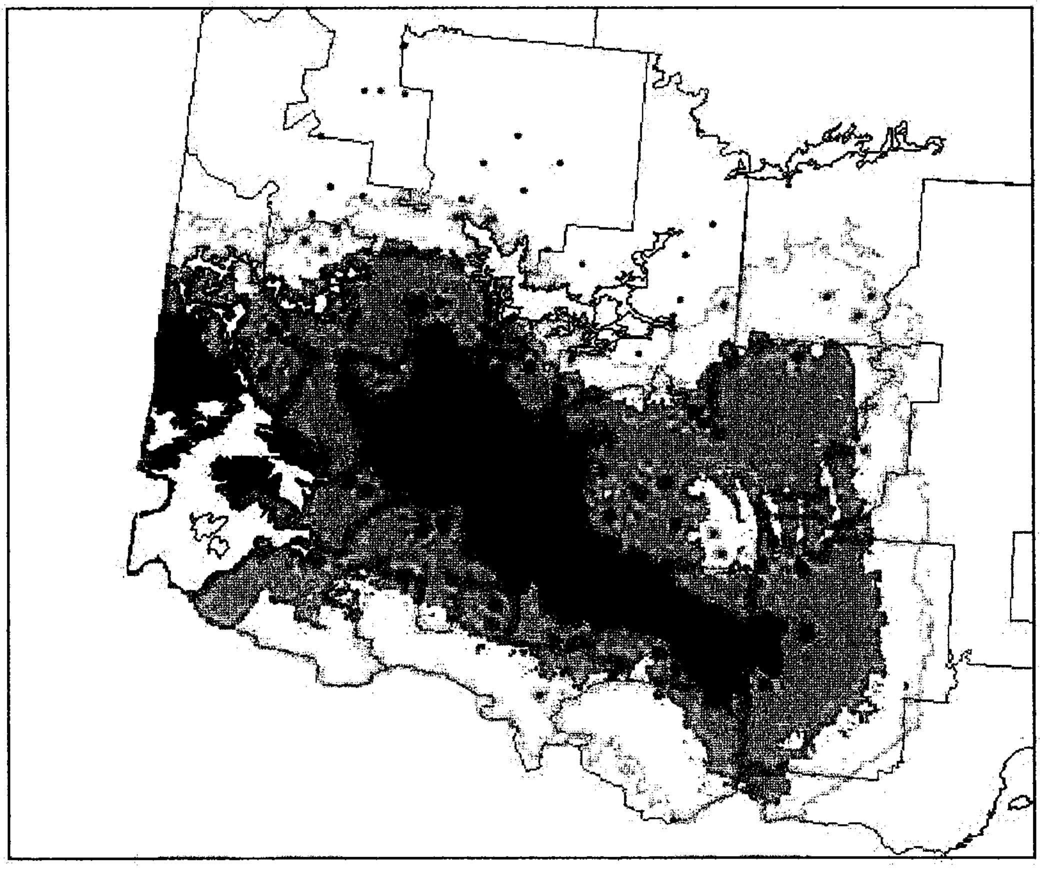


Figure 67. Focal point seed zones at point 49.5°N, 92.5°W based on OCM1 (Parker and van Niejenhuis 1996 a)

Compared with the Fig. 67, which produced in the former study, in general, Fig. 17 shows a bigger seed zone (stand deviation within 1) expanding to the southeast portion of the sampled area. Two separate most suitable areas for the focal point are shown in Fig. 67 in the former study.

Examination of focal point seed zones for the northcentral study area, found that seed zones created for a focal point south of approximately 49° latitude showed clear east west separation within the study area (maps are not shown here). Many zones show less suitable areas around Lake Nipigon. Excluding the most southwest and northeast portion of study area, most of the area is suitable for seed transfer within the study area. The eastern shores of Lake Superior show less suitable area in most seed zones. As points move northeast, the zones become more general crossing the study area. Focal point seed zone at (49.9°N 89°W) appears to be the most equally suitable for seed transfer within the whole study area. This result is consistent with the findings from the 410 Series white spruce research by Morgenstern and Copis (1999) that the best growing provenances at more southern test sites are generally local or at least regional sources. While in northwestern Ontario area, focal point seed zones are most specialized and regional. When focal point is moved from west to east along 50.5°N latitude, focal point seed zones generally become more local and regional.

Future Focal Point Seed Zones

Significance

Forest managers are concerned not only with the short term risk associated with planting trees, but also with long term risk. Global warming is expected to affect seed selection in the future. Concern about climate change is increasing because ecological and social economic impacts are more and more perceptible. Research on the ecological consequences of global warming mainly concerns changes in plant community and species as whole (Chuine 2004, Davis, *et. al* 2005). Forest managers are becoming increasingly concerned about the effects of projected global warming on the growth of future forests. Maps of interpolated climate normals have recently become essential tools for many types of forestry research, such as studying genetic adaptation of trees to local environments, modeling species' range shifts or forest productivity under climate change scenarios. Scientists have suggested a number of adaptive management strategies to reduce the vulnerability of managed forests to climate change. One important strategy is to modify present seed transfer guidelines based on more up to date climate models and climate change scenarios. Eriksson *et al.* (1993) proposed the "dynamic conservation" concept to convey that breeding and conservation are not static, and that an evolutionary approach to manage forest tree genetic resources is necessary. Focal point seed zone is one operational approach, which provides an opportunity to develop dynamic maps.

Seed To and *Seed From*

Focal point seed zones, which prescribe *Seed To* and *Seed From* in terms of changing climate, provide an additional and more robust means to evaluate the adaptive suitability of potential seed transfers for jack pine, which can help ensure properly matched seed sources to planting sites according to expressed patterns of adaptive variation. Future focal point seed zones could help avoid future maladaptation resulting from climate change. The right seed sources can be identified by *Seed To* and *Seed From* to match the anticipated climate shift, and used in reforestation efforts.

Focal point seed zones based on future climate scenarios (*Seed To* and *Seed From*) show a consistent pattern that by the middle of this century, seeds from the study area will transfer to the north or northwest from the origin in the study area. The extent to which focal point seed zones changes were affected by the future condition was largely dependent on the choice of scenarios. Most seeds from the most northern portion of study area will not be suitable for anywhere in the sampled area. The best adapted seeds should come from the southwest area. Fig. 59 shows that no seed sources from the sampled area will be suitable to be planted at the focal point by 2050, while by 2099; seed sources from local points are suitable to the north of the sampled area (Fig. 60). The reason is that the precipitation projected to 2050 is decreasing by 1% and increasing projected to the end of this century by 6% based on the future climate model-- CSIROB2 .

Although much uncertainty exists in scenarios, by the middle of this century, seeds from this study area should be transferred north or northeast to best suit future conditions. We can also say that seeds should come from the south or the southwest portion of present study area now to be best adapted in the future to their plating site. By the end of this century, the trend shifts further north based on some scenarios. If climate change predictions are true, gain could be substantial by the use focal point seed zones generated for jack pine in northwest Ontario.

Focal point seed zone maps (*Seed To*) of both study areas show the similar trend that the seed zones move to the high elevations in the north or northeast portion of study area by the middle of this century, or out of the study area farther north or northeast by the end of this century based on these five different climate scenarios.

Focal point seed zone maps (*Seed From*) show that seeds should come from south or southwest area-- low elevations of the sampled area, to best match the future conditions. Similar results have been reported by Rehfeldt (2004) that the contemporary location of Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) best suited to the new climates shifts from the contemporary site to the low elevations at the north. But an exception was found that seeds should come from the north portion of the sampled area, to best match the future conditions based on CGCM2A2 by the end of this century (Fig. 33), which is not expected. All the pertinent research has demonstrated a close relationship between species' ranges and climate change.

Relevant Research

Future focal point seed zones of this study are consistent with the continuous zones of Rehfeldt (1990) in some respects. Rehfeldt gave rough descriptions on the adaptedness of populations when the environment changes. He found that if the environment were to warm, the appropriate seed sources tend to come from either elevations lower than the planting site itself or from elevations higher than the planting site toward the north and west where the climate is slightly milder. This case is somewhat similar to *Seed From* in this study. Adapted sources would come from higher elevations than that of the site and from geographic regions toward the southeast where the climate is more severe if the environment were to get cold. This case is somewhat similar to *Seed To* in this study. He used geographical variables (elevation, latitude and longitude) instead of climate variables in the locations of parent trees. Compared with the models that Rehfeldt and others developed using geographic variables as surrogates, focal point seed zones as in the current study provide a direct cause-response measure, and can be expected to improve in accuracy, reliability, robustness and flexibility.

The results of the present study join with those of numerous studies dealing with genetic responses to climate change. Ontario's northward-shifted boreal forest of 2050 will not have the same species composition as it does today (Hengeveld 1991). Climate change may result in dramatic northward shifts in the natural range of forest types and species (Parker *et al.* 2000). The present results also are consistent with the prevailing view of a major redistribution of tree species and genotypes across the landscape due to global warming in the long run (Rehfeldt *et al.* 1999).

The results of this study supported those studies that dealt with climate change effects on tree species. Matyas (1994) constructed a growth response model by principal component analysis and ecological distance and predicted that the southward transfer of more northerly jack pine provenances provided the source with conditions close to optimum and increased height growth by approximately 20%; Morgenstern and Teich (1969) reported increases in height were obtained by planting trees 2 to 3° north of their seed origin. A study done by Cherry and Parker (2003) in Ontario found that white spruce optimal habitats were expected to shift north by about 2° latitude as result of climate warming for 50 years into the future based on CGCM1 using response functions and Cauchy functions; More recently, Parker *et al.* (2004) using the same methodology with black spruce found that more northerly provenances in Ontario currently achieve better height growth when moved to more southern locations.

Focal point seed zones represent the areas of greatest similarity to the selected point, and the local seed is considered best to reforest efforts in Ontario. However, authors have reported that provenances moved 1°or 2° latitude north of the place of origin, or moderate northward shifts, would out perform local sources (Well and Wakeley 1966; Morgenstern and Teich, 1969; Maytas 1994, 1997; Maytas and Yeatman 1992, Rehfeldt 1999; Cherry and Parker 2003; Parker *et al.* 2004). One thing we should keep in mind is that focal point seed zones are the best adapted and do not ensure that the selected seed sources will maximize growth potential at the given point. However, the predicted factor score maps (Figure 7 in northwestern region of Ontario and Figure 35 in northcentral Ontario) from PC1 regression models do show the variation in growth potential, and it is highest in the southwest.

CLIMATE CHANGE AND CLIMATE CHANGE SCENARIOS

The real scenario of the climate change on earth environment in history (e.g. a somehow dramatic periodic fluctuation on temperature in a large temporal and space scale) can be determined by some research methods including climate monitoring, sampling ice cores and tree rings. These objective facts of past history of the earth are viewed as the base of specific images of the future climate change, and as an important database and supportive base when scientists simulate future climate change.

Necessity

Climate is the primary factor controlling the distribution of organisms (Brown and Gibson 1983, Woodward 1987, Rehfeldt 2004). Some relative impact studies have suggested that climate change may alter species distribution and seed transfer (Mayas 1994, Rehfeldt 1999, Parker *et al.* 2000, Cherry and Parker 2003). However, these studies were based on a single temperature or other single climate variable; the uncertainties of the projection could not be quantified. IPCC (2001) recommends that "users should design and apply multiple scenarios in impacts assessments, where these scenarios span a range of possible future climates, rather than designing and applying a single guess scenario". Six different climate change scenarios (CGCM1, CGCM2A2, CGCM2B2, HADCM3A2, HADCM3B2 and CSIROB2) are used in the present study. These alternative scenarios are based on different estimates of fossil-fuel reserves, rates of economic growth, or rates of technological change within a given scenario family (IPCC 2001).

Geographical Variables and Climate Variables

Geographical variables (longitude, latitude, elevation, aspect etc.) were more commonly used in past studies describing environmental variation because of the relative ease in obtaining their estimates; however, they are simply surrogates for local climate conditions based on broad scale relationships between geographic location and climate (Balduman 1999). In a study of genetic variation in ponderosa pine of the southwest, Rehfeldt (1993) used elevation and latitude as independent variables to approximate climate conditions. The use of ecological variables (i.e. temperature and precipitation) has many advantages over geographical ones. First, it links genetics and ecology by the possible assessment of the weight and importance of various environmental factors shaping and delimiting within-species genetic variation. Secondly, adaptive responses and variation patterns can be interpreted, generalized and compared more easily if cleared from strict geographic bonds. Thirdly, the use of ecological variables allows the modeling of effects of environmental change (Matyas 1997). Also, climatic variables can provide better estimates of components of the environment conditions of species as they directly measure temperature and moisture regimes.

Examination of the results of simple regression of biological variables against geographic and climate variables indicated that temperature variables were selected much more often than precipitation variables in both northcentral area and northwestern Ontario area. A similar observation is reported by Parker *et al.* (2004) in a white spruce provenance test study. These findings are consistent with a study done with ponderosa pine by Sorensen (1994) indicating that genetic differentiation of tree species across temperature gradients is much stronger than across moisture gradients. The R^2 values in both current studies for the temperature are much greater than those for precipitation, possibly indicating that regression models are more effective in describing gradients in temperature from geographic prediction than they are in describing geographic patterns of precipitation. The same observation was found in a genetic response to climate study by Rehfeldt (1999). It is most likely that precipitation is strongly influenced by local topographic effects.

Considered variables in six different climate change scenarios include monthly maximum temperatures, minimum temperatures and precipitation in the present study. Different temperature and precipitation are projected in the future based on different climate scenarios compared to today's climate conditions (OMNR 2000). From data extracted from these five different climate change scenarios (Table 3 and Figure 4, 5), we know precipitation projected in the study area for the future will be different. As such, precipitation projected to 2050 is decreasing based on CGCM2A2 while it is increasing based on CGCM2B2; or it is decreasing for 2050, and increasing for 2080 based on CSIROMB2. It is predicted that higher average temperatures will be accompanied by global increases in precipitation, but the amount and distribution of it will vary regionally, with some areas having a higher frequency and severity of droughts (IPCC 1996).

To What Extent Can We Trust Future Climate Change Scenarios?

Although knowing what has happened in the past and what is happening now could provide us some clues, can we accurately know future events? Climate change scenarios play an important role in revealing the future climate events, and show a degree of validity. The current generation of predictive climate models are effective in estimating the mean global and hemispheric sensitivity to altered climate forcing (Webb 1998; Joussaume *et al.* 1999). However, the simulation results among diverse climate models could be significantly different in predicting the same changing event, even on the same area and the same temporal range, owing to the differences in the structure, variables, sensitivity and parameters of models. In constructing climate change scenarios there are many sources of uncertainty. Where possible, they have been taken into account. Thus, the scenarios represent a multiplicity of plausible futures (CSIRO 1996). In this study, different climate change scenarios were used, different scales of resolution were used (i.e. 1-km grid scale for OCM2, 7.5-km grid scale for CGCM2, HADCM3 and CSIROS, 15-km resolution for CGCM1). CGCM's spatial resolution is still poor and the prediction of regional climate change remains limited, especially for precipitation. And, there were different width ranges of these models. Five are within Ontario and the west of Quebec, while CGCM1 is throughout all Canada; this difference can result in some uncertainties. For example, Fig. 19, Fig. 25 and Fig. 27 show future focal point seed zones based on point 49.5°N, 92.5°W by the middle of the 21st century under HADCM3, CGCM2 and CSIRO scenarios. These three climate modes predicted the same point (49.5°N, 92.5°W) at the same time (2050), but the results of *Seed To* maps are significantly different resulting from the different simulation results of climate models. By the middle of the 21st century (2050), the temperature increase is predicted to be 2.7°C, 2.3°C , 2.7°C, 2.6°C, and 3.9°C and precipitation decrease of 3%, 8%, increase of 15%, increase of 10%; and increase of 6% based on CGCM2A2, GCM2B2, HADCM3A2, HADCM3B2 and CSIROMB2, respectively. Hence, This large discrepancy of simulated results, 1.6°C (ranging from 2.3 to 3.9°C) in temperature and 23 %(from -8% to 15%) in precipitation among these climate models, which results in some uncertainty, such as the diverse *Seed To* maps shown in the present study.

It is a great goal to approach reality in modern models. The results of model simulation are still uncertain. Current scientific understanding predicts with confidence global warming in this century (CSIRO 1996). Uncertainty surrounding future greenhouse gas and sulfate emissions, shortcomings in climate modelling, and difficulties in determining regional patterns of climate change from global estimates mean that predictions of future climate change at a regional level still cannot be made (CSIRO 1996). At present, almost all climate change model simulations usually focus on one or two main factors, which serve as major forcing and expressing factors (e.g. temperature or precipitation) and redisplay the historical scenario by ceaselessly revising parameters of a model according to the real climate database. At the same time, global climate models are continuously being improved. Horizontal and vertical resolution are being increased as computing power advances, with many modelling groups taking advantage of the ability to split intensive calculations between multiple, parallel processors on a single computer (Flato et. al 2000). Improvements in parameterizations of physical processes in all component models are being made (Zhang and McFarlane 1995). We should remember that some limitations to the use of the modeled climate variables exist. They are predicted values interpolated from climate models instead of true values; there might be some discrepancy from true values. Different technical skills for extracting data result in some estimate uncertainty.

Moreover, it is an additional challenge to effectively deal with the uncertain stress effects of human activities on the change of the earth environment in climate models. The dynamic pressures of human activities (emission of greenhouse gas, decreasing coverage vegetated lands due to forest cutting and cultivated farm lands) produced by increasing conflicts between rapid population growth and resource limitation, explained an increasing ratio and magnitude leading to global warming (Ledig and Kitzmiller 1992, Parker *et al.* 2000). As such, more up-to-date emission scenarios A2 and B2 were applied in the present study. The A2 scenario envisions population growth to 15 billion by the year 2100 and rather slow economic and technological development (IPCC 2001). The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability (IPCC 2001). Its scenario envisions slower population growth (10.4 billion by 2100) with a more rapidly evolving economy and more emphasis on environmental protection. It therefore produces lower emissions and less future warming (IPCC 2001). Fig. 19 and 21 and Fig. 24 and Fig. 26 show different future focal point seed zones by the middle of the 21st century and by the end of the 21st century based on HADCM3 and CGCM2 climate scenario in the form of A2 and B2. Fig. 21 shows a large suitable area in Quebec and Fig. 26 shows no suitable area by 2099 for seed sources from the focal point.

Future focal point seed zones (*Seed To* and *Seed From*) of this study are based on different climate change scenarios. Although they are uncertain, they are a significant prediction. The reliability of future focal point seed zones for jack pine is dependent on the accuracy of climate change scenarios as well as the improvement of the statistical models that predict adaptive variation. These alternative scenarios are based on different estimates of social policy, rates of economic growth, rates of technological change, natural eco-environment change within a given scenario family. However, the focal point seed zone method is one operational approach, which provides an opportunity to develop dynamic maps. In this study, these future focal point seed zones are probably more reliable when based upon temperature rather than precipitation, due to the high degree of uncertainty surrounding currently available estimates of changes in precipitation within Ontario as result of climate change (IPCC 2001). The same observations were found in other relevant research (Maytas 1994, Cherry and Parker 2003, Parker *et al.* 2004). Given the uncertainty about precipitation changes in the future, caution must be exercised in interpreting the predictions of increasing adaptation lag in global warming scenarios based solely on temperature change. Until a regional-scale climate circulation model becomes available for Ontario with fine resolution, and until one that can model the effects of the Great Lakes on local climate patterns, no model of individual focal point seed zones can give reliable guidelines for seed election.

RECOMMENDATIONS

Although there are limitations and uncertainties, the results of this study are able to serve as seed transfer guidelines for jack pine for both the present day and the future in northwestern Ontario. Seed source selection based on the best available information is the first step to realize the greatest yields in jack pine and other species (Zobel and Talbert 1984). We must use the best genetic material for the locale and the best techniques available for establishing and managing plantations.

It is recommended using seeds from selected stands near the planting site where local seed sources appear to be superior; I consider selecting stands within focal point seed zones or a little south of local stands within the range of jack pine where local sources lack superiority and the use of nonlocal sources is indicated. Forest managers could mix the local seed source and one they expect to be better adapted to future conditions under a worst-case scenario (Ledig and Kitzmiller 1992). There have been no reports of planting of non-local sources from more moderately southern locations resulting in losses. Especially when climate change is concerned, the use of non-local sources will reduce this risk of maladaptation in the long term. It is obvious that using the wrong seed source will result in maladaptation and will result in volume losses. Using the right seed source can result in gains in volume production. Schmidtling (1994) reported in his study that loblolly pine and Norway spruce models predicted a loss of about 5 to 10% in height growth below that expected for a genetically adapted seed source, if the average yearly temperature increases by 4°C.

In conclusion, despite significant improvements as compared with the previous studies, the results of this study cannot considered as final. The focal point seed zone models are dynamic and will be improved by more refined biological data, more reliable climate scenarios and more advanced technological skills. Continued effort in research to improve focal point seed zone models will better position us in taking adaptive or mitigating measures once climate change scenarios becomes clear.

LITERATURE CITED

Alm, A. A., B. A. Brown and Jensen, R. A. 1966. Height and diameter variation in a Minnesota jack pine seed source plantation. Minnesota For. Note 178, 2 p.

Anonymous. 1997. Ontario Seed Zone policy. Ministry of Natural Resources.

Arend, J.L., N.F. Smith., S. H. Spurr and Wright, J.W. 1961. Jack pine geographic variation- five-year results from Lower Michigan tests. Michigan Acad. Sci., Arts, and Letters Proc. 46:219-236.

Balduman, L.M., S.N. Aitken, M. Harmon and Adams, W.T. 1999. Genetic variation in cold hardiness of Douglas-fir in relation to parent-tree environment. Can. J. For. Res. 29(1):62-72.

Batzer, H.O. 1962. White-pine weevil damage differs significantly by seed source on two Northern Minnesota jack pine plantations. USDA For. Serv. Lake St. For. Exp. Stn. Tech. Notes No. 618. 2 pp.

Beaulieu, J., M. Perron and Bousquet, J. 2004. Multivariate patterns of adaptive genetic variation and seed source transfer in *Picea mariana*. Can. J. For.Res.34: 531-545.

Beuker, E., V. Koski, and Matyas, C. 1997. Adaptation of Tree Populations to Climate as Reflected by Aged provenance Tests. Perspectives of forest genetics and tree breeding in a changing world. IUFRO-World-Series.6: 103-108. 12 Ref.

Bolin, B., B.R. Doos, J. Jager and Warrick, R.A. 1986. The Greenhouse Effect, Climate Change and Ecosystems, SCOPE 29. John wiley and Sons, New York. 541p.

Brown, J.H and Gibson, A.C. 1983. Biogeography. Mosby, Saint Louis, Missouri, USA.

Caldwell, M.M. 1979. Plant life and ultraviolet radiation: some perspective in the history of earth's UV climate. Bioscience 29: 520-525.

Cannell, M.G.R. 1987. Climate Warming and spring phenology of trees. IN: Ledig, F.T. and Kitzmiller, J.H. 1992. Genetic strategies for reforestation in the face of global climate change. Forest Ecology and Management, 50: 153-169.

Campbell, R. K. 1974. A provenance-transfer model for boreal regions. Meddl. Norsk Institutt for Skogsforskning. 31:544-500.

Campbell, R. K. 1975. Global-forestry-and-the-Western-role-1975-Permanent-Association-Committees-Proceedings,-Western-Forestry-and-Conservation-Association,-Portland,-Oregon,-USA. 103-107 pp.

Campbell, R. K. 1986. Mapped genetic variation of Douglas-fir to guide seed transfer in southwest Oregon. Silvae Genet. 35: 85-96.

Cherry, M. and Parker, W.H. 2003. Utilization of genetically improved stock to increase carbon sequestration. Ont. Forest Research Institute, Min. Nat. Res. Forest Research Report No.160. Sault Ste. Marie, Ont.

Chuine, I. 2004. Impacts of climate change on population and species distributions. Proceedings in CTIA 29th Biennial Meeting, Kelowna, BC.Climate Change & Forest Genetics.

Colombo, S.J., M.L. Cherry, C. Graham, S. Greifenhagen, R.S. McAlpine, C. Papadopol, W.C. Parker, T. Scarr and Ter-Mikaelian, M.T. 1998. The impacts of climate change on Ontario's forests. Ont. Min. Nat. Res., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Info. Pap. No. 143. 50 pp.

Crithfield, W.B. and Little, E.L. 1966. Geographic distribution of the pines of the world. USDA For.Serv. Misc.Publ. 992. 97pp.

CSIRO 1996. Climate Change Scenarios for the Australian Region, media release, Commonwealth Scientific & Industrial Research Organisation, Division of Atmospheric Research, Melbourne

Davis, M. B., R. G. Shaw and Etterson, J. R. 2005. Evolutionary responses to changing climate. Ecology. 86: 1704-1714.

Davradou, M. 1992. Genetic variation in the frost hardiness of *Pinus banksiana* Lamb. (jack pine) in Northwestern Ontario. M.Sc. (For.) thesis, Lakehead University, Thunder Bay, Ont. 102pp.

Environment Canada. 1997. Canada's Second national Report on Climate Change. 'Actions to meet commitments under the United Nations Framework Convention on cloamte Change.' Crit. Rev. Environ. Sci. Tech. 27:S139-S149.

Environment Systems Research Institute. 2000. ARC/INFO user's guide. Redlands, CA.

Eriksson, G., G. Namkoong and Roberds, J.H. 1993. Dynamic gene conservation for uncertain futures. For. Ecol. Manage. 62: 15–37.

Flato, G.M. and Hibler, W.D. III. 1992. Modelling Pack Ice as a Cavitating Fluid. J. Phys. Oceanogr., 22, 626-651.

Flato, G.M., Boer, G.J., Lee, W.G., McFarlane, N.A., Ramsden, D., Reader, M.C. and Weaver, A.J. 2000. The Canadian Centre for Climate Modelling and Analysis Global Coupled Model and its Climate. Climate Dynamics, 16: 451-467.

Giannini R. and Magnani, F. 1994. Effects of climate change on the genetic diversity of forest trees. Significance and uncertainties. Giornale Botanico Italiano 128: 903-910

Giertych, M. 1997. Effect of thinnings on the evaluations of provenance experiments as exemplified by a Norway spruce (*Picea abies* Karst.) trial. IUFRO-World-Series.

Gordon, C., C. Cooper, C.A. Senior, H. Banks, J.M. Gregory, T.C. Johns, J.F.B. Mitchell and Wood, R.A. 2000. The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. *Climate Dynamics* 16: 147-168.

Hamann, A., M.P. Koshy, G. Namkoong and Ying, C. C. 2000. Genotype x environment interactions in *Alnus rubra*: developing seed zones and seed-transfer guidelines with spatial statistics and GIS. Forest Ecology and Management, 136: 107-119.

Hengeveld, H. 1991. Understanding atmospheric change: a survey of the background science and implications of climate change and ozone depletion. State of Env.Rep. No. 91-2. 68 pp.

Hill, G.A. 1959. A ready reference to the description of the land of Ontario and its productivity. Ontario Department of Lands and forests, Division of Research, Maple, ON. 142p.

Holst, M.J. 1967. All -range jack pine provenance experiment. Petawawa For. Expt. Sta., Internal Report PET-PS-6.

Houghton, J. 1997. Global Warming. The Complete Briefing. Cambridge University Press, Cambridge, UK. 251 p.

Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden and Xiao, D. 2001. Climate Change 2001: The Scientific Basis contribution of working Group I to the third Assessment Report of the intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, p.944.

Hunt. R.S. and Van Sickle, G.A. 1984. Variation in susceptibility to sweet fern rust among *Pinus contorta* and *P. banksina*. Can. J. For. Res. 14: 672-675.

Hyun, J. O. 1979. Geographic varation of jack pine (*Pinus banksiana* Lamb.) pp. 107-116 in Proc. Thirteenth Lake States For. Tree Improv. Conf. Aug. 17-18, 1977. Univ. Minn. St. Parl, MN

IPCC. 1996. Climate Change 1995 Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Cambridge Univ. Press, Cambridge, UK.

IPCC. 2001. Climate Change 2001: The Scientific Basis. J.T. Houghton *et al.* (eds.), Cambridge University Press, 881pp.

Jonsson, A., G. Eriksson and Dormling, I. 1980. A summary of studies of frost hardiness of *Pinus contorta* seedlings grown in climatic chambers in *Pinus contorta* as an Exotic Species. Swed. Uni. Agric. Sci., Res. Note No. 30. 75-81pp.

Joussaume, S., K.E. Taylor, P. Braconnot *et al.* 1999. Monsoon changes for 6000 years ago: results of 18 simulations from the Paleoclimate Modeling Intercomparison Project. Geophysical Research Letters 26: 859-862.

Kimmins, J.P. and Lavender, D.P. 1987. Implications of climate change for the distribution of biogeoclimatic zones in British Columbia and for the growth of temperate forest species. In: D.P., Woody Plant Growth in a Changing Chemical and Physical Environment. Proc. Workshop IUFRO Working Party on shoot Growth Phsiology. Vancouver, BC, pp. 297-309.

King, J. P. 1966. Ten-year height growth variation in Lake States jack pine. In Joint Proc. This paper presents 20-year results of the Lake Second Genetics Workshop of the SAF and Seventh Lake States For. Tree Improv. Conf. 1965:84-88. Pap. NC-6, 110 p. U.S. Dep. Agric. For. Serv., Station. North Cent. For. Exp. Stn., St. Paul, MN

King, J. P. 1971. Pest susceptibility variation in Lake States jack pine seed sources. U.S. Dep. Agric, For. Serv., Res. Pap. NC-53, 10 p.U.S, Dep. Agric. For. Serv., North Cent. For. Exp. Stn., St. Paul, MN.

Ledig, F.T. and Kitzmiller, J.H. 1992. Genetic strategies for reforestation in the face of global climate change. Forest Ecology and Management, 50: 153-169.

Lindgren, D. and Ying, C.C. 2000. A model integrating seed source adaptation and seed use. New Forests, 20: 87-104.

Mackey, B.G., D.W. McKenney, Y.Q. Yang, J.P. McMahon and Hutchinson, M.F. 1996. Site regions revisited: a climatic analysis of Hills' site regions for the province of Ontario using a parametric method. Can. J. For. Res. 26: 333 - 354.

Maley, M. 1990. Phenotypic variation in cone and needle characters of *Pinus banksiana* Lamb. (jack pine) in northwestern Ontario. M. Sc. For. Thesis. Lakehead University.

Maley, M. and Parker, W.H. 1993. Phenotypic variation in cone and needle characters of *Pinus Banksiana* (jack pine) in northwestern Ontarion. Can. J. For. Res. 71 (1): 43-51.

Mangold, R.D. and W.J. Libby. 1978. A model for Reforestation with optimal and suboptimal tree populations. Silv. Genet. 27, 66-68.

Matyas, C. 1990. Adaptation lag: a general feature of natural populations. Proceedings Joint Meeting of Western Forest Genetics Association and IUFRO Woring Parties, 02-06, 12 and 14 September, Olympia, WA, pp. 132-139.

Matyas, C. 1994. Modelling climate change effects with provenances with provenace test data. Tree Physiol. 14 (7-9): 797-804.

Matyas, C. 1996. Climatic adaptation of trees: Rediscovering provenance tests. EUPHYTICA. 92 (1-2): 45-54.

Matyas, C. 1997. Effects of environmental change on the productivity of tree populations. IUFRO-World-Series. 6: 109-121.

Matyas, C. and Yeatman, C.W. 1992. Effect of geographical transfer on growth and survival of jack pine (*Pinus bankisana* Lamb.) populations. Silvae Genet. 41 (6): 370-376.

McCreay, R.D, D.P. Lavender and Hermann, R.K. 1990. Predicted global warming and Douglas-fir chilling requirements. Ann. Sci. For., 47: 325-330.

Morgenstern, E.K. and Copis, P. 1999. Best white spruce provenances in Ontario. Information Report ST-X-16. Science Branch Canadian Forest Service. Natural Resources Canada. Ottawa. 34 pp.

Morgenstern, E.K. and Teich, A.H. 1969. Phenotypic stability of height growth of jack pine provenances. Can. J. Genet. Cytol. 9: 110-117.

Morris, D.M and Parker, W.H. 1992. Variable-quality form in mature jack pine stands-quantification and relationship with environmental factors. Can. J. For. Res. 22 (3): 279-289.

Morris, D.M., Parker, W.H and Seabrook, R. 1992. Some considerations when selecting young jack pine families using growth and form traits. Can. J. For. Res. 22 (4): 429-435.

Mosseler, A., D.J. Innes and Roberts, B.A. 1991. Lack of allozymic variation in disjunct Newfoundland populations of red pine (*Pinus resinosa*). Can. J. For, Res. 21: 525-528.

Mullin, T.J., Adams, G.W., Simpson, J.D., Tosh, K.J. and Greenwood, M.S. 1995. Genetic parameters and correlations in tests of open-pollinated black spruce families in field and retrospective nursery test environments. Can. J. For. 25: 270-285.

Namkoong, G. 1969. Nonoptimality of local races. In: Proceedings of the 10th Southern Conference on Forest Tree Improvement, Texas A&M University, College Station, TX, pp. 149-153.

Namkoong, G. 1984. Strategies for gene conservation. Cited in W.C.Parker *et al.* 2000. Third Millennium Forestry: What climate change might mean to forests and forest management in Ontario.For. Chron. 76 (3): 445-463.

Nkongolo, K.K and Gratton, W.S. 2001. Genetic variation in *Pinus banksiana* populations from the Sudbury (Ontario, Canada) region. Silvae Genet. 50 (3-4): 122-127.

O'Malley, D.M., F.W. Allendorf and Blake, G.M. 1979. Inheritance of isozymes variation and heterozygosity in *Pinus ponderosa*. Biochem. Genet. 17: 233-250.

O'Malley, M. 1984. Population genetics studies in Pinaceae. Ph.D. thesis, Department of Forestry, University of Wisconsin-Madison, Madison, Wisc.

OMNR. 1987. Tree improvement master plan for Ontario. Ontario Ministry of Natural resources. 81pp.

OMNR. 1991. Statistics 1989-1990. Ontario Ministry of Natural Resources. 106pp.

OMNR. 2000. Ontario Climate Model, v. 2.0 Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. CD-ROM.

Papadopol, C.S. 2000. Impacts of climate warming on forests in Ontario: Options for adaptation and mitigation. For. Chron. 76: 139-149.

Parker, W.C., S. J. Colombo., M. L. Cherry, M. D. Flammingan, *et, al.* 2000. Third millennium forestry: what climate change might mean to forests and forest management in Ontario. For. Chron. 76(3):445-460.

Parker, W.H. 1992. Focal point seed zones site-specific seed zone delination using geographic informatioin system. Can. J. For. Res. 22 (2): 267-271.

Parker, W.H., A., Van Niejenhuis and Charrette, P. 1994. Adaptive variation in *Picea mariana* from northwestern Ontario determined by short-term common environment tests. Can. J. For. Res. 24(8):1653-1661.

Parker, W.H., C. Riddell and Lesser, M.R. 2004. Identification of Black Spruce Seed Sources to Compensate for Loss of Growth Resulting from Climate Change. Final Report– Living Legacy Trust Project 04-059/478-02. 105pp.

Parker, W.H. and Van Niejenhuis, A. 1996 a. Seed zone delineation for jack pine in the former Northwest Region of Ontario using short-term testing and geographic information systems. Nat. Resour. Can., Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON. Tech.Rep. NODA/NFp TR-35. 34 pp.

Parker, W.H, A. van Niejenhuis and Ward, J. 1996 b. Genecological variation corresponding to forest ecosystem classification vegetation and soil types for jack pine and black spruce from northwestern Ontario. Environment Monitoring and Assessment. 39 (1-3): 589-599.

Parker, W.H. and Lesser, M.R. 2004. Focal point seed zones for white spruce in Ontario. Final Report Part 2 – Living Legacy Trust Project 04-012. Development of Focal Point Seed Zones for White Spruce in Northern Ontario. 82 pp.

Peter, R.L. 1990. Effects of global warming on forest. For. Ecol. Manag. 35: 13-33.

Pope, V. D., M. L. Gallani, P. R. Rowntree and Stratton, R. A. 2000. The impact of new physical parameterizations in the Hadley Centre climate model -- HadAM3. *Climate Dynamics*, 16: 123-146.

Raymond, C.A. and Lindgren, D. 1990. Genetic flexibility – a model for determining the range of suitable environments for a seed source. Silvae Genet. 39: 112-120.

Rouilliond , D.P. 1999. FPSeedZ: an interactive tool for delineating focal point seed zones for jack pine and black spruce in northwestern Ontario. 27 pp. Bachelor thesis, Lakehead University, Thunder Bay.

Rehfeldt, G.E. and Wykoff, W.R. 1981. Periodicity in shoot elongation among populations of P*inus contorta* from the northern Rocky Mountains. Ann. Bot.48:371-377.

Rehfeldt, G.E. 1987. Adaptive variation and seed transfer for ponderosa pine in central Idaho. US For. Ser. Res. Note Intermt. For. Sta. NO. INT-373. 6pp.

Rehfeldt, G.E. 1984. Microevolution of conifers in the northern Rocky Mountains: a view from common gardens. Pp. 132-146 In Proc. Eighth North American Forest Biology Workshop. Logan, UT.

Rehfeldt, G. E. 1990. Adaptability versus zone size: continuous zones for the rocky Mountains (USA). In: Joint meeting of Western Forest Genetics Association and IUFRO Working Parties S 2.02-5, 06, 12, and 14, Olympia, Washington.

Rehfeldt, G.E. 1993. Genetic Variation in the Ponderosa of the Southwest. American Journal of Botany 80 (3): 330-343. 1993.

Rehfeldt, G.E., C.C. Ying, D.L. Spittlehouse and Hamilton, D.A. 1999. Genetic responses to climate in *Pinus contorta*: niche breadth, climate change, and reforestation. Ecol. Monogr. 69(3): 375-407.

Rehfeldt, G.E., N.M., Tchebakova, Y.I., Parfenova, R.A., Wykoff, N.A., Kuzmina and Milyutin, L. I. 2002. Intraspecific responses to climate in Pinus sylvestris. Global Change Biology. 8: 912-929.

Rehfeldt, G. E. 2004. Interspecific and Intraspecific Variation in *Picea engelmannii* and its Congeneric Cohorts: Biosystematics, Genecology, and Climate Change. Tech. Rep. RMRS-GTR-134. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research. 18 p. Rep. No. 91-2. 68 pp.

Rudolph, T.D. 1958. Silvical characteristics of jack pine (Pinus Banksiana) U.S. F.S. Lake States Station Pap. 61.31 pp.

Rudolph, T. D. 1964. Laminas growth and prolepsis in jack pine in the Lake States. For. Sci.Monogr.6: 70.

Rudolph, T. D. 1980. Autumn foliage color variation among inbred jack pine families. Silv. Genet. 29: 177-183.

Rudolph, T.D. and Yeatman, C.W. 1982. Genetics of jack pine. U.S.D.A. For. Serv. Pap. WO-38. 60 pp.

SAS Institute Inc. 2000. SAS system for Windows. SAS Institute Inc.

Schantz-Hansen, T. and Jensen, R.A. 1952. The effect of seed source on growth of jack pine. J. For. 50:539-544.

Schmidtling, R.C. 1994. Use of provenance tests to predict response to climatic change: loblolly pine and Norway spruce. Tree Physiol. 14:805-817.

Schoenike, R.E. 1976. Geographical variations in jack pine (*Pinus banksiana* Lambert). Ph. D. Thesis. University of Minnesota.

Schoenike, R.E. and Brown, B.A. 1963. Variation in bark thickness of jack pine seed sources. Minn. For. Notes No. 130. 2 pp.

Sims, R.A., Kershaw, H.M. and Wickware, G.M. 1990. The autecology of major tree species in the North Central Region of Ontario. COFRDA Rep. 3302. NWOFTDU Tech. Rep.48. 126 pp.

Sims, R.A., Towill, W.D., Baldwin, K.A. and Wickware, G.M. 1989. Field guide to the forest ecosystem classification for Northwestern Ontario. COFRDA. 191pp.

Smith, J., B. Lavender, H. Auld, D. Broadhurst and Bullock, T. 1998. The Canada Country Study: Climate Impacts and Adaptation-Volume IV. Adapting to climate variability and change in Ontario Envrion, Can., Ontario Region. 117 p.

Sokal, R.R and Rohlf, F.J. 1981. Biometry: The principles and practice of statistics in biological research (2nd Ed.). W.H. Freeman and Company, San Francisco, 859 pp.

Sorensen, F.C. 1994. Genetic variation and seed transfer guidelines for ponderosa pine in central Oregon. Res. Pap. PNW-RP-472. Portland, OR: U.S, Department of Agriculture, Forest Service, PACIFIC Northwest Research Station, 24 pp.

Suffling, R. 1995. Can disturbance determine vegetation distribution during climate warming? A boreal test. J. Biogeogr. 22: 501-508.

Van Niejenhuis, A. 1995. Genecology of jack pine in North central Ontario. M. Sc. (For) thesis. Lakehead University, Thunder Bay. Ont.193 pp.

Van Niejenhuis, A. and Parker, W.H. 1996. Adaptive variation in jack pine from north central Ontario determined by short-term common garden tests. Can. J. For. Res. 26 (11): 2006-2014.

Wang, Z., M.J. Lechowiez and Potvin, C. 1995. Responses of black spruce seedlings to simulated present versus future seedbed environments. Can. J. For. Res. 25: 545-554.

Webb, E. 1998. Late quaternary climates: data synthesis and model experiments. Quaternary Science Reviews 17:463-688. In processing: Jackson, S.T. and Overpeck, J.T. 2000. Responses of plant populations and communities to environmental changes of the late Quaternary. The Paleontological Society 194-220.

Weiser, C.J. 1970. Cold resistance and injury in woody plants. Science 169:1269-1278.

Well, O.O. and Wakeley, P.C. 1966. Geographic variation in survival, growth, and fusiform rust infection of planted loblolly pine. For. Sci. Monogr. 11, 40p.

Whetton, P. 2001. Climate change projections for Australia. CSIRO Atmospheric Research, Victoria.

Woodward, D.I. 1987. Climate and plan distribution. Cambridge University Press, London, UK.

Wilkinson, L., Hill, M. and Vang, E. 1992. Systat: Statistics, Version 5.2. Systat, Inc., Evanston, IL.

Yeatman, C.W. 1966. Geographic variationin jack pine (pinus banksiana Lamb.) seedlings. Ph.D dissertation. Yale Uni., New Haven, Conn. 231pp.

Yeatman, C.W. and Holst, M.J. 1972. Hardiness of jack pine hybrids and provenances in the boreal forest. For. Chron. 48: 30-31.

Yeatman, C.W. 1976. Seed origin -- first, last and always. Petawawa For. Exp. Stn., Can. For. Serv. Inf. Rep. PS-X-64.

Yeh, F.C. and Layton, C. 1979. The organization of genetic variablility in central and marginal populations of lodgepole pine *Pinus contorta var latifolia*. Can. J.Genet. Cytol. 21: 2201-2211.

Ying, C.C. 1991. Genetic resistance to the white pine weevil in Sitka spruce. B.C. Min. For., Res. Note No. 106.

Ying, C.C. 1997. Effects of site, provenance, and provenance ad site interaction in Sitka spruce in coastal British Columbia. For. Genet. 4, 99-112.

Zhang, G.J. and McFarlane, N. A. 1995. Sensitivity of climate simulations to the parameterization of cumulus convection in the CCC-GCM. Atmos.-Ocean, 3, 407-446.

Zobel, B. and Talbert, J. 1984. Applied forest tree improvement. John Wiley & Sons, Inc. U.S.A. 505 pp.

APPENDIX I

SITE AND COLLECTION DATA SUMMARY FOR 102 STANDS OF JACK PINE IN NORTHWESTERN ONTRARIO

Appendix I

Site and collection data summary for 102 stands of jack pine in Northwestern Ontario

	Age(year)		Height(m)		DBH(cm)		Latitude (dd)	Longitude(dd)	Elev(m)	V-type	S-type
Site	Mean	S.D	Mean	S.D	Mean	S.D					
1	66.6	-9.0	19.24	1.28	22.72	1.36	49°41′48"	92°55′38"	360	28	S2
2	55.5	-20.1	19.07	1.11	22.54	1.18	50°8′15"	92°53′11"	424	29	S7
3	74.1	-1.5	19.71	1.75	32.22	10.86	49°25′15"	92°8′50"	460	17	SS6
4	70.3	-5.3	20.78	2.82	26.18	4.82	49°30′30"	91°48′0"	440	29	S2
5	69.1	-6.5	19.79	1.83	22.75	1.39	50°9′45"	90°46′10"	440	18	S8
6	65.5	-10.1	18.8	0.84	22.59	1.23	50°22′15"	91°18′30"	410	29	S2
7	74	-1.6	16.51	-1.45	18.01	-3.35	50°27′15"	90°36′10"	415	32	S7
8	115.2	39.6	22.06	4.10	28.64	7.28	50°22′15"	90°23′0"	440	18	SS4
9	67.5	-8.1	17.85	-0.11	20.31	-1.05	50°7′15"	91°52′10"	390	31	S2
10	52.2	-23.4	16.22	-1.74	16.65	-4.71	50°27′30"	90°17′45"	410	32	SS5
11	71.7	-3.9	21.47	3.51	25.18	3.82	49°53′30"	91°27′0"	410	31	S2
12	89.3	13.7	20.83	2.87	23.64	2.28	48°49′14"	92°16′23"	502	17	S10
13	62.4	-13.2	18.15	0.19	22.1	0.74	49°2′17"	90°58′42"	388	18	.
14	76.4	0.8	18.82	0.86	23.8	2.44	49°1′57"	93°17′42"	433	31	SS7
15	105.1	29.5	20.05	2.09	31.59	10.23	49°17′21"	93°12′18"	510	18	SS1
16	73.3	-2.3	17.87	-0.09	21.65	0.29	49°15′5"	90°47′29"	551	18	SS6
17	91.8	16.2	17.92	-0.04	23.49	2.13	49°13′50"	93°13′47"	414	17	SS2
18	57.3	-18.3	16.25	-1.71	20.27	-1.09	48°51′26"	92°41′38"	402	18	SS7
19	65	-10.6	16.61	-1.35	18.83	-2.53	48°56′26"	92°41′4"	426	17	SS6
20	51.9	-23.7	17.84	-0.12	24.43	3.07	48°56′26"	92°41′5"	426	17	SS6
21	99.3	23.7	19.3	1.34	24.79	3.43	49°3′26"	93°53′47"	426	28	S10
22	82.1	6.5	18.03	0.07	25.27	3.91	49°44′7"	95°3′52"	436	17	SS5
23	53.1	-22.5	15.92	-2.04	22.77	1.41	50°3′46"	94°22′41"	387	32	SS5
24	65.2	-10.4	18.81	0.85	28.27	6.91	49°51′21"	94°23′41"	375	17	S7
25	74.2	-1.4	18.78	0.82	23.88	2.52	49°47′31"	94°32′8"	385	31	SS5
26	83.4	7.8	17.35	-0.61	25.73	4.37	49°42′3"	94°56′3"	355	17	SS7
27	110.8	35.2	15.25	-2.71	27.04	5.68	49°52′15"	94°47′35"	356	17	SS5
28	89.5	13.9	16	-1.96	25.58	4.22	49°42′25"	94°14′54"	373	30	SS1
29	57.7	-17.9	14.88	-3.08	18.77	-2.59	49°23′10"	93°37′21"	370	31	SS5
30	53.7	-21.9	14.5	-3.46	19.12	-2.24	49°25′27"	93°44′23"	345	18	SS7
31	77.6	2.0	17.48	-0.48	20.79	-0.57	50°3′3"	92°55′12"	399	29	S3
32	95.3	19.7	13.25	-4.71	24.03	2.67	49°49′35"	93°29′23"	377	30	SS1
33	54.3	-21.3	14	-3.96	18.97	-2.39	49°38′33"	92°26′30"	418	30	SS4
34	70.1	-5.5	18.51	0.55	20.2	-1.16	48°54′49"	91°52′46"	463	32	S1
35	68.9	-6.7	17.81	-0.15	20.72	-0.64	48°47′49"	91°33′53"	465	32	SS5
36	76.2	0.6	19.23	1.27	24.95	3.59	48°55′1"	91°16′3"	413	32	SS6
37	87.5	11.9	19.81	1.85	24.57	3.21	49°9′14"	92°2′41"	442	28	SS5
38	87	11.4	19.56	1.60	24.16	2.8	48°42′59"	91°14′10"	440	30	SS4
39	62.6	-13.0	18.33	0.37	20.34	-1.02	48°57′49"	92°0′10"	465	17	SS5
40	85	9.4	20.7	2.74	28.82	7.46	48°40′40"	91°0′43"	481	30	SS4
41	93.9	18.3	15.82	-2.14	19.53	-1.83	49°10′42"	92°14′14"	394	29	SS1
42	59.7	-15.9	18.81	0.85	25.42	4.06	48°59′58"	92°5′9"	450	32	S1
43	68.2	-7.4	19.62	1.66	21.03	-0.33	48°39′58"	92°10′43"	410	18	S1
44	60.9	-14.7	17.06	-0.90	22.53	1.17	48°33′55"	92°19′16"	428	30	SS1
45	63.6	-12.0	17.47	-0.49	19.6	-1.76	48°43′57"	91°47′50"	350	28	SS2
46	80.3	4.7	17.94	-0.02	20.13	-1.23	48°4′16"	91°21′58"	263	32	S2
47	93.1	17.5	17.3	-0.66	20.84	-0.52	49°8′15"	92°23′24"	415	30	SS1
48	67.3	-8.3	17.21	-0.75	19.63	-1.73	49°2′34"	92°20′57"	334	32	S10
49	90.8	15.2	16.21	-1.75	20.09	-1.27	48°43′41"	91°25′59"	427	32	SS2
50	64.3	-11.3	17.33	-0.63	17.53	-3.83	50°18′2"	91°39′41"	373	18	SS4

	Age(year)		Height(m)		DBH(cm)		Latitude (dd)	Longitude(dd)	Elev(m)	V-type	S-type
Site	Mean	S.D	Mean	S.D	Mean	S.D					
51	95	19.4	20.77	2.81	24.28	2.92	50°35'4"	91°36'34"	.	29	S2
52	69	-6.6	16.73	-1.23	18.54	-2.82	50°4'14"	92°19'51"	324	30	S2
53	57.3	-18.3	19.23	1.27	21.26	-0.1	50°23'1"	91°37'10"	470	32	S1
54	77.8	2.2	21.46	3.50	20.63	-0.73	49°54'48"	92°22'50"	458	29	S1
55	84.8	9.2	18.18	0.22	18.88	-2.48	50°44'1"	91°25'55"	397	32	SS4
56	79.9	4.3	18.23	0.27	19.8	-1.56	50°1'15"	92°36'14"	570	29	S2
57	71.4	-4.2	19.13	1.17	20.35	-1.01	49°58'104"	91°38'19"	365	29	S1
58	66.2	-9.4	17.85	-0.11	17.56	-3.8	49°21'16"	91°15'43"	492	32	S2
59	79.7	4.1	17.31	-0.65	18.76	-2.6	49°33'50"	91°36'31"	475	32	SS5
60	71.3	-4.3	19.36	1.40	21.9	0.54	49°48'32"	91°16'7"	446	32	S2
61	64.2	-11.4	17.5	-0.46	18.71	-2.65	49°35'32"	92°2'39"	485	29	S1
62	102.8	27.2	21.67	3.71	25.61	4.25	49°44'59"	92°3'29"	487	32	S2
63	72.3	-3.3	18.57	0.61	22.9	1.54	49°23'32"	91°58'22"	485	32	SS4
64	74	-1.6	16.32	-1.64	15.98	-5.38	49°16'27"	91°54'30"	489	32	S2
65	77.8	2.2	18.75	0.79	20.61	-0.75	49°22'52"	91°31'12"	506	29	S2
66	71.9	-3.7	14.98	-2.98	16.27	-5.09	49°15'31"	91°11'34"	477	29	SS4
67	120	44.4	12.74	-5.22	17.42	-3.94	50°56'32"	94°12'48"	458	30	SS2
68	74.9	-0.7	15.51	-2.45	18.19	-3.17	50°32'47"	92°33'27"	358	32	S2
69	55.8	-19.8	17.61	-0.35	19.51	-1.85	50°29'36"	92°19'1"	345	29	S2
70	75.6	0.0	16.03	-1.93	17.64	-3.72	51°10'18"	93°39'52"	298	32	S2
71	74.8	-0.8	15.95	-2.01	19.36	-2	50°48'9"	92°46'16"	454	32	SS5
72	65.2	-10.4	17.45	-0.51	18.58	-2.78	50°56'25"	92°31'60"	448	32	S6
73	94.4	18.8	19.23	1.27	22.32	0.96	51°23'2"	93°42'7"	510	29	S1
74	71.1	-4.5	17.65	-0.31	17.33	-4.03	51°10'16"	93°49'43"	375	30	S2
75	46.9	-28.7	16.92	-1.04	21.49	0.13	50°44'2"	93°11'27"	410	29	S1
76	76.7	1.1	18.09	0.13	18.55	-2.81	51°9'53"	93°56'25"	537	32	S2
77	71.3	-4.3	18.86	0.90	22.56	1.2	51°2'38"	92°50'7"	461	18	SS5
78	78	2.4	18.65	0.69	18.89	-2.47	50°54'5"	93°3'40"	353	32	S6
79	88.2	12.6	21.53	3.57	21.32	-0.04	50°39'16"	93°12'31"	362	32	SS5
80	83.7	8.1	16.62	-1.34	17.79	-3.57	50°26'23"	94°6'12"	417	29	SS5
81	78.1	2.5	20.28	2.32	23.81	2.45	50°28'19"	94°14'35"	259	18	SS6
82	75.2	-0.4	20.81	2.85	22.04	0.68	50°35'26"	94°12'50"	453	29	S6
83	82.3	6.7	18.55	0.59	20.05	-1.31	50°31'31"	94°1'35"	406	32	S2
84	92.7	17.1	11.85	-6.11	17.11	-4.25	50°43'23"	94°6'34"	389	30	SS1
85	77.1	1.5	17.57	-0.39	20.07	-1.29	50°42'3"	93°52'28"	340	29	S5
86	81.4	5.8	14.33	-3.63	18.65	-2.71	50°15'33"	93°16'54"	416	30	SS1
87	91.5	15.9	18.38	0.42	21.57	0.21	50°3'47"	93°16'9"	449	17	S6
88	66.8	-8.8	19.37	1.41	18.59	-2.77	49°18'55"	90°51'41"	423	.	S1
89	51.9	-23.7	15.27	-2.69	19.93	-1.43	49°13'59"	90°39'50"	649	29	S1
90	58.8	-16.8	20.3	2.34	20.26	-1.1	48°57'34"	90°44'59	445	32	S2
91	75.8	0.2	17.86	-0.10	20.32	-1.04	49°34'52"	90°30'39	555	29	SS5
92	61.7	-13.9	18.59	0.63	17.61	-3.75	49°25'21"	90°26'47"	478	.	S2
93	84	8.4	17.73	-0.23	16.12	-5.24	49°46'5"	90°15'57"	370	18	SS4
94	58.7	-16.9	17.98	0.02	19.96	-1.4	49°13'30"	90°54'48"	635	32	S1
95	64.1	-11.5	21.07	3.11	21.44	0.08	49°12'48"	90°37'34"	502	32	S1
96	70.4	-5.2	16.92	-1.04	20.69	-0.67	49°46'56"	93°11'29"	505	29	S1
97	118.9	43.3	19.35	1.39	28.19	6.83	49°30'19"	93°9'46"	290	32	SS4
98	72.2	-3.4	16.9	-1.06	17.69	-3.67	49°56'55"	93°31'31"	400	29	SS4
99	85.6	10.0	16.02	-1.94	17.99	-3.37	49°35'51"	93°3'41"	300	30	SS1
100	73.9	-1.7	16.84	-1.12	17.49	-3.87	49°23'10"	92°38'7"	450	32	SS4
101	93.7	18.1	19.85	1.89	23.25	1.89	49°41'17"	90°49'60"	180	17	S3
102	70.3	-5.3	19.22	1.26	19.74	-1.62	49°52'16"	92°36'18"	411	29	S6

APPENDIX II

SITE AND COLLECTION DATA SUMMARY FOR 64 STANDS OF JACK PINE IN NORTH CENTRAL ONTRARIO

Appendix II

Site and collection data summary for 64 stands of jack pine in North Centre Ontario

Site	Latitude(dd)	Longitude(dd)	Elevation(m)	V-Type	S-Type
1	50°12′	86°52′	1050	V32	S1
2	50°07′	86°47′	1080	V29	S1
3	50°03′	86°54′	1150	V32	S1
4	50°05′	87°01′	1100	V18	S1
5	49°48′	87°00′	1150	V18	S1
6	50°09′	87°37′	1050	V32	S1
7	49°59′	87°44′	1050	V32	S1
8	49°11′	88°25′	950	V32	S2
9	49°37′	87°57′	1050	V28	S3
10	49°01′	88°20′	950	V18	S1
11	49°12′	87°43′	1500	V30	SS1
12	49°13′	87°52′	1400	V30	SS1
13	48°54′	88°21′	650	V28	S1
14	49°43′	87°44′	1150	V32	S1
15	49°12′	88°13′	800	V32	S1
16	48°54′	88°31′	900	V28	S1
17	49°54′	87°24′	1100	V31	S3
18	49°43′	87°27′	1100	V17	S1
19	49°43′	87°16′	1100	V18	S1
20	49°33′	87°10′	1250	V29	S1
21	49°17′	87°13′	1300	V32	S1
22	48°47′	87°06′	900	V32	S2
23	50°16′	89°03′	1200	V32	S1
24	50°18′	89°01′	1150	V32	S4
25	50°04′	89°42′	1450	V30	SS1
26	50°02′	89°29′	1350	V32	S1
27	50°07′	89°13′	1100	V32	SS3
28	50°17′	88°53′	1050	V30	S2
29	50°26′	88°32′	1050	V32	S2
30	50°27′	88°42′	1050	V32	S5
31	48°05′	89°47′	1100	V29	S6
32	48°10′	89°37′	1250	V30	SS2
33	48°14′	90°30′	1700	V29	SS3
34	48°14′	90°11′	1600	V28	S6
35	48°50′	89°06′	1550	V32	S6
36	48°39′	89°04′	1500	V18	S1
37	49°17′	89°14′	1350	V31	SS5
38	49°15′	89°25′	1450	V32	SS2
39	49°20′	89°09′	1150	V32	S5
40	49°07′	90°03′	1550	V32	S2
41	48°55′	89°53′	1600	V32	S5

Appendix II

Site and collection data summary for 64 stands of jack pine in North Centre Ontario (cont')

Site	Latitude(dd)	Longitude(dd)	Elevation(m)	V-Type	S-Type
42	48°59′	89°57′	1450	V17	S1
43	48°44′	90°15′	1600	V18	S1
44	48°54′	88°44′	1100	V17	SS5
45	48°57′	89°11′	1500	V30	SS1
46	49°26′	88°56′	750	V32	S1
47	49°21′	89°50′	1500	V25	S2
48	48°30′	90°36′	1600	V31	SS6
49	48°47′	89°36′	1500	V30	SS6
50	48°38′	89°51′	1450	V32	S1
51	48°35′	90°09′	1500	V31	SS5
52	49°18′	90°11′	1600	V29	S1
53	48°41′	90°54′	1600	V32	SS6
54	49°46′	90°17′	1450	V18	SS7
55	49°33′	90°17′	1550	V31	S3
56	49°34′	90°32′	1600	V29	S1
57	49°26′	90°26′	1550	V32	S1
58	49°17′	90°20′	1550	V28	SS5
59	49°13′	90°37′	1550	V29	S1
60	49°37′	89°51′	1450	V29	S2
61	49°31′	89°38′	1500	V32	S1
62	49°32′	87°40′	1350	V32	S1
63	49°28′	87°32′	1450	V32	S1
64	48°25′	90°08′	1450	V30	SS1

APPENDIX III

PROVENANCE MEAN VALUES FOR GROWTH, PHENOLOGICAL AND FREEZING VARIABLES IN NORTHWESTERN ONTRIAO (102) CASE

Prov	GH94FLSH	GH94STRT	GH94STOP	GH94INCR	GH93HT	GH94HT	DR94FLSH	DR94STRT	DR94STOP	DR94INCR	DR93HT	DR94HT
1	7.13	8.44	82.8	33.88	95.96	185.56	24.86	16.31	78.45	52.72	142.67	225.52
2	6.30	3.72	84.40	25.56	99.28	169.60	23.62	14.93	75.17	58.66	131.03	210.21
3	6.92	4.52	78.12	35.48	97.48	186.24	24.64	14.87	78.30	53.50	130.77	215.20
4	7.04	5.56	80.60	31.36	95.36	177.60	24.24	14.76	78.83	50.38	133.07	221.03
5	6.25	2.80	79.76	26.52	101.48	173.00	22.83	14.72	78.48	46.14	136.87	217.38
6	5.84	3.72	79.40	30.48	103.64	186.20	22.31	13.59	77.45	57.51	127.77	214.07
7	5.52	2.28	81.48	29.64	92.28	169.52	21.86	14.70	79.90	55.80	126.10	200.20
8	5.45	2.48	80.04	25.68	95.04	164.12	22.36	14.54	82.57	46.78	129.93	203.24
9	7.32	4.48	79.00	28.72	106.36	190.64	23.79	14.60	75.03	56.50	125.63	215.87
10	6.20	2.52	77.92	29.36	109.64	194.88	22.35	15.32	75.68	63.11	117.45	196.90
11	6.68	3.96	77.60	34.96	114.44	205.52	23.03	14.23	83.47	66.37	118.67	206.17
12	7.63	5.44	76.08	40.24	129.24	220.48	24.07	14.97	80.27	68.97	125.33	319.37
13	7.36	7.36	77.96	38.92	116.64	206.20	24.72	15.24	78.97	72.10	118.97	216.72
14	7.40	5.84	82.72	41.60	114.32	215.84	24.93	15.33	81.90	59.07	115.40	199.69
15	7.29	6.96	77.88	35.80	118.20	209.28	25.23	14.62	76.14	53.66	117.63	194.50
16	7.44	6.04	79.88	36.80	115.64	207.28	24.67	12.68	74.32	58.32	129.90	216.72
17	7.33	7.28	76.24	39.64	108.40	201.88	24.69	14.62	75.93	60.45	133.50	218.66
18	7.78	7.12	77.72	37.28	100.76	192.76	24.52	15.73	78.23	65.07	137.10	226.00
19	7.52	6.44	81.44	35.56	103.56	196.36	24.96	14.67	79.23	52.97	122.30	197.70
20	7.74	7.52	79.04	35.92	106.08	202.72	24.93	14.71	75.96	60.50	143.07	225.14
21	8.14	6.60	75.08	30.00	103.32	184.24	25.39	15.07	80.17	51.03	147.13	226.03
22	7.52	8.00	80.20	28.68	94.04	173.28	24.87	12.77	77.20	52.50	144.63	225.47
23	6.79	5.20	81.32	30.48	96.68	175.08	23.96	13.93	77.33	55.33	131.17	217.47
24	7.38	6.56	79.04	34.28	108.04	197.32	24.00	14.30	77.40	57.93	131.27	218.37
25	7.16	7.44	75.96	31.84	110.13	203.40	24.00	14.63	77.67	57.23	139.34	220.17
26	6.68	4.88	78.56	31.24	97.24	175.80	24.03	16.33	83.23	46.57	131.87	213.77
27	7.00	6.00	80.00	32.24	104.48	192.92	24.54	15.40	80.40	57.20	135.30	219.27
28	7.29	5.40	77.44	35.44	102.00	191.08	24.31	15.63	72.10	52.09	139.83	224.00
29	7.40	4.76	81.40	41.60	114.04	207.96	24.83	14.33	77.03	58.37	142.37	219.97
30	7.61	6.36	78.08	33.68	110.56	202.72	24.48	14.63	74.90	65.90	143.40	232.87
31	6.76	3.96	81.16	2.92	108.72	195.88	23.52	15.52	74.41	53.62	136.50	220.43
32	6.61	5.08	78.76	29.72	101.32	179.60	24.70	14.20	76.17	60.66	137.97	218.73
33	7.13	3.50	80.00	37.25	112.92	207.52	23.90	14.53	78.03	73.77	129.20	224.80

Prov	GH94FLSH	GH94STRT	GH94STOP	GH94INCR	GH93HT	GH94HT	DR94FLSH	DR94STRT	DR94STOP	DR94INCR	DR93HT	DR94HT
34	7.04	4.21	75.00	34.63	112.28	194.08	24.92	14.29	72.17	61.03	131.37	204.68
35	7.24	7.04	82.16	31.36	103.04	181.16	25.00	14.48	78.69	63.79	137.40	223.62
36	7.38	4.80	80.04	31.60	102.96	184.40	24.57	14.33	82.23	65.63	137.50	222.17
37	7.12	7.96	79.50	38.13	107.80	198.96	23.97	15.17	74.40	62.13	141.10	225.67
38	7.96	6.28	78.68	41.00	109.60	208.08	25.39	14.37	82.83	60.36	131.90	213.73
39	7.64	6.58	79.17	31.63	109.24	199.48	24.04	15.20	77.67	78.90	130.53	229.53
40	7.50	6.44	82.80	32.84	98.76	180.56	23.48	15.20	75.63	66.77	130.87	217.57
41	6.96	5.72	81.56	36.48	97.12	192.04	23.68	14.29	82.43	64.93	132.37	217.43
42	7.48	6.28	79.88	35.72	106.00	195.04	25.04	15.00	80.90	65.79	128.47	215.97
43	7.28	5.12	79.48	43.96	109.28	209.88	24.18	13.45	74.90	70.55	126.37	214.66
44	7.56	6.84	83.12	38.40	97.76	182.24	24.69	14.33	76.53	55.79	124.60	197.93
45	7.54	5.84	80.96	36.16	104.24	194.20	25.26	15.73	80.87	54.65	129.77	200.03
46	7.39	9.16	76.12	34.80	103.68	196.60	24.04	15.36	76.89	57.00	141.43	222.64
47	7.32	4.64	78.32	33.20	101.40	187.36	25.28	15.57	79.27	51.40	138.67	220.40
48	7.60	3.84	82.24	40.28	97.92	187.32	24.85	14.52	73.93	54.57	137.17	217.50
49	7.12	4.08	80.72	37.20	96.00	183.68	24.86	14.97	76.73	64.72	139.20	225.57
50	6.21	3.04	80.67	32.92	105.20	184.48	23.43	13.37	79.60	46.93	120.17	188.77
51	6.41	3.63	77.29	33.29	107.16	197.25	23.10	13.72	77.79	42.66	119.43	188.20
52	6.38	5.04	77.79	33.38	100.52	184.50	22.97	13.67	79.50	45.60	126.97	197.63
53	5.77	1.79	77.88	30.21	99.08	179.76	23.14	15.07	74.45	36.00	122.73	186.23
54	6.56	5.08	80.32	32.24	110.08	198.72	24.68	14.36	83.75	44.36	137.40	207.86
55	6.17	3.60	81.08	24.68	98.92	176.04	23.24	13.72	82.21	47.41	140.90	218.66
56	6.40	4.76	75.92	35.48	104.28	197.48	24.37	14.13	82.50	42.33	137.53	208.33
57	5.92	4.24	75.40	35.48	104.32	195.60	23.62	14.45	82.03	57.48	131.90	210.93
58	6.60	4.16	76.48	35.48	110.44	205.00	23.33	14.38	76.24	64.34	139.83	234.80
59	6.28	5.60	82.92	39.12	107.48	200.68	23.90	14.31	79.48	49.16	132.73	204.90
60	7.36	7.28	81.40	33.68	112.88	206.52	23.54	13.75	78.79	44.43	146.20	215.83
61	6.88	4.44	78.84	32.28	103.96	186.08	23.56	14.50	74.89	61.03	137.97	228.93
62	6.77	6.36	76.84	35.92	92.80	183.76	24.07	14.17	73.90	51.30	140.03	225.13
63	6.96	5.25	78.25	27.79	89.80	163.88	24.52	14.82	77.82	53.82	142.17	235.43
64	6.96	3.44	80.72	31.56	93.96	178.20	23.93	15.00	79.27	64.13	136.93	221.87
65	7.17	4.76	80.84	30.12	98.80	177.56	24.39	14.46	76.82	64.11	138.57	229.07
66	6.68	4.68	79.48	33.28	101.92	184.76	23.21	15.38	80.90	63.83	135.17	221.83
67	6.08	5.28	77.68	26.84	90.00	170.88	22.54	14.30	74.93	57.47	121.03	200.23
68	6.28	4.08	77.00	31.40	96.00	184.12	22.83	14.90	78.03	44.77	120.17	190.50

Prov	GH94FLSH	GH94STRT	GH94STOP	GH94INCR	GH93HT	GH94HT	DR94FLSH	DR94STRT	DR94STOP	DR94INCR	DR93HT	DR94HT
69	6.04	6.00	81.84	31.28	105.28	197.08	22.83	14.07	78.21	51.65	122.80	204.14
70	6.04	5.38	82.33	30.25	93.48	174.56	21.86	14.34	77.79	37.97	127.23	187.63
71	5.95	4.64	80.12	28.44	88.80	166.04	22.93	14.72	75.69	47.21	111.07	187.79
72	5.73	3.84	78.56	34.16	101.60	190.24	22.07	13.61	80.46	53.46	113.20	179.00
73	5.12	4.08	83.00	27.50	90.44	159.20	22.63	16.57	84.13	52.43	110.67	181.20
74	5.60	3.04	78.28	25.72	101.36	176.72	22.34	12.97	76.34	59.17	112.57	190.50
75	6.12	3.28	77.44	31.52	99.32	186.56	23.04	13.61	78.00	42.81	123.30	188.31
76	5.42	5.32	74.56	21.76	87.64	163.28	22.43	13.70	81.77	50.67	114.43	190.97
77	6.29	4.38	79.96	28.50	97.17	180.84	22.43	14.79	78.03	44.14	123.63	196.00
78	5.73	4.96	76.20	29.96	98.21	180.32	22.53	14.60	79.73	48.73	122.47	195.77
79	6.64	4.44	78.36	28.32	98.68	184.88	23.73	14.37	79.57	52.00	127.70	202.97
80	6.32	7.46	77.71	36.79	95.36	184.00	23.38	15.50	81.00	50.33	125.00	200.60
81	7.12	5.28	79.60	32.48	96.36	187.12	23.79	14.90	78.00	52.90	131.00	208.60
82	5.77	4.40	74.84	28.40	96.56	173.88	22.55	15.03	80.17	48.77	114.47	181.63
83	7.04	5.20	83.36	31.44	97.68	177.96	24.23	14.77	84.00	45.57	126.13	192.43
84	6.08	4.52	73.32	29.48	88.32	167.60	23.29	13.30	75.23	49.83	119.33	194.00
85	6.76	5.88	80.56	28.20	96.48	176.92	23.89	15.07	76.90	48.66	125.63	205.69
86	6.74	6.12	84.32	34.84	87.20	171.44	23.17	14.43	79.57	53.70	132.33	210.47
87	6.83	6.08	82.68	33.16	102.60	192.92	23.64	15.79	80.39	47.64	134.80	208.76
88	7.00	5.12	80.24	29.92	92.16	183.44	23.53	13.70	77.77	51.60	129.07	207.70
89	6.46	4.60	79.40	31.60	97.64	180.21	23.46	14.93	76.56	56.81	127.83	195.55
90	7.24	4.00	84.08	36.56	90.08	183.52	24.30	14.86	75.75	70.21	121.50	211.61
91	6.39	5.42	78.63	28.75	97.52	183.75	22.80	13.33	81.43	70.03	124.23	214.17
92	6.72	3.00	76.04	36.56	113.64	206.28	23.22	14.32	80.82	60.64	121.10	201.17
93	6.63	3.42	76.63	28.25	111.36	186.56	22.93	14.43	77.87	60.50	134.83	210.00
94	5.79	1.92	81.08	34.12	103.24	193.44	23.64	12.38	79.48	53.41	134.33	212.17
95	6.24	3.28	79.76	28.76	92.80	171.64	23.30	14.00	78.33	53.00	138.20	223.13
96	6.32	3.68	79.24	30.96	98.16	179.80	24.72	14.48	78.86	57.69	149.17	230.62
97	6.57	3.80	84.12	31.96	98.28	180.92	23.96	14.86	83.66	54.24	143.03	224.13
98	7.00	6.24	79.04	37.24	111.40	207.04	23.36	15.52	72.18	55.01	143.90	228.78
99	7.20	8.16	82.44	37.16	115.80	206.84	24.32	16.00	76.28	52.17	152.63	236.57
100	6.60	7.52	81.40	36.60	102.28	201.84	24.23	14.37	74.53	52.73	141.63	231.63
101	7.46	6.80	80.88	34.20	104.60	189.40	24.30	14.90	73.66	62.00	133.70	213.41
102	6.63	5.60	77.40	37.04	117.16	220.84	23.83	13.90	77.73	60.77	143.87	226.77

Prov	KE94FLSH	KE94STRT	KE94STOP	KE94INCR	KE93HT	KE94HT	KE97SURV	KE97HT	KE04SURV	KE04HT	KE04DIAM
1	29.80	13.46	71.04	31.93	124.57	169.73	10.00	644.00	8.00	3151.6	25.78
2	27.40	14.82	72.00	36.25	118.20	165.27	10.00	732.00	8.67	3157.9	25.49
3	28.78	12.36	74.24	35.88	124.27	165.03	9.67	649.22	8.33	2843.3	22.87
4	29.37	14.56	70.93	30.48	124.46	172.61	9.00	669.06	6.00	2995.3	26.39
5	27.21	12.86	71.48	25.84	129.55	177.34	9.67	626.57	7.33	3153.2	25.88
6	27.90	13.57	73.11	35.21	129.30	184.07	9.67	647.59	7.67	2923.6	23.53
7	27.39	15.04	73.38	38.75	128.77	179.79	9.67	727.67	7.33	3518.9	25.10
8	26.79	14.57	73.47	39.25	128.70	187.03	9.67	688.35	8.33	3131.9	22.11
9	27.62	12.68	75.57	40.28	124.32	177.41	9.67	691.22	7.33	3568.4	26.92
10	28.55	12.68	70.79	26.33	115.45	154.38	9.33	642.92	7.67	3219.3	23.90
11	28.41	12.79	72.36	30.89	115.70	162.23	9.67	681.09	8.00	3136.6	29.80
12	28.76	12.00	72.04	29.84	125.62	167.00	9.67	664.17	7.00	3215.1	22.25
13	28.53	13.67	72.17	31.77	126.52	181.57	10.00	699.67	8.00	3261.7	24.22
14	29.33	12.64	67.00	38.29	118.63	171.19	9.00	690.54	8.33	3068.1	22.50
15	29.43	12.93	69.69	28.86	117.70	158.55	9.00	630.69	6.00	3305.8	23.32
16	27.96	13.35	75.23	40.77	127.63	178.33	10.00	686.33	8.33	3187.6	22.28
17	29.00	13.48	65.19	32.04	131.88	173.64	8.33	709.31	6.33	3485.1	26.68
18	29.92	13.69	72.85	45.34	127.43	179.19	8.67	724.32	8.67	3161.0	27.40
19	28.39	12.93	76.18	38.90	131.86	185.75	9.33	639.88	7.00	3175.2	22.73
20	29.07	13.00	69.58	29.85	128.70	177.17	9.67	650.85	8.00	3177.6	25.02
21	29.43	13.90	67.93	29.73	133.72	181.86	9.33	651.11	6.00	3003.8	22.31
22	30.21	13.93	64.68	28.68	133.47	189.90	9.67	661.56	6.33	3316.0	22.73
23	28.66	13.84	71.84	33.20	138.07	189.93	9.67	679.96	6.67	3421.2	24.16
24	29.81	12.58	70.79	29.67	134.17	192.25	9.33	653.48	5.67	3262.6	24.77
25	29.14	14.20	71.90	34.50	130.60	186.20	10.00	720.17	8.00	3458.8	27.86
26	28.93	13.00	72.48	28.65	119.60	162.18	9.33	624.24	7.33	3000.7	24.19
27	28.93	12.70	77.44	26.93	127.78	177.45	10.00	688.83	7.00	3139.3	27.20
28	28.28	13.31	71.21	31.18	132.83	188.28	9.00	712.03	6.67	3585.5	28.29
29	27.29	13.19	61.30	44.23	144.42	204.79	9.00	734.67	7.67	3143.8	26.92
30	27.82	13.65	67.27	47.38	133.57	195.62	9.33	744.72	8.33	3151.4	23.58
31	27.93	12.86	74.69	34.70	131.43	184.93	10.00	703.67	7.00	3469.2	26.43
32	29.20	11.69	68.23	33.27	128.80	175.20	10.00	654.17	7.67	3030.6	25.45
33	28.37	13.15	69.00	39.15	137.00	189.63	9.67	703.63	7.00	3404.4	25.14

Prov	KE94FLSH	KE94STRT	KE94STOP	KE94INCR	KE93HT	KE94HT	KE97SURV	KE97HT	KE04SURV	KE04HT	KE04DIAM
34	28.21	12.12	70.36	44.44	133.00	194.19	8.67	747.64	7.67	3547.3	24.54
35	27.93	13.93	74.33	36.49	141.07	200.17	9.33	761.96	8.00	3194.1	22.75
36	28.14	11.52		40.56	132.54	188.72	9.00	721.11	7.33	3495.1	26.34
37	28.14	12.41	71.90	40.45	127.10	180.63	10.00	718.67	8.00	3174.1	24.23
38	28.13	12.10	70.77	38.47	137.83	195.90	10.00	671.67	7.00	3562.1	25.52
39	29.03	12.17	65.24	33.38	132.93	188.55	9.67	654.20	7.33	3004.1	23.17
40	28.43	12.48	70.41	31.42	131.85	180.03	9.67	659.52	6.33	3121.9	21.65
41	28.19	14.11	70.59	36.96	125.88	174.27	8.67	726.43	6.67	3468.8	28.59
42	29.10	11.93	76.66	34.03	128.07	174.30	10.00	666.33	8.00	3302.5	25.22
43	29.48	13.30	79.78	35.59	128.80	179.23	10.00	717.17	8.67	3424.4	24.49
44	28.52	13.46	70.54	37.46	122.24	177.17	9.67	671.17	7.67	3152.5	23.48
45	28.96	12.28	67.48	36.04	131.60	180.34	9.67	640.70	6.00	3414.2	23.49
46	28.81	13.82	71.18	36.46	126.92	180.71	8.67	632.85	5.67	3024.8	24.78
47	27.85	13.23	71.58	38.15	136.57	189.04	9.33	674.30	6.33	2986.4	20.63
48	28.43	12.50	71.73	41.33	125.18	181.04	9.33	729.00	8.67	3213.3	24.17
49	29.04	13.44	65.22	31.14	127.83	169.61	8.67	560.36	5.00	2735.4	22.28
50	28.20	14.04	79.36	21.12	119.90	157.76	9.67	620.74	8.00	2886.1	21.24
51	28.82	13.26	71.00	29.60	121.47	165.90	9.67	641.59	7.00	2814.9	23.98
52	27.11	14.20	78.84	29.59	116.24	157.59	9.00	681.55	8.00	3184.6	22.62
53	28.00	13.48	74.48	19.46	118.23	152.83	10.00	605.33	8.33	2887.2	22.69
54	28.30	12.50	72.39	28.21	137.97	193.53	10.00	682.33	6.33	3085.5	24.08
55	28.10	12.19	71.19	27.31	138.70	188.86	9.67	673.31	8.67	3202.1	23.84
56	29.68	13.23	83.12	23.58	115.59	156.34	9.33	602.46	7.67	3261.5	23.08
57	27.69	13.21	67.07	33.14	133.41	184.31	9.33	690.88	8.00	3282.1	25.32
58	27.90	12.57	68.74	40.22	140.19	195.57	9.33	738.26	7.67	3491.4	24.61
59	28.30	13.81	73.08	31.04	135.60	186.87	10.00	711.83	8.33	3378.7	24.71
60	27.86	13.54	68.50	40.31	143.77	209.97	9.67	737.67	8.67	3143.8	23.96
61	27.43	13.58	67.42	37.46	142.13	194.40	9.67	707.22	8.67	3288.4	25.81
62	28.57	12.43	73.32	30.40	135.77	185.63	10.00	688.50	8.00	3117.7	26.28
63	28.30	11.81	77.30	35.67	137.83	188.17	9.67	683.96	7.67	3165.9	26.02
64	27.68	11.96	77.67	42.07	132.28	193.66	9.67	732.44	7.67	3135.6	25.36
65	28.60	12.29	73.64	37.18	139.97	194.07	10.00	709.33	7.00	3384.6	22.81
66	27.64	13.00	67.79	47.97	134.52	191.78	9.00	728.50	7.33	3307.0	27.33
67	28.10	13.51	75.46	42.89	124.27	168.52	9.67	650.87	8.00	2909.7	23.43
68	28.00	11.87	75.70	31.20	115.66	162.45	9.67	705.22	7.33	3154.7	24.23

Prov	KE94FLSH	KE94STRT	KE94STOP	KE94INCR	KE93HT	KE94HT	KE97SURV	KE97HT	KE04SURV	KE04HT	KE04DIAM
69	27.76	12.31	76.00	35.86	127.13	170.17	10.00	651.50	7.67	3137.2	23.09
70	27.03	11.69	75.76	24.60	117.30	159.55	9.33	642.09	8.67	2721.0	24.34
71	26.67	12.97	67.87	32.05	122.30	172.17	10.00	634.17	8.67	2559.4	20.51
72	26.63	11.68	77.54	37.57	118.30	160.63	9.67	694.30	7.33	3247.3	23.66
73	26.03	14.42	76.04	25.67	117.17	156.13	10.00	701.17	8.67	3023.9	23.82
74	28.00	13.79	64.83	29.07	121.22	165.55	9.67	690.50	8.67	3300.2	25.65
75	27.45	12.21	67.41	34.55	129.86	180.38	9.67	647.56	6.33	3108.4	24.28
76	28.27	13.26	66.89	30.65	125.20	170.70	10.00	626.67	8.00	2991.0	21.02
77	28.56	15.13	69.96	32.53	121.86	162.71	9.00	659.98	6.67	3390.6	24.64
78	28.43	12.83	70.43	27.00	126.23	162.83	9.67	648.22	7.67	3009.0	21.17
79	28.31	12.48	74.41	38.75	133.59	187.52	9.33	705.56	7.00	2995.8	23.47
80	28.29	13.62	74.50	24.73	135.12	178.96	9.33	618.72	6.33	2942.5	24.33
81	28.79	12.71	81.21	29.50	134.40	177.76	9.33	629.18	7.00	2531.3	25.39
82	28.67	13.89	70.48	29.78	117.33	161.27	10.00	637.83	7.33	3335.9	24.57
83	27.96	13.04	76.74	30.49	116.38	168.07	9.67	677.43	7.67	3356.0	23.32
84	29.21	13.56	70.92	25.45	134.07	181.11	9.33	657.00	7.67	3209.8	21.75
85	28.55	13.15	65.42	20.46	124.90	163.07	9.67	634.06	6.67	3452.3	23.20
86	28.00	13.59	70.15	33.03	123.03	173.25	9.00	630.93	7.67	3110.8	23.18
87	28.03	11.64	63.11	30.07	134.03	180.74	9.67	662.11	7.00	3404.7	24.28
88	29.41	13.38	68.58	27.54	129.93	168.72	9.67	599.80	7.00	2605.4	23.24
89	27.40	12.00	71.65	34.77	125.73	177.41	9.67	675.15	8.00	3479.2	28.21
90	28.07	12.66	74.38	35.66	125.07	167.77	10.00	655.67	7.67	3393.7	21.90
91	27.70	13.11	69.05	43.21	123.67	173.11	9.33	684.46	7.67	3078.8	23.93
92	26.96	12.80	67.52	33.17	127.73	171.48	9.67	656.72	8.33	3102.4	22.66
93	27.41	12.72	74.12	38.16	126.14	183.15	9.00	725.53	8.00	3384.0	24.63
94	29.18	14.04	79.31	33.77	131.63	183.14	9.67	663.72	8.33	3244.5	25.37
95	28.85	14.91	71.70	30.57	127.02	173.15	9.00	669.81	6.33	3080.4	27.39
96	30.07	12.88	75.92	26.46	130.30	174.83	10.00	690.00	9.00	3234.6	25.00
97	29.10	12.45	71.97	35.28	129.23	191.93	9.67	647.35	6.00	3207.4	23.32
98	29.00	13.92	73.64	35.53	148.08	210.72	9.67	690.52	7.33	3118.6	22.72
99	29.03	14.87	67.00	31.10	139.75	195.38	9.67	669.26	8.67	3008.0	22.14
100	28.37	12.48	71.52	29.48	121.60	169.90	9.33	708.56	8.67	2893.6	21.89
101	28.29	13.32	72.32	35.50	137.00	184.11	9.00	758.33	7.67	3587.0	26.46
102	28.03	13.00	69.45	32.41	131.23	179.62	9.67	707.33	5.67	3379.8	25.09

Prov	SL94STRT	SL94STOP	SL94INCR	SL93HT	SL94HT	SL97SURV	SL97HT	SL04SURV	SL04HT	SL04DIAM
1	17.31	78.62	37.87	125.3	193.2	9.67	615.2	8.67	269.47	17.34
2	17.38	74.21	30.70	119.9	176.4	9.00	643.6	9.33	258.96	16.67
3	17.81	76.38	46.74	126.0	192.0	6.67	634.6	6.33	252.38	14.53
4	17.52	71.37	43.68	122.2	187.8	9.00	678.0	8.33	283.18	19.50
5	17.18	80.21	29.98	122.5	182.0	9.67	557.1	9.00	250.30	16.20
6	17.93	75.22	46.37	136.5	209.3	8.67	647.9	8.33	258.80	17.29
7	16.64	77.50	46.07	119.7	188.2	9.33	638.8	10.00	267.99	18.90
8	17.82	75.11	34.31	115.9	173.8	8.67	626.9	8.00	252.24	15.68
9	17.65	69.00	48.43	122.8	191.3	9.00	671.6	9.00	273.09	19.94
10	18.38	71.46	33.38	114.5	168.2	9.00	573.4	9.33	254.57	16.04
11	18.88	78.12	43.76	123.0	188.0	8.00	604.0	7.00	259.05	18.13
12	16.69	74.00	39.01	119.3	182.9	7.00	633.0	6.00	260.92	17.13
13	18.30	70.07	38.24	118.0	178.7	8.67	650.1	8.67	257.22	16.22
14	18.04	72.30	37.70	116.7	173.7	8.33	704.4	7.00	279.49	18.71
15	18.20	77.20	32.84	111.7	169.5	9.33	534.0	8.00	242.13	14.64
16	17.72	75.90	39.66	115.1	182.6	9.33	709.1	9.67	287.71	17.87
17	18.83	78.33	28.67	124.3	180.5	9.33	570.2	9.00	244.16	14.75
18	16.48	77.36	32.60	117.6	162.5	7.67	604.0	8.00	255.10	17.27
19	17.41	72.48	32.79	116.5	169.7	8.33	581.0	7.33	255.79	15.24
20	17.07	80.03	33.28	120.6	180.5	8.67	606.3	8.00	258.30	16.14
21	17.76	78.88	33.76	116.3	170.5	8.00	572.7	8.33	252.14	15.93
22	17.68	79.29	35.18	133.1	195.1	7.67	580.6	8.33	251.28	16.38
23	18.83	73.48	32.39	121.2	192.1	9.33	629.7	9.33	258.01	18.54
24	18.55	71.24	31.89	127.4	187.3	7.67	630.3	7.67	263.53	18.45
25	19.00	68.85	34.55	127.5	180.1	8.33	542.4	7.67	243.66	15.69
26	17.69	78.54	33.73	121.3	191.4	7.33	665.3	7.67	257.14	18.55
27	17.26	73.19	30.33	118.1	174.5	7.67	576.9	7.33	264.00	17.01
28	18.04	74.37	39.23	125.3	191.1	7.33	611.2	9.00	279.65	19.55
29	17.43	75.64	47.20	128.6	207.0	8.33	679.5	8.33	265.08	19.10
30	16.57	72.71	49.35	126.5	195.0	8.67	666.9	8.33	258.79	17.85
31	18.10	77.93	39.18	126.8	190.2	8.33	584.7	8.33	262.09	17.27
32	17.00	70.04	45.08	118.1	180.2	9.33	592.1	8.67	248.49	15.76
33	17.67	76.41	46.23	124.1	187.6	8.33	646.1	8.67	261.62	15.62

Prov	SL94STRT	SL94STOP	SL94INCR	SL93HT	SL94HT	SL97SURV	SL97HT	SL04SURV	SL04HT	SL04DIAM
34	17.78	71.26	47.70	119.3	182.5	9.00	632.0	8.33	265.84	17.12
35	17.38	70.62	51.19	127.5	206.2	8.67	660.5	8.67	261.56	16.44
36	17.28	77.52	33.50	122.1	175.1	8.67	625.2	8.33	248.50	14.15
37	17.55	77.79	44.86	129.0	198.0	7.67	623.1	8.33	268.13	19.30
38	17.36	66.04	47.51	123.1	185.6	7.33	641.1	7.00	281.46	19.06
39	17.52	76.17	42.89	122.7	183.8	7.00	638.2	7.33	265.30	18.57
40	16.85	75.69	40.22	119.1	184.4	7.67	569.9	7.00	233.15	13.64
41	16.73	70.93	41.60	121.9	186.6	8.67	649.0	8.00	251.72	17.78
42	18.89	69.85	36.85	121.3	188.3	9.00	644.5	9.33	252.93	16.29
43	17.80	75.83	38.76	122.9	187.2	8.67	651.5	8.67	259.14	16.01
44	17.39	68.43	42.82	121.0	186.0	8.00	616.7	8.00	259.23	15.50
45	19.32	69.04	41.62	111.7	157.3	6.33	730.0	6.67	280.01	18.63
46	17.11	77.32	42.50	122.4	187.3	8.00	685.9	8.67	258.63	17.11
47	17.67	75.33	34.03	128.9	184.0	8.33	593.5	7.33	238.74	18.03
48	17.21	73.86	38.36	124.9	188.8	9.67	666.0	8.67	270.80	16.95
49	18.25	75.64	41.34	126.3	193.6	9.33	668.1	9.33	257.27	18.22
50	17.70	74.20	27.97	117.8	173.2	8.33	568.9	8.33	234.86	16.69
51	18.56	75.60	28.36	117.7	162.4	8.33	556.3	7.67	235.75	15.51
52	16.82	74.18	35.40	118.2	167.9	7.67	568.5	6.67	241.69	16.74
53	17.54	81.73	25.95	106.7	157.8	9.00	567.6	9.00	245.95	16.71
54	17.63	72.48	36.67	130.9	191.4	8.67	610.9	8.33	234.98	16.28
55	17.07	81.04	30.64	122.4	181.9	8.67	545.6	8.33	230.12	16.08
56	17.18	78.76	36.94	115.9	166.4	8.33	631.6	7.67	250.26	16.19
57	18.70	75.44	34.63	131.6	189.2	9.67	627.1	9.33	263.58	18.62
58	18.15	76.69	39.92	135.6	195.8	8.00	668.8	8.00	278.98	20.06
59	17.24	76.45	43.72	132.0	205.7	8.33	675.6	8.33	280.52	18.45
60	16.64	75.39	33.20	135.6	190.2	9.67	622.4	9.00	266.10	17.34
61	17.04	76.71	43.80	131.6	190.9	9.00	609.2	8.00	262.37	18.03
62	17.71	78.36	34.08	124.5	182.4	8.67	700.0	8.33	286.53	20.13
63	17.14	74.93	37.46	132.4	196.2	9.00	621.7	8.33	273.30	17.75
64	17.76	79.41	45.07	134.2	200.7	8.67	631.4	9.00	262.61	17.33
65	17.63	79.56	39.41	134.6	194.2	8.00	604.4	7.00	241.11	15.53
66	17.87	73.33	40.32	132.0	192.6	8.33	631.5	8.67	253.16	19.20
67	18.34	72.93	35.13	116.0	168.2	9.00	570.6	9.00	245.82	17.13
68	17.25	66.57	36.07	119.9	175.5	8.00	629.4	8.33	255.63	18.27

Prov	SL94STRT	SL94STOP	SL94INCR	SL93HT	SL94HT	SL97SURV	SL97HT	SL04SURV	SL04HT	SL04DIAM
69	17.63	70.93	39.04	116.9	172.4	8.67	638.1	8.67	271.33	18.69
70	18.93	76.86	26.54	115.4	158.9	9.00	536.1	9.67	253.07	16.86
71	17.74	73.44	29.96	111.6	160.6	8.33	539.5	8.67	255.98	16.93
72	18.90	68.67	30.84	109.1	154.5	8.67	576.7	9.00	253.17	15.81
73	17.41	76.66	28.66	106.7	154.0	10.00	534.0	9.00	241.42	15.89
74	16.68	73.46	38.76	107.7	159.1	9.00	579.6	9.00	258.66	17.04
75	16.93	79.39	36.06	129.8	189.4	9.00	652.8	8.67	259.10	16.74
76	18.00	75.58	37.98	117.2	171.8	8.67	603.8	7.67	245.77	17.63
77	18.54	70.25	34.09	118.3	176.9	8.67	597.0	8.67	226.17	17.94
78	18.68	77.61	27.96	112.8	167.6	8.33	557.3	8.33	230.36	14.99
79	18.04	71.54	37.27	125.8	189.0	8.67	647.0	8.33	249.86	16.37
80	17.96	69.19	39.43	121.2	192.1	9.00	669.2	9.33	269.43	17.92
81	18.71	77.79	37.41	122.8	182.8	7.33	721.5	7.00	287.05	20.16
82	18.89	77.82	27.29	121.4	170.4	9.33	528.8	8.33	222.42	15.00
83	18.93	74.00	34.63	114.4	167.2	9.00	526.7	7.67	245.87	16.40
84	18.03	79.17	26.21	118.8	171.6	8.67	618.6	9.00	260.05	16.96
85	17.62	78.73	28.57	112.2	159.3	8.67	595.2	9.00	244.44	16.31
86	17.55	66.21	41.86	115.8	179.2	8.67	607.6	8.00	245.91	18.27
87	18.67	77.70	35.71	128.7	186.6	9.00	659.6	8.33	270.79	20.01
88	17.86	71.93	36.96	113.4	168.7	8.67	662.2	8.00	281.51	19.85
89	16.86	76.00	41.07	125.8	184.4	8.33	658.6	8.00	262.34	17.54
90	18.30	72.78	44.96	112.1	169.2	8.67	634.6	8.33	252.51	14.73
91	17.38	70.23	45.51	117.1	178.8	8.67	634.0	9.00	245.66	16.27
92	18.25	77.92	32.63	119.3	170.3	8.33	682.2	8.67	253.65	17.87
93	17.63	71.83	39.57	123.1	182.1	8.67	603.3	9.33	262.57	18.53
94	17.43	73.82	48.49	128.1	203.5	7.67	595.6	6.67	241.60	16.33
95	17.46	76.36	38.98	119.8	188.5	8.33	618.9	8.67	288.42	20.14
96	18.00	74.73	30.15	135.8	191.4	8.67	596.7	8.00	236.82	16.45
97	18.12	79.46	36.41	129.1	200.3	8.33	663.9	8.00	271.12	17.28
98	18.68	79.48	31.21	130.5	190.4	9.00	627.7	7.67	270.06	18.45
99	17.00	73.82	29.23	139.9	202.2	8.00	616.9	7.33	240.63	15.37
100	17.27	76.67	32.30	122.3	186.6	8.33	632.8	7.33	269.56	16.56
101	16.97	77.20	44.44	123.3	192.9	9.33	680.2	9.33	273.39	19.61
102	17.89	79.15	42.41	127.2	185.2	9.00	627.2	9.33	265.55	18.53

Prov	TB93HT	TB94HT	TB97SURV	TB97HT	TB03HT	TB03DIAM	FRZ1T1	FRZ1T2	FRZ2T1	FRZ2T2	FRZ3T1	FRZ3T2
1	130.52	275.72	8.7	176.20	488.29	35.1	5.45	9.02	17.31	19.69	8.37	8.69
2	128.71	247.77	9.3	167.36	458.11	29.9	4.43	7.24	14.27	14.02	9.59	8.92
3	121.76	242.50	6.3	189.55	482.26	36.3	4.34	10.96	16.62	15.86	9.33	9.44
4	114.77	236.24	8.3	174.06	480.20	33.4	4.12	7.44	19.35	23.64	8.43	8.30
5	124.64	233.88	9.0	169.17	474.36	31.5	6.87	6.48	14.44	14.33	8.15	8.21
6	126.48	260.44	8.3	170.81	464.78	32.9	4.89	8.48	12.23	14.40	7.54	9.37
7	111.60	234.54	10.0	169.98	467.78	32.7	3.62	8.04	15.16	17.71	8.58	8.14
8	123.24	240.50	8.0	146.84	448.88	28.7	5.40	6.11	13.12	22.02	7.83	8.98
9	116.72	264.72	9.0	170.30	470.05	33.1	3.43	16.72	13.86	15.83	8.84	8.86
10	122.99	242.16	9.3	174.14	465.90	31.3	4.89	9.41	11.83	12.13	8.58	9.47
11	122.76	258.88	7.0	185.25	493.92	35.3	3.71	7.16	13.92	13.12	8.11	10.31
12	121.12	237.79	6.0	172.33	503.76	36.6	4.54	6.06	14.46	14.97	8.84	11.42
13	118.52	236.09	8.7	180.50	491.12	32.9	3.60	10.87	20.04	15.74	8.13	9.58
14	112.66	261.73	7.0	184.35	496.34	36.3	4.08	11.32	15.93	14.56	10.16	11.67
15	118.11	223.96	8.0	169.12	481.71	32.0	4.49	19.49	11.62	16.12	11.60	14.62
16	119.56	257.52	9.7	176.94	483.61	32.6	3.77	25.89	11.54	15.67	9.65	9.25
17	122.06	248.16	9.0	186.74	518.03	38.8	3.93	17.14	12.83	18.77	10.38	10.92
18	139.96	267.96	8.0	182.21	505.33	35.6	6.00	18.97	13.75	24.50	11.38	10.38
19	110.13	230.13	7.3	165.14	486.05	33.3	4.57	6.25	15.33	15.55	10.91	9.75
20	126.07	253.36	8.0	180.70	526.53	37.4	9.15	11.52	12.63	20.96	9.87	12.54
21	126.67	248.84	8.3	176.89	471.74	33.8	3.46	5.53	20.13	16.92	10.10	10.69
22	137.66	268.36	8.3	169.93	446.27	32.1	3.16	7.76	13.81	18.38	9.45	14.78
23	130.00	258.17	9.3	183.08	501.88	35.7	3.68	8.45	14.90	15.35	10.48	10.93
24	127.17	229.04	7.7	163.62	469.97	32.8	4.85	13.83	9.44	13.04	9.38	11.98
25	124.31	249.32	7.7	174.56	483.45	34.5	3.18	5.49	12.80	16.60	8.60	9.80
26	121.87	243.76	7.7	176.98	483.14	33.4	4.23	12.35	16.71	14.49	10.71	9.42
27	119.16	236.25	7.3	171.57	487.57	34.5	5.38	10.72	10.99	15.00	9.47	10.78
28	133.19	257.71	9.0	175.83	489.04	34.8	4.15	8.89	12.92	17.74	9.41	10.47
29	135.04	284.96	8.3	191.36	492.43	38.9	4.11	5.44	14.06	17.62	10.04	12.38
30	130.50	271.17	8.3	190.87	521.84	39.2	4.74	10.76	13.92	20.68	9.40	10.58
31	132.64	261.24	8.3	179.02	474.65	35.1	5.96	14.95	15.27	15.19	10.95	11.34
32	125.20	253.96	8.7	181.24	484.04	32.2	5.35	8.75	13.72	18.70	8.61	9.69
33	125.71	256.80	8.7	187.00	493.62	35.4	3.11	8.66	16.82	16.41	9.14	12.11

Prov	TB93HT	TB94HT	TB97SURV	TB97HT	TB03HT	TB03DIAM	FRZ1T1	FRZ1T2	FRZ2T1	FRZ2T2	FRZ3T1	FRZ3T2
34	112.55	235.58	8.3	186.05	508.13	37.6	6.01	17.90	16.02	15.61	9.65	14.90
35	119.66	241.63	8.7	178.80	477.90	33.2	3.12	8.83	19.38	25.17	9.33	9.37
36	129.87	253.63	8.3	167.62	486.33	32.3	3.39	19.78	12.91	14.24	10.26	9.80
37	122.00	274.63	8.3	181.74	498.12	37.0	3.45	8.58	14.75	20.10	9.35	10.51
38	123.88	272.92	7.0	189.13	491.51	35.2	3.34	12.03	24.37	21.98	8.94	11.45
39	122.00	257.64	7.3	181.86	505.38	35.8	6.45	10.42	19.15	19.98	9.00	14.00
40	121.17	257.28	7.0	181.24	494.55	32.3	3.28	13.30	12.83	17.84	10.08	11.10
41	123.80	266.24	8.0	178.43	521.86	40.6	3.11	9.83	13.29	17.53	9.49	11.27
42	113.95	262.50	9.3	177.64	478.84	34.8	3.48	15.58	11.19	13.73	9.51	12.13
43	125.48	257.79	8.7	188.39	508.43	37.2	7.11	25.74	16.67	22.69	11.23	11.44
44	108.92	250.48	8.0	175.20	510.76	37.3	4.14	12.70	14.04	15.36	12.37	13.57
45	129.08	267.48	6.7	186.56	500.73	35.7	4.13	8.62	18.00	15.32	12.25	10.94
46	117.55	255.88	8.7	185.61	492.57	35.7	3.88	5.71	15.56	22.02	10.81	11.41
47	121.87	260.56	7.3	186.02	523.88	41.3	3.70	12.40	20.56	29.15	10.32	8.82
48	110.15	246.54	8.7	194.26	489.13	34.7	7.22	19.54	8.03	22.27	9.00	9.88
49	120.35	250.24	9.3	174.11	471.79	32.8	4.06	7.21	19.03	20.87	9.57	16.69
50	120.48	227.20	8.3	168.34	468.84	32.0	10.64	7.23	14.67	15.80	11.13	11.90
51	105.96	211.72	7.7	156.02	430.80	26.9	5.20	6.34	13.09	18.76	9.57	10.88
52	108.92	219.84	6.7	167.89	450.15	29.7	4.52	6.84	19.38	32.03	7.76	8.68
53	109.43	225.32	9.0	162.80	449.68	32.4	3.69	6.17	11.11	15.45	9.45	10.72
54	130.16	240.88	8.3	169.14	447.73	28.2	3.17	12.10	15.27	14.30	8.74	9.78
55	126.44	247.84	8.3	166.90	472.94	31.7	3.98	9.10	14.35	14.40	8.56	9.71
56	124.42	235.08	7.7	174.95	473.11	33.9	4.09	11.55	16.94	14.85	10.56	8.44
57	126.74	260.28	9.3	170.50	485.85	33.8	6.63	14.52	12.23	13.47	10.07	13.20
58	133.44	283.80	8.0	178.02	487.35	32.9	4.27	9.15	15.33	14.05	10.12	11.58
59	135.40	267.00	8.3	181.71	500.46	36.4	3.67	10.28	14.01	18.73	10.10	11.95
60	134.36	271.92	9.0	180.84	488.54	33.0	4.66	15.16	15.96	15.20	13.57	14.57
61	134.75	256.24	8.0	179.23	482.14	35.7	4.13	5.23	12.00	14.20	9.08	9.67
62	129.20	260.48	8.3	170.15	478.61	34.1	4.38	7.08	12.80	22.82	11.05	12.04
63	130.28	261.08	8.3	180.10	699.33	31.9	3.94	6.58	14.61	18.83	10.91	8.32
64	126.32	264.12	9.0	181.42	480.78	36.8	4.34	14.64	13.49	15.42	8.35	9.92
65	129.48	254.08	7.0	184.09	503.32	35.1	5.55	13.82	14.21	14.78	12.04	12.77
66	128.56	271.88	8.7	185.24	509.09	38.0	3.41	4.74	14.18	13.70	6.04	8.89
67	110.84	212.40	9.0	148.27	441.90	31.9	4.13	12.13	12.63	17.68	10.10	11.66
68	110.55	205.84	8.3	154.74	469.30	30.7	4.10	12.88	13.35	18.03	9.79	9.16

Prov	TB93HT	TB94HT	TB97SURV	TB97HT	TB03HT	TB03DIAM	FRZ1T1	FRZ1T2	FRZ2T1	FRZ2T2	FRZ3T1	FRZ3T2
69	112.95	228.67	8.7	169.00	463.36	31.2	4.48	8.04	13.20	19.69	10.22	11.60
70	118.41	213.68	9.7	166.64	453.46	28.6	3.95	3.71	18.46	22.69	8.11	9.97
71	100.43	216.58	8.7	156.76	442.76	30.4	4.34	7.95	13.23	14.56	10.06	9.30
72	119.67	248.42	9.0	161.58	442.78	28.6	5.60	13.25	16.22	18.35	9.37	11.33
73	119.09	219.83	9.0	158.86	452.52	29.6	4.06	3.86	12.49	15.26	8.13	8.96
74	110.16	209.08	9.0	164.57	456.26	31.4	5.86	13.79	15.33	20.58	8.35	9.05
75	115.32	235.17	8.7	168.42	482.27	32.8	6.41	11.49	10.90	16.37	8.66	9.17
76	113.70	219.28	7.7	162.63	461.27	27.8	5.64	8.40	10.94	16.66	9.28	11.63
77	121.75	232.01	8.7	171.96	463.16	31.0	4.53	14.45	17.60	21.13	9.67	12.57
78	109.84	230.00	8.3	167.68	477.63	31.7	3.93	5.53	13.46	16.57	9.29	11.61
79	119.40	246.52	8.3	173.80	501.85	32.1	4.06	5.29	16.02	23.16	9.90	11.88
80	124.92	247.59	9.3	174.86	485.98	34.7	6.40	5.22	16.75	17.49	8.80	9.87
81	117.63	230.04	7.0	178.96	476.42	33.5	5.99	25.60	16.36	19.21	10.79	11.27
82	122.68	231.80	8.3	181.02	480.13	33.4	5.00	13.65	19.58	24.28	8.96	11.11
83	108.20	239.25	7.7	168.54	478.20	32.3	14.27	18.88	22.88	15.87	9.59	10.88
84	111.69	213.53	9.0	165.43	479.60	32.6	4.50	11.37	10.28	19.91	8.98	10.12
85	126.52	236.80	9.0	171.96	469.47	31.2	4.67	15.54	13.46	19.18	9.37	10.11
86	123.87	247.61	8.0	166.77	455.16	31.2	3.86	7.55	19.78	16.31	9.00	10.14
87	124.88	248.44	8.3	178.38	491.71	34.2	5.18	8.90	14.49	13.04	10.75	11.61
88	129.04	252.96	8.0	170.14	483.92	31.7	3.47	8.57	15.30	17.33	8.90	8.88
89	114.88	241.25	8.0	167.28	448.83	28.8	4.46	13.25	16.04	20.84	9.28	9.97
90	128.76	237.08	8.3	172.30	483.49	34.2	3.56	14.33	17.39	17.17	8.98	10.47
91	136.59	248.76	9.0	179.85	481.02	33.7	3.81	7.81	21.67	22.75	8.76	11.01
92	117.15	232.33	8.7	157.64	471.44	31.2	7.44	22.16	16.51	14.75	9.53	9.94
93	115.20	223.63	9.3	168.05	456.11	31.5	4.75	19.76	12.95	17.27	8.70	8.51
94	126.76	241.72	6.7	173.24	465.97	32.3	8.65	33.73	11.45	22.59	11.21	11.79
95	125.76	238.54	8.7	168.58	446.05	33.8	5.38	11.86	10.44	15.86	9.47	10.10
96	129.56	244.58	8.0	172.67	486.12	34.3	7.77	14.06	16.62	20.39	10.34	9.89
97	127.44	259.52	8.0	179.20	488.34	32.1	3.53	8.16	13.66	19.56	10.12	10.99
98	127.83	264.67	7.7	178.71	489.78	37.0	5.03	12.32	13.52	13.22	10.22	13.73
99	135.76	267.75	7.3	178.81	493.71	35.3	3.81	13.67	17.60	16.41	11.30	10.74
100	107.31	218.70	7.3	163.90	480.72	31.2	5.69	11.81	15.53	12.55	10.00	9.05
101	124.80	240.12	9.3	173.75	473.99	33.8	10.58	17.85	14.72	13.60	9.35	13.23
102	124.88	242.88	9.3	180.87	468.98	27.6	3.59	10.87	14.98	17.33	10.06	9.89

APPENDIX IV
PROVENANCE VALUES FOR 36 CLIMATE VARIABLES IN NORTH CENTRE ONTRIAO (102 PROVENANCES)

Prov	Janmaxt	Febmaxt	Marmaxt	Aprmaxt	Maymaxt	Junmaxt	Julmaxt	Augmaxt	Sepmaxt	Octmaxt	Novmaxt	Decmaxt	Janmint	Febmint	Marmint	Aprmint	Maymint	Junmint
1	-12.96	-8.75	-0.91	8.54	16.99	21.45	24.66	22.65	15.88	8.65	-1.43	-10.43	-23.32	-20.36	-12.73	-3.36	4.22	9.92
2	-13.69	-9.33	-1.35	7.98	16.44	21.14	24.41	22.37	15.51	8.2	-1.83	-10.94	-23.61	-20.82	-13.21	-3.78	3.82	9.66
3	-12.64	-8.38	-0.75	8.4	16.68	21.27	24.47	22.5	15.92	8.84	-1.16	-9.67	-23.76	-20.95	-13.27	-3.81	3.66	9.37
4	-12.84	-8.46	-0.75	8.29	16.56	21.31	24.46	22.46	15.95	8.94	-1.1	-9.63	-24.1	-21.33	-13.66	-4.06	3.5	9.32
5	-14.24	-9.79	-1.87	6.94	15.46	20.54	23.76	21.48	14.89	7.99	-2.14	-10.79	-25.81	-23.39	-15.94	-5.79	2.37	8.38
6	-14.31	-9.84	-1.74	7.27	15.73	20.84	24	21.8	15.13	8.03	-2.13	-11.09	-25.13	-22.71	-15.26	-5.19	2.86	8.97
7	-14.58	-10.19	-2.17	6.71	15.22	20.37	23.67	21.35	14.67	7.6	-2.51	-11.24	-26.34	-24.06	-16.65	-6.28	1.93	7.89
8	-14.39	-9.94	-1.94	6.95	15.45	20.52	23.91	21.58	14.92	7.87	-2.24	-10.88	-26.61	-24.24	-16.72	-6.31	1.87	7.71
9	-13.83	-9.4	-1.39	7.71	16.14	21.07	24.23	22.12	15.42	8.29	-1.82	-10.75	-24.31	-21.72	-14.16	-4.4	3.4	9.41
10	-14.5	-10.07	-2.05	6.87	15.37	20.47	23.88	21.54	14.85	7.75	-2.35	-11.04	-26.8	-24.49	-17.01	-6.51	1.7	7.52
11	-13.66	-9.19	-1.29	7.64	16.05	21.03	24.13	22.01	15.46	8.51	-1.62	-10.35	-24.61	-22.04	-14.51	-4.68	3.21	9.24
12	-11.27	-7.07	0.27	9.53	17.52	21.82	25.11	23.32	16.93	9.83	-0.08	-8.3	-23.36	-20.42	-12.53	-3.28	3.75	9.15
13	-11.72	-7.59	-0.12	9.41	17.59	21.78	25.03	23.15	16.62	9.47	-0.57	-9.26	-23.09	-20.03	-12.26	-3.08	4.16	9.56
14	-11.65	-7.55	-0.12	9.51	17.68	21.8	25.06	23.19	16.67	9.51	-0.57	-9.35	-23.12	-19.97	-12.22	-3.06	4.18	9.52
15	-12.15	-8	-0.42	9.16	17.42	21.67	24.92	22.99	16.38	9.19	-0.9	-9.75	-23.36	-20.21	-12.55	-3.25	4.19	9.67
16	-12.14	-7.96	-0.35	9.1	17.37	21.68	24.92	22.99	16.39	9.22	-0.82	-9.56	-23.2	-20.2	-12.45	-3.17	4.18	9.7
17	-12.14	-7.96	-0.35	9.1	17.37	21.68	24.92	22.99	16.39	9.22	-0.82	-9.56	-23.2	-20.2	-12.45	-3.17	4.18	9.7
18	-12.03	-7.88	-0.32	9.28	17.53	21.74	24.99	23.08	16.49	9.3	-0.79	-9.64	-23.29	-20.14	-12.45	-3.17	4.22	9.67
19	-11.33	-7.18	0.21	9.66	17.73	21.92	25.2	23.37	16.92	9.8	-0.19	-8.69	-23.02	-20	-12.15	-2.99	4.08	9.44
20	-11.5	-7.33	0.11	9.54	17.66	21.88	25.14	23.3	16.82	9.69	-0.3	-8.84	-23.08	-20.07	-12.23	-3.04	4.09	9.49
21	-11.5	-7.33	0.11	9.54	17.66	21.88	25.14	23.3	16.82	9.69	-0.3	-8.84	-23.08	-20.07	-12.23	-3.04	4.09	9.49
22	-11.49	-7.32	0.14	10.05	18.19	22.22	25.46	23.62	17.17	9.98	-0.3	-9.31	-23.14	-19.88	-11.99	-2.76	4.41	9.63
23	-12.7	-8.42	-0.71	9.24	17.57	22	25.15	23.33	16.87	9.68	-0.95	-9.89	-24.36	-21.37	-13.27	-3.28	4.19	9.46
24	-13.05	-8.63	-0.76	9	17.28	21.8	25.02	23.12	16.49	9.16	-1.2	-10.31	-24.52	-21.37	-13.52	-3.52	4.08	9.58
25	-12.82	-8.49	-0.72	9.06	17.33	21.77	24.98	23.09	16.49	9.21	-1.15	-10.19	-24.38	-21.21	-13.38	-3.51	4.08	9.51
26	-12.67	-8.32	-0.54	9.33	17.6	22	25.2	23.34	16.78	9.52	-0.93	-10.01	-24.28	-21.12	-13.19	-3.29	4.22	9.6
27	-12.66	-8.44	-0.79	9.12	17.43	21.83	25	23.16	16.68	9.5	-1.07	-9.97	-24.34	-21.33	-13.3	-3.4	4.08	9.35
28	-12.83	-8.51	-0.76	9.11	17.41	21.87	25.05	23.19	16.65	9.41	-1.09	-10.09	-24.45	-21.4	-13.42	-3.41	4.12	9.47
29	-12.62	-8.32	-0.6	9.19	17.44	21.81	25.04	23.14	16.56	9.3	-1.05	-10.07	-24.2	-20.97	-13.19	-3.45	4.13	9.55
30	-12.25	-8.07	-0.49	9.18	17.43	21.67	24.92	23	16.41	9.19	-0.97	-9.9	-23.73	-20.44	-12.85	-3.43	4.14	9.59
31	-12.2	-7.95	-0.31	9.44	17.68	21.91	25.16	23.26	16.68	9.44	-0.78	-9.8	-23.75	-20.4	-12.75	-3.27	4.28	9.73
32	-13.55	-9.24	-1.3	8.05	16.52	21.17	24.42	22.38	15.53	8.25	-1.79	-10.87	-23.55	-20.72	-13.13	-3.71	3.9	9.71
33	-12.99	-8.68	-0.89	8.66	16.99	21.47	24.73	22.77	16.04	8.74	-1.38	-10.41	-24.11	-20.82	-13.37	-3.77	4.03	9.71

Prov	Janmaxt	Febmaxt	Marmaxt	Aprmaxt	Maymaxt	Junmaxt	Julmaxt	Augmaxt	Sepmaxt	Octmaxt	Novmaxt	Decmaxt	Janmint	Febmint	Marmint	Aprmint	Maymint	Junmint
34	-12.94	-8.68	-0.85	8.46	16.87	21.43	24.62	22.61	15.89	8.73	-1.33	-10.18	-23.42	-20.6	-12.91	-3.48	4.05	9.8
35	-11.6	-7.36	-0.08	8.96	16.94	21.42	24.7	22.89	16.53	9.49	-0.37	-8.34	-23.93	-21.04	-13.24	-3.85	3.29	8.79
36	-11.3	-6.96	0.28	9.25	17.13	21.65	24.94	23.18	16.92	9.91	0.07	-7.77	-24.02	-20.97	-13.23	-3.79	3.25	8.71
37	-11.93	-7.55	-0.29	8.5	16.61	21.31	24.44	22.52	16.29	9.54	-0.36	-8.47	-24.61	-21.8	-14.1	-4.5	2.7	8.28
38	-12.08	-7.81	-0.32	8.81	16.94	21.47	24.7	22.81	16.34	9.28	-0.68	-8.97	-23.78	-20.9	-13.13	-3.71	3.6	9.2
39	-11.35	-7.01	0.12	8.98	16.99	21.53	24.75	22.89	16.7	9.9	0.08	-7.94	-24.38	-21.54	-13.79	-4.3	2.69	8.11
40	-11.68	-7.44	-0.09	9.03	17.05	21.51	24.78	22.95	16.55	9.48	-0.42	-8.52	-23.77	-20.87	-13.06	-3.69	3.48	8.99
41	-11.51	-7.2	-0.17	8.58	16.74	21.3	24.46	22.52	16.35	9.71	-0.09	-8.23	-24.64	-21.9	-14.27	-4.77	2.23	7.63
42	-12.1	-7.89	-0.39	8.81	16.98	21.44	24.68	22.78	16.26	9.17	-0.79	-9.16	-23.6	-20.72	-12.96	-3.6	3.71	9.29
43	-11.77	-7.55	-0.16	8.98	17.04	21.49	24.75	22.9	16.47	9.4	-0.51	-8.68	-23.71	-20.82	-13.02	-3.66	3.54	9.06
44	-10.98	-6.79	0.45	9.69	17.61	21.87	25.19	23.44	17.1	10.02	0.15	-7.95	-23.36	-20.43	-12.51	-3.28	3.65	8.98
45	-10.74	-6.56	0.67	9.99	17.9	22.07	25.4	23.66	17.34	10.25	0.37	-7.83	-23.06	-20.1	-12.16	-3.02	3.84	9.11
46	-11.07	-6.78	0.45	9.53	17.38	21.79	25.12	23.39	17.1	10.02	0.19	-7.68	-23.92	-21.02	-13.05	-3.64	3.3	8.69
47	-9.85	-5.93	0.71	9.64	17.49	21.53	24.98	23.22	17.1	10.29	0.8	-7.01	-23.04	-20.26	-12.73	-3.87	2.69	7.73
48	-11.99	-7.79	-0.27	9.02	17.19	21.59	24.83	22.94	16.41	9.3	-0.68	-9.15	-23.41	-20.5	-12.71	-3.4	3.88	9.42
49	-11.76	-7.53	-0.04	9.25	17.37	21.73	24.99	23.13	16.65	9.54	-0.44	-8.85	-23.39	-20.45	-12.61	-3.3	3.89	9.4
50	-11.29	-7	0.13	9.02	16.95	21.47	24.74	22.94	16.71	9.8	0	-7.83	-24.25	-21.33	-13.59	-4.14	2.87	8.3
51	-14.15	-9.69	-1.61	7.45	15.9	20.93	24.09	21.94	15.23	8.1	-2.04	-11.02	-24.68	-22.19	-14.69	-4.77	3.14	9.22
52	-14.53	-10.07	-1.9	7.19	15.65	20.78	23.96	21.78	15.01	7.8	-2.34	-11.45	-25.02	-22.62	-15.18	-5.12	2.87	8.99
53	-13.66	-9.3	-1.31	7.92	16.38	21.16	24.35	22.28	15.49	8.29	-1.79	-10.79	-23.8	-21.12	-13.51	-3.94	3.73	9.64
54	-14.27	-9.81	-1.71	7.35	15.8	20.87	24.04	21.87	15.15	8	-2.14	-11.15	-24.81	-22.35	-14.87	-4.91	3.04	9.14
55	-13.41	-9.1	-1.16	8.1	16.55	21.25	24.44	22.38	15.62	8.43	-1.64	-10.59	-23.64	-20.91	-13.26	-3.75	3.87	9.73
56	-14.75	-10.31	-2.1	6.99	15.45	20.66	23.85	21.64	14.85	7.62	-2.54	-11.69	-25.38	-23.07	-15.68	-5.47	2.59	8.74
57	-13.58	-9.29	-1.33	7.96	16.46	21.14	24.36	22.29	15.46	8.22	-1.83	-10.87	-23.55	-20.82	-13.21	-3.75	3.88	9.73
58	-13.68	-9.22	-1.27	7.76	16.16	21.11	24.24	22.13	15.52	8.48	-1.65	-10.47	-24.45	-21.85	-14.29	-4.49	3.35	9.36
59	-12.92	-8.47	-0.91	7.85	16.16	21.08	24.1	22.05	15.72	9.01	-1.04	-9.46	-24.85	-22.2	-14.53	-4.76	2.83	8.69
60	-13.03	-8.61	-0.88	8.08	16.38	21.22	24.33	22.3	15.82	8.88	-1.19	-9.73	-24.34	-21.63	-13.99	-4.3	3.34	9.23
61	-13.59	-9.08	-1.22	7.66	16.07	21.07	24.14	22.01	15.52	8.66	-1.48	-10.18	-24.72	-22.14	-14.61	-4.75	3.17	9.21
62	-12.95	-8.64	-0.89	8.23	16.56	21.25	24.42	22.41	15.81	8.73	-1.3	-9.92	-23.89	-21.13	-13.47	-3.93	3.64	9.44
63	-13.23	-8.89	-1.05	8.09	16.47	21.21	24.38	22.33	15.68	8.57	-1.49	-10.23	-23.91	-21.19	-13.55	-3.98	3.65	9.52
64	-12.59	-8.29	-0.69	8.38	16.62	21.27	24.45	22.49	15.97	8.93	-1.06	-9.48	-23.94	-21.14	-13.45	-3.95	3.52	9.25
65	-12.43	-8.18	-0.68	8.34	16.53	21.16	24.36	22.42	15.94	8.92	-1.03	-9.29	-24.01	-21.2	-13.53	-4.05	3.37	9.06
66	-12.76	-8.34	-0.74	8.15	16.41	21.22	24.33	22.32	15.92	9.05	-0.98	-9.38	-24.44	-21.69	-14.03	-4.36	3.19	9.01
67	-12.77	-8.31	-0.81	7.92	16.22	21.12	24.13	22.09	15.81	9.14	-0.9	-9.29	-24.94	-22.28	-14.57	-4.8	2.71	8.52
68	-14.27	-9.84	-1.73	7.77	16.05	20.95	24.16	22.22	15.36	7.89	-2.34	-11.47	-25.35	-22.48	-14.69	-4.36	3.29	9.08

Prov	Janmaxt	Febmaxt	marmaxt	aprmaxt	maymaxt	junmaxt	julmaxt	augmaxt	sepmaxt	octmaxt	novmaxt	decmaxt	janmint	febmint	marmint	aprmint	maymint	junmint
69	-14.38	-9.98	-1.92	7.27	15.72	20.68	23.94	21.86	14.95	7.63	-2.39	-11.51	-24.21	-21.66	-14.14	-4.5	3.19	9.19
70	-14.3	-9.85	-1.72	7.49	15.94	20.92	24.14	22.04	15.19	7.89	-2.19	-11.36	-24.28	-21.72	-14.17	-4.43	3.31	9.34
71	-14.83	-10.36	-2.15	7.22	15.49	20.58	23.81	21.82	14.88	7.38	-2.77	-11.95	-25.33	-22.62	-14.92	-4.71	2.91	8.92
72	-14.59	-10.06	-1.89	7.37	15.76	20.81	24.1	22.04	15.11	7.7	-2.35	-11.63	-24.36	-21.79	-14.22	-4.48	3.14	9.18
73	-14.86	-10.38	-2.19	7.03	15.45	20.57	23.84	21.74	14.8	7.41	-2.65	-11.93	-24.75	-22.27	-14.79	-4.89	2.87	8.98
74	-15.03	-10.55	-2.29	7.11	15.41	20.52	23.75	21.76	14.77	7.27	-2.91	-12.2	-25.58	-22.9	-15.24	-4.89	2.81	8.86
75	-14.72	-10.22	-1.98	7.45	15.71	20.78	23.98	22.01	15.09	7.58	-2.62	-11.83	-25.4	-22.63	-14.86	-4.56	3.06	9.04
76	-14.39	-9.82	-1.71	7.58	15.91	20.9	24.23	22.24	15.32	7.86	-2.15	-11.38	-24.14	-21.47	-13.81	-4.22	3.24	9.18
77	-14.7	-10.26	-2.08	7.33	15.6	20.64	23.84	21.87	14.95	7.46	-2.74	-11.87	-25.49	-22.73	-14.99	-4.67	2.98	8.92
78	-14.9	-10.38	-2.18	7.08	15.45	20.58	23.87	21.8	14.84	7.4	-2.65	-11.96	-24.76	-22.23	-14.69	-4.8	2.87	8.96
79	-14.68	-10.14	-1.99	7.28	15.63	20.7	24.01	21.98	15.03	7.58	-2.45	-11.71	-24.5	-21.9	-14.3	-4.54	3.03	9.05
80	-14.3	-9.73	-1.65	7.63	15.96	20.92	24.27	22.28	15.37	7.92	-2.08	-11.29	-24.01	-21.33	-13.67	-4.16	3.28	9.2
81	-13.66	-9.2	-1.2	8.38	16.65	21.38	24.61	22.68	15.92	8.5	-1.73	-10.84	-24.76	-21.71	-13.95	-3.91	3.73	9.41
82	-13.68	-9.25	-1.28	8.32	16.6	21.32	24.54	22.62	15.86	8.46	-1.8	-10.88	-24.9	-21.88	-14.09	-3.96	3.68	9.32
83	-13.8	-9.33	-1.29	8.3	16.57	21.34	24.56	22.63	15.85	8.42	-1.84	-10.97	-24.96	-21.96	-14.15	-3.97	3.66	9.35
84	-13.9	-9.52	-1.58	7.89	16.17	20.96	24.2	22.24	15.45	8.04	-2.13	-11.12	-24.89	-21.94	-14.24	-4.24	3.42	9.14
85	-14.09	-9.66	-1.62	7.87	16.14	21	24.22	22.27	15.45	8	-2.2	-11.27	-25.1	-22.19	-14.42	-4.25	3.38	9.14
86	-14.15	-9.7	-1.63	7.81	16.07	20.97	24.2	22.24	15.41	7.95	-2.21	-11.28	-24.9	-22.01	-14.26	-4.24	3.36	9.18
87	-13.73	-9.29	-1.34	8.03	16.4	21.14	24.45	22.46	15.61	8.24	-1.79	-10.91	-23.87	-20.97	-13.38	-3.9	3.67	9.48
88	-13.44	-9.08	-1.19	8.23	16.61	21.24	24.52	22.53	15.72	8.39	-1.67	-10.74	-23.86	-20.84	-13.3	-3.81	3.85	9.61
89	-13.22	-8.67	-1.12	7.46	15.91	20.99	23.86	21.71	15.5	9.07	-1.05	-9.64	-25.68	-23.2	-15.37	-5.37	2.22	8.1
90	-13.37	-8.83	-1.38	7.02	15.58	20.76	23.5	21.3	15.17	8.98	-1.15	-9.8	-26.35	-24.01	-16.06	-5.93	1.57	7.4
91	-12.55	-8.1	-0.88	7.66	16.08	20.99	23.89	21.8	15.66	9.28	-0.7	-9.14	-25.65	-23.13	-15.38	-5.52	1.73	7.34
92	-13.71	-9.2	-1.62	6.93	15.49	20.51	23.61	21.34	14.98	8.5	-1.61	-9.98	-26.43	-23.88	-16.12	-6.02	1.83	7.61
93	-13.47	-8.89	-1.36	7.18	15.74	20.75	23.78	21.55	15.27	8.88	-1.25	-9.69	-26.5	-23.92	-16.05	-5.92	1.75	7.47
94	-13.78	-9.3	-1.69	6.98	15.53	20.36	23.79	21.48	14.96	8.28	-1.78	-9.91	-26.74	-24.01	-16.31	-6.19	1.79	7.42
95	-13	-8.47	-0.98	7.61	16.03	21.05	23.93	21.82	15.62	9.19	-0.9	-9.45	-25.57	-23.05	-15.22	-5.28	2.22	8.04
96	-13.41	-8.89	-1.47	6.89	15.47	20.67	23.38	21.18	15.05	8.89	-1.22	-9.86	-26.46	-24.16	-16.2	-6.06	1.44	7.26
97	-12.96	-8.65	-0.78	8.74	17.12	21.59	24.84	22.86	16.1	8.82	-1.28	-10.37	-23.61	-20.49	-12.9	-3.43	4.21	9.9
98	-12.55	-8.36	-0.67	8.86	17.2	21.55	24.79	22.83	16.14	8.92	-1.16	-10.09	-23.48	-20.36	-12.75	-3.39	4.18	9.76
99	-13.11	-8.7	-0.81	8.76	17.08	21.62	24.88	22.93	16.19	8.85	-1.29	-10.42	-24.1	-20.84	-13.31	-3.66	4.09	9.79
100	-12.7	-8.45	-0.65	8.88	17.26	21.66	24.88	22.91	16.19	8.95	-1.15	-10.17	-23.37	-20.29	-12.64	-3.25	4.3	9.94
101	-12.44	-8.25	-0.56	8.83	17.16	21.56	24.78	22.82	16.17	9.01	-1.04	-9.8	-23.27	-20.34	-12.61	-3.28	4.14	9.75
102	-11.65	-7.33	-0.36	8.33	16.6	21.17	24.29	22.3	16.14	9.59	-0.21	-8.43	-24.86	-22.18	-14.64	-5.11	1.9	7.27

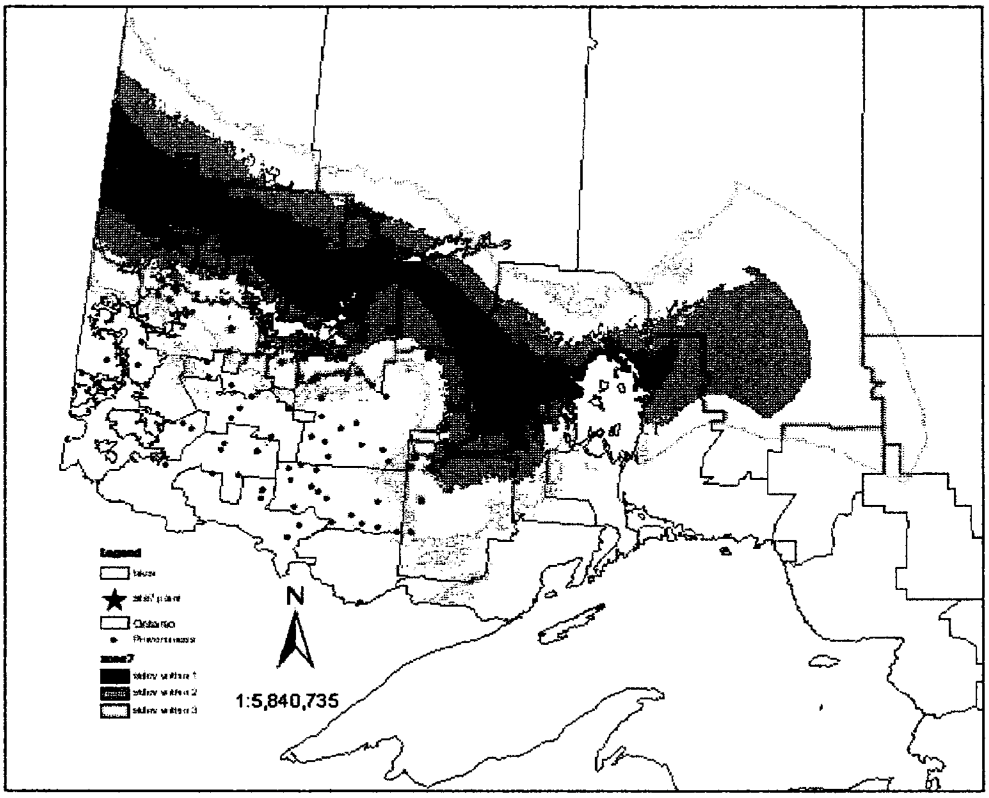
Prov	Julmint	Augmint	Sepmint	Octmint	Novmint	Decmint	Janprec	Febprec	Marprec	Aprprec	Mayprec	Junprec	Julprec	Augprec	Sepprec	Octprec	Novprec	Decprec
1	13.19	11.63	6.29	0.69	-8.46	-19.54	30.83	24.25	33.98	38.92	63.85	103.62	94.96	89.34	82.37	58.59	38.92	31.11
2	13	11.47	6.13	0.54	-8.75	-19.83	31.55	24.85	34.78	39.12	62.76	99.85	96	91.22	80.31	55.97	40.23	32.22
3	12.77	11.17	5.83	0.44	-8.54	-19.45	31.98	26.18	34.16	37.85	66.7	102.34	98.41	85.76	89.51	64.5	33.49	32.1
4	12.78	11.11	5.74	0.46	-8.48	-19.62	33.91	28.21	34.91	38.04	66.52	98.35	96.43	86.97	89.51	64.29	35.61	34.08
5	12.01	10.02	4.67	-0.43	-9.69	-21.62	42.88	37.54	40.32	36	64.46	88.87	93.38	97.62	89.95	61.25	45.79	41.48
6	12.52	10.69	5.27	-0.05	-9.25	-21.22	38.9	32.94	38.37	38.86	62.07	91.06	93.61	93.64	85.81	58.8	45.82	37.9
7	11.57	9.64	4.38	-0.8	-10.33	-22.06	40.73	34.84	39.77	39.03	64.85	89.19	98.51	97.21	87.65	61.77	47.83	39.93
8	11.44	9.48	4.31	-0.78	-10.43	-22.01	40.09	34.39	39.28	38.94	65.48	87.4	98.44	95.88	86.16	62.14	47.63	39.49
9	12.87	11.17	5.75	0.33	-8.82	-20.39	35.25	28.43	38.44	44.19	64.21	96.67	94.52	88.02	82.35	60.13	48	34.64
10	11.26	9.33	4.19	-0.92	-10.64	-22.18	39.67	33.71	39.21	40.05	65.44	87.47	100.23	95.81	85.58	62.35	48.42	39.32
11	12.74	10.91	5.47	0.23	-8.72	-20.54	39.41	33.62	38.51	38.1	64.29	93.36	91.98	92.35	88.65	61.24	43.33	38.5
12	12.5	11.01	5.9	0.58	-8.15	-18.67	32.79	25.18	34.31	45.58	71.24	104.04	97.13	90.3	86.65	68.33	37.28	35.09
13	12.83	11.3	6.11	0.61	-8.22	-19.11	31.31	24.44	34	41.47	67.21	110.23	94.21	90.1	84.42	62.91	39.24	31.46
14	12.78	11.25	6.06	0.54	-8.26	-19.25	31.05	24.12	33.94	40.91	66.05	112.09	92.77	90.33	83.19	61.37	40.4	30.62
15	12.94	11.38	6.11	0.59	-8.34	-19.4	30.63	23.8	33.71	39.68	64.62	108.63	93.32	89.69	82.75	59.98	39.62	30.46
16	12.98	11.44	6.19	0.68	-8.27	-19.19	30.97	24.38	33.68	40.35	66.43	106.83	95.12	88.87	84.63	62.29	37.72	31.35
17	12.98	11.44	6.19	0.68	-8.27	-19.19	30.97	24.38	33.68	40.35	66.43	106.83	95.12	88.87	84.63	62.29	37.72	31.35
18	12.94	11.39	6.14	0.61	-8.28	-19.34	30.55	23.74	33.53	39.81	64.83	109.08	93.05	89.61	82.72	60.18	39.54	30.36
19	12.72	11.23	6.1	0.67	-8.07	-18.79	31.89	24.7	33.98	43.34	69.22	108.67	95.02	90	85.43	65.39	38.38	32.86
20	12.77	11.27	6.11	0.68	-8.11	-18.86	31.62	24.6	33.8	42.64	68.71	108.01	95.17	89.59	85.41	64.92	37.88	32.52
21	12.77	11.27	6.11	0.68	-8.11	-18.86	31.62	24.6	33.8	42.64	68.71	108.01	95.17	89.59	85.41	64.92	37.88	32.52
22	12.85	11.3	6.14	0.61	-8.19	-19.4	29.17	21.91	31.64	38.08	61.37	108.62	88.64	86.36	78.08	55.69	39.18	27.85
23	12.67	11.02	5.74	0.34	-8.91	-20.09	28.99	20.52	27.56	32.61	56.59	96.17	84.57	78.7	63.4	42.46	32.31	27.19
24	12.94	11.34	5.99	0.53	-8.78	-20.23	27.14	18.8	29.29	33.28	53.34	96.05	84.2	82.25	72.69	48.19	37.46	25.93
25	12.84	11.22	5.89	0.43	-8.78	-20.16	27.01	18.99	30.11	33.93	53.26	97.81	84.97	82.63	74.14	49.41	38.73	25.95
26	12.88	11.27	5.96	0.51	-8.68	-20.06	26.79	18.79	28.86	33.2	53.31	97.01	84.06	80.95	71.25	47.4	36.9	25.53
27	12.57	10.92	5.64	0.22	-9.01	-20.17	29.38	20.89	28.77	33.41	56.51	97.66	85.77	80.08	65.79	44.23	34.01	27.54
28	12.75	11.12	5.81	0.39	-8.89	-20.21	27.87	19.54	28.45	33	54.77	96.3	84.02	80.12	67.99	45.3	34.92	26.3
29	12.87	11.24	5.92	0.45	-8.66	-20.02	26.98	19.27	30.76	34.66	53.86	99.68	85.9	83.6	76.05	51.12	39.72	26.08
30	12.89	11.29	5.99	0.48	-8.44	-19.67	29.86	22.68	33.17	38.25	61.56	107.26	91.24	88.64	80.57	57.05	40.27	29.23
31	13.02	11.41	6.12	0.62	-8.3	-19.61	28.81	21.64	31.91	37.1	59.9	105.48	89.5	87.12	78.95	55.33	39.5	28.13
32	13.04	11.49	6.14	0.55	-8.72	-19.79	31.51	24.8	34.79	39.08	63.05	100.88	95.91	90.95	80.93	56.62	40.1	32.07
33	13.06	11.45	6.05	0.56	-8.52	-19.82	29.98	22.69	33.12	37.15	60.46	102.58	92.1	89.3	79.64	55.13	39.74	29.91

Prov	Julmint	Augmint	Sepmint	Octmint	Novmint	Decmint	Janprec	Febprec	Marprec	Aprprec	Mayprec	Junprec	Julprec	Augprec	Sepprec	Octprec	Novprec	Decprec
34	13.12	11.54	6.19	0.67	-8.45	-19.51	31.35	25.18	34.24	39.16	65.05	102.08	96.24	86.94	84.88	61.02	37.46	31.49
35	12.27	10.75	5.55	0.33	-8.45	-18.8	34.34	26.6	35.54	47.53	73.2	100.19	99.59	92.2	88.18	71.08	37.67	37.63
36	12.32	10.85	5.61	0.49	-8.22	-18.27	35.18	26.61	35.44	51.5	75.4	95.75	99.07	94.57	86.47	73.1	40.23	40.23
37	11.81	10.17	5.1	0.16	-8.62	-19.18	37.64	29.94	36.92	47.51	74.98	96.37	99.03	95.81	91.15	72.98	42.98	41.41
38	12.63	11.06	5.79	0.48	-8.39	-19.08	32.42	26.01	33.95	40.98	69.17	101.48	98.43	87.81	89.06	67.06	33.87	33.85
39	11.61	10.05	5.1	0.18	-8.48	-18.86	37.94	28.94	37.07	50.38	76.12	96.57	99.39	95.95	90.68	74.45	44.57	42.46
40	12.42	10.89	5.69	0.42	-8.38	-18.87	33.35	26.06	34.76	45.1	71.59	101.48	98.85	90.4	88.18	69.34	36.22	35.87
41	11.1	9.48	4.67	-0.12	-8.77	-19.28	39.94	30.77	38.62	49.18	76.84	98.16	100.61	96.83	94.43	75.72	48.06	43.84
42	12.67	11.12	5.85	0.48	-8.42	-19.14	32.14	25.67	34.19	40.95	68.73	103.63	98.26	87.93	88.49	66.25	34.73	33.19
43	12.47	10.94	5.72	0.43	-8.39	-18.93	33.04	25.97	34.64	43.96	70.88	102.34	98.75	89.74	88.4	68.6	35.75	35.13
44	12.33	10.86	5.81	0.55	-8.11	-18.54	33.64	25.39	34.87	47.93	72.64	103.43	97.34	91.48	86.52	69.81	38.59	36.59
45	12.42	10.97	5.96	0.67	-7.93	-18.39	33.46	25.12	34.61	47.6	72.17	105.03	96	91.13	85.94	68.94	39.12	36.05
46	12.11	10.64	5.6	0.45	-8.25	-18.55	34.24	25.6	34.96	51.02	74.6	97.99	98.61	93.2	85.79	72.15	39.02	38.86
47	11.13	9.73	4.98	0.02	-8.17	-18.14	43.66	30.53	42.19	55.86	77.48	102.69	99.81	97.26	94.55	77.52	51.31	47.54
48	12.76	11.23	5.99	0.58	-8.32	-19.07	31.73	25.14	33.91	41.23	68.38	104.67	97.21	88.2	87.18	65.38	35.62	32.72
49	12.74	11.22	6.01	0.63	-8.2	-18.91	31.7	24.92	33.59	42.09	68.97	104.15	96.84	88.39	86.81	65.98	35.56	33.08
50	11.85	10.34	5.25	0.23	-8.46	-18.61	37.02	27.96	36.95	52.28	76.53	96.66	100.05	96.12	88.69	74.67	42.94	42.01
51	12.72	10.98	5.54	0.15	-9.04	-20.81	36.61	30.17	38.26	41.9	62.78	94.04	94.29	90.65	83.47	59.06	46.9	35.87
52	12.54	10.81	5.39	-0.04	-9.37	-21.2	35.92	29.56	37.44	41.53	61.19	92.52	95.75	91.85	82.49	57.79	46.39	35.42
53	13.02	11.42	6.03	0.5	-8.73	-20	32.62	26.09	36.05	41.38	63.77	99.08	96.02	88.23	82.17	58.87	42.47	32.61
54	12.66	10.91	5.48	0.07	-9.15	-20.95	36.69	30.31	38.13	41.57	62.31	93.43	94.64	91.3	83.45	58.7	46.75	35.97
55	13.08	11.48	6.1	0.57	-8.62	-19.82	32.17	25.8	35.45	40.47	64.26	100.23	96.12	87.63	83.26	59.66	40.64	32.18
56	12.33	10.58	5.19	-0.25	-9.65	-21.55	36.05	29.81	37.11	41.03	60.51	91.19	96.95	93.02	82.77	57.66	46.3	35.65
57	13.06	11.49	6.12	0.54	-8.73	-19.86	32.01	25.47	35.43	40.21	63.75	100.55	96.44	89.59	82.09	58.22	40.79	32.3
58	12.84	11.07	5.64	0.32	-8.72	-20.41	37.1	30.9	38.11	40.68	64.19	94.88	93.14	89.7	85.74	60.75	44.89	36.33
59	12.2	10.38	5.16	0.17	-8.71	-20.03	39.17	33.34	37.49	40.02	70.01	94.58	95.02	95.01	92.24	67.52	41.2	40.38
60	12.71	10.97	5.6	0.38	-8.54	-19.87	36.34	30.57	36.33	38.67	66.7	96.21	94.8	89.8	89.69	64.21	38.66	36.48
61	12.71	10.83	5.4	0.24	-8.63	-20.59	41.27	35.84	38.61	35.81	64.15	91.51	90.15	94.37	90.53	61.23	42.24	40.28
62	12.85	11.22	5.85	0.46	-8.56	-19.66	32.63	26.85	34.82	38.06	65.77	100.59	97.31	85.59	88.49	63.25	35.7	32.42
63	12.92	11.28	5.89	0.46	-8.61	-19.84	33.18	27.05	35.92	40.06	65.26	99.85	96.38	86.31	86.15	61.97	39.69	32.86
64	12.7	11.07	5.73	0.41	-8.53	-19.44	32.4	26.79	33.93	37.07	67.02	100.95	98.59	85.55	90.89	65.35	32.11	32.64
65	12.53	10.91	5.59	0.3	-8.61	-19.36	33.47	27.37	34.94	39.77	68.94	101.23	99.37	87.94	91.03	67.29	33.88	34.38
66	12.52	10.79	5.47	0.33	-8.54	-19.68	36.77	30.8	36.26	40.05	68.82	96.03	95.72	91.66	90.65	66.52	38.48	37.83
67	12.02	10.22	5.08	0.15	-8.74	-19.94	38.82	32.82	37.24	41.29	71.41	94.81	95.94	95.45	92.33	68.91	41.8	40.64
68	12.68	11.17	5.68	0.12	-9.71	-21.29	30.5	19.78	30.73	34.82	53.36	92.82	85.76	84.98	73.19	48.62	38.09	28.15

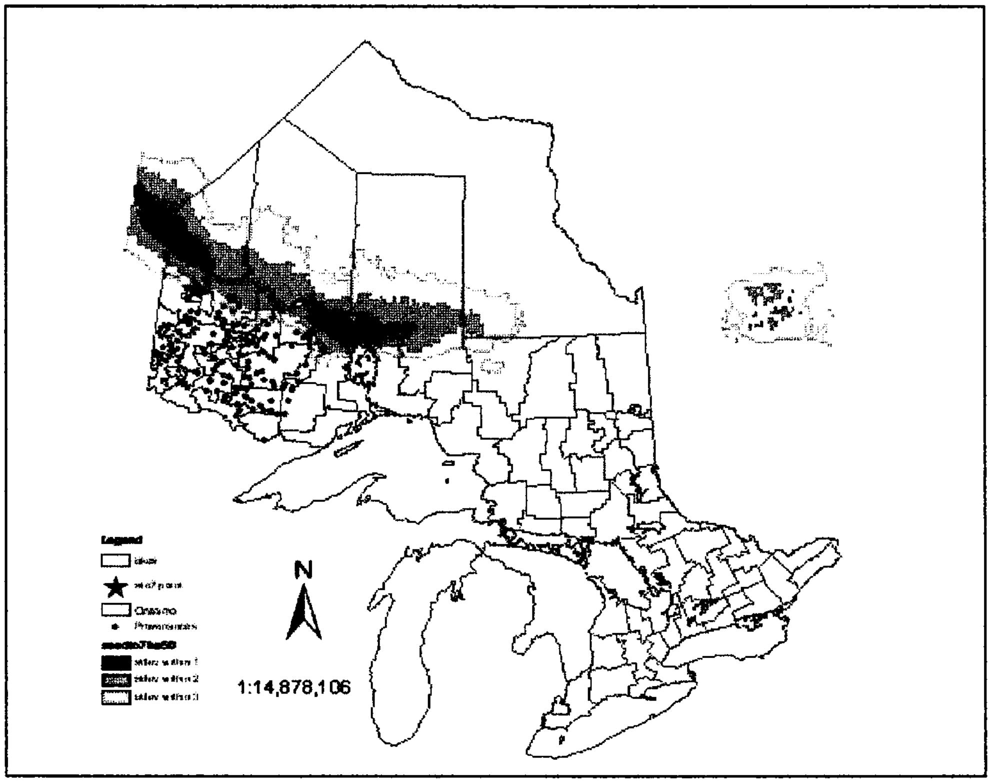
Prov	julmint	augmint	sepmint	octmint	novmint	decmint	janprec	febprec	marprec	aprprec	mayprec	junprec	julprec	augprec	sepprec	octprec	novprec	decprec
69	12.66	11.11	5.73	0.16	-9.27	-20.5	32.82	25.93	36.3	41.59	61.8	97.22	97.74	92.3	79.81	55.81	42.84	33.33
70	12.81	11.22	5.83	0.28	-9.09	-20.51	32.73	26.03	36	41.96	61.46	95.92	96.44	90.39	79.64	56.2	43.72	32.95
71	12.61	11.13	5.64	0	-9.91	-21.37	31.89	20.91	32.25	37.36	53.92	92.52	90.64	88.53	74.5	49.67	39.38	30.13
72	12.7	11.2	5.83	0.25	-9.28	-20.55	31.41	24.32	34.31	40.32	59.33	94.53	96.56	92.22	77.02	52.79	40.7	32.19
73	12.55	11.01	5.61	0.02	-9.56	-21	31.66	24.7	34.89	41.85	58.58	93.93	97.54	92.03	77.47	53.64	41.92	32.21
74	12.59	11.12	5.59	-0.05	-10.04	-21.67	30.39	20.06	31.53	38.59	52.28	91.07	90.32	88.04	73.16	48.76	38.32	29.02
75	12.72	11.24	5.73	0.1	-9.83	-21.38	31.38	20.03	31.2	36.15	52.9	91.67	88.39	86.76	73.59	48.87	38.75	29.2
76	12.68	11.23	5.92	0.34	-9.17	-20.22	31.58	23.84	33.73	37.94	59.62	94.98	95.4	93.25	76.3	51.26	39.3	32.49
77	12.61	11.12	5.6	-0.02	-9.97	-21.51	31.68	20.28	31.71	36.32	53.16	92.4	88.29	86.85	74.03	49.32	39.12	29.34
78	12.55	11.06	5.66	0.06	-9.59	-20.96	31.08	23.58	33.96	40.87	57.5	93.48	96.67	92.24	76.11	51.9	40.27	31.66
79	12.61	11.14	5.77	0.18	-9.43	-20.64	31.47	23.6	33.88	39.43	58.36	94.2	95.91	92.68	76.16	51.49	39.82	32.06
80	12.67	11.23	5.94	0.37	-9.1	-20.08	31.67	24.14	33.94	37.76	60.33	95.5	95.69	93.77	76.59	51.45	39.27	32.8
81	12.88	11.32	5.92	0.41	-9.09	-20.53	29.45	20.01	30.68	34.08	54.7	95.33	86.53	85.27	74.25	49.3	38.34	27.99
82	12.8	11.24	5.83	0.33	-9.22	-20.69	29.29	19.76	30.44	34	54.28	94.98	85.57	84.37	73.49	48.77	37.95	27.57
83	12.85	11.3	5.88	0.36	-9.25	-20.76	29.38	19.55	30.09	33.81	53.93	94	85.22	84.22	73.07	48.38	37.64	27.52
84	12.66	11.1	5.67	0.15	-9.42	-20.75	31.08	21.17	32.39	35.24	55.82	96.51	88.61	87.22	75.8	50.64	39.69	29.47
85	12.7	11.17	5.72	0.17	-9.54	-20.98	30.9	20.37	31.38	34.71	54.5	94.42	86.96	85.87	74.31	49.41	38.81	28.8
86	12.74	11.22	5.79	0.22	-9.45	-20.78	31.69	21.13	32.1	35.05	55.56	94.95	88.96	87.62	75.38	50.19	39.5	29.93
87	12.87	11.36	6.03	0.48	-8.81	-19.86	31.23	23.94	33.99	37.42	61.19	98.92	94.65	92.11	78.54	53.53	39.63	31.95
88	12.98	11.42	6.07	0.52	-8.69	-19.82	30.91	23.74	33.93	37.62	61.46	100.74	94.17	91.07	79.55	54.8	39.75	31.35
89	11.55	9.59	4.68	-0.03	-9.1	-20.63	39.77	34.74	37.67	39.11	71.98	93.29	95.45	96.84	93.36	68.77	44.08	41.19
90	10.81	8.79	4.18	-0.31	-9.59	-21.01	38.71	33.96	37.94	40.94	75.51	95.09	99.2	97.23	94.23	71.96	46.76	40.81
91	10.76	8.93	4.28	-0.31	-9.29	-20.3	38.36	32.13	37.5	44.35	77.21	97.58	100.94	97.09	95.51	74.65	47.92	41.7
92	11.24	9.15	4.2	-0.51	-9.95	-21.33	40.97	36.42	39.94	37.74	71.59	90.42	96.3	96.74	91.31	67.54	46.38	40.88
93	11.04	8.98	4.21	-0.39	-9.85	-21.11	38.82	34.49	38.41	38.43	73.27	90.6	97.17	95.13	90.54	68.73	46.33	39.55
94	11.24	9.13	4.08	-0.73	-10.44	-21.47	40.46	35.63	40.58	38.22	70.59	87.67	97.02	95.04	87.61	66.29	47.23	39.71
95	11.48	9.57	4.7	-0.01	-9.04	-20.42	39.05	33.67	37.26	40.65	73.07	94.31	96.57	96.64	93.45	70.06	44.22	41.08
96	10.66	8.63	4.06	-0.4	-9.71	-21.1	38.79	34.02	38.3	41.39	76.2	95.67	100.07	97.51	94.63	72.66	47.39	40.94
97	13.2	11.63	6.29	0.73	-8.38	-19.57	30.01	23.22	33.01	37.69	62	102.53	93.14	89.27	80.3	56.22	38.9	30.28
98	13.05	11.47	6.15	0.61	-8.41	-19.51	30.58	23.79	33.76	39.01	63.79	106.23	93.83	89.59	82.34	58.91	39.37	30.59
99	13.16	11.56	6.18	0.68	-8.44	-19.78	29.36	21.98	32.12	36.13	59.24	100.32	90.97	88.58	78.11	53.43	38.98	29.39
100	13.21	11.65	6.33	0.76	-8.31	-19.44	30.16	23.56	33.15	38.45	63.37	104.23	93.66	88.88	81.7	58.15	38.55	30.37
101	13.04	11.49	6.2	0.68	-8.35	-19.29	31.06	24.67	33.81	39.73	66.07	104.92	95.93	88.07	85.11	62.1	37.02	31.43
102	10.71	9.06	4.37	-0.33	-8.99	-19.6	40.83	31.72	39.35	47.97	77.3	98.94	101.54	96.92	96.65	76.38	50.39	44.32

APPENDIX V

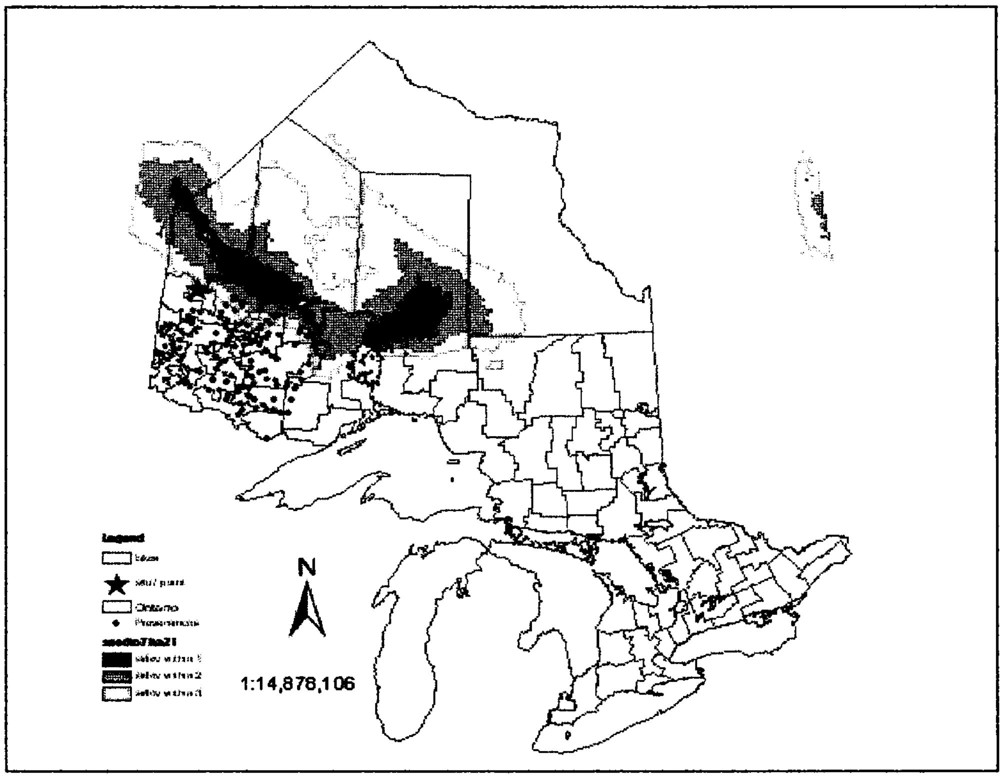
PRESENT AND FUTURE FOCAL POINT SEED ZONES BASED ON POINT (51.2°N, 94°W) THE MOST NORTH AREA OF NORTHWESTERN REGION ONTRIAO (102 PROVENANCES)



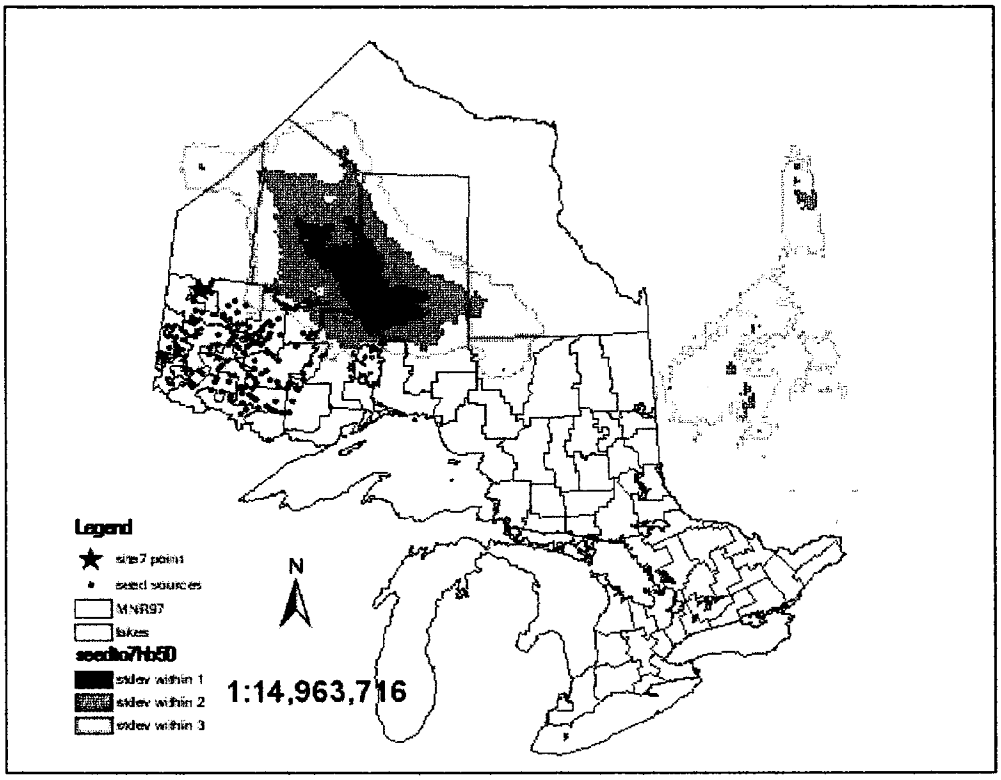
Focal point seed zones at coordinate 51.2°N, 94°W based on OCM2



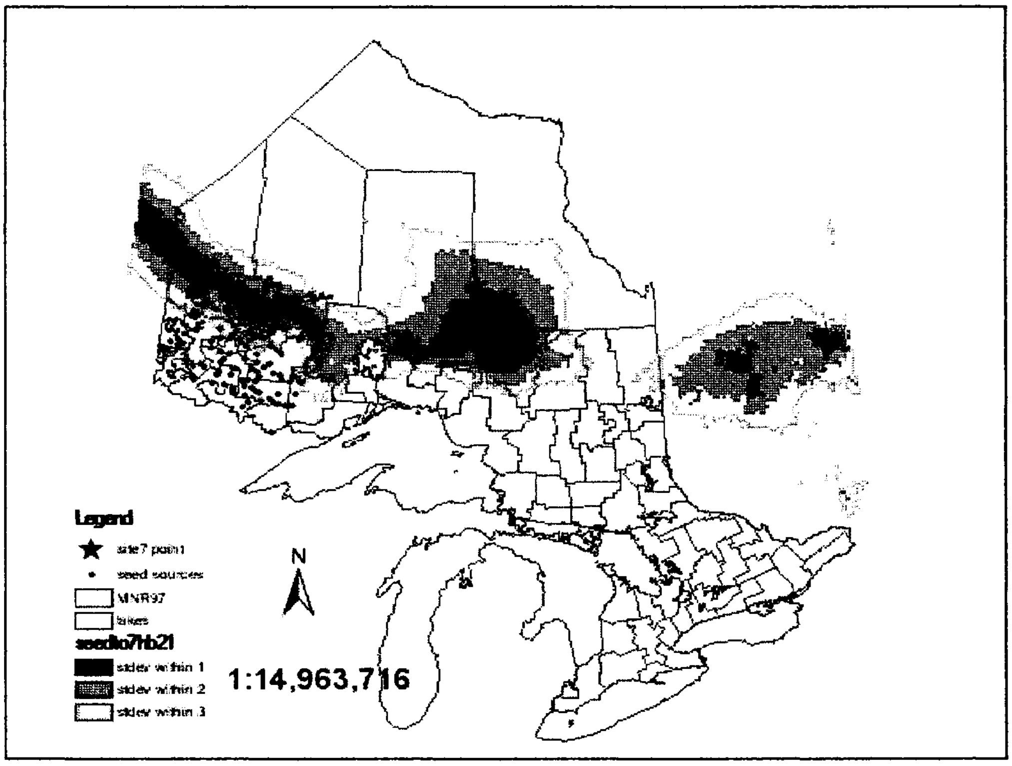
Best '*Seed To*' transfer zone in 2050 for seed from point 51.2°N, 94°W based on HADCM3A2



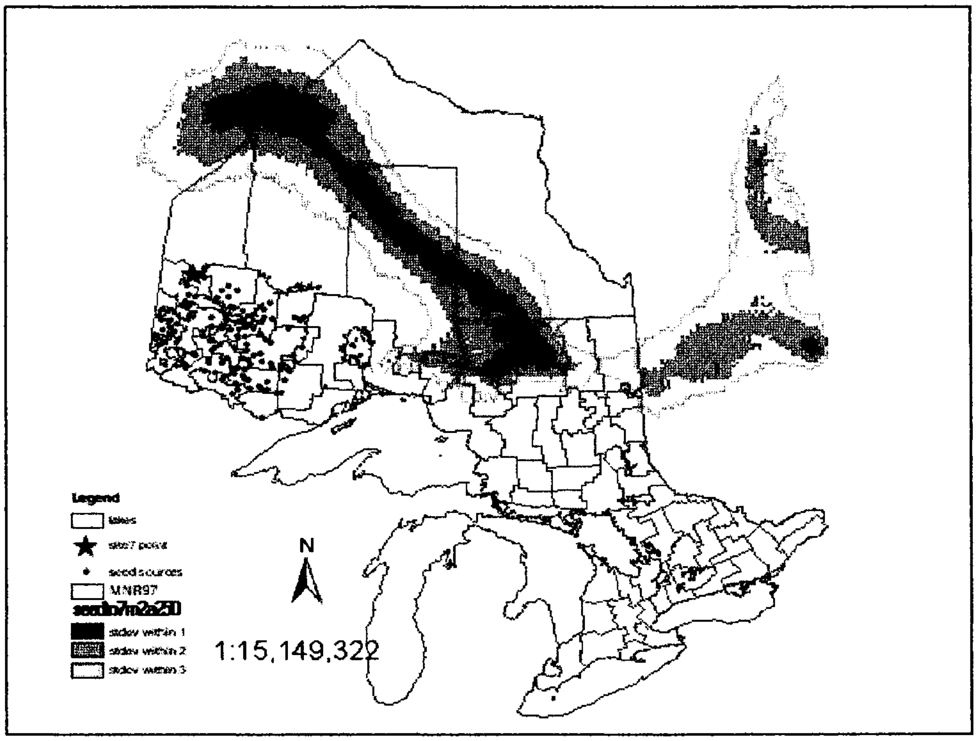
Best '*Seed To*' transfer zone in 2099 for seed from point
51.2°N, 94°W based on HADCM3A2



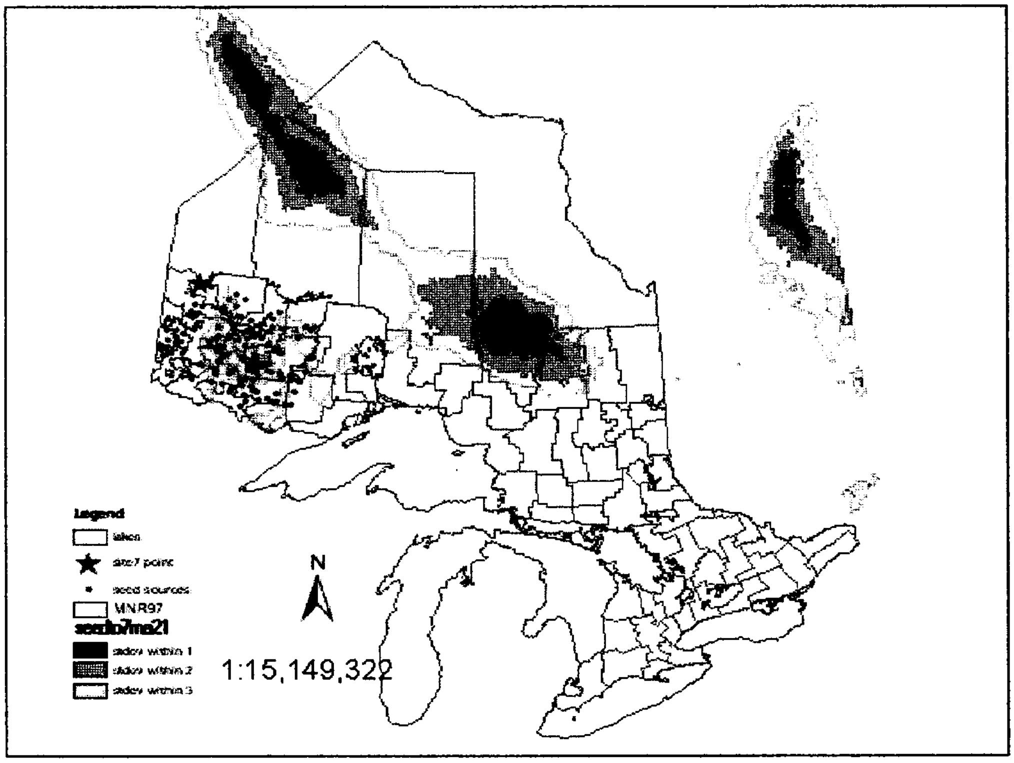
Best '*Seed To*' transfer zone in 2050 for seed from point
51.2°N, 94°W based on HADCM3B2



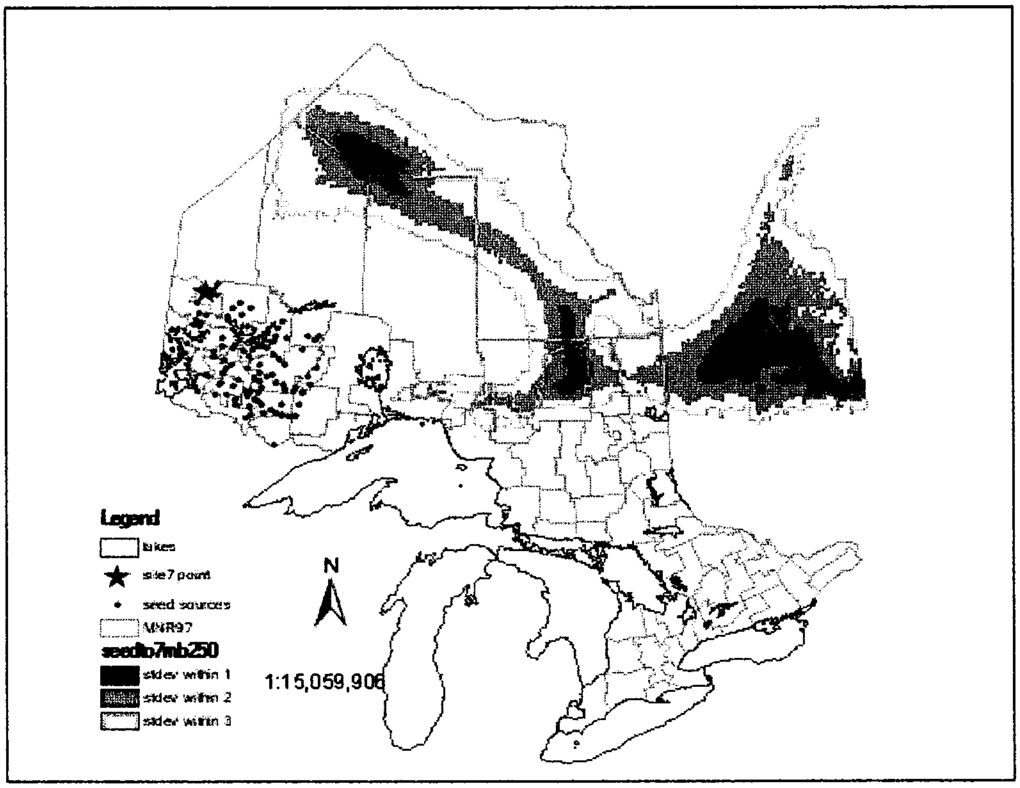
Best '*Seed To*' transfer zone in 2099 for seed from point 51.2°N, 94°W based on HADCM3B2



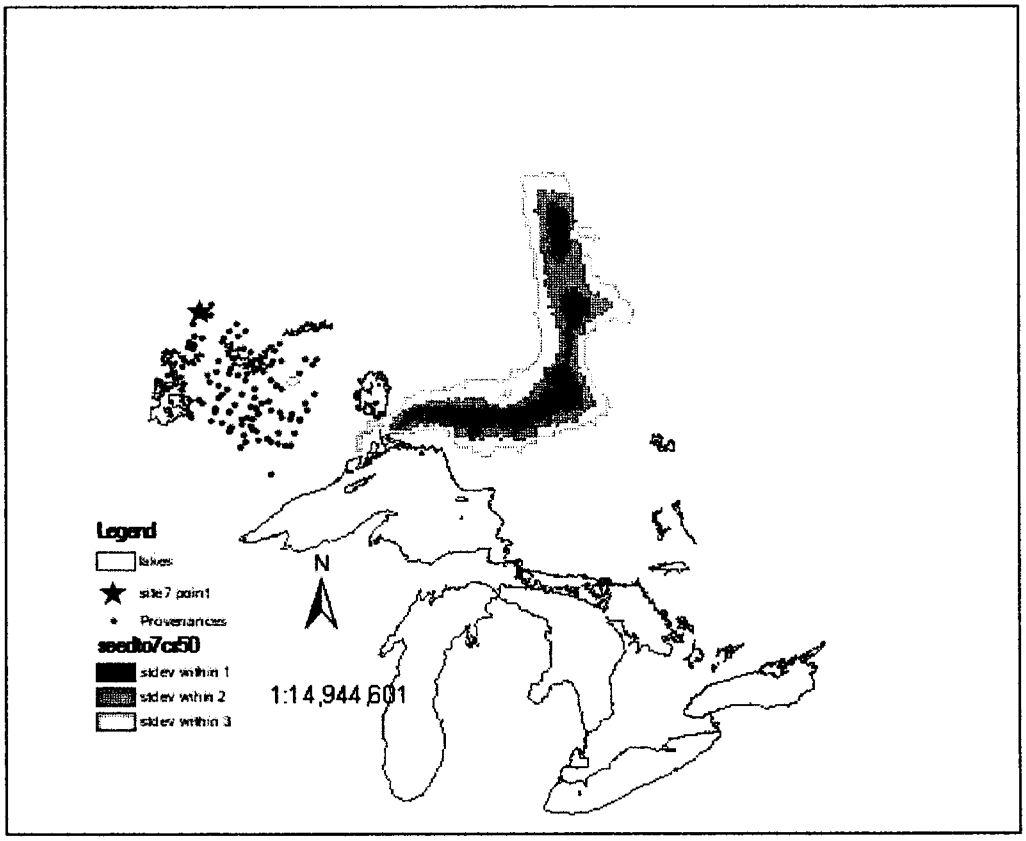
Best '*Seed To*' transfer zone in 2050 for seed from point 51.2°N, 94°W based on CGCM2A2



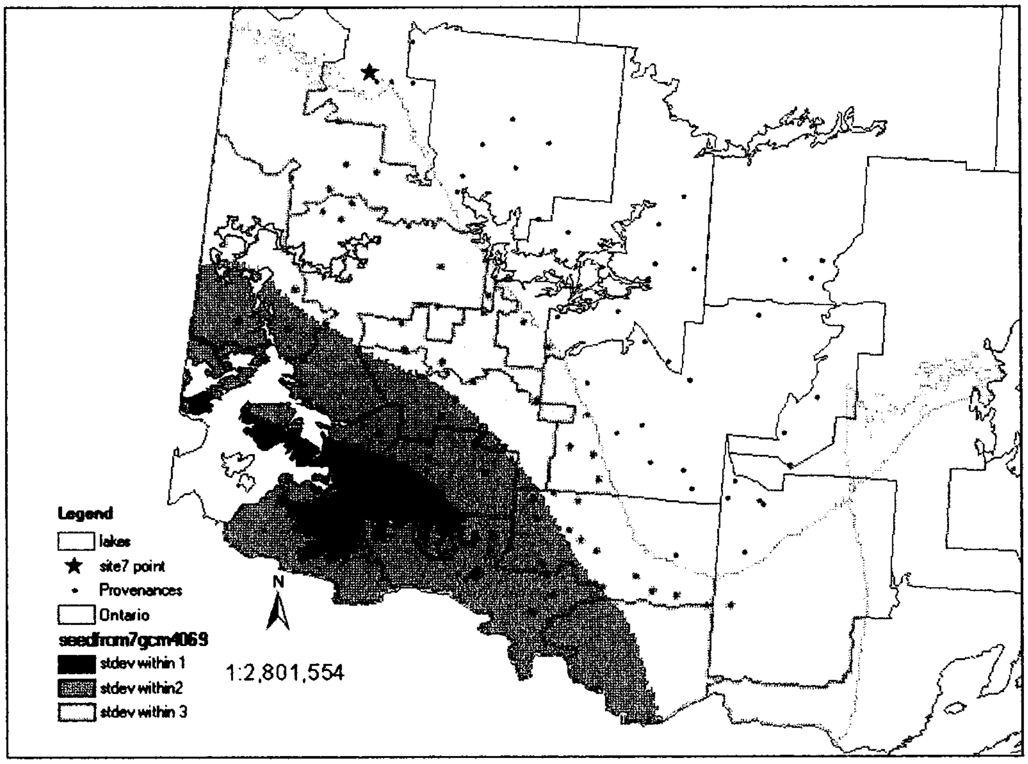
Best '*Seed To*' transfer zone in 2099 for seed from point 51.2°N, 94°W based on CGCM2A2



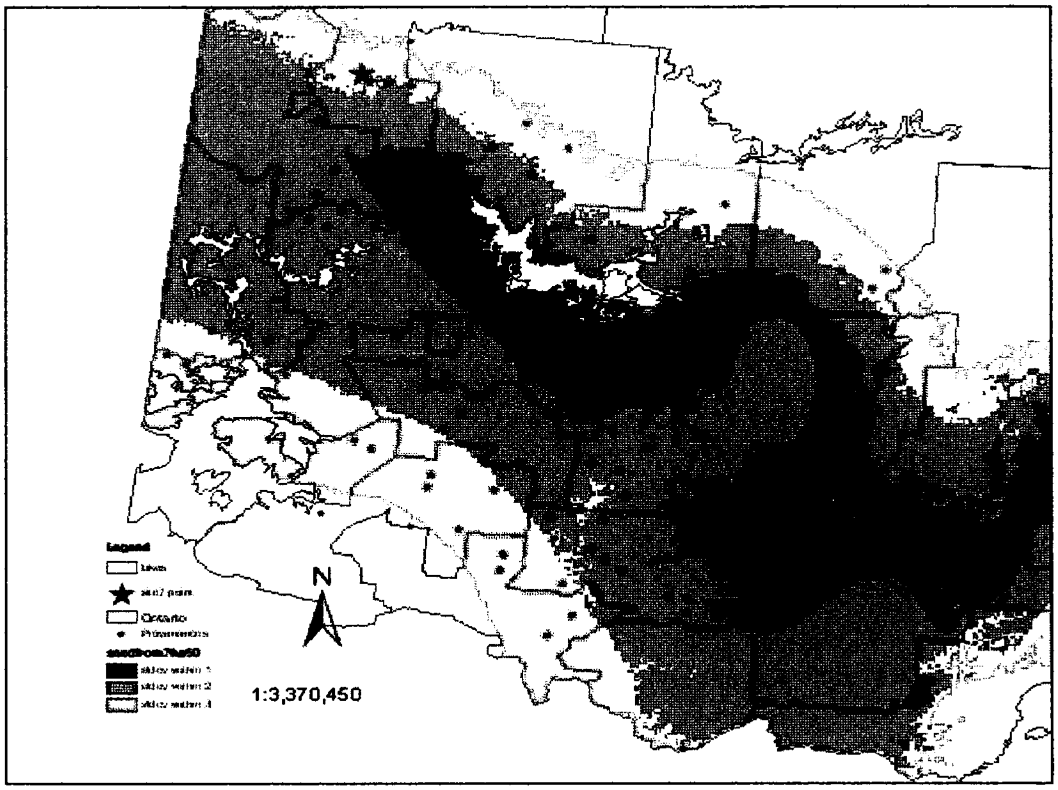
Best '*Seed To*' transfer zone in 2050 for seed from point 51.2°N, 94°W based on CGCM2B2



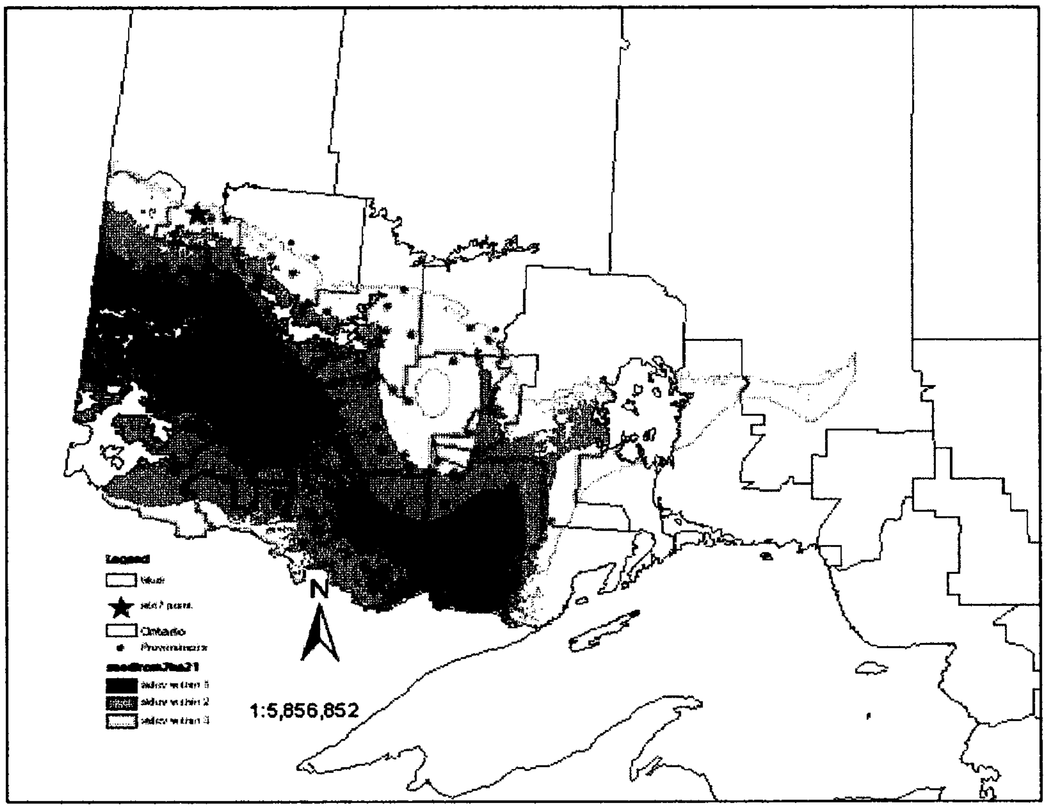
Best '*Seed To*' transfer zone in 2050 for seed from point 51.2°N, 94°W based on CSIROB2



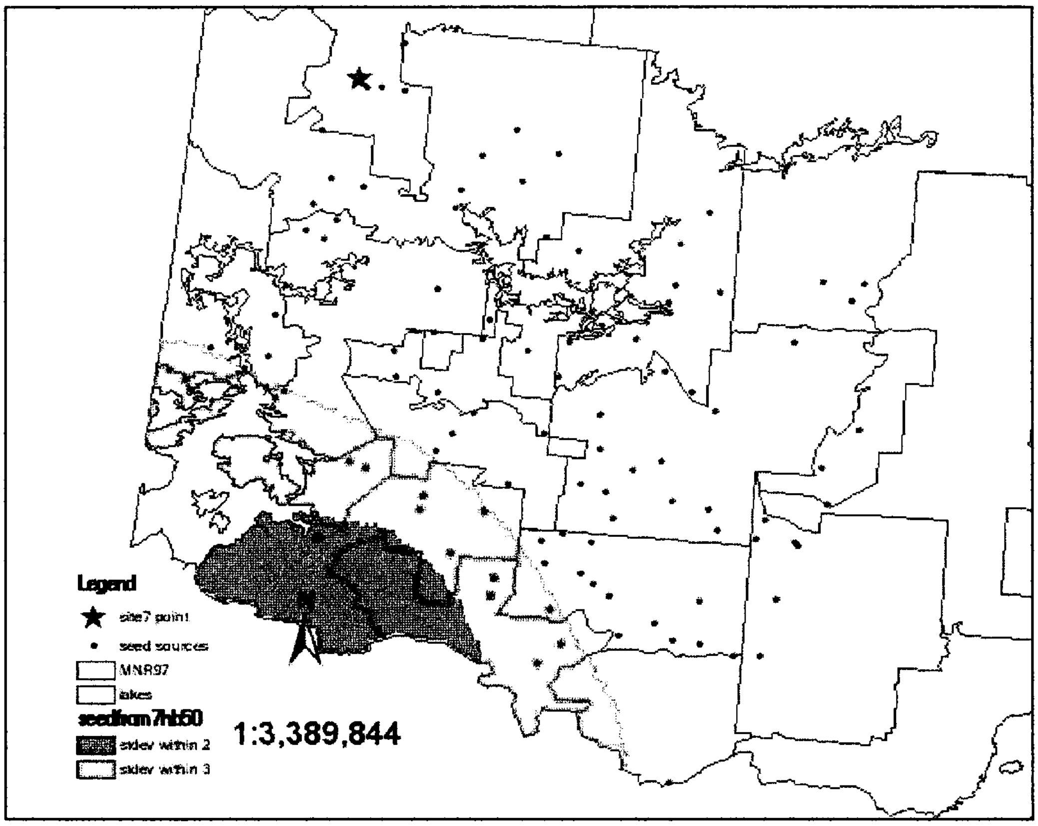
Best '*Seed From*' transfer zone in 2069 to best match climate of point 50.1N, 87.9W based on CGCM1



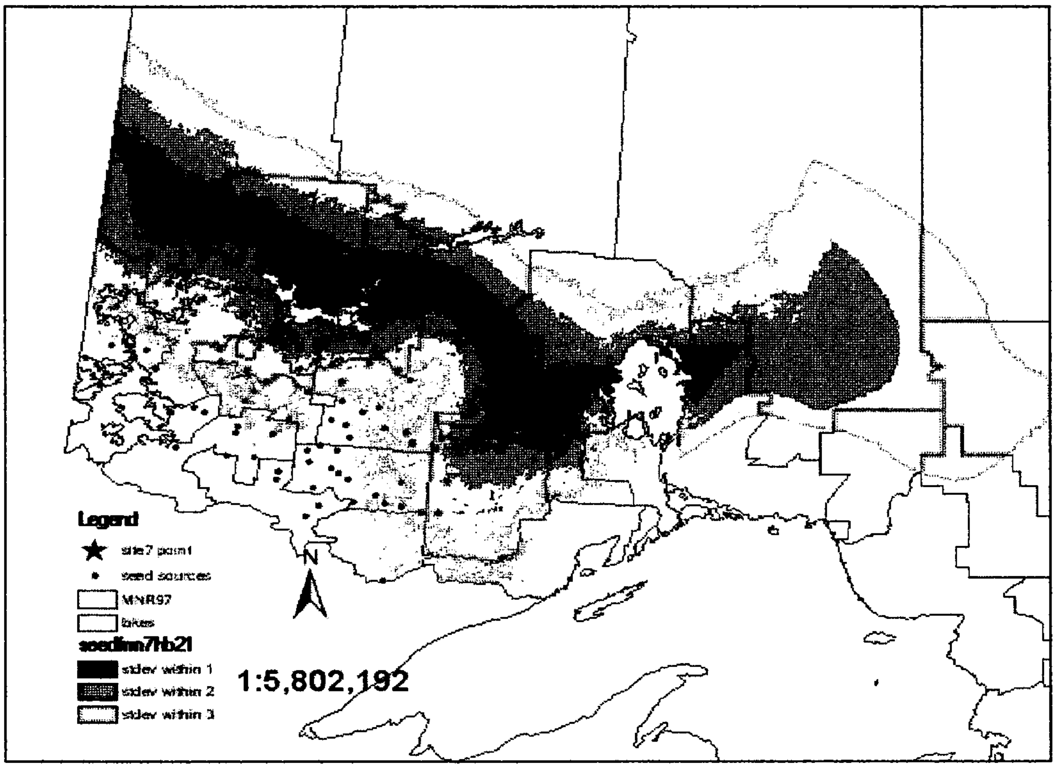
Best '*Seed From*' transfer zone in 2050 to best match climate of point 51.2°N, 94°W based on HADCM3A2



Best '*Seed From*' transfer zone in 2099 to best match climate of point 51.2°N, 94°W based on HADCM3A2



Best '*Seed From*' transfer zone in 2050 to best match climate of point 51.2°N, 94°W based on HADCM3B2



Best '*Seed From*' transfer zone in 2099 to best match climate of point 51.2°N, 94°W based on HADCM3B2

APPENDIX VI

PROVENANCE MEAN VALUES FOR GROWTH, PHENOLOGICAL AND FREEZING VARIABLES IN NORTH CENTRE ONTRIAO (64) CASE

Prov	GH88	GH89	GHIN	GHCS	GHDR	GHNF	GHR	LU88	LU89	LU90	LUIN	LUCS	LUDR	LUNF	LUR
1	64.80	83.59	27.19	79.87	52.70	29.50	50.77	73.8	270.03	685.93	13.40	87.14	73.74	25.53	52.54
2	110.20	99.20	26.98	84.41	57.43	31.10	45.00	99.47	333.20	730.13	13.29	89.96	76.67	27.27	50.77
3	93.50	104.30	26.76	81.17	54.42	30.00	56.79	73.63	286.14	657.31	13.60	86.77	73.17	27.33	55.55
4	86.60	91.90	26.96	81.76	54.81	29.60	45.00	103.60	317.10	691.50	13.25	85.94	72.69	26.80	35.06
5	91.50	114.90	26.55	84.00	57.45	29.80	56.79	118.50	367.93	838.67	13.14	93.49	80.35	25.93	36.87
6	66.90	92.40	26.75	78.38	51.61	29.10	63.44	85.27	335.37	810.70	13.12	89.42	76.30	26.70	33.21
7	82.60	92.70	30.43	85.43	54.99	30.67	56.79	108.13	294.47	682.80	13.30	81.82	68.52	27.40	35.06
8	80.40	84.20	27.23	83.14	55.91	30.30	39.23	101.57	290.66	687.38	13.16	83.80	70.64	27.40	53.73
9	112.10	117.80	26.78	89.28	62.47	30.00	45.00	102.90	326.90	742.13	13.32	90.09	76.77	27.00	36.87
10	90.10	83.00	27.11	70.79	43.69	29.50	45.00	89.24	306.14	756.66	13.16	83.86	70.70	28.77	33.21
11	74.60	107.00	26.57	82.42	55.83	30.67	50.77	76.17	251.60	654.93	13.41	84.35	70.93	28.00	60.67
12	70.67	119.20	26.47	83.55	57.06	29.30	63.44	102.33	337.77	756.97	13.17	82.99	69.83	25.87	33.21
13	93.10	123.40	26.35	78.32	51.97	28.50	33.21	125.83	389.10	804.87	13.51	84.24	70.73	27.13	33.83
14	84.30	126.11	26.52	86.94	60.41	29.00	56.79	70.97	283.20	716.62	13.31	89.99	76.68	27.20	36.87
15	139.60	120.00	26.54	85.60	59.05	29.80	26.57	119.67	382.80	848.87	13.21	88.63	75.42	28.00	28.66
16	110.78	119.00	26.66	80.44	53.81	30.11	61.87	124.77	414.20	861.07	12.98	85.85	72.87	27.27	26.57
17	99.30	89.00	26.69	79.29	52.61	29.80	63.44	98.70	305.80	730.83	13.27	87.94	74.68	27.07	50.77
18	105.80	120.40	26.39	80.79	54.40	29.70	50.77	92.07	363.90	830.28	13.04	88.90	75.87	28.30	37.47
19	91.90	91.80	26.97	82.46	55.51	29.70	50.77	70.17	256.07	658.60	13.37	82.92	69.55	26.67	54.33
20	69.78	71.30	27.30	74.20	46.89	31.00	56.79	61.07	223.79	560.39	13.46	84.64	71.19	27.25	67.21
21	101.60	107.60	26.67	77.78	51.12	30.40	63.44	91.00	308.38	711.79	13.45	80.98	67.53	28.07	41.55
22	61.60	93.70	26.75	81.77	55.01	29.50	71.57	58.30	217.37	609.90	13.31	78.48	65.17	26.57	50.77
23	120.40	96.70	26.78	81.32	54.55	29.60	39.23	107.87	292.37	724.31	13.60	89.51	75.91	28.63	42.71
24	78.00	93.70	27.06	81.14	54.10	30.80	50.77	67.10	215.63	589.35	13.59	83.33	69.74	27.83	50.77
25	131.78	123.20	27.31	83.98	56.67	30.00	39.23	126.80	397.07	823.63	12.87	91.04	78.17	26.13	26.57
26	96.40	105.90	26.67	76.52	49.86	29.40	71.57	108.43	366.86	799.72	13.06	91.12	78.06	28.17	33.21
27	134.33	108.90	26.77	85.91	59.14	30.10	56.79	84.20	279.41	682.73	13.18	84.23	71.05	27.47	43.85
28	80.90	110.30	26.61	80.19	53.59	29.80	90.00	109.50	325.55	762.86	13.32	82.88	69.55	26.40	52.54
29	107.22	90.00	27.03	83.10	56.06	30.89	90.00	115.43	300.47	733.93	13.43	92.35	78.92	26.60	50.77
30	85.00	107.80	26.44	82.47	56.03	29.10	63.44	75.41	253.54	642.14	13.25	83.74	70.49	27.52	47.87
31	99.40	95.00	26.82	76.24	49.39	32.00	50.77	97.50	308.40	727.67	13.14	89.64	76.50	28.43	42.71
32	84.40	138.90	26.33	82.48	56.14	29.70	45.00	114.07	416.20	882.80	13.33	92.66	79.32	28.33	14.18

Prov	GH88	GH89	GHIN	GHCS	GHDR	GHNF	GHR	LU88	LU89	LU90	LUIN	LUCS	LUDR	LUNF	LUR
33	131.90	141.70	26.22	71.78	45.55	32.20	18.44	124.87	462.30	979.50	12.86	91.97	79.11	30.77	21.13
34	107.00	119.59	26.76	78.59	51.81	30.20	50.77	140.17	426.00	920.72	13.18	90.52	77.34	29.83	39.23
35	106.40	127.44	26.30	88.42	62.13	30.10	56.79	109.80	309.37	780.53	13.65	88.61	74.96	27.47	46.72
36	105.60	74.69	26.94	74.73	47.80	30.20	45.00	75.72	265.61	693.32	13.71	91.65	77.93	28.14	53.13
37	110.60	97.50	26.64	81.41	54.77	31.00	56.79	118.63	355.13	806.93	13.21	90.43	77.22	28.53	35.06
38	133.00	115.10	26.83	85.16	58.32	31.70	63.44	118.43	378.13	858.67	13.05	85.42	72.37	27.27	39.23
39	92.80	98.50	26.77	84.77	58.00	30.80	56.79	107.17	324.48	803.83	13.09	93.93	80.84	27.62	46.72
40	61.80	76.90	26.77	74.94	48.17	29.60	71.57	52.80	224.10	605.04	13.58	86.86	73.28	27.40	48.45
41	102.20	115.90	26.58	82.27	55.70	29.60	50.77	113.77	416.80	910.80	13.18	89.18	76.00	28.10	33.21
42	81.30	101.40	26.55	86.33	59.78	30.00	56.79	98.00	367.97	837.86	12.95	87.90	74.95	28.07	33.21
43	80.00	98.90	26.97	76.55	49.57	30.90	50.77	96.13	328.20	777.57	13.17	87.88	74.71	28.47	39.23
44	93.13	92.13	26.59	80.01	53.44	29.13	45.00	94.27	302.67	726.21	13.39	87.15	73.76	27.00	35.06
45	75.10	83.60	27.48	78.89	51.42	30.00	63.44	107.60	338.60	781.53	12.96	86.19	73.23	27.03	52.54
46	131.22	103.44	26.96	83.64	56.67	31.78	61.87	127.13	377.86	880.87	13.10	92.59	79.48	28.27	36.87
47	64.20	96.30	26.89	79.08	52.17	31.00	56.79	64.50	232.90	634.03	13.42	85.26	71.84	28.23	48.45
48	105.20	120.70	26.47	72.20	45.75	30.30	26.57	113.60	428.07	898.76	13.01	83.50	73.49	29.70	26.57
49	95.50	82.32	27.48	77.09	49.61	33.20	63.44	103.37	347.47	875.60	13.12	92.40	79.28	27.80	30.66
50	111.60	101.00	26.92	76.16	49.24	31.50	50.77	130.57	385.27	836.47	13.42	87.91	74.49	28.33	40.98
51	68.80	80.30	27.05	80.88	53.82	31.40	50.77	95.57	295.70	744.50	13.42	92.78	79.35	27.73	39.23
52	65.40	96.30	26.94	87.84	60.90	30.40	50.77	152.73	406.41	845.04	13.22	86.81	73.60	28.80	29.33
53	88.40	102.30	26.75	84.15	57.41	30.80	56.79	118.30	437.70	969.27	12.95	94.40	81.45	30.10	18.44
54	75.60	87.60	26.77	84.58	57.83	29.80	71.57	112.17	348.80	794.90	12.23	91.24	78.00	27.07	48.45
55	59.80	76.33	27.00	81.87	54.83	29.56	63.44	89.00	274.47	720.10	13.31	82.23	68.93	28.00	46.72
56	109.90	87.80	27.06	83.69	56.64	31.00	45.00	104.03	313.67	773.97	13.21	90.56	77.34	27.40	42.71
57	119.00	97.00	26.88	84.10	57.21	31.10	39.23	109.60	329.59	796.14	13.33	88.27	74.94	26.17	40.98
58	120.20	106.09	26.73	78.69	51.96	31.00	39.23	118.73	390.25	833.20	13.06	90.82	77.75	27.67	30.66
59	68.20	83.10	27.16	82.20	55.04	31.70	45.00	95.72	312.21	758.83	13.11	88.62	75.51	27.34	40.98
60	130.30	85.99	27.12	75.51	48.37	31.70	39.23	155.70	444.31	904.83	13.09	90.50	77.41	27.41	37.47
61	119.00	100.22	26.84	77.74	50.90	31.44	33.21	110.10	363.93	766.54	13.14	83.48	70.34	28.70	33.83
62	87.20	94.30	27.37	81.13	53.77	30.30	56.79	82.60	284.17	676.86	13.69	87.39	73.71	26.90	52.54
63	108.10	81.88	27.26	79.90	52.65	32.67	39.23	95.33	283.90	660.93	13.28	87.99	74.70	28.25	49.60
64	83.90	81.77	27.23	79.88	52.66	32.25	56.79	108.83	384.00	874.27	12.92	88.88	75.96	27.37	39.23

Prov	R88	R89	R90	RIN	RCS	RDR	RNF	RSU	D1T1	D1T2	D1T3	D2T1	D3T1	D4T1	D5T2	D7T2	D7T3
1	73.35	195.12	355.08	21.84	72.98	51.14	29.96	68.58	35.91	41.46	82.92	97.76	98.81	95.27	58.63	44.46	16.06
2	59.26	141.48	256.00	23.71	70.12	46.42	32.05	61.12	35.96	41.50	67.92	85.37	95.45	101.13	60.79	44.46	74.74
3	61.96	186.65	327.87	23.47	78.27	54.80	31.00	63.44	38.23	59.36	86.47	95.63	97.23	99.33	95.90	58.63	35.90
4	48.57	155.29	268.20	23.34	68.87	45.53	31.85	56.79	49.06	58.63	.	86.57	93.26	97.58	0.00	50.78	37.08
5	69.30	194.74	366.96	23.68	75.91	52.23	31.24	61.12	30.92	36.52	67.67	98.46	100.53	.	0.00	42.48	81.35
6	63.28	205.39	369.72	22.68	77.74	55.07	29.87	50.77	33.22	31.30	50.57	91.96	99.16	99.67	87.46	39.33	58.63
7	104.31	252.29	457.96	22.89	81.48	58.59	31.56	65.91	29.32	48.84	72.43	91.96	98.63	101.21	50.78	50.78	74.16
8	64.14	164.54	311.54	22.84	69.82	46.98	30.38	43.09	32.81	53.87	72.52	93.44	100.53	101.55	69.37	49.92	42.48
9	57.22	132.67	272.57	24.51	75.36	50.85	35.83	33.21	29.32	51.62	78.66	96.70	99.50	101.21	73.58	38.22	37.08
10	60.35	147.39	288.95	25.39	76.01	50.62	35.52	52.73	41.47	64.09	88.47	98.81	101.55	100.36	91.77	73.58	80.29
11	72.86	181.50	335.95	24.59	76.74	52.15	33.46	58.91	44.47	54.06	69.99	98.11	93.44	100.70	0.00	52.44	63.56
12	64.22	179.96	322.56	21.59	78.36	56.77	31.93	71.57	62.89	71.81	79.75	94.18	83.54	96.52	92.71	83.44	63.56
13	72.24	170.21	324.05	23.44	76.57	53.13	33.10	56.79	44.47	70.60	89.40	97.76	100.87	100.87	0.00	75.88	75.88
14	49.56	138.06	264.11	24.04	68.91	44.88	31.62	50.77	35.91	46.39	78.90	92.33	101.55	100.70	58.63	34.69	79.21
15	72.53	198.53	337.00	24.63	74.74	50.11	36.55	48.83	53.26	65.55	84.97	95.99	101.55	99.16	82.92	44.46	18.54
16	78.58	186.54	330.79	19.37	78.57	59.20	32.78	63.44	32.12	54.06	88.92	97.41	96.88	94.18	82.92	71.21	57.89
17	66.29	183.55	340.40	22.36	81.30	58.94	33.65	56.79	40.42	49.06	82.40	100.87	101.55	100.53	61.49	0.00	62.19
18	76.44	183.44	351.65	21.95	77.15	55.20	32.05	50.77	54.85	72.41	90.36	98.11	97.41	96.88	35.90	26.22	82.40
19	50.50	148.60	296.53	21.47	74.67	52.93	32.26	54.74	52.45	55.62	74.74	88.53	98.11	99.67	78.66	49.92	81.35
20	61.73	164.33	303.47	24.71	77.38	52.67	30.11	45.00	54.06	60.79	79.75	101.21	85.17	100.70	59.36	54.85	35.90
21	95.44	186.00	318.13	23.29	76.34	53.04	33.00	46.91	19.63	33.83	87.93	99.50	100.70	101.38	48.17	38.22	0.00
22	46.12	114.06	216.13	23.74	70.51	46.77	31.61	48.83	49.72	59.42	84.03	97.32	94.54	97.58	0.00	79.21	89.88
23	55.36	121.39	239.08	22.08	71.99	49.91	32.00	43.09	60.09	66.21	86.97	98.11	95.45	94.72	42.48	46.35	75.88
24	53.25	124.75	228.19	21.41	69.73	48.33	30.81	46.91	45.42	54.85	52.44	97.76	97.76	99.33	59.36	59.36	32.11
25	77.96	166.15	303.40	24.89	76.78	51.89	31.04	61.12	53.26	50.78	64.89	100.87	.	79.32	0.00	64.89	81.88
26	57.60	134.11	248.22	23.63	70.85	47.22	32.73	35.26	50.79	57.89	55.62	92.71	72.05	.	67.49	43.48	47.27
27	62.67	112.75	212.63	24.30	69.74	45.45	36.08	33.21	47.28	49.92	71.21	97.71	99.85	95.75	51.62	58.63	60.08
28	53.19	120.63	221.32	23.58	67.64	44.05	34.00	56.79	54.85	59.36	85.47	100.87	84.15	101.04	22.71	20.73	30.75
29	66.00	120.67		23.90	72.33	48.43	34.06	41.17	46.36	54.06	82.40	98.13	98.39	99.85	55.62	33.43	22.71
30	61.00	156.57	291.45	22.84	72.30	49.46	32.58	56.79	41.47	68.12	83.44	94.90	100.87	100.87	90.83	54.85	74.16
31	65.29	150.43	274.36	24.20	77.14	52.94	37.94	48.83	40.33	54.40	41.42	101.55	100.19	93.99	49.06	33.43	80.82
32	49.38	123.50	206.88	25.24	72.74	47.50	35.33	31.09	39.07	45.83	89.54	98.11	100.02	100.02	45.42	71.21	45.42

Prov	R88	R89	R90	RIN	RCS	RDR	RNF	RSU	D1T1	D1T2	D1T3	D2T1	D3T1	D4T1	D5T2	D7T2	D7T3
33	107.78	279.78	478.78	25.14	83.25	58.11	32.78	71.57	33.43	49.92	81.35	101.55	101.55	101.55	0.00	62.19	60.79
34	59.39	149.00	272.62	22.07	72.70	50.63	37.20	41.17	47.28	50.78	84.46	100.19	94.90	97.76	9.27	37.08	39.33
35	66.13	162.83	304.26	22.85	76.60	53.75	32.57	61.12	33.43	48.17	79.21	90.83	.	101.37	33.43	42.48	.
36	86.00	168.78	298.78	25.52	69.14	43.62	33.09	33.21	52.45	44.46	83.95	98.11	97.23	101.04	43.48	60.08	0.00
37	62.20	158.43	262.86	21.11	73.69	52.58	36.27	45.00	47.28	44.46	68.12	.	101.55	98.11	30.75	34.69	29.32
38	72.79	156.07	293.07	24.44	74.09	49.64	33.65	43.09	34.69	49.06	86.47	101.55	100.19	97.58	0.00	30.75	40.41
39	52.63	140.00	254.86	27.87	66.29	38.42	38.13	31.09	43.49	49.06	75.88	98.81	67.87	92.89	33.43	32.11	34.69
40	44.33	115.62	232.23	22.38	73.05	50.67	35.88	50.77	41.47	41.46	81.35	101.55	101.38	101.38	58.63	26.22	9.27
41	67.26	185.58	352.37	24.87	81.19	56.32	32.00	52.73	61.50	64.89	79.21	100.87	101.38	92.33	73.00	0.00	0.00
42	42.88	95.00	190.13	23.74	74.58	50.84	36.50	46.91	42.49	57.89	.	81.67	99.50	.	0.00	16.06	13.11
43	53.14	140.52	244.57	22.38	72.07	49.70	35.17	56.79	35.28	62.57	83.46	95.27	98.46	100.53	0.00	44.46	29.32
44	74.11	163.00	293.56	23.02	72.00	48.98	33.95	52.73	45.42	68.75	86.97	100.19	99.67	101.55	56.39	38.22	52.44
45	88.58	220.57	375.55	22.82	76.15	53.33	33.80	63.44	47.28	62.19	73.00	98.46	99.33	95.99	0.00	54.85	74.74
46	67.23	175.39	338.39	25.61	81.19	55.58	32.60	41.17	62.89	60.79	78.12	100.19	100.36	98.81	39.33	70.60	40.41
47	53.18	127.31	249.63	23.40	75.19	51.79	35.71	48.83	38.23	42.48	75.88	96.34	94.72	95.45	0.00	34.69	0.00
48	64.25	155.86	281.71	22.78	72.49	49.79	37.60	31.09	47.28	66.85	98.55	101.18	100.79	96.52	43.48	59.36	26.22
49	62.55	185.18	330.94	21.84	74.62	52.78	35.55	54.74	49.06	49.92	82.92	101.55	86.97	88.14	16.06	13.11	45.42
50	57.70	127.75	236.88	23.64	70.53	46.88	35.54	35.26	47.28	66.21	83.95	99.85	101.55	98.29	39.33	32.11	34.69
51	64.91	128.70	247.44	27.60	72.14	44.54	36.31	37.27	48.85	62.60	82.27	101.55	.	98.11	0.00	20.73	43.48
52	81.82	169.50	280.50	22.84	74.97	52.12	32.59	37.27	59.46	62.55	75.66	100.79	101.55	97.58	66.85	49.06	68.75
53	43.83	121.90	247.90	27.79	71.58	43.79	33.70	39.23	39.34	57.15	85.97	101.55	100.53	95.95	49.06	37.08	63.56
54	70.33	177.60	305.07	23.89	72.78	48.89	33.05	45.00	32.81	60.42	87.28	101.55	98.81	95.99	0.00	34.69	33.43
55	53.70	111.25	259.25	28.65	72.00	43.35	33.50	35.26	35.91	68.75	85.97	100.87	98.29	99.67	24.53	27.81	9.27
56	87.30	197.10	337.10	23.59	77.27	53.68	34.77	35.26	41.47	47.27	81.88	99.16	99.85	97.23	0.00	58.63	62.88
57	65.06	137.53	255.21	24.08	68.96	44.88	34.44	46.91	27.82	45.42	75.88	98.50	89.56	87.40	74.16	49.06	0.00
58	65.00	188.36	328.00	21.16	72.95	51.78	32.57	37.27	42.49	50.78	80.82	98.11	101.55	68.63	0.00	55.62	26.22
59	54.00	132.00	219.92	23.59	68.56	44.97	35.29	41.17	13.11	55.62	87.46	98.34	100.36	98.46	42.48	64.23	29.32
60	78.06	201.35	347.77	23.52	74.99	51.47	32.16	48.83	49.06	69.37	81.88	.	100.70	93.99	0.00	86.47	73.58
61	47.55	148.63	283.37	23.20	77.74	54.54	33.65	54.91	44.00	54.85	84.80	.	100.53	98.63	54.06	48.17	74.74
62	57.05	158.59	288.96	22.24	78.62	56.38	32.88	58.91	37.37	56.79	80.24	95.10	85.17	98.81	0.00	58.63	80.29
63	78.88	171.50	300.81	22.10	75.60	53.50	32.30	48.83	52.91	50.81	88.55	97.60	98.81	79.75	58.63	.	47.27
64	62.94	165.25	299.60	21.80	76.57	54.77	36.78	48.83	37.41	50.81	91.51	95.99	97.57	99.50	.	53.26	46.35

APPENDIX VII
PROVENANCE MEAN VALUES FOR 36 CLIMATE VARIABLES IN NORTH CENTRE ONTRIAO (64 PROVENANCES)

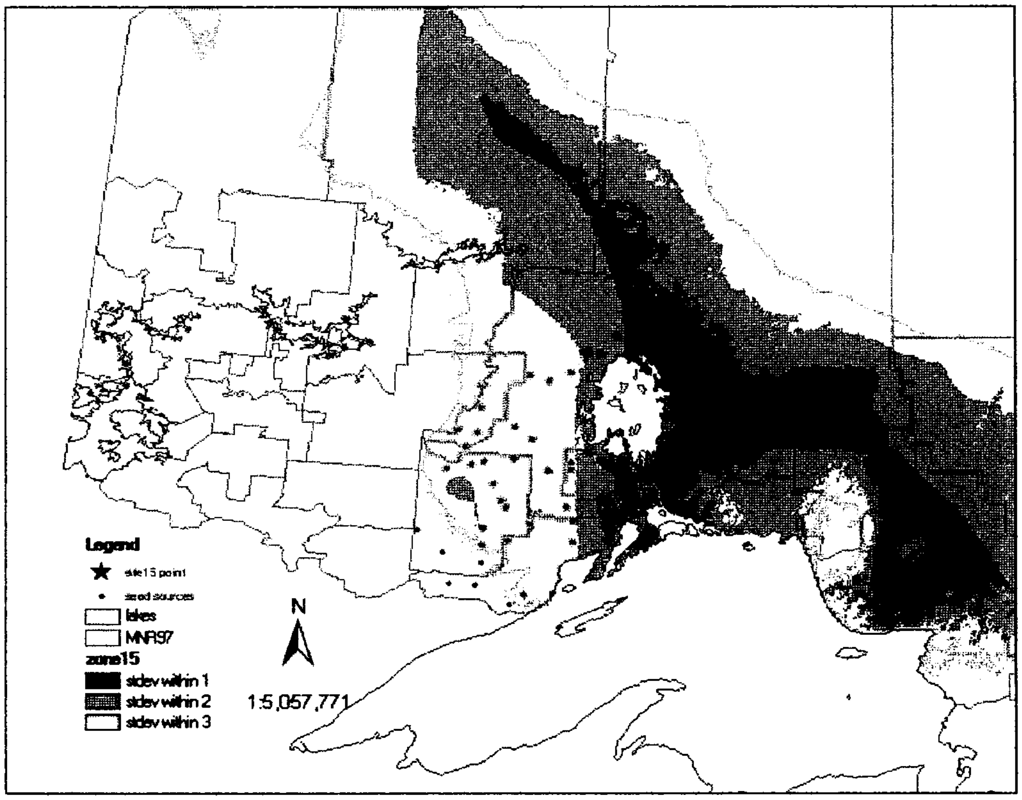
Prov	Janmaxt	Febmaxt	Marmaxt	Aprmaxt	Maymaxt	Junmaxt	Julmaxt	Augmaxt	Sepmaxt	Octmaxt	Novmaxt	Decmaxt	Janmint	Febmint	Marmint	Aprmint	Maymint	Junmint
1	-14.14	-10.33	-2.58	6.15	14.25	20.44	23.23	20.74	14.92	7.94	-1.79	-10.91	-27.19	-25.73	-18.99	-7.39	0.27	6.18
2	-14.06	-10.29	-2.51	6.20	14.26	20.55	23.24	20.74	15.02	8.02	-1.77	-10.85	-27.04	-25.70	-18.96	-7.30	0.28	6.22
3	-13.85	-10.11	-2.43	6.25	14.34	20.36	23.18	20.77	14.96	8.02	-1.63	-10.64	-27.00	-25.51	-18.76	-7.24	0.39	6.22
4	-13.87	-10.09	-2.47	6.23	14.36	20.24	23.17	20.78	14.88	7.96	-1.61	-10.64	-27.12	-25.48	-18.73	-7.31	0.39	6.18
5	-13.22	-9.71	-2.33	6.19	14.26	19.75	22.74	20.58	14.73	7.94	-1.39	-10.07	-26.56	-24.93	-18.22	-7.05	0.58	6.14
6	-13.90	-9.89	-2.47	6.35	14.78	19.94	23.43	21.09	14.62	7.76	-1.47	-10.58	-27.82	-25.48	-18.63	-7.64	0.42	5.96
7	-13.52	-9.55	-2.27	6.55	15.01	19.87	23.50	21.22	14.68	7.89	-1.16	-10.20	-27.66	-25.08	-18.21	-7.47	0.58	5.94
8	-11.69	-7.96	-1.17	7.21	15.32	19.85	23.57	21.85	15.61	8.96	0.28	-7.98	-24.54	-21.99	-14.87	-5.89	1.29	6.30
9	-12.68	-8.73	-1.80	7.04	15.63	19.78	23.78	21.64	14.87	8.22	-0.38	-9.37	-27.27	-23.96	-17.09	-7.01	1.00	5.98
10	-11.03	-7.47	-0.72	7.61	15.45	19.89	23.57	22.06	16.09	9.50	0.93	-7.29	-23.38	-20.93	-13.77	-5.12	1.70	6.58
11	-11.73	-8.75	-2.32	5.80	13.72	17.90	21.49	19.91	13.87	7.62	-0.60	-8.59	-24.99	-22.67	-16.01	-6.67	0.71	5.45
12	-11.94	-8.84	-2.42	5.75	13.84	18.05	21.75	20.04	13.82	7.50	-0.75	-8.78	-25.33	-22.87	-16.20	-6.92	0.57	5.37
13	-10.71	-7.32	-0.68	7.55	15.24	19.67	23.29	21.88	16.02	9.53	1.04	-7.04	-22.93	-20.60	-13.48	-4.94	1.75	6.60
14	-12.99	-9.20	-2.19	6.53	14.97	19.47	23.21	21.07	14.52	7.88	-0.88	-9.75	-27.24	-24.43	-17.63	-7.26	0.71	5.83
15	-11.81	-8.27	-1.62	6.72	14.88	19.23	23.00	21.26	14.97	8.42	-0.07	-8.30	-24.93	-22.31	-15.36	-6.30	1.03	5.94
16	-11.01	-7.54	-0.94	7.26	15.06	19.71	23.28	21.75	15.76	9.23	0.64	-7.37	-23.38	-21.12	-14.00	-5.34	1.48	6.52
17	-13.41	-9.68	-2.38	6.28	14.54	19.67	23.01	20.80	14.58	7.83	-1.30	-10.18	-27.15	-24.97	-18.20	-7.32	0.53	5.96
18	-12.83	-9.22	-2.09	6.52	14.70	19.48	22.92	20.89	14.70	8.07	-0.83	-9.60	-26.62	-24.26	-17.48	-6.92	0.81	6.02
19	-12.91	-9.40	-2.20	6.34	14.42	19.46	22.70	20.66	14.65	7.99	-1.04	-9.72	-26.47	-24.44	-17.69	-6.94	0.72	6.04
20	-12.41	-9.19	-2.16	6.19	14.08	18.96	22.13	20.31	14.49	7.96	-0.90	-9.28	-25.73	-23.91	-17.19	-6.67	0.81	5.99
21	-11.53	-8.75	-2.07	6.02	13.59	18.02	21.21	19.80	14.21	7.96	-0.48	-8.44	-24.49	-22.77	-16.08	-6.19	0.99	5.81
22	-9.41	-7.61	-1.50	6.00	12.50	16.24	19.14	18.81	14.07	8.49	0.79	-6.31	-21.10	-19.99	-13.27	-4.59	1.66	5.74
23	-14.17	-9.78	-2.18	6.69	15.24	20.17	23.95	21.59	14.77	7.73	-1.88	-10.42	-28.41	-26.57	-19.01	-8.13	0.18	5.51
24	-14.21	-9.83	-2.22	6.66	15.20	20.16	23.93	21.56	14.75	7.70	-1.91	-10.49	-28.45	-26.66	-19.11	-8.19	0.14	5.48
25	-14.00	-9.65	-2.07	6.71	15.25	19.97	23.80	21.41	14.66	7.70	-2.13	-10.09	-27.66	-25.05	-17.46	-7.12	1.08	6.47
26	-13.79	-9.38	-1.84	6.98	15.49	20.19	24.08	21.72	14.95	7.98	-1.77	-9.79	-27.74	-25.18	-17.54	-7.16	1.00	6.31
27	-13.84	-9.40	-1.79	7.09	15.59	20.41	24.24	21.90	15.12	8.10	-1.57	-9.93	-27.99	-25.79	-18.14	-7.50	0.69	5.99
28	-14.13	-9.74	-2.14	6.75	15.29	20.24	24.02	21.66	14.85	7.81	-1.73	-10.40	-28.50	-26.78	-19.22	-8.25	0.06	5.36
29	-14.45	-10.14	-2.56	6.32	14.89	19.99	23.70	21.30	14.49	7.47	-1.99	-10.91	-28.57	-26.64	-19.39	-8.35	0.01	5.53
30	-14.49	-10.15	-2.52	6.37	14.93	20.03	23.74	21.35	14.53	7.48	-2.05	-10.91	-28.60	-26.80	-19.45	-8.39	-0.01	5.48
31	-9.32	-6.03	-0.18	8.41	16.61	20.40	24.15	22.17	15.98	9.47	0.69	-7.21	-22.28	-19.62	-13.39	-5.30	1.19	5.96
32	-9.31	-5.95	0.08	8.57	16.61	20.74	24.32	22.58	16.51	10.02	1.14	-6.63	-22.06	-19.52	-12.94	-4.80	1.53	6.41

Prov	janmaxt	febmaxt	marmaxt	aprmaxt	maymaxt	junmaxt	julmaxt	augmaxt	sepmaxt	octmaxt	novmaxt	decmaxt	janmint	febmint	marmint	aprmint	maymint	junmint
33	-10.21	-6.28	0.14	8.96	17.17	21.14	24.65	22.66	16.48	9.86	0.49	-7.65	-23.51	-20.69	-13.79	-4.94	1.71	6.64
34	-10.17	-6.42	-0.26	8.51	16.82	20.69	24.32	22.25	16.00	9.39	0.21	-7.86	-23.46	-20.66	-14.16	-5.48	1.19	6.02
35	-11.76	-7.81	-1.21	7.00	15.09	20.54	23.65	21.86	15.43	8.84	-0.19	-8.16	-24.79	-22.59	-15.56	-6.22	1.05	6.78
36	-11.03	-7.42	-0.97	7.19	14.99	20.21	23.48	21.83	15.67	9.17	0.29	-7.57	-23.64	-21.56	-14.50	-5.57	1.27	6.77
37	-12.53	-8.20	-1.17	7.38	15.72	20.73	24.26	22.24	15.61	8.82	-0.51	-8.53	-26.23	-23.59	-16.22	-6.45	1.20	6.66
38	-12.86	-8.54	-1.63	6.85	15.33	20.30	23.80	21.68	14.97	8.22	-1.26	-8.90	-26.72	-23.95	-16.69	-6.88	0.89	6.36
39	-12.52	-8.17	-1.08	7.53	15.86	20.81	24.39	22.36	15.73	8.93	-0.43	-8.49	-26.27	-23.59	-16.17	-6.37	1.29	6.70
40	-12.78	-8.26	-1.19	7.42	15.96	20.68	23.97	21.86	15.45	8.85	-1.06	-8.98	-26.43	-23.56	-16.10	-6.21	1.20	6.51
41	-12.21	-7.68	-0.82	7.89	16.35	21.04	24.32	22.37	15.94	9.18	-0.62	-8.50	-25.85	-22.95	-15.79	-6.05	1.12	6.29
42	-12.48	-7.99	-1.12	7.52	16.04	20.74	24.01	21.99	15.55	8.86	-0.95	-8.79	-26.15	-23.28	-16.08	-6.29	0.99	6.21
43	-11.88	-7.50	-0.79	7.90	16.39	20.90	24.12	22.13	15.81	9.17	-0.59	-8.61	-25.41	-22.62	-15.57	-6.00	1.00	6.10
44	-11.33	-7.69	-1.06	7.16	15.07	19.98	23.45	21.80	15.63	9.07	0.31	-7.68	-23.98	-21.73	-14.60	-5.68	1.32	6.58
45	-12.24	-8.03	-1.30	6.99	15.28	20.79	23.86	21.96	15.36	8.70	-0.50	-8.51	-25.60	-23.25	-16.19	-6.57	0.97	6.79
46	-12.74	-8.55	-1.54	7.00	15.40	20.27	23.93	21.86	15.21	8.43	-0.75	-8.86	-26.52	-23.98	-16.67	-6.88	0.88	6.21
47	-12.95	-8.51	-1.36	7.30	15.80	20.34	24.06	21.85	15.25	8.53	-1.30	-8.82	-26.86	-23.68	-16.12	-6.29	1.42	6.66
48	-11.05	-6.85	-0.13	8.63	16.91	21.22	24.51	22.51	16.33	9.75	0.11	-8.09	-24.40	-21.64	-14.40	-5.12	1.71	6.85
49	-11.79	-7.48	-0.84	7.72	16.03	20.97	24.19	22.35	15.91	9.16	-0.35	-8.20	-25.19	-22.53	-15.57	-6.06	1.02	6.34
50	-11.44	-7.05	-0.51	8.27	16.67	21.13	24.41	22.62	16.27	9.42	-0.24	-8.11	-24.89	-22.03	-15.31	-5.86	0.91	5.81
51	-11.31	-7.04	-0.46	8.31	16.73	21.04	24.37	22.40	16.11	9.43	-0.19	-8.27	-24.77	-21.94	-15.05	-5.71	1.12	6.11
52	-13.20	-8.69	-1.42	7.13	15.69	20.50	23.77	21.56	15.17	8.67	-1.33	-9.34	-26.71	-23.91	-16.24	-6.25	1.36	6.81
53	-11.60	-7.32	-0.36	8.33	16.56	21.12	24.26	22.28	16.12	9.54	-0.24	-8.39	-24.79	-22.11	-14.56	-5.06	1.95	7.33
54	-13.78	-9.30	-1.69	6.98	15.53	20.36	23.79	21.48	14.96	8.28	-1.78	-9.91	-26.74	-24.01	-16.31	-6.19	1.79	7.42
55	-13.58	-9.09	-1.64	6.94	15.51	20.35	23.68	21.40	14.95	8.41	-1.63	-9.70	-26.79	-24.04	-16.30	-6.24	1.59	7.17
56	-13.69	-9.17	-1.60	6.95	15.51	20.54	23.62	21.36	15.01	8.54	-1.57	-9.97	-26.41	-23.86	-16.09	-5.99	1.84	7.64
57	-13.49	-8.92	-1.39	7.14	15.70	20.71	23.76	21.52	15.22	8.82	-1.30	-9.70	-26.53	-23.94	-16.08	-5.96	1.73	7.44
58	-13.24	-8.66	-1.28	7.25	15.81	20.75	23.81	21.61	15.33	8.94	-1.13	-9.46	-26.58	-23.93	-16.11	-6.03	1.51	7.10
59	-13.41	-8.89	-1.47	6.89	15.47	20.67	23.38	21.18	15.05	8.89	-1.22	-9.86	-26.46	-24.16	-16.20	-6.06	1.44	7.26
60	-13.26	-8.87	-1.53	7.20	15.68	20.08	24.04	21.72	15.06	8.28	-1.59	-9.03	-27.16	-23.90	-16.18	-6.30	1.62	6.82
61	-13.06	-8.71	-1.52	7.18	15.65	20.07	24.07	21.79	15.08	8.26	-1.46	-8.79	-27.17	-23.90	-16.29	-6.47	1.43	6.58
62	-12.47	-8.95	-2.11	6.43	14.68	19.03	22.72	20.78	14.42	7.92	-0.65	-9.27	-26.46	-23.75	-16.99	-6.93	0.82	5.80
63	-12.30	-9.02	-2.26	6.11	14.18	18.60	22.13	20.32	14.18	7.76	-0.77	-9.15	-25.96	-23.57	-16.87	-6.86	0.74	5.70
64	-10.74	-6.72	-0.35	8.42	16.79	20.89	24.36	22.35	16.08	9.42	0.01	-8.06	-24.12	-21.30	-14.63	-5.61	1.12	6.02

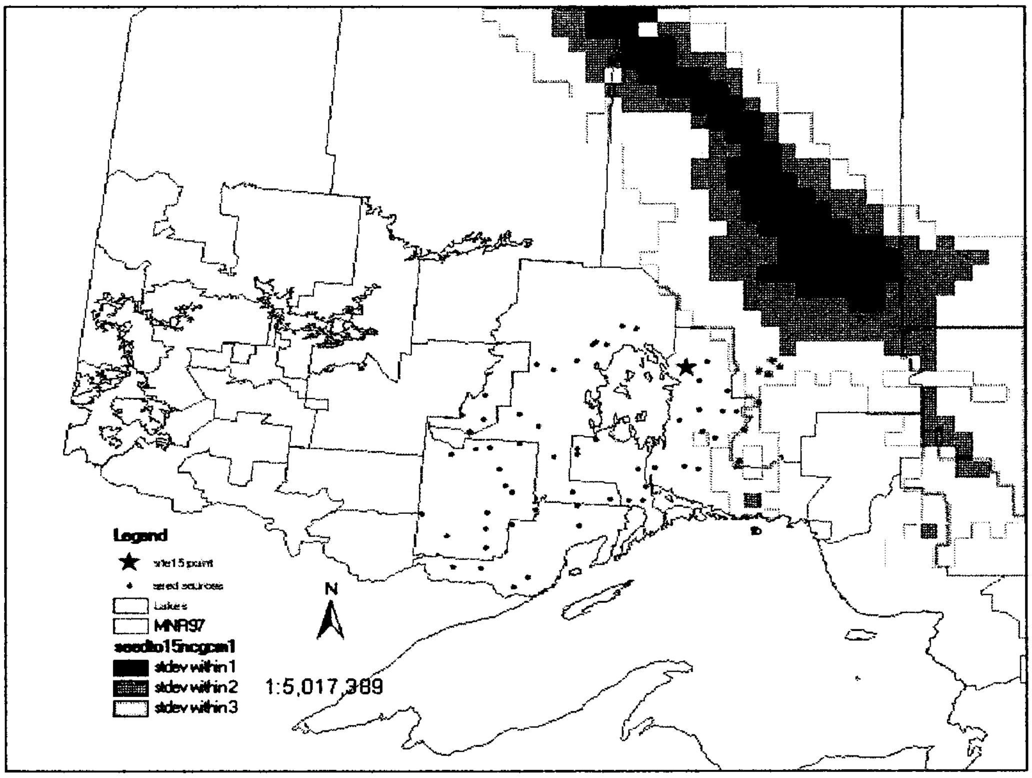
Prov	Julmint	Augmint	Sepmint	Octmint	Novmint	Decmint	Janprec	Febprec	Marprec	Aprprec	Mayprec	Junprec	Julprec	Augprec	Sepprec	Octprec	Novprec	Decprec
1	9.69	7.94	3.47	-1.09	-10.82	-22.03	33.07	27.35	32.73	40.67	61.29	86.73	94.56	83.16	91.35	67.62	57.37	40.21
2	9.70	7.92	3.49	-1.04	-10.81	-21.96	34.38	28.23	34.04	40.62	61.46	86.79	92.95	83.34	90.65	67.95	57.74	41.14
3	9.74	8.05	3.61	-0.97	-10.57	-21.76	34.30	28.09	34.34	40.72	62.75	87.85	92.61	84.70	90.81	68.72	57.94	41.47
4	9.72	8.06	3.58	-1.02	-10.55	-21.79	33.50	27.47	33.51	40.86	62.76	87.92	93.79	84.81	91.41	68.75	57.80	41.10
5	9.71	8.24	3.84	-0.83	-10.03	-21.14	37.27	29.81	38.19	41.46	66.58	91.00	89.64	88.91	90.64	71.80	59.63	44.54
6	9.61	8.06	3.39	-1.29	-10.54	-22.07	33.31	26.94	33.33	42.61	61.87	87.52	97.81	86.38	93.22	70.39	58.54	42.90
7	9.59	8.12	3.46	-1.22	-10.22	-21.74	35.85	28.04	35.28	42.73	63.35	88.61	95.23	87.68	92.62	72.42	59.97	45.74
8	9.98	9.03	4.53	-0.25	-8.06	-18.58	47.67	33.13	43.48	43.65	65.95	91.25	86.07	92.38	91.16	82.08	72.11	61.29
9	9.67	8.39	3.70	-1.05	-9.39	-20.90	42.00	30.54	39.11	43.16	65.55	90.26	90.15	89.91	92.13	77.26	64.30	52.98
10	10.24	9.53	5.19	0.34	-7.16	-17.46	49.13	33.08	42.54	42.87	64.65	91.03	82.24	91.77	92.17	82.49	73.22	64.08
11	9.03	8.28	3.89	-0.89	-8.79	-19.31	53.84	36.43	47.26	47.52	73.02	95.72	89.66	95.15	99.05	85.78	69.70	62.42
12	9.00	8.13	3.66	-1.12	-9.03	-19.59	53.41	36.54	47.89	47.88	72.50	96.52	91.16	96.17	99.06	86.40	71.66	63.15
13	10.23	9.58	5.25	0.39	-7.00	-17.16	50.14	33.40	43.66	43.73	66.24	90.56	82.08	91.78	92.77	82.06	71.62	63.55
14	9.49	8.18	3.55	-1.17	-9.79	-21.18	40.67	30.29	38.73	43.51	66.26	90.97	92.33	90.05	93.42	76.26	62.95	50.56
15	9.61	8.69	4.20	-0.59	-8.40	-18.97	49.89	34.40	44.89	45.10	67.73	93.72	87.84	94.04	94.49	84.22	73.05	62.97
16	10.14	9.30	4.81	0.00	-7.51	-17.72	49.04	33.44	45.36	44.62	68.02	90.14	84.94	92.38	91.61	80.98	70.16	60.77
17	9.57	8.13	3.58	-1.09	-10.16	-21.46	36.45	28.59	36.00	42.31	65.12	89.96	93.54	88.09	92.79	72.47	59.97	45.22
18	9.61	8.37	3.88	-0.83	-9.56	-20.79	39.66	29.81	37.85	42.41	66.55	90.52	90.14	89.09	92.45	74.62	61.12	48.49
19	9.61	8.32	3.89	-0.81	-9.69	-20.82	38.93	29.88	38.18	42.13	67.08	91.03	89.80	89.35	91.92	73.77	60.49	47.02
20	9.53	8.44	4.12	-0.62	-9.29	-20.20	42.96	32.10	41.41	43.01	69.41	92.44	87.58	91.03	92.37	76.25	61.76	49.95
21	9.28	8.62	4.45	-0.33	-8.53	-19.07	51.24	35.64	45.33	45.42	72.14	93.10	86.17	91.96	95.49	81.51	64.16	56.71
22	8.94	9.33	5.63	0.81	-6.50	-16.14	65.24	41.47	50.58	49.31	75.16	90.98	81.77	90.19	99.22	88.18	65.31	66.27
23	9.24	7.49	2.74	-1.80	-11.66	-23.02	34.61	29.24	39.08	44.10	64.10	86.79	100.62	89.77	83.49	67.25	51.35	40.19
24	9.20	7.45	2.71	-1.82	-11.69	-23.09	34.39	29.10	38.85	44.20	63.69	86.93	100.89	89.77	83.88	67.15	51.40	40.24
25	10.46	8.44	3.39	-1.43	-11.49	-22.14	38.93	33.11	42.01	42.49	69.60	85.69	101.06	92.68	82.70	67.28	50.55	39.05
26	10.27	8.32	3.35	-1.38	-11.37	-22.05	37.39	31.50	41.23	42.63	68.80	83.95	99.37	90.22	80.34	67.34	50.53	38.44
27	9.80	7.99	3.16	-1.45	-11.30	-22.39	35.38	29.68	39.43	42.88	65.87	84.36	98.49	88.88	80.56	66.83	50.57	39.02
28	9.04	7.35	2.67	-1.81	-11.59	-23.10	33.41	28.25	37.94	43.91	62.75	87.22	99.74	88.93	84.35	67.31	51.42	40.55
29	9.23	7.57	2.81	-1.80	-11.49	-23.11	32.66	27.68	36.19	44.88	60.30	86.33	102.92	88.75	89.34	68.06	54.58	41.29
30	9.18	7.50	2.74	-1.85	-11.64	-23.24	32.92	28.02	36.86	44.92	60.72	86.47	103.04	89.21	87.82	67.33	53.34	40.77
31	9.64	8.29	3.55	-1.18	-8.52	-18.25	61.52	39.12	55.92	53.08	71.96	101.52	97.80	98.52	110.50	78.78	69.99	61.32
32	10.04	8.73	4.06	-0.60	-7.94	-17.66	53.78	34.95	50.80	49.88	70.93	94.74	91.73	94.46	101.40	71.27	61.47	56.21

Prov	julmint	augmint	sepmint	octmint	novmint	decmint	janprec	febprec	marprec	aprprec	mayprec	junprec	julprec	augprec	sepprec	octprec	novprec	decprec
33	10.15	8.71	4.07	-0.69	-8.69	-18.85	51.41	35.21	47.09	51.10	74.93	101.85	101.31	96.98	104.47	78.88	61.12	52.64
34	9.58	8.18	3.52	-1.22	-9.05	-19.09	58.12	38.56	52.65	51.23	73.52	103.19	102.72	97.79	109.88	80.44	67.85	57.36
35	10.19	8.74	3.70	-0.85	-8.68	-19.48	44.84	32.81	48.71	45.70	74.04	85.62	92.52	90.51	86.20	73.82	59.85	48.25
36	10.26	9.01	4.13	-0.56	-8.14	-18.49	44.98	32.16	48.23	45.79	72.91	86.52	90.14	91.15	89.02	72.63	59.47	49.83
37	10.32	8.68	3.71	-0.87	-9.61	-20.35	40.23	30.90	45.02	43.71	73.00	79.03	92.63	86.18	75.84	72.04	55.80	40.72
38	10.08	8.25	3.17	-1.39	-10.48	-20.94	41.63	32.99	48.45	45.07	77.77	79.14	98.14	87.03	75.31	72.67	54.38	37.55
39	10.39	8.75	3.80	-0.79	-9.59	-20.33	39.45	30.42	44.05	43.18	72.22	78.56	92.07	85.66	75.28	71.34	55.10	40.20
40	10.12	8.28	3.57	-0.97	-10.26	-20.78	38.93	33.21	41.72	40.42	76.49	89.49	101.48	90.29	88.14	70.90	50.59	39.13
41	9.75	8.16	3.51	-1.03	-9.86	-20.33	40.27	33.12	43.73	39.35	74.93	87.16	100.68	86.14	86.82	68.65	51.82	40.19
42	9.72	8.03	3.36	-1.17	-10.18	-20.63	40.61	33.77	44.01	40.44	76.31	89.18	102.34	88.44	88.41	70.61	52.41	40.46
43	9.49	7.95	3.42	-1.12	-9.75	-20.23	43.77	34.49	44.24	42.59	76.14	95.55	104.00	91.28	96.64	73.68	55.67	44.77
44	10.17	9.09	4.40	-0.33	-8.02	-18.41	46.77	32.81	46.29	44.96	70.00	87.90	87.54	91.54	88.72	78.15	66.13	55.52
45	10.19	8.58	3.45	-1.02	-9.14	-20.15	43.80	32.82	48.60	45.30	75.02	83.67	94.26	89.17	82.79	73.44	58.42	45.18
46	9.91	8.36	3.49	-1.10	-9.85	-20.65	41.36	31.49	44.64	44.38	70.81	83.90	93.25	88.90	80.92	74.77	59.75	45.74
47	10.61	8.61	3.63	-1.05	-10.78	-20.84	39.00	33.03	43.20	40.96	75.39	83.96	99.26	88.87	81.53	69.52	50.18	37.29
48	10.30	8.75	4.14	-0.55	-8.94	-19.36	45.07	33.12	42.49	48.43	76.32	99.85	101.86	96.07	100.07	77.24	55.51	47.50
49	9.74	8.26	3.47	-1.07	-9.37	-19.89	42.67	33.16	46.85	41.61	74.32	85.71	97.67	86.36	86.16	68.28	53.96	43.12
50	9.11	7.83	3.35	-1.20	-9.47	-19.80	45.01	34.94	46.88	39.26	72.80	90.41	101.73	85.16	92.84	67.99	55.50	45.47
51	9.51	8.07	3.54	-1.06	-9.41	-19.79	47.54	35.28	46.08	44.06	74.47	96.86	103.03	91.78	99.89	74.41	58.61	48.09
52	10.49	8.50	3.73	-0.84	-10.38	-21.06	38.61	33.71	40.54	40.23	75.93	90.09	100.52	92.89	88.72	70.75	49.12	38.91
53	10.78	9.14	4.40	-0.33	-8.98	-19.52	41.05	31.72	39.68	48.84	77.45	99.24	101.72	97.36	96.45	76.65	50.13	44.63
54	11.24	9.13	4.08	-0.73	-10.44	-21.47	40.46	35.63	40.58	38.22	70.59	87.67	97.02	95.04	87.61	66.29	47.23	39.71
55	10.94	8.84	3.92	-0.77	-10.45	-21.32	39.81	35.11	40.66	39.12	73.32	89.11	98.50	94.67	88.56	68.65	47.89	39.50
56	11.25	9.16	4.22	-0.48	-9.90	-21.30	40.89	36.36	39.78	37.70	71.61	90.52	96.19	96.73	91.43	67.56	46.24	40.87
57	11.03	8.96	4.17	-0.43	-9.91	-21.14	38.99	34.63	38.68	38.47	73.27	90.52	97.31	95.17	90.45	68.73	46.50	39.61
58	10.66	8.66	3.98	-0.55	-10.00	-21.01	37.71	33.28	38.44	39.70	75.48	91.39	99.41	93.97	90.34	70.59	47.70	38.92
59	10.66	8.63	4.06	-0.40	-9.71	-21.10	38.79	34.02	38.30	41.39	76.20	95.67	100.07	97.51	94.63	72.66	47.39	40.94
60	10.99	8.86	3.77	-1.03	-11.15	-21.08	38.85	33.29	42.25	40.73	73.30	84.09	98.70	90.56	81.63	68.38	49.34	37.46
61	10.74	8.68	3.57	-1.18	-11.16	-20.96	39.06	32.59	44.10	42.29	74.60	81.48	98.43	88.41	78.02	69.67	50.89	36.77
62	9.42	8.31	3.79	-0.96	-9.31	-20.45	44.77	32.09	41.17	44.19	68.50	92.35	89.96	91.42	94.55	79.04	64.73	54.17
63	9.28	8.28	3.84	-0.91	-9.23	-20.16	46.88	33.30	42.87	44.95	70.28	93.46	89.69	92.42	95.63	80.33	65.13	55.26
64	9.49	8.08	3.50	-1.17	-9.24	-19.45	53.55	37.18	49.80	47.42	73.51	99.95	102.88	94.54	105.36	77.29	63.83	53.20

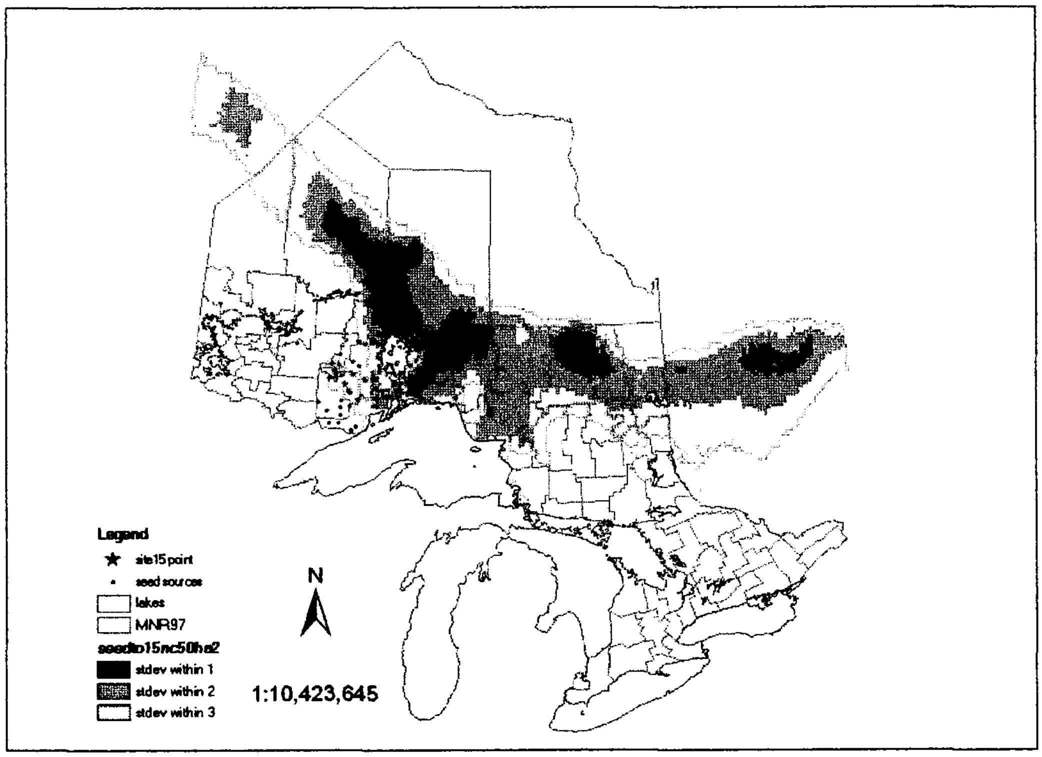
APPENDIX VIII
PRESENT AND FUTURE FOCAL POINT SEED ZONES BASED ON POINT (50.1°N, 87.9°W) UNDER DIFFERENT CLIMATE SCENARIO IN NORTH CENTRAL ONTRIAO (64 PROVENANCES)



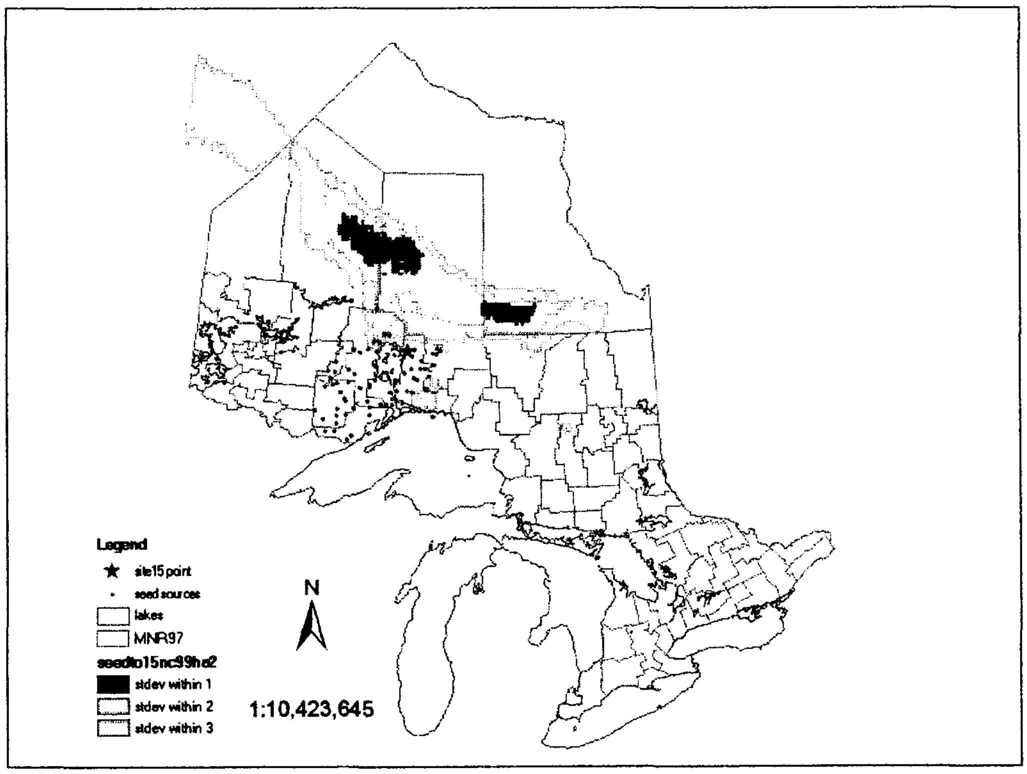
Focal point seed zones at coordinate 50.1°N, 87.9°W based on OCM2



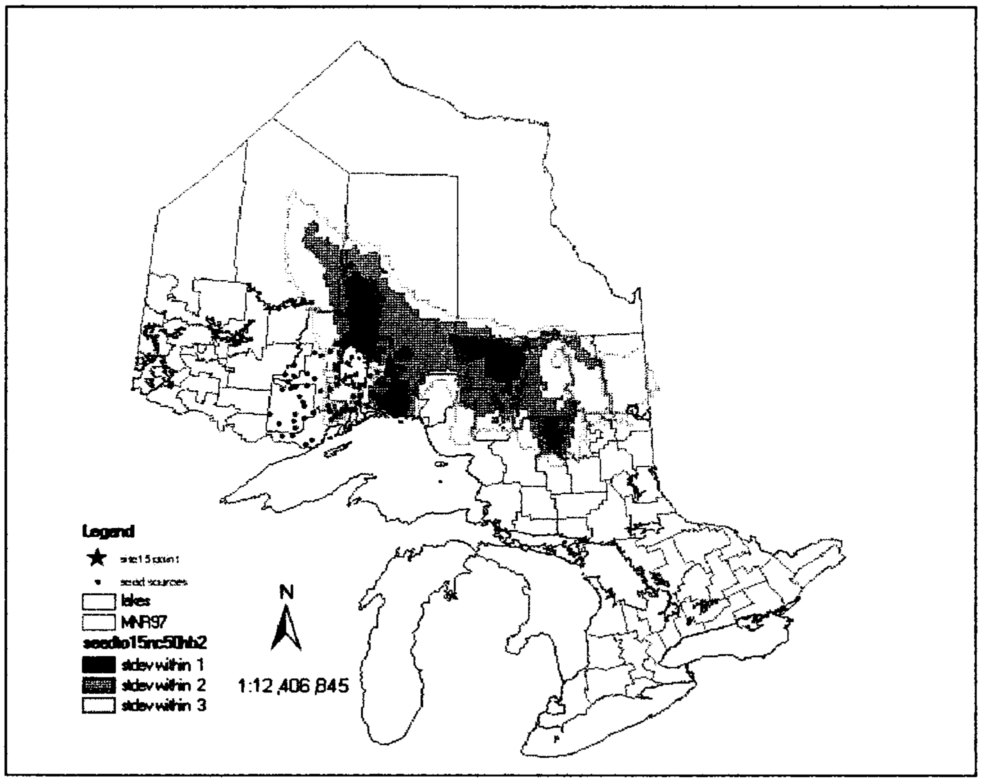
Best '*Seed To*' transfer zone in 2069 for seed from point 50.1°N, 87.9°W based on CGCM1



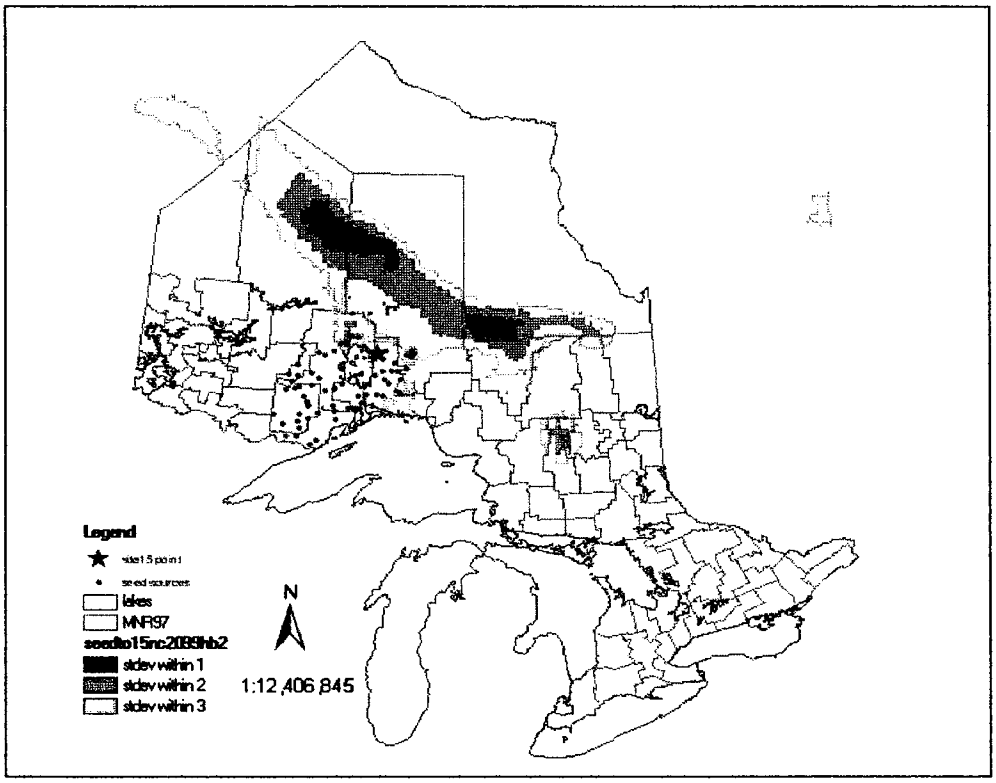
Best '*Seed To*' transfer zone in 2050 for seed from point 50.1°N, 87.9°W based on HADCM3A2



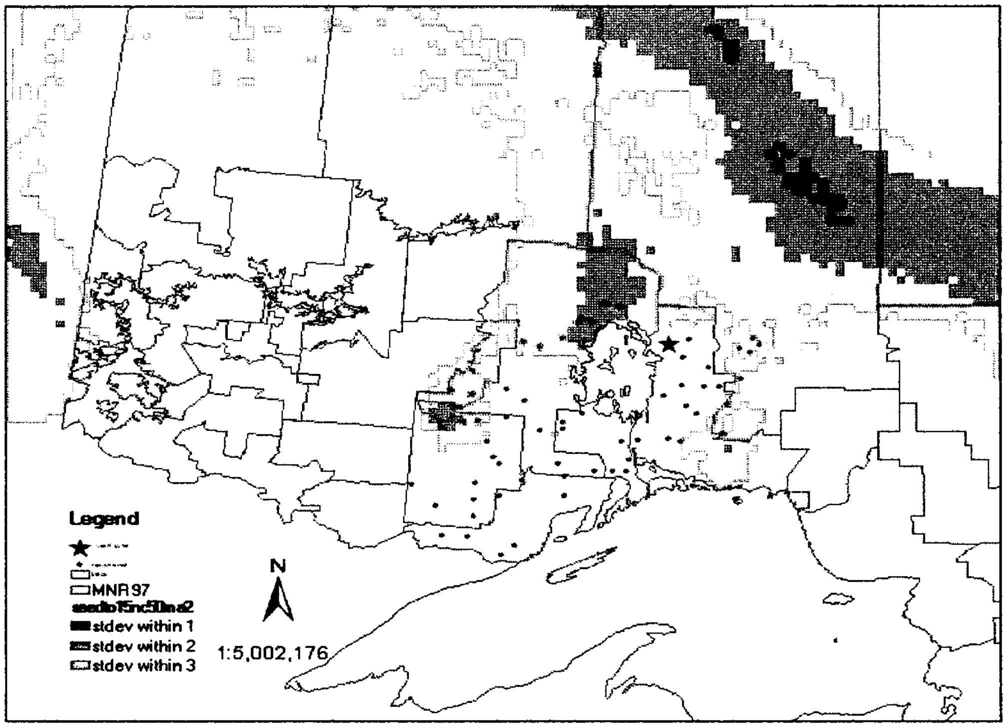
Best '*Seed To*' transfer zone in 2099 for seed from point 50.1°N, 87.9°W based on HADCM3A2



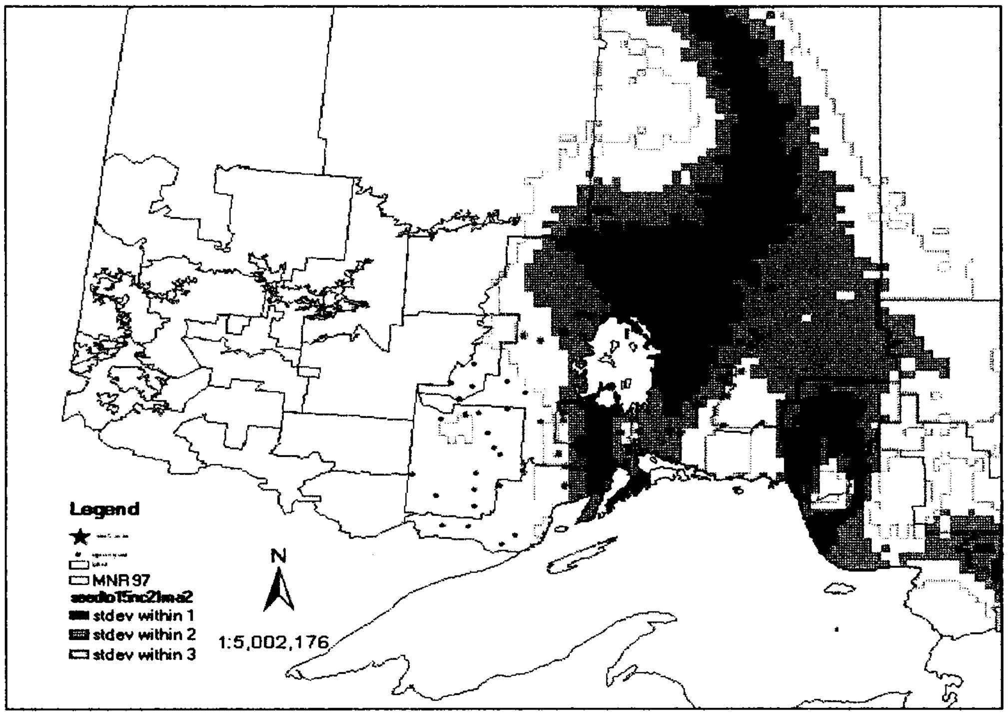
Best '*Seed To*' transfer zone in 2050 for seed from point 50.1°N, 87.9°W based on HADCM3B2



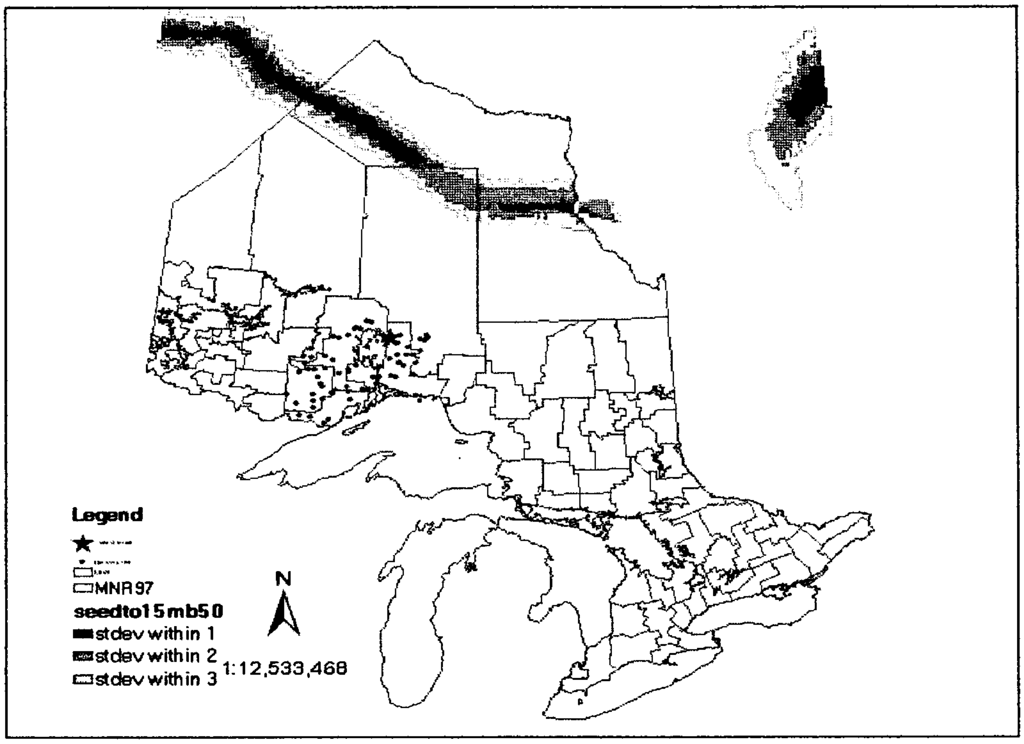
Best '*Seed To*' transfer zone in 2099 for seed from point 50.1°N, 87.9°W based on HADCM3B2



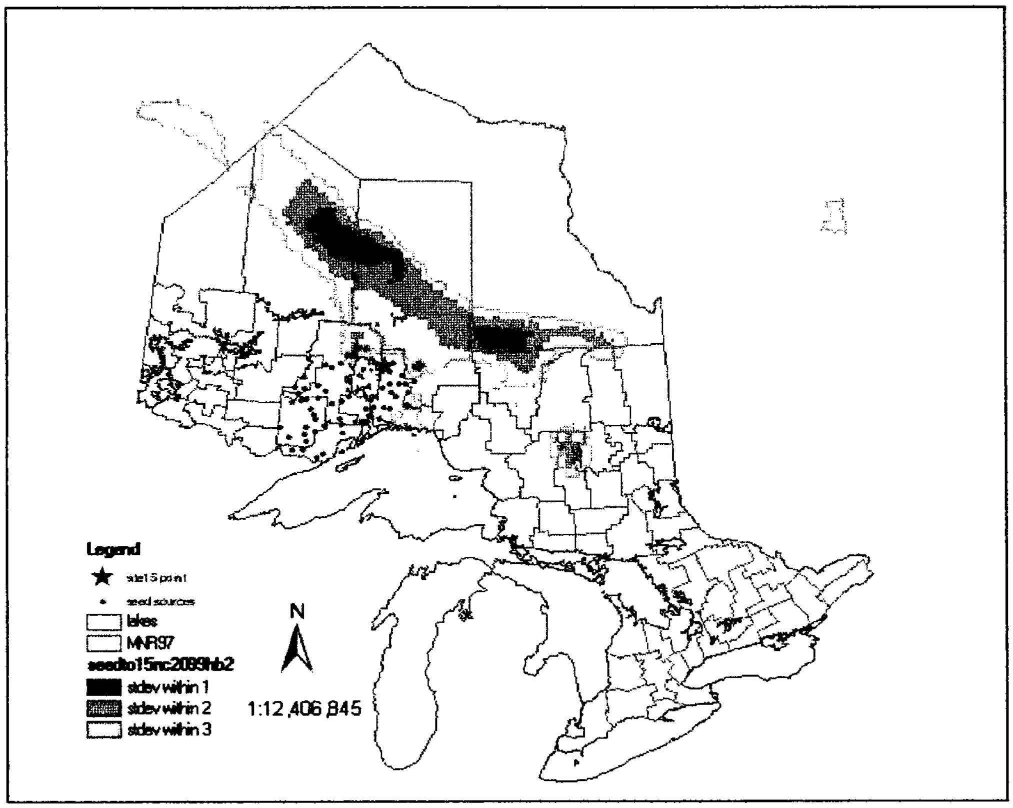
Best '*Seed To*' transfer zone in 2050 for seed from point 50.1°N, 87.9°W based on CGCM2A2



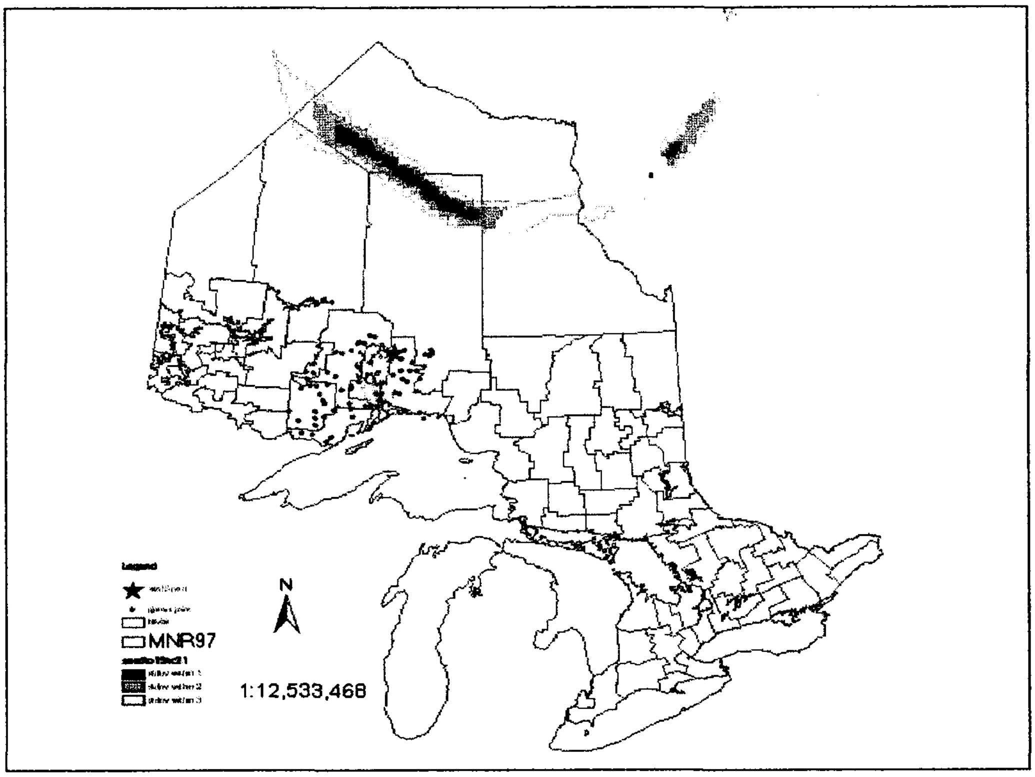
Best '*Seed To*' transfer zone in 2099 for seed from point 50.1°N, 87.9°W based on CGCM2A2



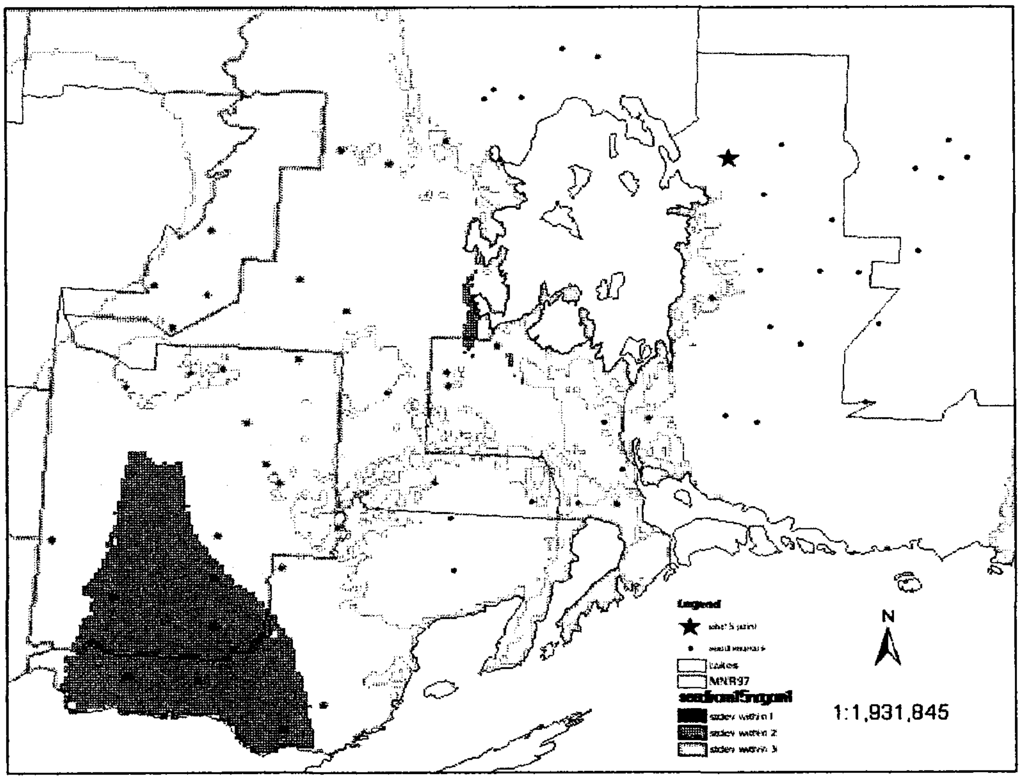
Best '*Seed To*' transfer zone in 2050 for seed from point 50.1°N, 87.9°W based on CGCM2B2



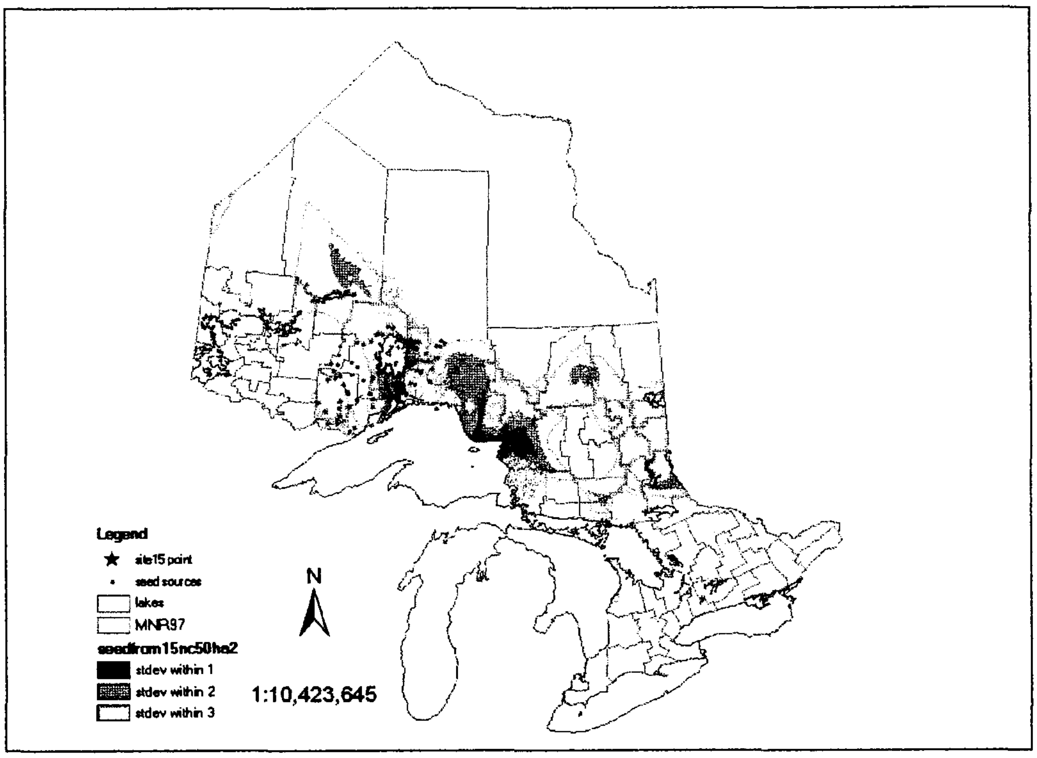
Best '*Seed To*' transfer zone in 2099 for seed from point 50.1°N, 87.9°W based on CGCM2B2



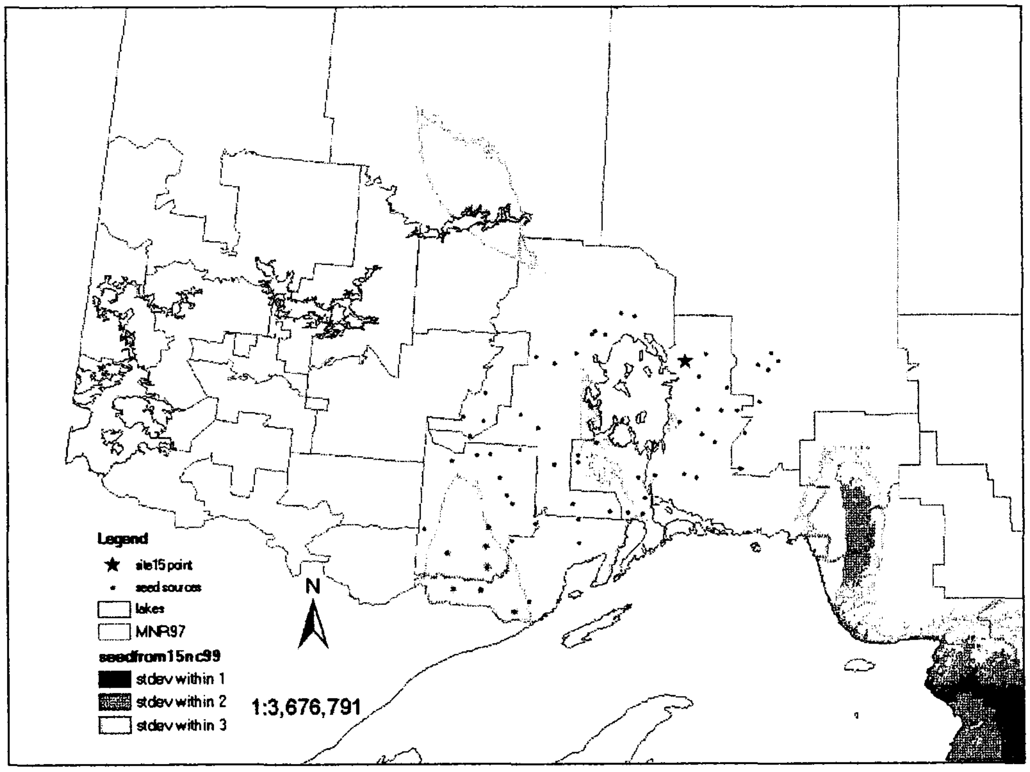
Best '*Seed To*' transfer zone in 2099 for seed from point 50.1°N, 87.9°W based on CSIROB2



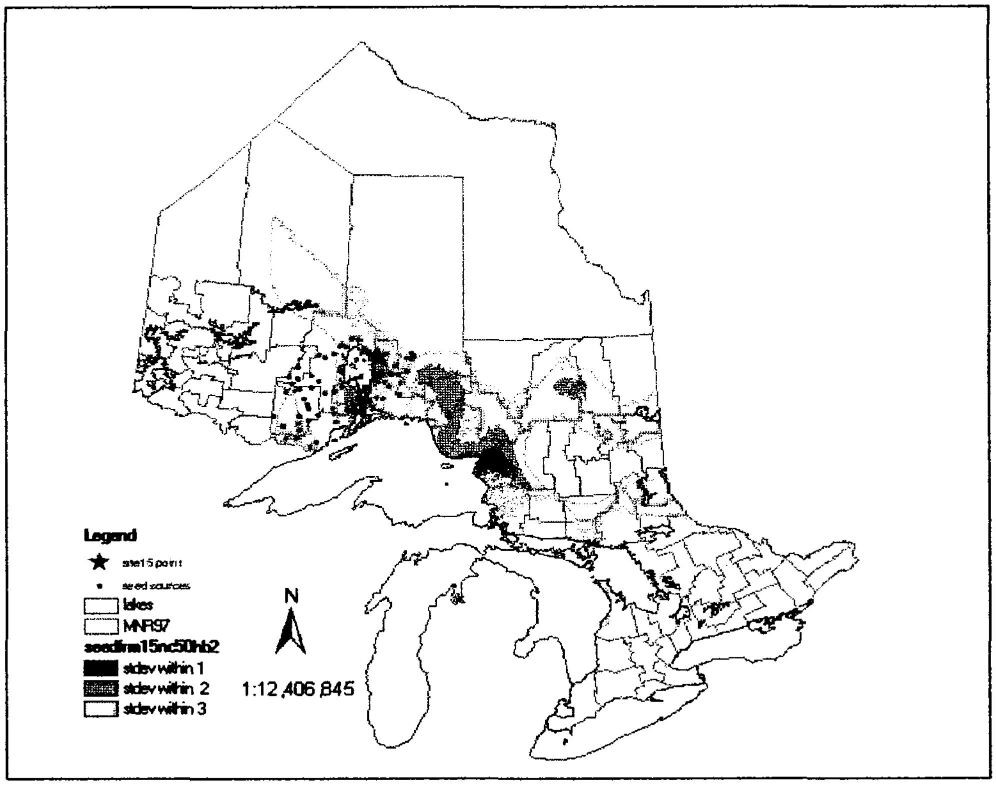
Best '*Seed From*' transfer zone in 2069 to best match climate of point 50.1°N, 87.9°W based on CGCM1



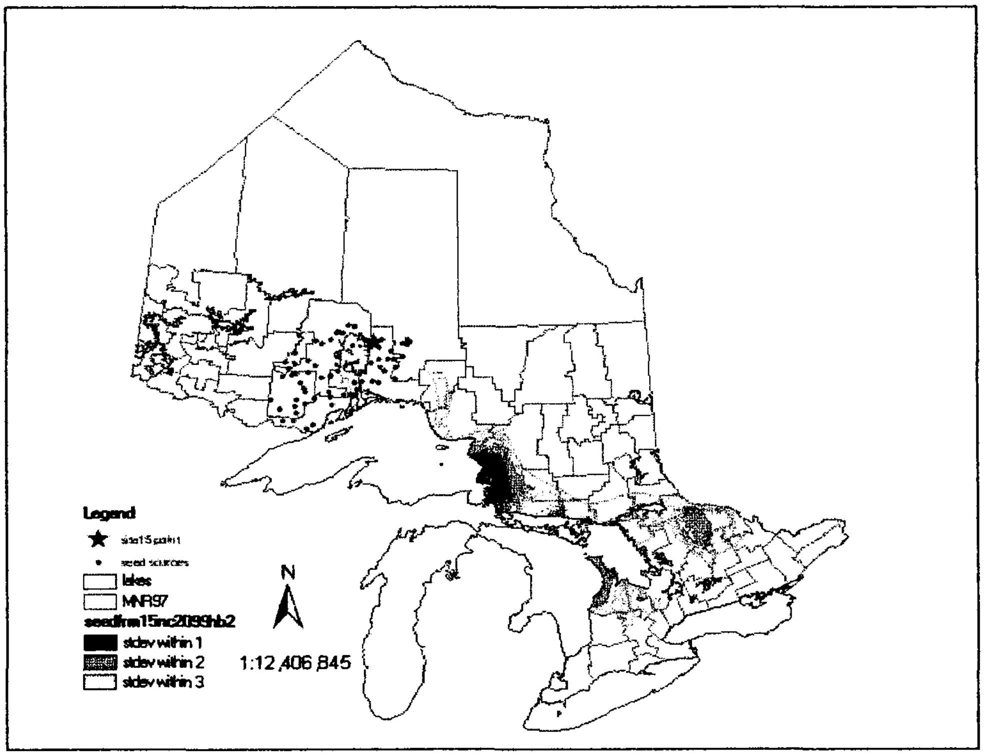
Best '*Seed From*' transfer zone in 2050 to best match climate of point 50.1°N, 87.9°W based on HADCM3A2



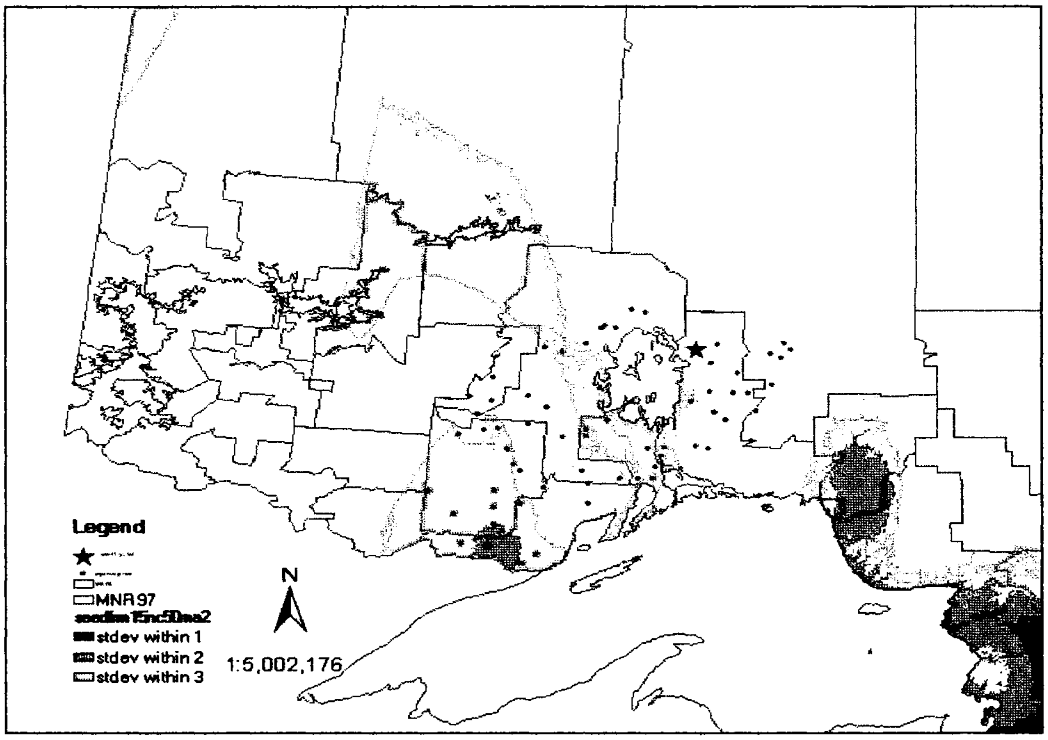
Best '*Seed From*' transfer zone in 2099 to best match climate of point 50.1°N, 87.9°W based on HADCM3A2



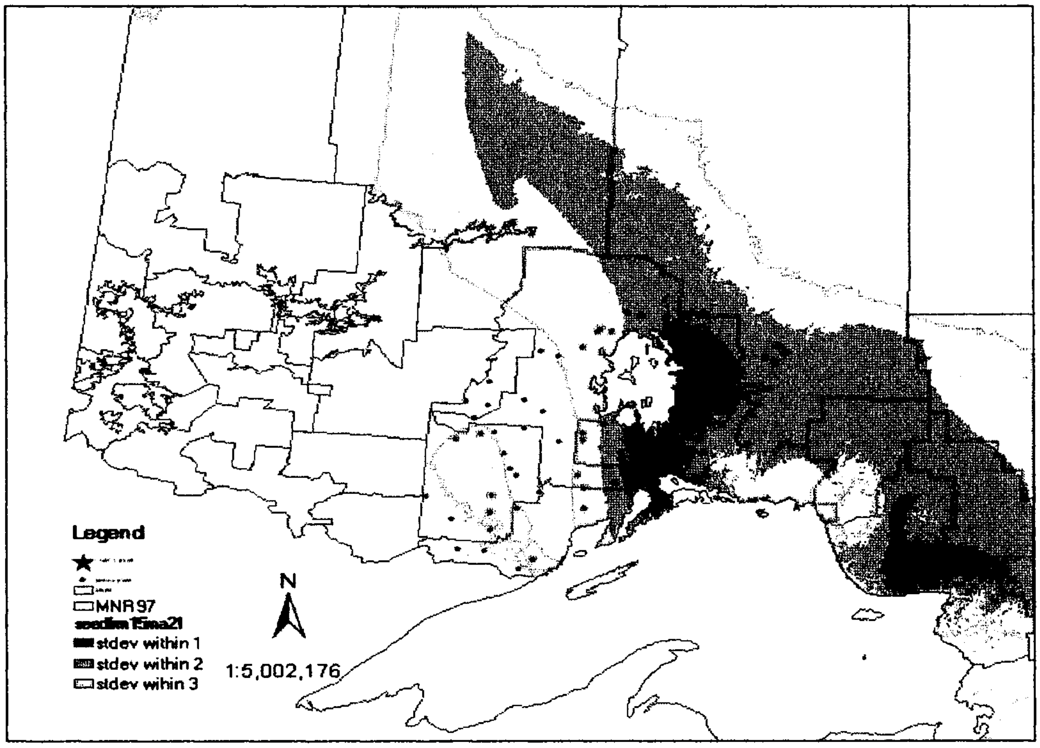
Best '*Seed From*' transfer zone in 2050 to best match climate of point 50.1°N, 87.9°W based on HADCM3B2



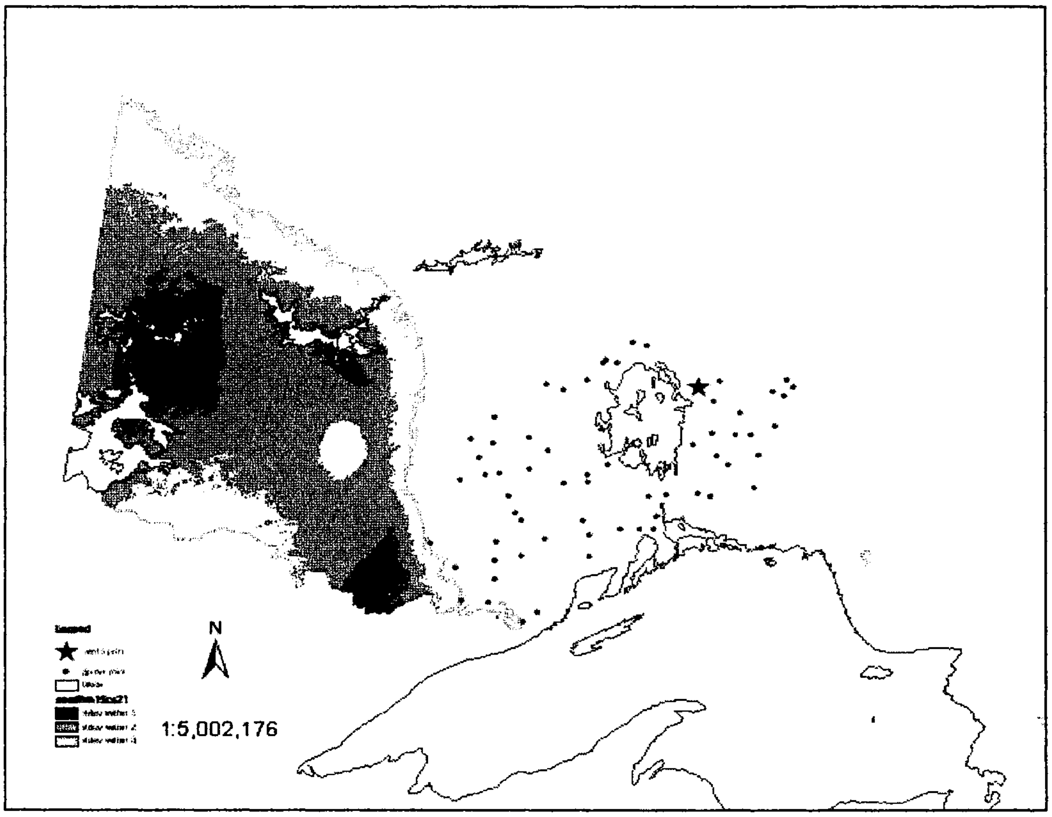
Best '*Seed From*' transfer zone in 2099 to best match climate of point 50.1°N, 87.9°W based on HADCM3A2



Best '*Seed From*' transfer zone in 2050 to best match climate of point 50.1°N, 87.9°W based on CGCM2A2



Best '*Seed From*' transfer zone in 2099 to best match climate of point 50.1°N, 87.9°W based on CGCM2A2



Best '*Seed From*' transfer zone in 2099 to best match climate of point 50.1°N, 87.9°W based on CSIROB2