GENECOLOGY, PATTERNS OF ADAPTIVE VARIATION AND A COMPARISON OF FOCAL POINT SEED ZONE DEVELOPMENT METHODOLOGIES FOR WHITE SPRUCE (*Picea glauca*)

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MAJOR ADVISOR'S COMMENTS

ABSTRACT

Lesser, M.R. 2005. Genecology, patterns of adaptive variation, and a comparison of focal point seed zone development methodologies for white spruce (*Picea glauca*). Master of Science in Forestry, Lakehead University. Advisor, Dr. W.H. Parker.

Key Words: white spruce, *Picea glauca*, seed source, provenance trial, genecology, adaptive variation, focal point seed zones, seed transfer.

Ecologically based management of white spruce (*Picea glauca* [Moench] Voss.) requires an understanding of its patterns of adaptive variation. Six common garden trials and a greenhouse trial established in 2002 and 2003 across Ontario were used to assess levels of genetic variation in 127 seed sources from Ontario and western Quebec and relate this variation to local climate. Using this information focal point seed zones were developed. The focal point seed zone methodology determines spatially explicit areas of ecological compatibility for any selected point. This approach will assist in properly matching seed sources and planting sites based on current and predicted future climate conditions.

Growth and phenological variables, including height, root collar diameter, survival, budflush timing, and budset timing were measured. Intraclass correlation coefficients were calculated for all traits to determine levels of genetic variation. Levels of between-provenance genetic variation ranged from 0 percent for several of the budflush variables, up to 22 percent of the total amount of variation expressed for 2003 survival at the Englehart field trial. Overall, growth variables showed higher levels of between-provenance variation than phenological variables. Simple linear regressions were used to relate these differences to local climate conditions. Variation was explained by a wide range of temperature and precipitation related variables. Late budset stages, which had r^2 values ranging from 0.55 to 0.46, were explained by temperature and precipitation variables related to the growing season. Generally, the primary patterns of adaptive variation followed a southeast to northwest trend across Ontario. A secondary east-west trend was evident in northwestern Ontario. Northern sources flushed earlier and set bud earlier, while southern sources demonstrated superior growth. Results support previous white spruce genecology studies showing superior growth of sources from the Ottawa Valley region of Ontario and Quebec.

Two statistical approaches were used to develop focal point seed zones. The first used principal components analysis (PCA) to summarize patterns of variation based on selected variables. Provenance factor scores were then regressed against climate variables and the resulting equations used to model the PC axes. The second approach used canonical correlation analysis (cancorr) to simultaneously find the relationship within and between biological and climate data sets. Standardized climate coefficients

from each significant canonical variate were used to model patterns of adaptation. For both methods parallel seed zones were constructed using GIS tools to intersect grids standardized to sample points selected from across the study area. Results showed overall similar trends for the two methods, however, cancorr based zones showed stronger longitudinal trends for northern points and became more fragmented for southern points. Cancorr zones were also more affected by lake shore effect from Lake Superior and Georgian Bay than regression based zones.

TABLE OF CONTENTS

TABLES

FIGURES

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CHAPTER I
INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

White spruce (*Picea glauca* [Moench] Voss.) has a transcontinental range in North America and is found extensively throughout both the Boreal and Great Lakes-St. Lawrence forest regions of Ontario (Rowe 1972, Nienstaedt and Zasada 1990). Despite its widespread distribution and the high quality of both its lumber and pulp, research and tree improvement efforts for this species have fallen far behind Ontario's two most economically important boreal species – black spruce (*Picea mariana* [Mill] B.S.P.) and jack pine (*Pinus banksiana* Lamb.). As forest management in Ontario is becoming more balanced and accountable, more attention is being paid to reforestation and afforestation of white spruce together with a renewed interest in starting a comprehensive tree improvement program for this species.

Although often taken for granted or simply ignored, one of the most important decisions that a forester can make is proper seed selection – no amount of intensive silviculture will produce acceptable growth if maladapted seed is used (Yeatman 1976, Rehfeldt 1982, Morgenstern 1996). This is why seed zones have to be developed based upon demonstrated patterns of adaptive variation on a per species level. Wise selection of seed source may result in significant gains. Carlisle and Teich (1971) presented a model indicating that a fifteen percent increase in yield could be expected by using superior provenances of white spruce. Likewise, the ultimate success of any tree improvement program depends on the proper delineation of breeding zone boundaries based upon the species' pattern of adaptive variation. While generic seed zones and breeding zones based upon climate have been established in Ontario, these can be, and most definitely should be, refined based upon biological test data representing adaptive variation as it becomes available.

The purposes of this thesis were threefold. The first objective, covered in Chapter Two, was to determine levels and patterns of adaptive variation of white spruce in Ontario. Determination of these patterns of adaptive variation will not only be important to the forest industry in terms of maximizing fibre production through the use of the best adapted seed, but also to our understanding of biodiversity in white spruce at the genetic level.

The second and third objectives were to develop continuous, or focal point, seed zones for white spruce across Ontario and western Quebec using two different statistical approaches. First, in Chapter Three the principal components analysis and multiple regression methodology, previously employed by Parker (1991) and Parker and van Niejenhuis (1996a, 1996b) to delineate focal point seed zones for black spruce and jack pine in northwestern Ontario, was used.

Chapter Four deals with an alternative methodology to develop focal point seed zones. This second approach used canonical correlation analysis (cancorr) as an alternative statistical technique in identifying patterns of variation in relationship to climatic factors. Although Parker and van Niejenhuis (1996b) found this approach less satisfactory for focal point seed zone development with black spruce, cancorr is statistically a more favourable method and highly suitable for ecological applications such as seed zone development (Gittins 1985, Westfall 1992). While the lack of an independent data set suitable for model validation makes comparison of the two methodologies somewhat ambiguous in terms of which is actually showing the truer pattern of adaptation, it is possible to draw comparisons and make inferences based on visual and intuitive interpretation.

Project goals were accomplished through the establishment of six common garden, or provenance, field trials and one greenhouse trial. Three seasons of measurements were carried out to determine levels and patterns of variation that were related to climatic factors and mapped. Building on these patterns of adaptive variation and through the use of GIS tools, focal point seed zones can be created, using either of the two methodologies mentioned above, for any point within the study area. The focal point approach allows a unique seed zone to be delineated for any selected point, with the basis of the zone being true adaptive variation for the species; not boundaries imposed by management jurisdictions or untested climatic gradients. In its fully developed stage this approach will be an interactive operational tool available to forest managers to help aid in reforestation decisions. This approach will also provide the means to help define breeding zones, and provide the basis for developing a gene conservation strategy for white spruce. At a future date, the same models of adaptive variation may be used to determine the necessary changes in seed zones and breeding zones resulting from a changing global climate.

LITERATURE REVIEW

SILVICS

White spruce has a transcontinental range in North America (Figure 1), extending from Newfoundland in the east to Alaska in the west. The northern boundary of its range travels along the tree line from Labrador to Hudson Bay and into Nunavut, Northwest Territories, and Yukon. The southern extent of the range extends across southern British Columbia, the Canadian Prairies and into the Lake States and northern New England (Nienstaedt and Zasada 1990).

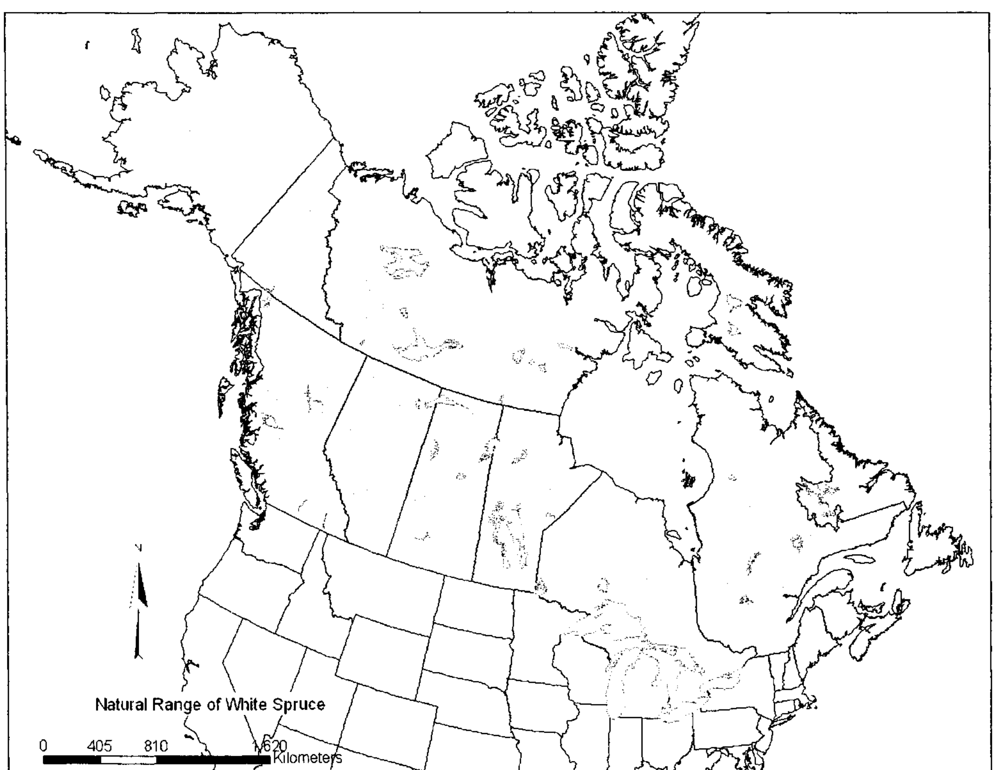

Figure 1. Native range of white spruce (U.S. Dept. Interior 2004)

White spruce occupies an elevational range between sea level and approximately 1520 metres. In western areas of its range (British Columbia, Montana and Wyoming) white spruce overlaps with Engelmann spruce (*Picea engelmannii* Perry ex Engelm.). White spruce predominates at lower elevations up to 1520 metres, with Engelmann spruce occurring above 1830 metres altitude. Hybridization is common on intervening slopes and shows a strong continuous cline from lower altitudes where white spruce occurs in a pure form, to the alpine timberline where nearly pure Engelmann spruce exists (Daubenmire 1974). White spruce also hybridizes with Sitka spruce (*Picea sitchensis* [Bong.] Carr.) throughout north coastal British Columbia and south coastal Alaska, especially along river drainages where white spruce occurs at higher elevations and Sitka spruce at lower elevations near the coast (Copes and Beckwith 1977).

Natural hybridization between white and black spruce is rare, if not non-existent, most likely due to asynchronous female receptivity (Niensteadt and Zasada 1990), and although occurrences have been reported in Minnesota, British Columbia, and along the tree-line in northern forest tundra (Little and Pauley 1958, Larsen 1965, Roche 1970), a study by Parker and McLachlan (1978) showed no evidence of natural hybridization occurring between the two species.

White spruce grows in a wide array of climatic and edaphic conditions. Minimum winter temperatures reach as low as -54° Celsius in northern parts of the range, while summer temperatures reach as high as 43° Celsius in Manitoba (Niensteadt and Zasada 1990). Annual Precipitation amounts range from 1270mm in eastern portions of the range to 250 mm in the Northwest Territories, Yukon and parts of Alaska. The growing season varies from approximately 180 days in Maine to only 20 days in northern Canada; however, the growing season generally exceeds 60 days

(Niensteadt and Zasada 1990). Soil types can be glacial, lacustrine, marine, or alluvial origin. Soil can be acidic or alkaline, with pH values ranging from 4.7 to 7.0. White spruce can also tolerate a range of fertility levels and moisture conditions. While white spruce is capable of growing on a diverse range of sites it is generally more demanding than associated conifers in terms of achieving best development (Niensteadt and Zasada 1990).

GENETIC VARIATION

Genetic variation in plant species is of great importance to forestry, agriculture and to a general understanding of fundamental biology (Linhart and Grant 1996). Of specific interest to this study is the interaction of genetic variation with environmental factors that leads to patterns of adaptive variation across the landscape. This variation can be either clinal or ecotypic depending on the environmental factors controlling it (Zobel and Talbert 1984).

Extensive literature exists on patterns of geographic variation for a multitude of plant species clearly illustrating the link between environmental differences and genetic heterogeneity (Linhart and Grant 1996). Work done throughout the early and middle parts of the twentieth century clearly showed that morphological and physiological traits of most woody plant species had high levels of genetic variation that could be associated with environmental factors (Libby *et al.* 1969). Hamrick *et al.* (1992) suggests that high levels of genetic diversity in woody plants are most probably a result of large continuous population ranges, large size, a relatively long life span, predominately out-crossing breeding systems, and relatively long distance seed and pollen dispersal.

Allozyme studies have shown that tree species show the highest amounts of genetic diversity in comparison to other plants (Hamrick 2004). While the significance of such high levels of diversity is not understood the processes behind its maintenance is thought to be associated with the wide range of selection pressures that trees experience over their relatively long lives and large geographic ranges (Godt *et al.* 2001). However, the bulk of this diversity is within populations, not among populations, and it has been shown that generally, genetic marker data does not reflect the usually much higher amount of diversity occurring in quantitative traits. While useful for observing overall levels of diversity in species and populations, allozyme data has limited use for ecological studies concerned with adaptive trait differences (Mullin and Bertrand 1999). Quantitative traits have been found to be far more useful in revealing adaptive variation. However, quantitative trait diversity, while present amongst populations, is also predominately found within populations (Hamrick 2004).

White spruce is considered, genetically, a highly variable conifer species (Nienstaedt and Teich 1972, Hamrick *et al.* 1992). Allozyme studies have shown total genetic diversity levels between 0.21 and 0.29. Diversity due to population differences, however, is much lower, ranging between 0.02 and 0.04 (Mullin and Bertrand 1999). Furnier *et al.* (1991) found no evidence of geographic trends in allozyme variation while height growth measurements for the same sources showed clear geographic patterns. A study on genetic structure of two white spruce populations in Newfoundland showed similar results in that while allozyme differences were found within populations, differences between populations were not significant and showed no geographic pattern (Innes and Ringius 1990). A study by Godt *et al.* (2001) showed a similar pattern of low levels of allozyme diversity amongst populations sampled from natural white spruce stands.

Evidence of clinal variation has been shown through numerous provenance tests for many quantitative traits. Early work utilizing 28 provenances from across the entire range of white spruce showed significant amounts of variation in 32 out of 36 measured traits. Measured traits included height, branching characteristics, needle morphology, bud timing and morphology, and component dry weights. Variation was explained by a combination of photoperiod, temperature regime and precipitation patterns (Niensteadt and Teich 1972).

In a study using 57 provenances from across Quebec and Ontario Li *et al.* (1993) found on average 3.1 percent of the total variation in growth characteristics attributable to between provenance differences. Khalil (1986) found significant between provenance variation for all measured traits in a range-wide greenhouse trial. Growth related variables that were measured included cotyledon numbers, hypocotyl length and four-month seedling height. Geographic trends were evident from regression against latitude and longitude showing both north-south and east-west gradients. A range-wide field trial located in Newfoundland of 32 provenances showed similar north-south and east-west geographic trends for height measurements taken at 20 years of age (Khalil 1985). Provenances from between 45 and 50 degrees latitude and 67 and 80 degrees longitude showed superior growth and form characteristics (Khalil 1985).

Phenological timing dictates the timing and duration of the growing season and reproductive period and is therefore considered an important adaptive trait (Chuine *et al.* 2000). Budflush timing in white spruce has been extensively studied. Later bud flush is useful in avoiding spring frost damage. Later flushing can also be a useful strategy in avoiding spruce budworm predation (*Choristoneura fumiferana* Clemens) (Pollard and Ying 1979, Blum 1988). Budflush timing has also been connected to seasonal changes in shoot water relations that affect drought tolerance, which can have implications on seedling survival (Grossnickle 1989).

Niensteadt and King (1969) developed a six stage scoring system for determining budflush timing. In a study on both clones and progeny a strong relationship (r^2= 0.994) between date of flushing and degree day requirements was found (Niensteadt and King 1969). Pollard and Ying (1979) in a study located in south-eastern Ontario showed high levels of differentiation within provenances that was strongly related to photoperiod. However, no significant variation between provenances was found (Pollard and Ying 1979). Li *et al.* (1993) also found no significant differences between provenances, located throughout Quebec and Ontario, for budflush date. However, this is thought to be a result of conditions at the nursery trial site, and perhaps not indicative of true field conditions (Li *et al.* 1993). Blum (1988) in a study located in Maine did find significant differences between provenances for date of budflush, with a slight north-south geographic trend being evident. In general Blum (1988) found that southern sources flushed later and also exhibited superior growth.

In terms of growth cessation, little work has been done with white spruce. Studies from other species, however, show budset occurring earlier as source latitude increases (Coursolle *et al.* 1998). In one study that was conducted on white spruce Coursolle *et al.* (1998) found no relationship between latitude of origin and shoot growth cessation. However only four provenances were used in the study and it is thought that the difference in provenance source locations may not have been extreme enough to detect differences. The same study did show a positive relationship between frost tolerance and increasing seed source latitude (Coursolle *et al.* 1998). Another study dealing with budset timing did find significant differences between provenances, with between provenance variation accounting for 5.2 percent of the total variation expressed (Li *et al.* 1993).

Simpson (1994) found evidence of geographic trends in bud cold hardiness of white spruce in British Columbia. Generally, buds from more northerly source trees were hardier in early fall than more southern source trees. The same trends were observed for cold hardiness in foliage and stem tissue.

Evidence has also been presented showing genetic variation in wood properties. Variation between provenances accounted for 11 percent of the total variation for wood specific gravity in a study on 23 provenances from the Great Lakes – St. Lawrence forest region (Beaulieu and Corriveau 1985). Another study in Quebec showed that 19 and 28 percent of the total variation in juvenile and mature wood density respectively, could be attributed to between provenance variation (Corriveau *et al.* 1987). Studies have also shown that significant gains, at the family level, could be realized in traits such as veneer quality, pulp fibre properties and tracheid length (Beaulieu 2003, Duchesne and Zhang 2004, Zhang *et al.* 2004).

A study on kiln-drying behaviour by Beaulieu *et al.* (2003) showed no differences between provenances. A study on decay resistance to white rot, brown rot and standing tree decay fungus also showed no significant differences between source origins, although differences were found in annual ring width (Yu *et al.* 2003).

Genetic resistance to insect predation and damage is of great concern, especially in intensively managed plantations. Spruce bud moth (*Zeiraphera Canadensis* Mut. & Free.) is one insect that can cause extensive leader damage in white spruce plantations

(Quiring *et al.* 1991). A study in New Brunswick showed relationships of half-sib families to susceptibility. A strong correlation between susceptibility and height growth was also observed, with least susceptible families showing the highest growth rates (Quiring *et al.* 1991). The study looked only at family differences, however, and tree origin was not considered. A study in British Columbia looking at genetic resistance of interior spruce to white pine weevil (*Pissodes strobi* Peck) showed source location as a significant source of variation for weevil attack. Analysis showed geographic patterns of resistance related to elevation, latitude and longitude (King *et al.* 1997). As with the New Brunswick study height growth was significantly related to resistance.

Edaphic variation has been found to exist among provenances (Nienstaedt and Teich 1972). Laboratory studies comparing growth of limestone and granite origin sources in different calcium concentrations showed evidence of genetic differences (Farrar and Nicholson 1967). This study, however, contained large amounts of unexplained variation and furthermore was unreplicated (Nienstaedt and Teich 1972). Another laboratory study showed evidence of genetic adaptation to soils high in nutrient availability, with progeny stem length and foliar calcium levels correlated with several parental soil elements (Cunningham 1971). Field tests have shown varying degrees of evidence for limestone ecotypes (Teich and Holst 1974, Timmer and Whitney 1983, Khalil 1985, Irving and Skeates 1988, Morgenstern and Copis 1999). Teich and Holst's 1974 study provides the most conclusive evidence in support of limestone ecotypes. Their findings, however, are contradicted by a more recent study based on 2001 measurements of the 410 Series of range-wide provenance tests, which found no evidence of limestone ecotypes in Ontario (Lesser 2003,Lesser *et al.* 2004).

PREVIOUS PROVENANCE TESTING IN ONTARIO

There have been three main series of provenance studies within Ontario over the course of the last 55 years. The oldest series of field trials is the 93 Series. This series of field experiments was implemented in 1953, in which thirty provenances from Ontario and western Quebec were planted at three field locations (Morgenstern and Copis 1999).

The 194 Series of provenance trials was the second experiment to be implemented. This experiment sampled 75 natural stands. Provenance locations ranged from New Brunswick and New York in the east to northwestern Ontario and the Lake States in the west. Nine field trials were planted in Ontario as part of this experiment (Morgenstern and Copis 1999). Both of these test series utilized experimental designs with large plots, few replicates, and occasionally very high densities (1.2 x 1.2 m). Site selection and maintenance was also often less than optimal. These issues create a variable and unreliable statistical efficiency for the trials and their usefulness is questionable (Morgenstern and Copis 1999).

The third series of trials implemented in Ontario was the 410 Series of range-wide provenance tests. This series of trials was implemented with the objectives of exploring genetic variation across the entire range of white spruce and to study within-region variability. Seedlots were obtained from 245 stands between 1972 and 1976 and field trials planted in Ontario between 1978 and 1985 (Morgenstern and Copis 1999). Fifteen trials were initiated in Ontario during this time.

Measurements from these trials all point to superior growth performance by Ottawa Valley seed sources in Ontario and elsewhere. Nicholson (1970) reports that the tallest provenances, growing at a field trial in Newfoundland utilizing 31 provenances from the 194 Series, were all from southern Ontario and adjacent Quebec. Growth of provenances from this region exceeded average growth by 15 percent. In central Ontario superior growth from the Beachburg-Douglas area of the Ottawa Valley has been shown in the 93, 194 and 410 Series trials (Focken 1992). Other reports also show provenances from this region performing above average throughout Ontario, and the northeastern United States (Nienstaedt and Teich 1972, Teich 1973, Teich *et al.* 1975). A more recent study by Brown (2001) using 194 Series data also showed that southern Ontario sources outperformed local sources in northwestern Ontario. Sarazin (2001) looked at 194 Series tests in the Petawawa Research Forest, and also found that southern sources performed the best.

SEED ZONE DEVELOPMENT

Seed zones can be defined as geographic subdivisions of a species range based on ecological and genetic criteria (Morgenstern 1996). A key element of seed zones is that they do not seek to optimize growth potential, but are developed to utilize the best adapted or local seed source. This goal can be seen as somewhat conservative and acting as a gene conservation measure (Morgenstern 1996).

The basis of seed zone development is the assumption that evolutionary forces have shaped native tree populations within any particular region, primarily through natural selection by climate and other ecological factors. As a result local populations are best adapted to that particular environment, and will also be less susceptible to native insects and diseases (Morgenstern 1996).

The process of microevolution for forest trees is wrought with unique barriers. Trees are long-lived, immobile and cover large geographic ranges and must therefore be adapted to heterogeneous environments (Rehfeldt 1984). Due to climatic fluctuation, seed dispersal and pollen migration native populations are not entirely restricted, but instead are equally well adapted to a certain range of conditions around their local. This allows for a level of movement away from any given location while maintaining the same level of fitness (Morgenstern 1996).

Depending on the species, population differentiation can take place across environmental gradients as small as a few metres, or in other populations over hundreds of kilometres (Bradshaw 1984). The distance itself has no direct bearing on the magnitude of the differences detected between populations. The actual pattern of differentiation is determined by the combined effects of natural selection, which tends to enhance differences, and migration, which tends to reduce differences (Bradshaw 1984). In the case of plants, which are essentially sedentary organisms, natural selection takes the dominant role over migration resulting in patterns of differentiation that closely follow environmental gradients (Bradshaw 1984).

Seed zones should be developed based on genetic information that is obtained from provenance testing or other genetic experiments (Morgenstern 1996). Provenance, or common garden, trials provide the simplest form of assessing patterns of variation, especially in regard to climate (Bradshaw 1984). Short or long-term provenance trials can be used to test for genetic differentiation among seed sources. The use of short-term trials makes the assumption that the study length, although short, is sufficiently long, and that environmental conditions differ sufficiently between trial locations (Westfall 1992). Given these conditions are met; data should reflect genetic differences across the study area. Long-term trials operate under the assumption that important changes in seed source ranking will occur both spatially, as with the short-term trials, and temporally as the trees age (Westfall 1992).

Campbell (1986) outlines assumptions implicit to seed zone development using not only his relative risk approach, but to all methodologies. These assumptions are 1) the area to be zoned is sufficiently sampled to determine true patterns of variation; 2) some adaptive variation can be attributed to the geographic origin of the parent tree and that this variation can be separated from other genetic and environmental variation; 3) seed source variation can be characterized by measurements of phenotypic traits in common garden environments; 4) the seed source variation can be related to measurable geographic or climatic attributes and can be mapped as a function of these attributes; 5) the resulting map of adaptive genetic variation is portraying the environmental complex active in natural selection; 6) a population is better adapted to its local conditions than any other population; 7) the relative risks in seed transfer indicated by seedlings are indicative of risks to older trees; and 8) seed transfer along any gradient imposes the same relative risk whether transfer is occurring to harsher or milder conditions.

In the absence of genetic information ecological criteria can be used (Morgenstern 1996). In Ontario, Hills site regions (Hills 1961) until recently formed the underlying basis of seed zones since the early 1970's (OMNR 1997). The Tree Improvement Master Plan for Ontario (OMNR 1987) clearly states that unless otherwise proven through testing, local seed will be used for reforestation practices. Seed zones have been fine-tuned based on the Ontario Climate Model (OMNR 1997). These seed zones are not species specific and used generalized climatic and ecological trends to delineate zones. Zones have been further modified based on management boundaries and practical limitations. In the absence of species-specific data, these generalized zones provide the best means of ensuring that maladapted seed is not used, and that seed movement is conservatively based. It is, however, recommended that as species level information becomes available it should be used to redefine seed zones for that particular species (OMNR 1997).

Discrete generic seed zones, such as those used in Ontario, have the advantage that administrative procedures for seed collection, storage, recordkeeping, identification, and distribution are all simplified (Morgenstern 1996). However, there are limitations created by the nature of discrete zones. Where environmental conditions are clinal, or continuous, discrete zone boundaries become artificial, and transfer of seed, especially from neighbouring areas, across these boundaries may be desirable (Morgenstern 1996).

The concept of continuous seed zones, or seed transfer guidelines, has existed since the middle of the twentieth century. Genetic-mapping procedures involve, at the simplest level, sampling indigenous trees within the prescribed study area, evaluating the genotypes of sampled trees, describing patterns of variation and quantifying risk in transfer (Campbell 1986). Olof Langlet, in Sweden, was the first to use multiple regressions in provenance studies and to demonstrate continuous variation in Scots pine (*Pinus sylvestris* L.) populations following a north-south transect (Langlet 1934, 1936). Lindquist (1948) shows mapped transfer guidelines for Scots pine across Sweden based on changes in latitude and elevation.

Since these initial efforts in Sweden there have been many more studies involving mapping seed transfer limits (Campbell 1986). A more recent study on Scots pine across the former Soviet Union showed high degrees of geographic differentiation based on height, diameter, stem straightness, and survival measurements from provenance trials. The study area was split into 10 seed-zones based on the information gathered (Shutyaev and Giertych 2000).

Griffin (1978) used regression models to explain patterns of variation in Douglas-fir (*Pseudotsuga menziesii* Mirb.) populations from coastal California. Elevation, latitude and distance from ocean explained 88 percent of the variation expressed between sources for epicotyl length after one growing season.

Campbell (1974) used timing of vegetative bud burst to determine seed transfer rules for Douglas-fir in western Washington and Oregon. Regression was used to correlate date of bud burst to temperature and seed transfer rules were developed based on distance from ocean, elevation, and latitude. For any given seed source predicted dates could be calculated for both the local and an introduced planting location. The difference between the two locations provided an index of the effect of transfer. A further study involved both phenological and growth traits in developing transfer guidelines for Douglas-fir (Campbell and Sorensen 1978). Limits on transfer depend on the regression slope along with an established criterion of acceptable adaptation (Campbell and Sorensen 1978). Relative risk of seed transfer can be quantified in terms of losses in growth and survival.

Campbell (1986) developed an index of relative risk in seed transfer for Douglas-fir in Oregon. The same methodology was used for sugar pine (*Pinus lambertiana* Dougl.) in southwestern Oregon (Campbell and Sugano 1987). This concept operates on the assumption that the degree of mismatch between the environment of the planting site and the home environment of the seed parents will differ, and that the degree of difference indicates the relative risk in seed transfer. An index can be developed by estimating the difference between frequency distributions of genotypes at the planting and seed source sites (Campbell 1986).

Providing further evidence that it is essential to model patterns of adaptation based on environmental factors, Campbell (1991) compared existing discrete seed zones and regional soils maps to models constructed from physiographic variables (e.g. latitude, longitude, distance from ocean, elevation, etc.). It was found that neither discrete seed zones or soils maps explained geographic variation in genotype to a satisfactory level. Physiographic variables accounted for significant levels of variation.

Beaulieu *et al* (2004) used the same relative risk approach as Campbell (1986) to develop seed transfer rules for black spruce in Quebec. Principal components analysis (PCA) of the genetic correlation matrix was used to summarize the variance followed by multiple regression to relate PC axes to geoclimatic variables. Regression equations were used to predict the mean genotypic value for any provenance. An index of seed transfer risk could then be determined based on the difference in frequency distribution between the seed source location and the intended plating site. Land classification units in southern Quebec were used as the basis of a GIS tool to determine relative risk of moving seed.

Rehfeldt (1982) used multiple regression to relate variation among populations to an array of geographic, ecologic and physiographic variables. Using the same regression techniques Rehfeldt (1981) developed mapped seed transfer guidelines for Douglas-fir in Northern Idaho. Further guidelines were developed for central Idaho and western Montana (Rehfeldt 1983a, 1983b). These guidelines present transfer risk as the percentage that populations differ genetically across environmental gradients. Limitations to seed transfer were defined as the minimum geographic or elevational interval across which genetic differences were detectable with a probability of approximately 80 percent. Contours, indicating relatively equal performance, were constructed based on one-half of the least significant difference among populations at the 80 percent level of probability. This relatively low level of probability was used in order to ensure type II errors, accepting no differences when differences really do exist, were not committed (Rehfeldt 1982). Contours could be used to define either discrete seed zones or floating transfer guidelines. It is noted that floating zones provide administrative flexibility with a single seed production area capable of serving several geographic bands, but that expanding the recommended limits of seed transfer increases risk of losses in productivity (Rehfeldt 1983a).

Test results from Idaho and Montana were synthesized into one study area using data scaling techniques (Rehfeldt 1988). Multiple regression was used to describe elevational and geographic patterns of variation. Geographic position and elevation were chosen over actual environmental factors due to the inaccuracy of climate data obtained from weather stations. It was felt that weather station data was both lacking in coverage and was also from predominately valley floor areas, or low elevations that did not truly represent the overall study area (Rehfeldt 1989). Results showed high correlations between elevation of the seed source, freezing injury and standardized height. Results are presented in the form of a three-dimensional grid with elevation, freezing injury and height forming the axes. This approach allows more than one variable to be considered simultaneously as opposed to the contour interval method used previously. Rehfeldt has also done similar work with lodgepole pine (*Pinus contorta* Dougl. ex Loud) (1988). This study showed regression results ranging from 43 to 77 percent, but utilized highly overfit models (models contained 9 to 16 variables).

A similar study addresses patterns of adaptive variation in ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) in central Idaho (Rehfeldt 1986). Seedlings grown in common garden tests were evaluated on growth and development characteristics. Shoot elongation was assessed in a greenhouse trial, and cold hardiness was also measured. Three regression models were developed to explain patterns of variation. The first model explained genetic variation in relation to elevation, the second explained genetic variation in relation to geographic variables not related to elevation, and the third explained variation as a combination of elevation and geography.

In a further study on ponderosa pine study areas throughout Montana and Idaho were combined (Rehfeldt 1991). This study used principal components analysis to summarize shoot elongation variables. Growth variables were also used in the analysis. Regressions against elevation, latitude and longitude produced significant equations that were used to produce univariate contour maps for each variable, based on a set elevation. Three-dimensional maps were produced based on elevation, latitude and longitude. These maps showed the actual geographic seed source location and could be used to group similarly performing genotypes. For any particular point, or site, populations could be shown that were genetically similar to that location. The underlying concept behind this mapping technique is that if sources are plotted into a two dimensional principal component space a confidence interval can be developed with points that fall within this interval being deemed genetically similar (Rehfeld 1990).

Building on the work of Rehfeldt (1984) and Campbell (1986), focal point seed zones, developed by Parker (1991) utilized GIS techniques to further refine continuous seed zone delineation. The focal point approach was applied to black spruce and jack pine in northwestern Ontario (Parker 1991, Parker and van Niejenhuis 1996a, 1996b)

Biological data was collected from short term common garden tests and a greenhouse trial. Variables were initially screened for evidence that they exhibited adaptive variation across the study area. The screening process was conducted in two stages. First analysis of variance was run and second variables were regressed against an array of climatic variables. The rationale behind this process was that traits that showed significant differences that could be related to an environmental factor were clearly exhibiting adaptive variation; and that only these traits should be retained for further analysis (Parker and van Niejenhuis 1996a).

Following the screening process principal components analysis was used to summarize the retained biological variables. Provenance factor scores were entered into multiple regressions against climatic variables. Resulting grids showed predicted patterns of variation for each modeled PC axis. Using GIS techniques these grids could be intersected, showing areas of overall adaptive similarity (Parker 1991, Parker and van Niejenhuis 1996a, 1996b).

The focal point seed zone approach allows a unique seed zone to be developed for any given point within the study area. The seed zone developed for that point will be unbiased with the criteria for source selection being driven by the site to be reforested (Parker 1991). Potential sources can be successively narrowed through decreasing the acceptable interval defining similarity. This criterion is similar to the approach developed by Monserud (1990). While based on the same principles as the focal point methodology, Monserud's approach was non-graphic; giving the user an effective interface, but not allowing for the interactive mapping capabilities that the focal point approach did. The focal point methodology is also applicable in defining breeding zones. Parker (2000) combined the use of the Differential Systematic Coefficient with focal point seed zone methodology to show the average rate of change in clinal adaptive variation over a geographic area. Breeding zones boundaries should be placed around areas where high rates of change are detected.

Although based on the same underlying principles presented by Rehfeldt (1988, 1989, 1991) and Campbell (1986, 1991) a slightly different approach to seed zone delineation using GIS techniques is given by Hamann *et al.* (2000). This study used ordinary kriging techniques to develop surfaces based on provenance means. This function calculated predicted values and the associated variances for unknown points. Maps constructed from these surfaces delineate seed zones based on the probability that any given source exceeds a threshold level of genetic differentiation.

All of the seed transfer guideline methodologies discussed to this point have operated under the basic assumption that the local population is the best adapted population for that site. An alternative assumption is that the local seed source may not be optimal in terms of the economic objectives of forestry due to an adaptational lag in response to continuously changing environmental conditions (Raymond and Lindgren 1990). Using non-linear methods it is possible to define the site that a given source will perform at its optimum and the range of sites that it can efficiently be utilized over. Kung and Clausen (1984) provide a graphical means of establishing suitable seed source and planting location based on best growth and survival parameters using a quadratic regression modal. Raymond and Lindgren (1990) and Lindgren and Ying (2000) use the Cauchy function to predict height growth in response to an environmental factor. The Cauchy function locates the condition that optimal performance will be achieved at and the loss in performance, or degree of maladaptation, that results in movement away from the optima; this function is considered to produce a better biological fit than a quadratic function (Lindgren and Ying 2000).

Roberds and Namkoong (1989) present another alternative methodology for predicting optimal growth performance. Using Gaussian functions population performance was calculated in response to a single environmental factor or an index of two or more environmental factors. A unique feature of this method is that it includes the distribution of environments as a factor in the assessment of value with rare environments being given little weight compared to common environments.

Another approach to seed transfer guidelines was developed by Matyas and Yeatman (1992) using a combination of ecological distance and mortality. Ecological distance was calculated as the change in environmental conditions between the source site and the planting location. The local source was given a value of 0 at any planting site, with differences taking on negative values as the source was moved to cooler or more northern environments, or positive values as the source was moved to warmer or more southern environments. Latitude and heat sum were found to be the decisive environmental factors.

As seed-zone determination continues to develop DNA markers may be utilized in identifying patterns of variation. One such study used DNA analysis in conjunction with traditional ecophysiological traits to identify population differences in British Columbian interior spruce (Sitka x white spruce), and used these differences to establish seed transfer guidelines (Grossnickle *et al* 1997).

CANONICAL CORRELATION ANALYSIS

Canonical correlation analysis (cancorr) is an alternative statistical technique to principal components analysis and multiple regression as previously used by Parker (1991) and Parker and van Niejenhuis (1996a, 1996b) to develop focal point seed zones. While still using the underlying principles put forth by Rehfeldt (1984) and Campbell (1986) cancorr offers an alternative and probably better statistical approach to determining relationships between biological and environmental variables (Gittins 1985). Gittins (1985) states that cancorr is the ideal statistical method for many ecological applications where a relationship between some set of biological variables and a set of environmental variables is desired.

Cancorr was first used in an ecological application by Austin (1968) in a study looking at differences in grassland communities. Since this time cancorr has received mixed reviews in its applicability to ecological problems. Studies have shown cancorr to be of little value (eg. Gauch and Wentworth 1976), while others have shown promising results (eg. Pélissier *et al.* 2001, Gimaret-Carpentier *et al.* 2003). Parker and van Niejenhuis (1996b) found cancorr to be less favourable than the principal component-regression based methodology in developing focal point seed zones for black spruce in northwestern Ontario, on the grounds that it created more geographic discontinuities and that the axes had no biological interpretation.

Westfall (1992) advocated the use of cancorr in developing seed transfer guidelines. Westfall pointed out that cancorr uses essentially the same theoretical mechanism as principal components analysis followed by multiple regression, but is more straightforward and can give more direct inferences about the original data. In developing seed transfer guidelines for white fir (*Abies concolor* [Gord. & Glend.] Lindl. ex Hildebr.) in California, cancorr was used to summarize biological variables in relation to geographic variables. Six canonical vectors were produced and the associated canonical scores were used to model patterns of variation. Regressions against canonical scores provided predicted scores that were plotted and could be used to assess transfer risk (Westfall 1992).

CHAPTER II
WHITE SPRUCE GENECOLOGY

INTRODUCTION

Patterns of variation in white spruce have been found to be generally clinal, following climatic and geographic gradients (Nienstaedt and Teich 1972, Morgenstern and Copis 1999). Also, evidence supporting ecotypic variation has been presented by Teich and Holst (1974), although this finding was not supported by a more recent study (Lesser *et al.* 2004). Significant differences have been found among white spruce provenances in terms of phenology, growth, wood density and other traits (Nienstaedt and Teich 1972, Beaulieu and Corriveau 1985, Khalil 1986, Blum 1988, Corriveau *et al.* 1987, Li *et al.* 1993). Differences between provenances have also been shown in allozyme studies although no geographic trend was evident (Furnier *et al.* 1991).

Based on the 194 Series of provenance tests Teich *et al.* (1975) found that non-local sources often performed better than local sources throughout Ontario. Other studies utilizing the 93 and 194 Series of provenance tests have shown superior growth from southern sources across much of the province (Focken 1992, Brown 2001, Sarazin 2001). Within Ontario the 410 Series of range-wide white spruce provenance-progeny tests has been the most extensive and useful to date in terms of establishing patterns of variation (Morgenstern and Copis 1999).

For the present study, a series of tests was planted in 2001 that utilized many of the same seed sources from the 410 Series. The goal of this study was to compare the results from the first two years of these tests to those of older tests in Ontario and to general patterns and levels of adaptive variation that have been found elsewhere for white spruce. A further goal was to relate seedling performance in a series of common garden trials to local climate variation.

METHODS AND MATERIALS

TEST ESTABLISHMENT

A total of 157 white spruce seed sources were seeded between January and March 2002 in the Lakehead University greenhouse. Seed sources were from across Ontario, western Quebec, and Manitoba. Seed were obtained through the Canadian Forest Service (CFS), the Ontario Ministry of Natural Resources (OMNR), Kimberly Clark, Weyerhaeuser, and Lakehead University specifically for this project in the summer of 2001. Most of the seed collections came from wild stands and were comprised of five or more open-pollinated families. Due to the scarcity of cones in western Ontario in 2001, the four sources provided by Weyerhaeuser from north-western Ontario were derived from open-pollinated families obtained from a seedling seed orchard.

Seed stratification began on December 24, 2001 and continued for three weeks prior to sowing in Jiffy pot 3065-140's. The total number of seedlings sown was just under 78,000. In order to maintain a reasonable test design and accommodate the size of the Lakehead university greenhouse the number of seed sources was reduced to utilize 132 provenances that were selected to give the most even distribution of source locations across Ontario and adjacent Quebec with one additional seed source from western Manitoba (Figure 2). Detailed location information for each provenance is given in Appendix I.

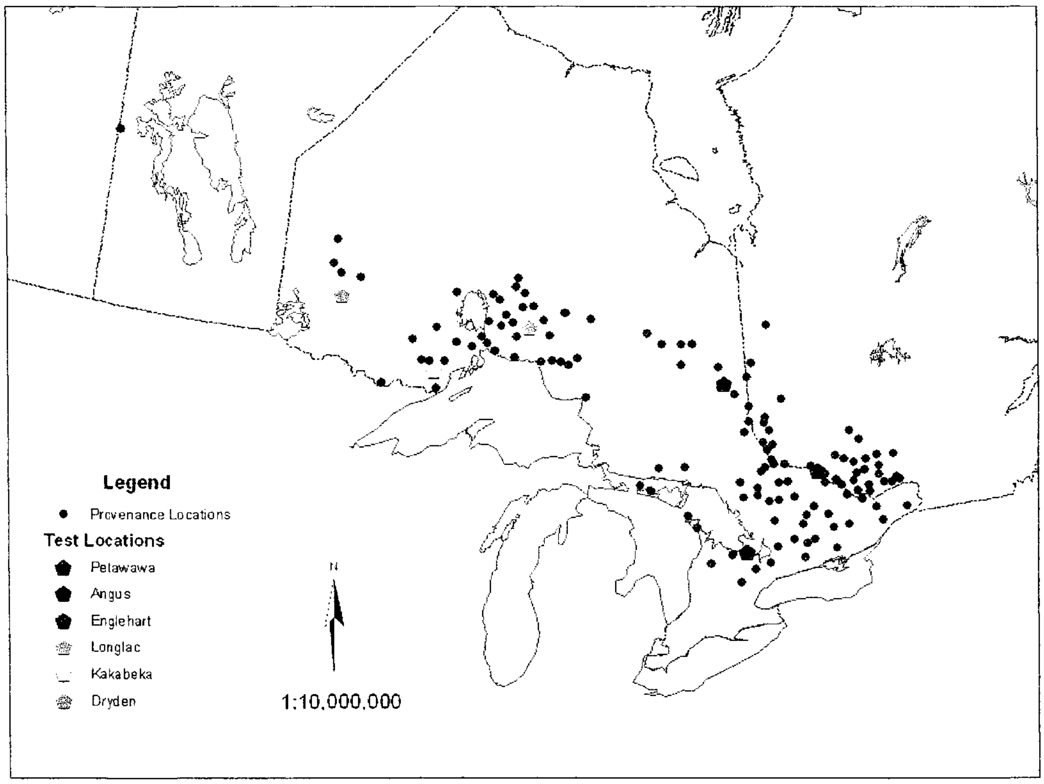

Figure 2. White spruce seed source and field trial locations

Following germination, seedlings were tagged and arranged within the greenhouse in a completely randomized design for six tests: 5 field trials and a greenhouse trial. Each test consisted of three blocks, each with 10 randomly located single tree plot repetitions for all 132 provenances. To facilitate this design each block was made 24 trees wide and 55 trees long. Each block was also surrounded by 2 rows of border trees to minimize edge effects and create a uniform growing environment for all test trees. This layout resulted in each of the 6 tests having a total of 4,956 seedlings (3,960 test trees).

Seedlings were hardened off beginning in mid-May 2002 to prepare them for field planting. This procedure was carried out through changes to the fertilizer treatment and by blacking out to reduce daylight hours. Seedlings were moved to an outdoor shade house in mid-June to further adjust them to field conditions.

Five field trials were planted in June and July 2002. Trial locations are referred to by the town or general area that they are located in. From west to east these trials are Dryden (with support from Weyerhaeuser), Kakabeka (with support from Bowater and Greenmantle), Longlac (with support from Kimberly Clark), Englehart (with support from Tembec), and Petawawa (with support from Tembec and Petawawa Research Forest). Trial locations are shown in Figure 2.

All tests were laid out prior to actual planting, with each plot being marked by a metal pin and tag bearing the provenance and repetition number. Two tests, Dryden and Kakabeka, were planted at 2 metre spacing. The remaining three tests, Longlac, Englehart, and Petawawa, were each planted at 1.8 metre spacing to accommodate test areas.

The greenhouse trial seedlings were allowed to recommence growing after the same dormant period as the field test seedlings. In November 2002 these seedlings were placed into cold storage at Hodwitz Nursery for over-wintering. The seedlings were brought out of cold storage and put back into their original design in the Lakehead University greenhouse on April 16, 2003.

Between August and October of 2003 a sixth field test was established at Angus with cooperation from the Ontario Seed Plant (Figure 2). This test utilized the seedlings from the greenhouse test. The test was laid out at 1.5 metre spacing.

DATA COLLECTION

Over the course of three field seasons, 2002, 2003 and 2004 growth variables were measured at the field trials and greenhouse trial. 2004 measurements included the Angus field trial which had been planted the previous fall. Growth variables included height for all three years and root collar diameter in 2003 and 2004. Heights were measured using a metal ruler and recorded in millimetres from the base of the seedling to the bottom edge of the terminal bud. Root collar diameters were measured using digital callipers and were recorded in millimetres.

Due to hardening off prior to field planting, height measurements for 2002 were not indicative of site location differences, and reflected greenhouse performance during the first growing season. Hence 2002 heights for all trials were treated as a single variable. Survival counts were also determined at each of the trials for all three years and used as variables in the ensuing analysis.

Phenological variables were measured in 2003. These variables were assessed at the onset of spring growth and onset of fall dormancy. Beginning in early May seedlings were scored for phase of bud flush based on a six stage system developed by Nienstaedt and King (1969) and used by Pollard and Ying (1979). Stage explanations are shown in Table 1.

Table 1. Phenological scoring stages for onset of spring growth

Phenological Stage	Score
Bud in winter condition	1
Bud just beginning to swell	2
Bud swelling	3
Bud green	4
Needles completely free of bud scales	5
Shoot beginning to elongate	6

Field trial and greenhouse seedlings were individually scored based on this system every 3 days until elongation began to occur. Field trial scores were based on the number of days from January 1, 2003, while greenhouse scores were based on the number of days after removal from cold storage. Shoot elongation increment was measured for the greenhouse trial five additional times following bud stage scoring. Measurements were made on a four day interval beginning May 3, 2003. Shoot elongation was measured in millimetres from the base of the terminal bud scar to the tip of new growth. The final total elongation measurement was taken on June 24, 2003 directly before hardening off was initiated.

Beginning in early August every seedling in each of the five field trials was individually scored for onset of dormancy. The scoring system was developed based on outwardly apparent changes that could be observed in the terminal bud of the seedling. Table 2 outlines the five stages that were assessed. Assistance in development of the index was provided by Dr. A. Macdonald (personal communication 2003). Stages identified for this study coincided well with a system of four budset stages developed by Beaulieu *et al.* (2004) for black spruce. Seedlings were scored every three days until the end of August.

Table 2. Phenological scoring stages for onset of fall dormancy

Phenological Stage	Score
No visible bud on terminal shoot	1
Bud visible and white	2
Bud fully swollen	3
Bud changing colour (beige)	4
Bud brown, scales visible (winter condition)	5

CLIMATE DATA

Climatic data for the period 1961 to 1990 were obtained from Dr. Dan McKenney, Canadian Forest Service, Landscape Analysis and Application Section, Great Lakes Forestry Centre (2004). Canada-wide grids along with point data for the 132 provenance locations were provided for sixty-seven climate variables. Maximum monthly temperature, minimum monthly temperature, and monthly precipitation constituted 36 of these variables. The remaining 31 variables were derived using the BIOCLIM/ANUCLIM and SEEDGROW prediction systems. These variables consisted of growing degree days, temperature and precipitation amounts by quarter and growing period along with growing season length, start time and end time. These variables may be more closely related to potential vegetation community responses than the primary climate variables (Mackey *et al.* 1996). Variables pertaining to quarter represent the three month blocks, starting at January 1, whether wettest, driest, warmest, or coldest. Variables designated by period are associated with the growing season. Period 1 corresponds to the three months prior to the growing season and is meant to provide an estimate of winter harshness and moisture availability. Period 2 corresponds to the first six weeks of the growing season and is meant to account for the main phase of leaf elongation. Period 3 corresponds to the entire growing season and period 4 corresponds to the difference between period 3 and 2 (period 3 – period 2) (Mackey *et al.* 1996). The growing season in this context was defined as starting at the point that, following March 1, there were 5 consecutive days where the mean daily temperature was greater than or equal to 5 degrees Celsius. The growing season is considered ended when the minimum temperature falls below -2 degrees Celsius following August 1 (Mackey *et al.* 1996). All variables are listed in Table 3, along with the range for the 132 provenance source points and the units of measure.

Table 3. Geographic and climatic variables with study area ranges and measured units

Definition	Range Min	Range Max	Units	Code
longitude	-101	-74	decimal degrees	long
latitude	43	52	decimal degrees	lat
elevation	15	640	metres	elev
mean diurnal range	8	13	C°	diurnran
isothermality 2/7	0.2	0.2	\	isotherm
temperature seasonality	3	5	C°	tempseas
max temperature warmest period	19	26	C°	maxtempwp
min temperature coldest period	-28	-11	C°	mintempcp
temperature annual range	34	52	C°	tempanran
mean temperature wettest quarter	-6	19	C°	mtempwetq
mean temperature driest quarter	-18	19	C°	mtempdryq
mean temperature warmest quarter	13	19	C°	mtempwarmq
mean temperature coldest quarter	-19	-5	C°	mtempcoldq
annual precipitation	548	1118	mm.	annprecip
precipitation of wettest period	78	116	mm.	precipwp
precipitation of driest period	20	72	mm.	precipdp
precipitation seasonality (c of v)	12	50	mm.	precipseas
precipitation of wettest quarter	226	335	mm.	precipwettq
precipitation of driest quarter	69	223	mm.	precipdryq
precipitation of warmest quarter	201	309	mm.	precipwarmq
precipitation of coldest quarter	69	303	mm.	precipcoldq
Julian day number of start of growing season	105	135	julian day	daystart
Julian day number of end of growing season	285	325	julian day	dayend
number of days in growing season	157	217	days	daygrow
total precipitation for period 1	84.1	229	mm.	tprecipp1
total precipitation for period 2	82.2	125.8	mm.	tprecipp2
total precipitation for period 3	348.7	608	mm.	tpprecipp3
total precipitation for period 4	259	506.8	mm.	tpprecipp4
gdd above base temp for period 3	946	1895	degree days	gddp3
annual mean temp	0	6	C°	annmtemp
annual min temp	-7	1	C°	annmintemp
annual max temp	5	11	C°	annmaxtemp
mean temp period 3	11	14	C°	mtempp3
Temperature range for period 3	21	28	C°	tempranp3
January mean monthly minimum temperature	-28	-10	C°	janmintemp
February mean monthly minimum temperature	-26	-11	C°	febmintemp
March mean monthly minimum temperature	-19	-6	C°	marmintemp
April mean monthly minimum temperature	-7	0.9	C°	aprmintemp
May mean monthly minimum temperature	0	6	C°	maymintemp
June mean monthly minimum temperature	5	11	C°	junmintemp
July mean monthly minimum temperature	8	14	C°	julmintemp
August mean monthly minimum temperature	7	13	C°	augmintemp
September mean monthly minimum temperature	2	10	C°	sepmintemp
October mean monthly minimum temperature	-2	5	C°	octmintemp
November mean monthly minimum temperature	-12	0	C°	novmintemp
December mean monthly minimum temperature	-22	-6	C°	decmintemp
January mean monthly maximum temperature	-14	-2	C°	janmaxtemp
February mean monthly maximum temperature	-11	-2	C°	febmaxtemp

Table 3. (cont.) Geographic and climatic variables with study area ranges and measured units

Definition	Range Min	Range Max	Units	Code
March mean monthly maximum temperature	-3	3	C°	marmaxtemp
April mean monthly maximum temperature	5	11	C°	aprmaxtemp
May mean monthly maximum temperature	13	19	C°	maymaxtemp
June mean monthly maximum temperature	16	23	C°	junmaxtemp
July mean monthly maximum temperature	19	26	C°	julmaxtemp
August mean monthly maximum temperature	19	25	C°	augmaxtemp
September mean monthly maximum temperature	13	20	C°	sepmaxtemp
October mean monthly maximum temperature	7	13	C°	octmaxtemp
November mean monthly maximum temperature	-4	6	C°	novmaxtemp
December mean monthly maximum temperature	-12	0	C°	decmaxtemp
January mean monthly precipitation	23	113	mm.	janprecip
February mean monthly precipitation	19	76	mm.	febprecip
March mean monthly precipitation	28	75	mm.	marprecip
April mean monthly precipitation	33	75	mm.	aprprecip
May mean monthly precipitation	49	87	mm.	mayprecip
June mean monthly precipitation	64	107	mm.	junprecip
July mean monthly precipitation	58	106	mm.	julprecip
August mean monthly precipitation	68	105	mm.	augprecip
September mean monthly precipitation	62	112	mm.	sepprecip
October mean monthly precipitation	38	107	mm.	octprecip
November mean monthly precipitation	29	116	mm.	novprecip
December mean monthly precipitation	25	116	mm.	decprecip

DATA ANALYSIS

Prior to analysis, the four sources collected by Weyerhaeuser in north-western Ontario (sources 127, 128, 129, 131), along with the source from western Manitoba (132) were removed from the data set. The decision to remove these sources from the analysis was made based on the poor performance of the four north-western sources in terms of growth and survival at all trials. This performance was not believed to be truly indicative of white spruce performance from north-west Ontario and was therefore distorting results. Although the removal of these sources decreased the study area extent it made the results far more reliable. Having removed these four sources from the analysis it was felt that the western Manitoba source was then too far removed from the rest of the study area to be included, so it too was removed. This removal resulted in the number of provenances included in the analysis totalling 127.

In the first stage of the analysis all variables were screened for data entry errors and outliers. Each variable was also checked to see if it followed a normal distribution. This was done by visually examining a histogram plot of the data, along with looking at the skewness and kurtosis values for the data set. The skewness measures the tendency of deviations in the data to be larger for one side of the distribution than the other; and the kurtosis measures the heaviness of the tails (SAS Institute 2000). In order for the data to be normally distributed both of these measures should be close to zero. Values beyond plus or negative one indicate that the data may not meet normal distribution requirements and a transformation is required.

Only survival variables needed transformation and were transformed using an arcsin transformation. The arcsin transformation acts to stretch out both tails of the distribution, while compressing the middle and is especially useful when dealing with percentage data, such as survival counts where the majority of the data falls outside of the 30-70 percent range (Sokal and Rohlf 1969).

All growth and phenological variables were tested by analysis of variance (ANOVA) for significant differences between provenances. All dependent variables were treated as random and the analysis was run using the GLM procedure in SAS (SAS Institute 2000). For each trial growth and phenological variables were run using the following model:

$$Y_{ijk} = \mu + B_i + \delta_{(i)} + P_j + BP_{ij} + \varepsilon_{(ij)k}$$

Where: i = 1 to 3 blocks;
j = 1 to 127 provenances;

k = 1 to 10 replicates of each provenance;

Y_{ijk} = the measured variable response of replication k of provenance j within block i;
μ = the population mean;
B_i = the random effect of the i^{th} block;
$\delta_{(i)}$ = the random effect of the randomization of the provenances within the i^{th} block;
P_j = the random effect of the j^{th} provenance;
BP_{ij} = the interaction effect of the i^{th} block with the j^{th} provenance;
$\varepsilon_{(ij)k}$ = the random residual error due to the k^{th} replication of the j^{th} provenance within the i^{th} block.

The expected mean squares associated with this model are shown in Table 4. Provenance tests against the block x provenance interaction term. Block tests against the restriction error. The restriction error has zero degrees of freedom thus there is no test for block effects (Lorenzen *et al.* 1993).

Table 4. Expected mean square table for growth and phenology variable ANOVA model

Source	D.F.	Expected Mean Square	Test Statistic
Block (B_i)	2	$\sigma^2 + 10\sigma^2_{BP} + 1270\sigma^2_{\delta} + 1270\sigma^2_B$	MS(B)/MS(δ)
Restriction error ($\delta_{(i)}$)	0	$\sigma^2 + 10\sigma^2_{BP} + 1270\sigma^2_{\delta}$	MS(δ)/MS(BP)
Provenance (P_j)	126	$\sigma^2 + 10\sigma^2_{BP} + 30\sigma^2_P$	MS(P)/MS(BP)
Block x Provenance (BP_{ij})	252	$\sigma^2 + 10\sigma^2_{BP}$	MS(BP)/MS(ε)
Experimental Error ($\varepsilon_{(ij)k}$)	3429	σ^2	

The model used to analyse the survival variables is modified to account for the lack of repetitions within blocks created by using the mean block value for each provenance to assess survival. The model is as follows:

$$Y_{ij} = \mu + B_i + \delta_{(i)} + P_j + \varepsilon_{ij}$$

Where: i = 1 to 3 blocks;
j = 1 to 127 provenances;

Y_{ij} = the measured variable response of provenance j within block i;
μ = the population mean;
B_i = the random effect of the i^{th} block;
$\delta_{(i)}$ = the random effect of the randomization of the provenances within the i^{th} block;
P_j = the random effect of the j^{th} provenance;
ε_{ij} = the random residual error due to the interaction of the j^{th} provenance with the i^{th} block.

The expected mean squares for the survival model are shown in Table 5. For this model, provenance tests against the error term. As with the preceding model there is no test for block effect due to the restriction term having zero degrees of freedom.

Table 5. Expected mean square table for survival variable ANOVA model

Source	D.F.	Expected Mean Square	Test Statistic
Block (B_i)	2	$\sigma^2 + 127\sigma_\delta^2 + 127\sigma_B^2$	MS(B)/MS(δ)
Restriction error ($\delta_{(i)}$)	0	$\sigma^2 + 127\sigma_\delta^2$	MS(δ)/MS(ε)
Provenance (P_j)	126	$\sigma^2 + 3\sigma_P^2$	MS(P)/MS(ε)
Experimental Error (ε_{ij})	252	σ^2	

Components of variance were calculated using the Varcomp procedure in SAS (SAS Institute 2000). The restricted maximum likelihood method (REML) was used for computing the variance components. Based on the components of variance, the intraclass correlation coefficient (ICC) was calculated for each variable. The ICC was calculated as the variation expressed between provenances divided by the total variation expressed for that trait. Total variation is calculated as the additive variation from the between block variation, the between provenance variation, the provenance-block interaction variation, and the error, or within provenance, variation. The equation used for the growth and phenological variables is shown in Equation 1.

$$\mathrm{ICC} = \frac{\mathrm{var}(prov)}{\mathrm{var}(block) + \mathrm{var}(prov) + \mathrm{var}(block\ x\ prov) + \mathrm{var}(error)} \qquad \text{(eq. 1)}$$

For the survival variables the equation used to calculate the ICC was modified so that total variation is the additive variation from the block, provenance and error variation (Equation 2).

$$\mathrm{ICC} = \frac{\mathrm{var}(prov)}{\mathrm{var}(block) + \mathrm{var}(prov) + \mathrm{var}(error)} \qquad \text{(eq. 2)}$$

Provenance mean values were calculated for each variable that showed significant differences, and simple linear regressions were run on these means against the 67 climatic and 3 geographic variables (longitude, latitude, and elevation). The purpose in calculating these regression models was to determine to what extent the variation expressed between provenances could be attributed to climatic effects. Longitude, latitude, and elevation were entered into the predictor variable set as surrogates for climatic influences not captured by the actual climate data.

Top performing provenances in terms of height growth were determined for all field trials for 2003 and 2004. Spearman rank correlations were calculated using the Corr procedure in SAS (SAS Institute 2000) to look at trends in provenance rank performance between trials and between years. This analysis provided insight not only into which provenances preformed the best, but also how provenances performed across trials and years.

Mapped patterns of growth and climatic variables are useful for comparison purposes to evaluate the utility of the models. To graphically show the observed patterns of variation, grids were produced using GIS tools. The Kriging raster interpolation method was used to create grids of measured variables based on the 127 source points using ArcMap 8.3 (ESRI 2002). The spherical semivariogram model was used along with the variable search radius. The search radius was set to 100 points with no maximum distance. These grids can be compared to the digital climate model that best predicted it (McKenney 2004).

RESULTS

ANALYSIS OF VARIANCE

Significant levels of between provenance differentiation were clearly shown for the majority of the 94 variables tested by ANOVA (Table 6). Of the 94 variables, 62 showed significant differences at the $p<0.05$ level. The variables that did not show significant differences were all phenological stage and survival variables. All growth variables (height, root collar diameter, and greenhouse elongation) at all tests showed significant differences at the $p<0.05$ level.

Mean heights in 2003 were similar at Dryden, Petawawa and Englehart, ranging from 156.75 to 152.66 mm. The Longlac trial had a mean height of 146.14 mm, and Kakabeka had the lowest mean height at 137.82 mm (Table 6). This last value is most probably a result of very low snowfall amounts in the Thunder Bay area during the 2002-2003 winter resulting in severe tip burning at the Kakabeka trial. The 2003 diameter means ranged from 4.01 mm at Englehart down to 3.51 at Kakabeka.

Trial mean heights in 2004 ranged from 318.57 mm at Angus to 187.6 mm at Longlac. The greater heights at the Angus trial are a result of 2 seasons of greenhouse growth prior to field-planting. Of the original five field trials, Kakabeka had the highest average growth at 272.1 mm. The Kakabeka trial showed the greatest amount of shoot elongation in 2004 increasing on average 134.3 mm, moving from the last ranked test in terms of height growth in 2003 to the highest ranked in 2004. The Longlac trial showed the least amount of growth in 2004, only increasing on average by 41.5 mm. Mean diameter in 2004 ranged from 5.88 mm at Petawawa to 4.43 at Kakabeka.

Provenance mean survival in 2002 was relatively constant for the Dryden, Kakabeka, and Longlac trials ranging from 88.8 percent at Longlac to 86.5 percent at Kakabeka. Englehart had a survival rate of 76.3 percent and Petawawa only had 54.2 percent survival. The lower survival rates at the Englehart and Petawawa trials can be attributed to high temperatures and little to no precipitation immediately following planting and continuing over the entire growing season. Survival in 2003 and 2004 remained relatively stable around initial levels at all of the trials except for Englehart and Longlac. In 2003 seedlings at the Englehart trial were subjected to major frost heaving that lowered mean survival to 57.9 percent. The Longlac trial, after having shown high survival rates at the end of 2002, showed a sharp decline in survival over both 2003 and 2004, resulting in a 2004 mean survival of only 45.7 percent.

Budflush values were consistently later at the Longlac, Englehart and Petawawa trials through the beginning stages; however, for the latest stage 6, Longlac (142 days) was similar to the other two northwest trials, Dryden and Kakabeka, ranging from 140 days in Dryden to 143 in Kakabeka. Englehart and Petawawa remained later at 147 and 145 days respectively. Early budset stages occurred at all trials within a four day period; however, most of these differences were not significant. This result was partly due to many of the seedlings having already passed the initial stages of budset when scoring commenced. Later stages of budset, which showed high levels of significant differences, indicated that the Dryden trial reached winter bud condition the earliest (223 days) and that budset came later to the east and south with the mean budset stage six value at Petawawa being 229 days.

ICC values ranged from zero percent for Kakabeka budflush stage 2 and 5, Longlac budset stage 2, Petawawa budset stage 2, and Dryden 2003 and 2004 survival, up to 26.27 percent for Englehart 2004 survival (Table 6). Generally, ICC values were higher for growth variables compared to phenological variables. Greenhouse budflush values, ranged from 0.99 to 8.79 percent, and were considerably higher than field trial budflush results which ranged from 0 to 3.21 percent. Overall, budflush ICCs were generally higher for the middle stages than beginning or end stages.

Budset ICC results ranged from 0 percent for Longlac stage 2 and Petawawa stage 2 to 10.41 percent for Kakabeka stage 4. Budset results showed higher ICC values in later stages, with stages 4 or 5 showing the highest values at every trial except Englehart where stage 3 showed the highest value (5.64%). ICC values for height ranged from 3.89 percent in Dryden for 2004 to 16.68 percent in Englehart for 2003. The 2002 height variable which reflects greenhouse growth showed a similarly high ICC (16.51%). Height ICC values decreased at all field trials, except Kakabeka between 2003 and 2004 measurements.

Root collar diameter ICC values showed a similar pattern with Englehart having the highest value (11.36% for 2003). Kakabeka showed the smallest amount of explained variation for the root collar diameter variables with 5.9 percent in 2003. ICC values for survival ranged from 0 percent for Dryden 2003 up to 26.27 for Englehart 2004. Similarly, the Englehart 2003 and 2002 survival variables also showed a high amount of genetic variation at 21.64 and 18.14 percent respectively.

Table 6. Mean, standard deviation, least significant difference and Intraclass Correlation Coefficient for 22 measured variables across 7 white spruce provenance trials

Measured Variable[a]	Dryden				Kakabeka				Longlac				Englehart			
	Mean	Std. Dev.	L.S.D.	I.C.C.(%)	Mean	Std. Dev.	L.S.D.	I.C.C.(%)	Mean	Std. Dev.	L.S.D.	I.C.C.(%)	Mean	Std. Dev.	L.S.D.	I.C.C.(%)
Ht03	156.75	55.45	48.59	6.20**	137.82	52.86	25.77	8.07**	146.14	44.30	26.51	14.17**	152.66	48.12	45.76	16.68**
Ht04	245.97	88.60	43.38	3.89**	272.08	91.21	44.96	8.89**	187.60	64.95	44.77	6.93**	239.48	81.38	47.82	11.01**
Dia03	3.69	1.12	0.98	7.35**	3.51	1.36	0.67	5.90**	3.87	1.28	0.79	7.40**	4.01	1.26	0.73	11.36**
Dia04	4.991	1.758	0.925	4.12**	4.43	1.62	0.79	7.97**	4.47	1.63	1.13	7.44**	5.41	1.82	1.06	10.97**
Surv02	87.64	6.35	10.10	2.12	86.52	7.58	11.96	1.97	88.75	4.76	7.24	9.26**	76.26	12.60	17.43	18.14**
Surv03	83.35	9.62	15.68	0.00	84.52	9.33	14.72	3.77	67.69	12.29	19.26	4.82	57.89	12.34	17.18	21.64**
Surv04	81.70	10.39	16.55	0.00	83.64	9.71	15.22	4.20	45.69	9.66	14.21	12.33**	57.39	12.49	16.44	26.27**
Budflush																
stage 2	122.68	7.53	3.89	1.49**	123.88	4.88	2.51	0.00	129.14	3.99	2.08	1.31**	129.81	9.36	5.85	0.38
stage 3	127.10	8.91	4.70	0.77**	126.99	5.32	2.84	0.20	132.31	3.95	2.06	3.11**	133.27	7.91	5.13	0.79
stage 4	129.68	7.27	4.05	1.33**	129.32	4.86	2.63	0.49	134.70	3.60	1.93	3.21**	135.66	6.91	4.55	0.19
stage 5	133.59	5.81	3.31	2.42**	133.59	4.35	2.40	0.00	138.31	2.89	1.71	2.41**	139.37	5.64	3.78	0.68
stage 6	140.02	4.91	2.91	3.05**	143.10	4.80	2.75	1.01*	141.98	2.83	1.76	1.29**	147.09	4.68	3.34	1.47
Budset																
stage 2	221.51	1.49	3.23	3.43	219.12	0.65	0.62	0.11	222.38	2.34	1.78	0.00	220.24	1.36	2.66	1.19
stage 3	222.22	2.01	3.66	1.11	220.38	1.79	1.04	3.50**	224.56	3.00	1.95	0.66	221.91	3.01	2.61	5.64**
stage 4	222.63	2.39	2.60	1.67	223.03	3.02	1.47	10.41**	226.51	3.64	2.22	2.58**	224.19	4.99	3.10	4.66**
stage 5	222.54	2.58	1.31	5.02**	227.42	3.55	1.84	6.65**	227.92	4.05	2.65	2.94**	228.60	4.07	3.22	2.27**

Measured Variable[a]	Petawawa				Angus				Greenhouse			
	Mean	Std. Dev.	LS.D.	I.C.C.(%)	Mean	Std. Dev.	LS.D.	I.C.C.(%)	Mean	Std. Dev.	L.S.D.	I.C.C.(%)
Ht02	\	\	\	\	\	\	\	\	110.97	34.12	6.25	16.51**
Ht03	156.28	58.64	33.70	8.65**	\	\	\	\	\	\	\	\
Ht04	234.44	87.19	50.82	7.53**	318.57	87.25	38.83	6.42**	\	\	\	\
Dia03	3.88	1.37	0.78	7.56**	\	\	\	\	\	\	\	\
Dia04	5.88	2.28	1.35	7.61**	5.76	1.25	0.59	8.92**	\	\	\	\
Surv02	54.21	20.42	16.78	3.57**	\	\	\	\	\	\	\	\
Surv03	59.41	16.68	18.14	0.73	\	\	\	\	\	\	\	\
Surv04	57.74	17.20	17.49	4.30**	86.13	8.27	12.00	8.34**	\	\	\	\
Budflush												
stage 2	130.02	11.94	7.04	1.64*	\	\	\	\	7.68	1.37	0.74	4.30**
stage 3	133.68	12.35	7.56	0.92	\	\	\	\	10.1	1.75	0.85	8.79**
stage 4	135.63	11.46	7.17	0.92	\	\	\	\	12.34	1.72	0.84	8.73**
stage 5	139.54	9.45	6.15	0.59	\	\	\	\	14.86	1.52	0.77	1.46**
stage 6	145.26	6.85	5.15	0.38	\	\	\	\	17.57	2.54	1.28	0.99**
Budset												
stage 2	222.37	1.52	2.89	0.00	\	\	\	\	\	\	\	\
stage 3	223.29	2.42	1.99	2.64**	\	\	\	\	\	\	\	\
stage 4	225.91	3.95	2.38	6.54**	\	\	\	\	\	\	\	\
stage 5	229.36	3.17	3.86	1.25	\	\	\	\	\	\	\	\
Greenhouse Elong.												
Day 18	\	\	\	\	\	\	\	\	20.28	5.9	3.03	5.80**
Day 22	\	\	\	\	\	\	\	\	38.31	11.06	5.47	4.98**
Day 26	\	\	\	\	\	\	\	\	54.76	13.94	6.96	3.75**
Day 30	\	\	\	\	\	\	\	\	72.73	17.51	8.66	2.43**
Day 70	\	\	\	\	\	\	\	\	269.1	61.8	28.67	13.61**

** - statistically significant at 0.05 level

* - statistically significant at 0.1 level

[a] Ht02 (height 2002), Ht03 (height 2003), Ht04 (height 2004), Dia03 (diameter 2003), and Dia04 (diameter 2004) measured in millimetres; Surv02 (survival 2002), Surv03 (survival 2003), and Surv04 (survival 2004) measured as percentage of surviving trees; field trial budflush and budset measured as number of days from Jan.1, 2003; Greenhouse budflush *and elongation (in mm.) measured as number of days from cold storage thawing.*

Greenhouse elongation ICC values ranged from 2.43 percent for shoot length on day 30 up to 13.61 for shoot length on day 70. Values dropped off from beginning dates and then increased dramatically between the last two dates.

REGRESSION ANALYSIS

Simple regression results of the 57 variables that showed significant regressions ($p<0.05$) against geographic and climatic predictor variables are shown in Table 7. Provenance mean values for each measured variable are shown in Appendix II. Provenance values for each climatic and geographic variable are shown in Appendix III. Coefficients of determination (r^2) values for significant regressions ranged from 0.55 for Kakabeka budset stage 4 down to 0.03 for Dryden and Kakabeka 2003 height, and Petawawa 2002 survival.

Height variables were explained predominately by temperature variables related to the summer months (Table 7). Mean temperature in the wettest quarter, which was selected 4 times as the best predictor, refers to the 3 month period of July to September. May maximum temperature, the temperature range and the mean temperature of period 3 (the growing season) were also selected. Longitude, which strongly influences precipitation patterns in Ontario and precipitation in the warmest quarter (July – September) were the only non-temperature related variables selected. Root collar diameter variables were predicted by longitude, total precipitation in period 4, and a mix of late spring/early fall temperature variables. Significant survival variables were all explained by temperature variables. Field trial growth and survival variables gave relatively lower r^2 values compared to greenhouse elongation and field trial phenological

Table 7. Simple regression results of 57 measured variables against geographic and climatic predictor variables

Measured Variable	R^2	Sig.	Retained Independent Variables[a]
Budflush			
Dryden stage2	0.06	0.0044	junmintemp
Dryden stage3	0.12	<0.0001	junmintemp
Dryden stage4	0.15	<0.0001	long
Dryden stage5	0.12	<0.0001	long
Dryden stage6	0.15	<0.0001	daygrow
Longlac stage2	0.14	<0.0001	long
Longlac stage3	0.18	<0.0001	long
Longlac stage4	0.17	<0.0001	long
Longlac stage5	0.13	<0.0001	long
Longlac stage6	0.05	0.0102	long
greenhouse stage2	0.10	0.0003	long
greenhouse stage3	0.14	<0.0001	long
greenhouse stage4	0.11	0.0002	long
greenhouse stage5	0.08	0.0011	junprecip
greenhouse stage6	0.06	0.0058	augprecip
Budset			
Dryden stage5	0.50	<0.0001	gddp3
Kakabeka stage3	0.45	<0.0001	gddp3
Kakabeka stage4	0.55	<0.0001	mtempwarmq
Kakabeka stage5	0.51	<0.0001	augmaxtemp
Longlac stage4	0.22	<0.0001	daygrow
Longlac stage5	0.29	<0.0001	tempranp3
Englehart stage3	0.33	<0.0001	novmaxtemp
Englehart stage4	0.44	<0.0001	gddp3
Englehart stage5	0.17	<0.0001	junmintemp
Petawawa stage3	0.18	<0.0001	dayend
Petawawa stage4	0.40	<0.0001	daystart
Height			
ht2002	0.05	0.0159	mtempwetq
Dryden ht2003	0.03	0.0356	mtempwetq
Kakabeka ht2003	0.03	0.0389	tempranp3
Longlac ht2003	0.08	0.0010	long
Englehart ht2003	0.05	0.0127	mtempwetq
Petawawa ht2003	0.09	0.0007	maymaxtemp
Dryden ht2004	0.07	0.0020	mtempwetq
Kakabeka ht2004	0.09	0.0005	maymaxtemp
Longlac ht2004	0.07	0.0020	long
Englehart ht2004	0.10	0.0004	mtempp3
Petawawa ht2004	0.11	0.0001	maymaxtemp
Angus ht2004	0.08	0.0016	precipwarmq
Diameter			
Dryden dia2003	0.07	0.0038	long
Longlac dia2003	0.17	<0.0001	long
Englehart dia2003	0.11	0.0002	long
Petawawa dia2003	0.07	0.0027	sepmaxtemp
Dryden dia2004	0.12	<0.0001	long
Kakabeka dia2004	0.04	0.0279	maymaxtemp
Longlac dia2004	0.10	0.0002	long
Englehart dia2004	0.17	<0.0001	octmaxtemp
Petawawa dia2004	0.13	<0.0001	sepmaxtemp
Angus dia2004	0.10	0.0002	tprecipp4
Survival			
Petawawa surv2002	0.03	0.044	mtempwetq
Englehart surv2003	0.08	0.0013	febmintemp
Englehart surv2004	0.10	0.0003	febmintemp
Longlac surv2004	0.10	0.0002	augmaxtemp
Greenhouse Elongation			
greenhouse Day 18	0.24	<0.0001	long
greenhouse Day 22	0.28	<0.0001	long
greenhouse Day 26	0.32	<0.0001	long
greenhouse Day 30	0.27	<0.0001	long
greenhouse Day 70	0.04	0.0351	tempran3

[a] see Table 3 for complete definition of independent variables

traits. The highest r^2 for a field trial growth or survival variable was 0.17 for the Longlac 2003 and Englehart 2003 root collar diameter variables.

Budflush r^2 values ranged from 0.05 for Longlac stage 6 up to 0.18 for Longlac stage 3. Generally, middle budflush stages showed the highest values within each trial location. Budflush variables were explained predominately by longitude. Budset variables were explained predominately by variables associated with the growing season. Late stage budset variables, which were best predicted by climate (r^2 of 0.55 for Kakabeka stage 4 to 0.29 for Longlac stage 5), all were related to growing season and summer month variables. These variables included growing degree days in period three (entire growing season), starting and ending date of the growing season, the number of days in the growing season, the temperature range during the growing season, and mean temperature in the wettest quarter (July - September). August maximum temperature and June minimum temperature were also indicated.

Greenhouse elongation regressions had relatively high r^2 values for the first four measurements (0.24 – 0.32). Longitude was selected for all four of these variables. Temperature range during the growing season was indicated for the fifth measurement time (day 70), but with a much lower r^2 value (0.04).

Six contour maps of measured variables are shown as examples (Figures 3-9). These six variables were selected in order to give a full representation of growth and phenological variables, and because of their relatively high levels of between-provenance variation and the degree to which that variation could be attributed to climate. Contour maps for the other 51 measured variables that expressed significant variation and had significant regressions are shown in Appendix IV. Contour maps of the other climate variables selected in the regressions are shown in Appendix V.

The contour map of mean height in 2004 at the Kakabeka field trial (Figure 3) shows the greatest heights in the south-eastern portion of the study area. Heights decrease to the west and north. Figure 4, mean diameter in 2004 at the Petawawa trial, shows a similar trend, with the largest diameters being in the south-east portion of the study area. Diameters decrease to the west and north, but show an increase to the west of Lake Nipigon.

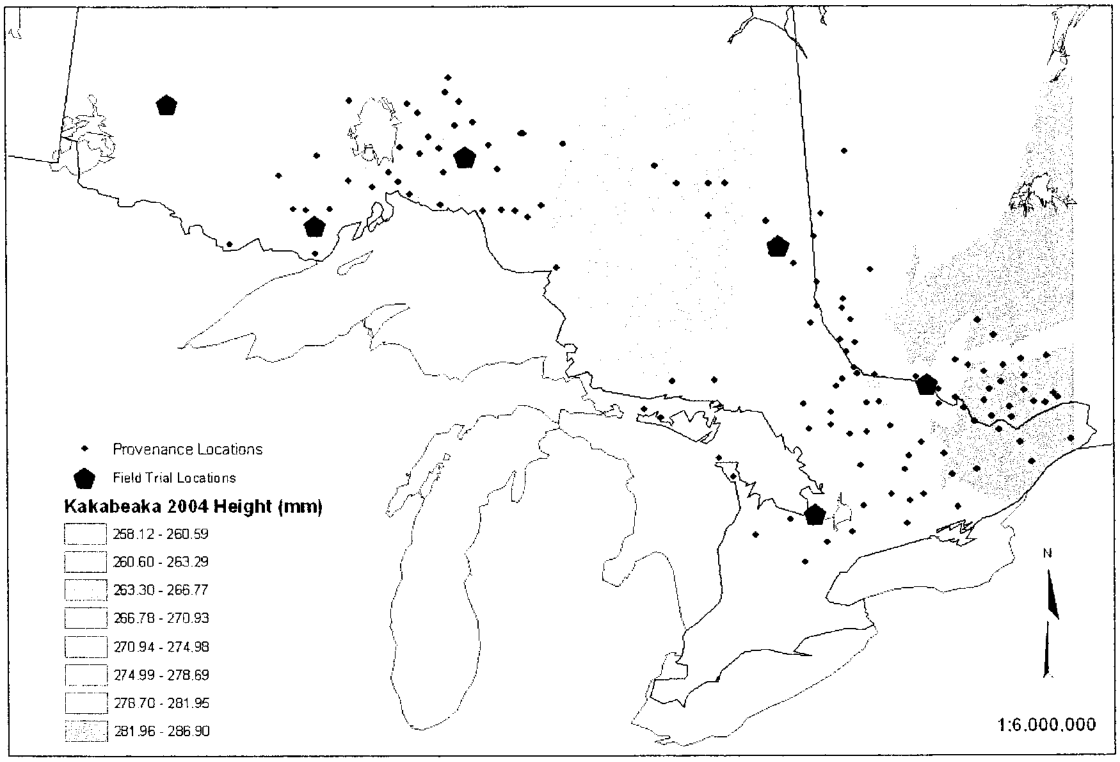

Figure 3. Contour map of mean height in 2004 at the Kakabeka field trial

The contour map for survival in 2004 at the Englehart trial (Figure 5) also shows the same trend. Survival in Englehart is greatest in sources from the southern area of the study, Survival decreases to the north, but increases again to the west of Lake Nipigon. February minimum temperature (Appendix V) was the best predictor for 2004 survival at Englehart. The clear north-south trend in the survival grid is indicative of the February temperature gradient.

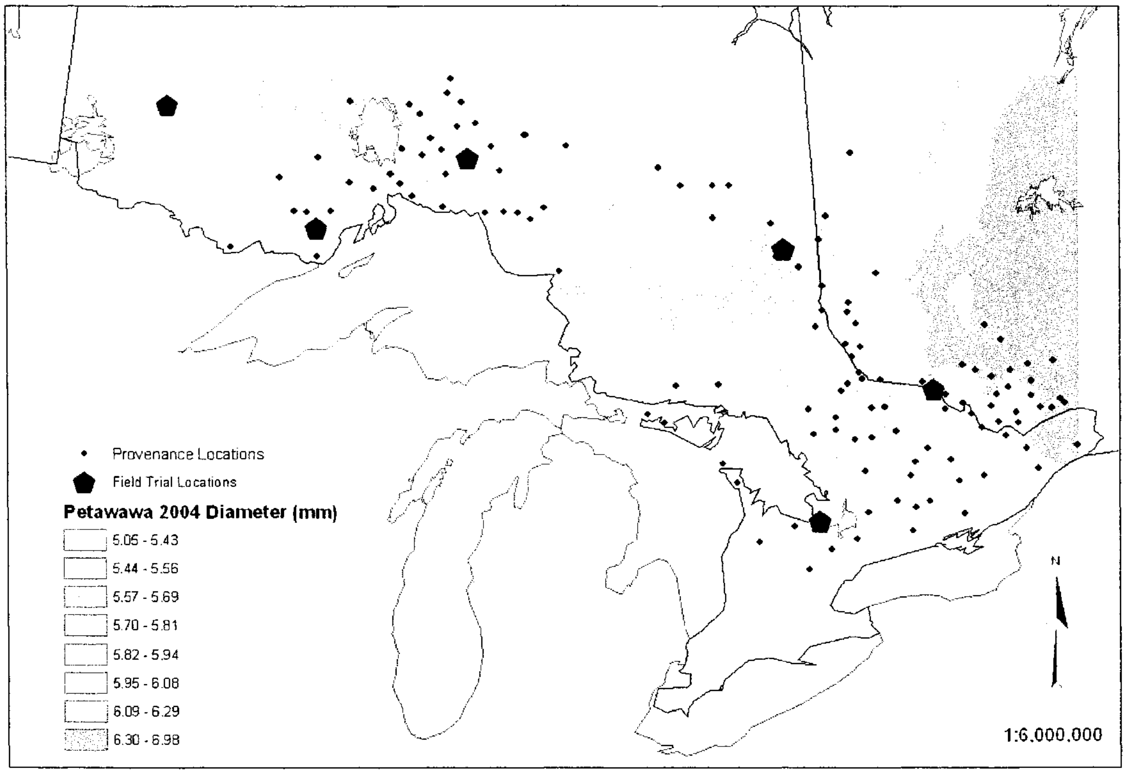

Figure 4. Contour map of mean root collar diameter in 2004 at the Petawawa field trial

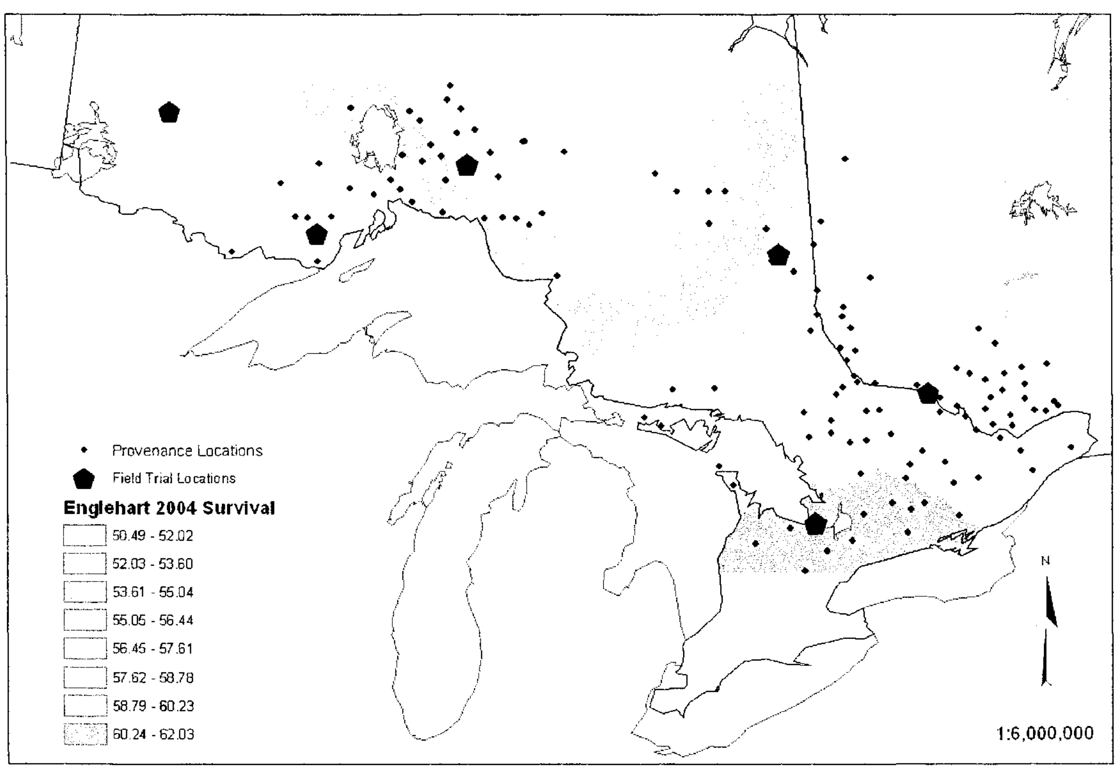

Figure 5. Contour map of mean survival in 2004 at the Englehart field trial

The contour map for shoot elongation at the greenhouse 26 days after removal from cold storage shows an opposite trend to what was seen for height, diameter, and survival (Figure 6). The greatest amounts of shoot elongation are in the north-west and north-central areas and elongation decreases to the south. This may be a result of southern sources flushing later and therefore not having had as long a period to grow as northern sources at the time of measurement. By the fifth elongation measurement on day 70, following removal from cold storage, southern sources were outperforming northern ones (Appendix IV). The influence of longitude as the best predictor of shoot elongation can be seen in the grid, especially moving across the northern portion of the study area. The influence of longitude is tempered by other factors off the eastern shore of Lake Superior and in the southern part of the study area.

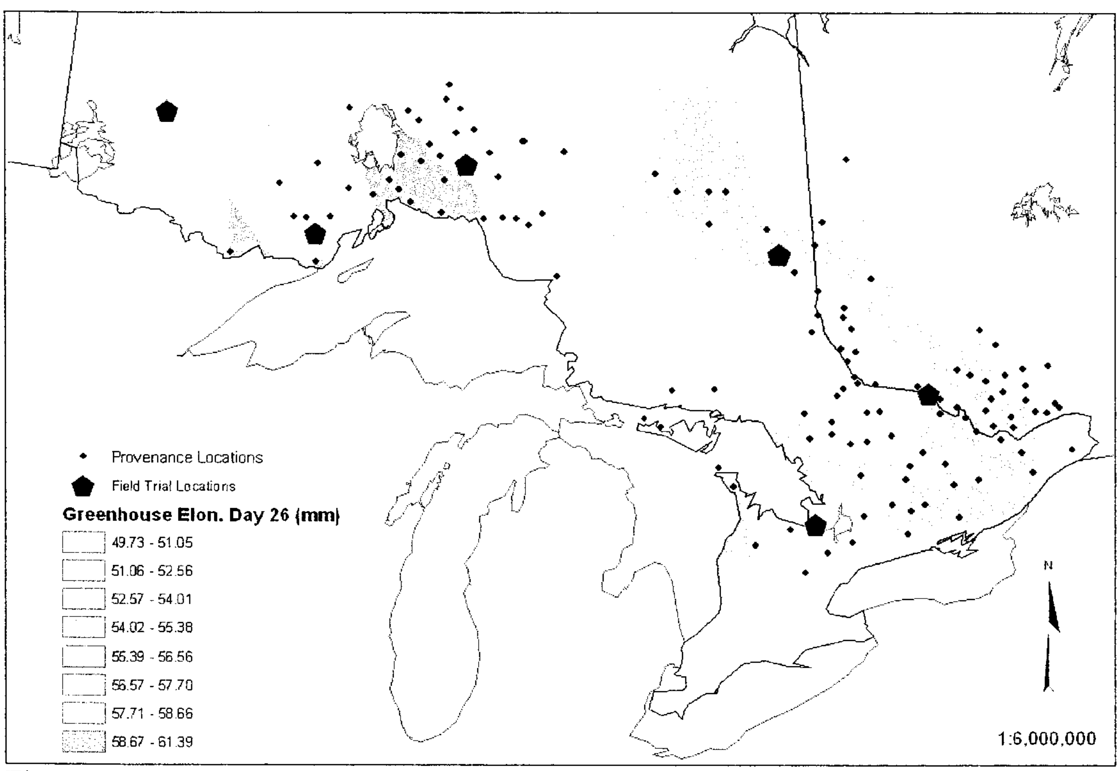

Figure 6. Contour map of shoot elongation at the Lakehead greenhouse trial 26 days after removal from cold storage

The contour map for the number of days from January 1st it took to reach budflush stage 3 at the Longlac trial shows that north-western areas and areas off the eastern shore of Lake Superior flushed earliest, with flushing occurring later moving east and south (Figure 7). A clear longitudinal influence, which was the variable picked as the best predictor, can be seen in the grid ($r^2 = 0.18$). The relationship, however, is clearly not linear across the study area and is influenced by other factors.

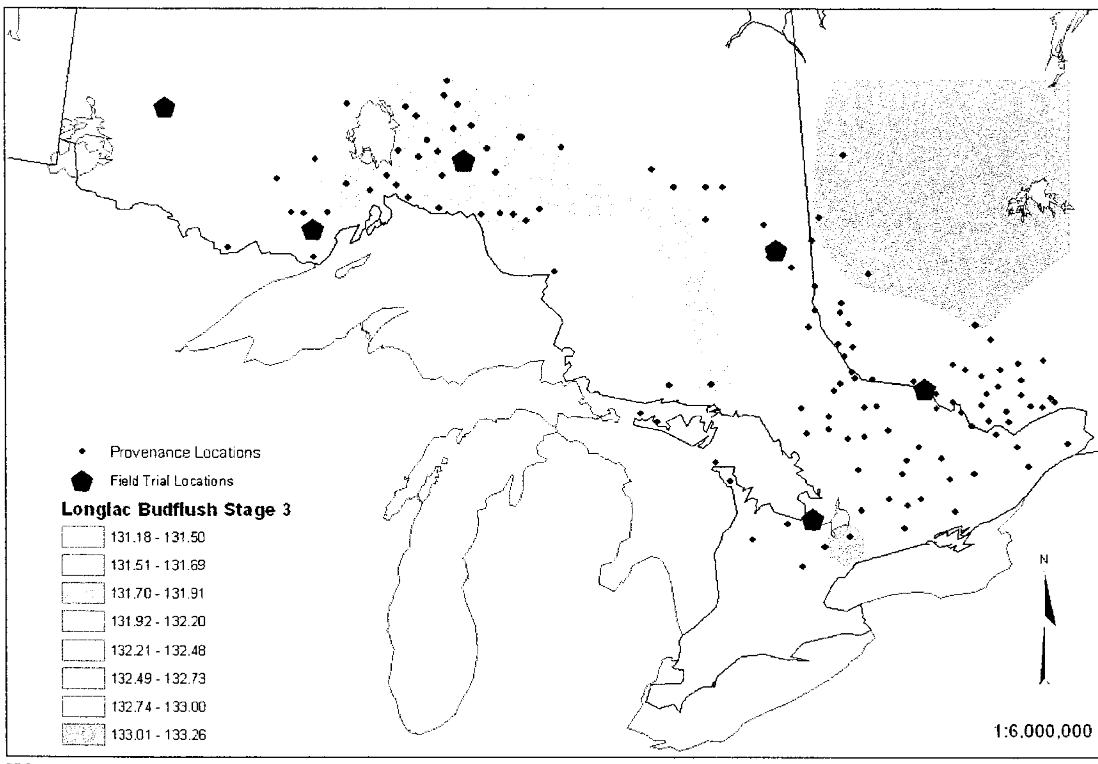

Figure 7. Contour map of mean number of days from Jan. 1 to reach budflush stage 3 at the Longlac field trial

The contour map for budset stage 5 at the Dryden trial shows a clear north-south trend (Figure 8). Budset occurred latest in the south-east and occurred earlier with movement north into north-eastern and north-central Ontario.

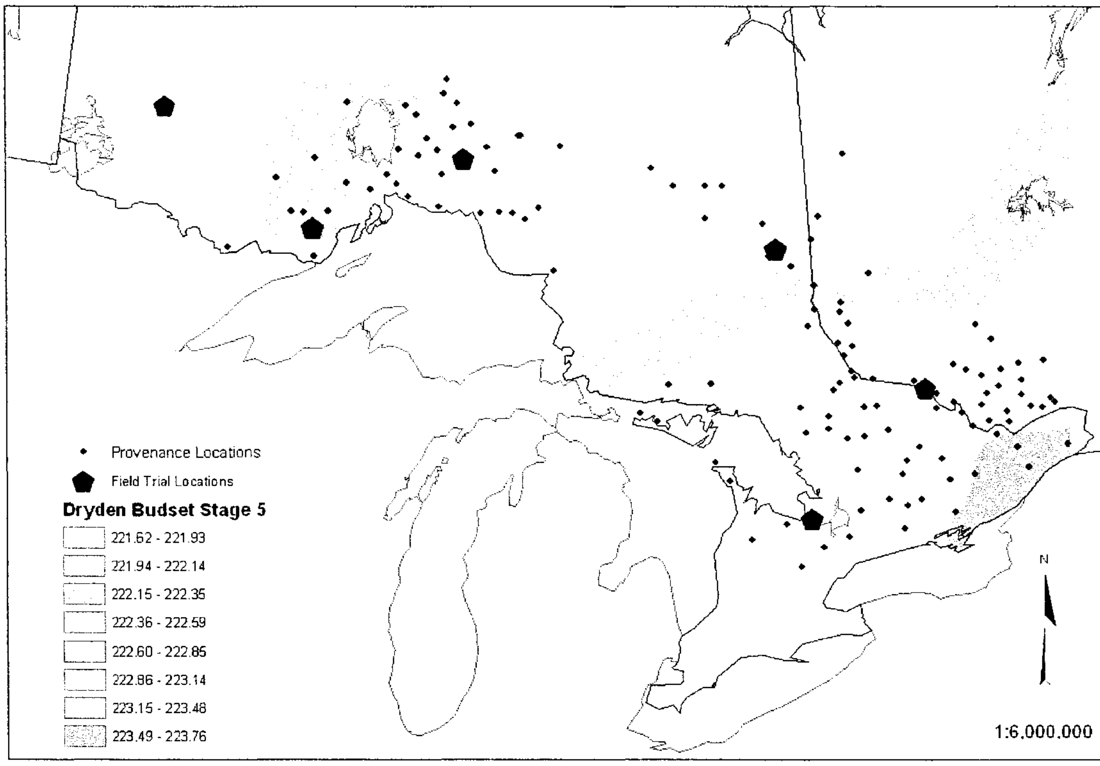

Figure 8. Contour map of mean number of days from Jan. 1 to reach budset stage 5 at the Dryden field trial

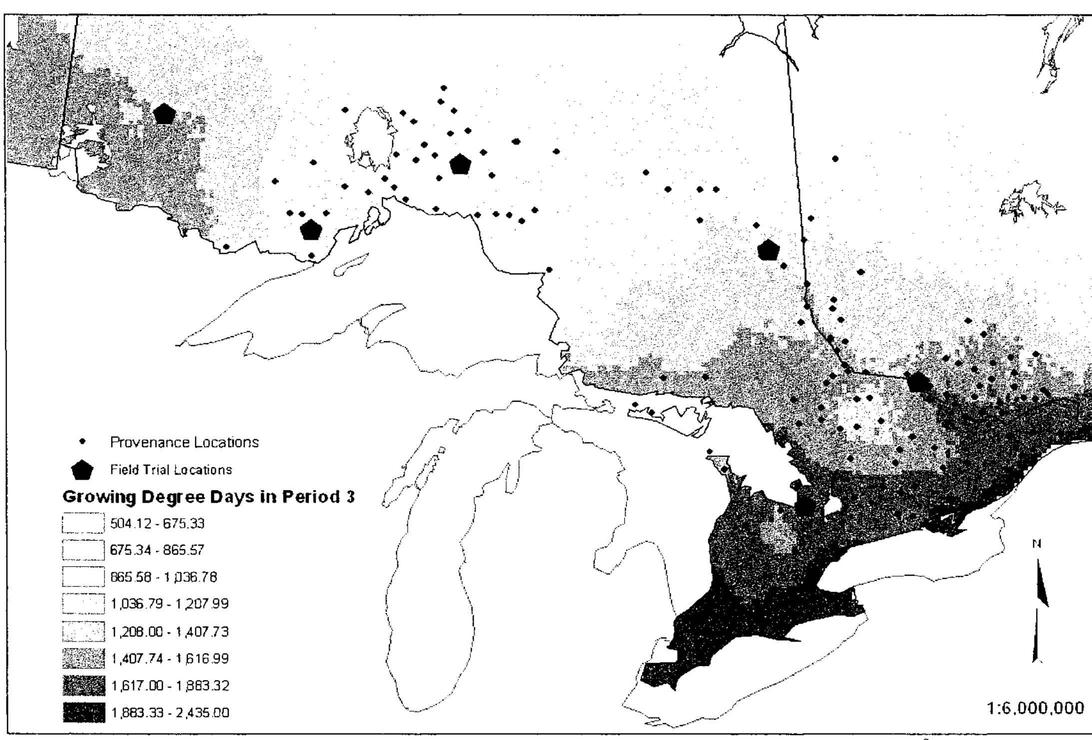

Figure 9. Contour map of growing degree days above the base temp. (5°C) during period three, the entire growing season

Budset timing for sources in the north-west area of the grid is similar to that of sources from more south-central areas. Budset stage 5 at Dryden was predicted by growing degree days in period three (Figure 9) with an r^2 of 0.50. The high level of correspondence between budset stage 5 at Dryden and growing degree days in period three is clearly illustrated in Figures 8 and 9, with the two grids showing extremely similar patterns.

BEST PERFORMING PROVENANCES

Based on 2003 and 2004 height measurements the top 5 performing provenances differed among planting locations (Table 8). For 2003 heights provenance 55 from Canton Gaboury, Quebec, is the best performing provenance at both the Longlac and Englehart trials, and is in the top 5 at the Kakabeka and Petawawa trials. Three of the 5 best performing provenances at the Dryden test site occur on the Quebec side of the Ottawa valley (12, 18, and 21). The second tallest provenance (117) is from the northwest part of the study area, and is also in the top five at the Kakabeka trial. Along with provenance 117, provenances 115 and 101 are also from the northwest region and performed in the top five at Kakabeka. Provenance 115 is the only northwestern source in the top five at the Longlac trial. The other 4 top sources are from western Quebec and south-eastern Ontario. The Englehart and Petawawa trials both showed the same trend with best performing sources extending across western Quebec and through eastern and southern Ontario. No sources from the northwestern region of the study area are in the top five at either of these trial locations. Table 9 shows Spearman rank correlations between tests and years. Correlations range from 0.66 to 0.71 between all tests in 2003, with the exception of Dryden which shows consistently lower correlations to all other tests (0.43 to 0.27).

Table 8 shows that although individual provenances are different, overall trends in 2004 are very similar to 2003 findings across trial locations. This conclusion is supported by the Spearman rank correlation values for the same trial between years (Table 9). Correlations between years at the same trial ranged from 0.56 at Dryden to 0.95 at Kakabeka and Petawawa.

In 2004 at the Dryden trial, provenance 18 remains the top performing source. The other four provenances were not in the 2003 top five (causing the lower correlation of 0.56) but are all from similar geographic areas (Table 8). Provenance 120 is from the northwest region and the other 3 are from eastern and southern areas of the study. The Kakabeka trial showed three of the same provenances from 2003 in the 2004 top five. Two northwest sources 117, and 101 remained, and provenance 55 moved up in the rankings to second highest. The most notable change is that provenance 1 from the extreme southeast of the study area, was not in the top five in 2003, but was the top performing source in 2004.

Provenance 55 remained in the top five at the Longlac trial, but dropped to second place. Provenance 115 dropped out of the top five in 2004, leaving no local sources in the top five. All five of the best performing sources at Longlac in 2004 are from more south-eastern areas. At the Englehart trial, the two top sources, 55 and 49, remained but switched positions. The other three sources changed but are still from the same geographic area. At the Petawawa trial four of the top five from 2003 remained in 2004. Provenance 55 fell out of the top five and was replaced by provenance 42, a slightly more southern source.

Table 8. Top five performing provenances based on 2003 and 2004 height growth in millimetres at each field trial

Trial											
Dryden				Kakabeka				Longlac			
2003		2004		2003		2004		2003		2004	
Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.
18	213.90	18	310.46	101	180.59	1	337.80	55	189.95	22	239.88
117	210.40	13	291.63	117	179.87	55	334.23	63	188.18	55	238.35
12	204.20	44	286.64	53	175.03	117	331.07	7	182.41	36	236.63
21	202.60	120	285.43	115	173.72	101	328.28	32	179.59	7	233.10
66	202.00	46	283.93	55	170.73	50	327.31	115	178.76	20	231.28

Trial											
Englehart				Petawawa				Angus			
2003		2004		2003		2004		2003		2004	
Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.	Prov. No.	Mean Ht.
55	225.00	49	324.48	74	219.5	1	321.00	\	\	59	385.73
49	217.75	55	323.14	1	205.7	42	298.68	\	\	9	380.00
7	209.00	59	308.76	53	202.9	49	297.83	\	\	44	379.86
66	202.43	63	300.27	49	197.3	53	296.09	\	\	5	375.00
86	199.78	50	298.35	55	194.4	74	295.65	\	\	22	366.27

Table 9. Spearman rank correlations for 2003 and 2004 heights at all field trials

Trial [a]	Dryden 03	Kakabeka 03	Longlac 03	Englehart 03	Petawawa 03	Dryden 04	Kakabeka 04	Longlac 04	Englehart 04	Petawawa 04
Kakabeka 03	0.34	\								
Longlac 03	0.43	0.68	\							
Englehart 03	0.27	0.70	0.70	\						
Petawawa 03	0.29	0.66	0.67	0.71	\					
Dryden 04	**0.56**	0.57	0.58	0.52	0.51	\				
Kakabeka 04	0.35	**0.95**	0.70	0.72	0.69	0.62	\			
Longlac 04	0.35	0.57	**0.88**	0.61	0.60	0.48	0.62	\		
Englehart 04	0.27	0.69	0.67	**0.92**	0.72	0.56	0.72	0.58	\	
Petawawa 04	0.22	0.62	0.65	0.65	**0.95**	0.45	0.66	0.57	0.67	\
Angus 04	0.28	0.58	0.62	0.63	0.57	0.51	0.60	0.52	0.62	0.55

[a] 03 refers to height in 2003 and 04 refers to height in 2004

Overall in 2004, the number of northern and northwestern sources in the top five at any trial location decreased from 5 to 3, with all three occurring at the Dryden and Kakabeka trials. Angus heights in 2004 show similar results with all five top performing provenances being from western Quebec and the south-eastern region of the study area. Correlation values between years and trials range from 0.22 between 2003-Dryden and 2004-Petawawa up to 0.72 between 2003-Englehart and 2004-Petawawa, and 2003-Petawawa and 2004-Englehart (Table 9).

Correlations between trials in 2004 show similar to 2003 results, but with Dryden more in line with other trial locations. However, the lower correlations still tend to be between Dryden and the southern tests (0.45 Dryden 2004 and Petawawa 2004, 0.51 Dryden 2004 and Englehart 2004). The highest correlation in 2004 is between Kakabeka and Englehart at (0.72). Overall, Spearman rank correlations which were based on all 127 sources, supported results of the top performing provenances in Table 8. Eastern and southern sources outperformed more northern sources in terms of height fairly consistently across all trial locations.

DISCUSSION

Significant differences were found for 62 of the growth and phenological variables. Overall, growth variables showed the highest levels of among provenance variation, with phenological traits generally lower. On average the amount of variation attributable to provenances was 5% of the total variation for all variables measured, and 7% when only significant variables were considered. The remaining variation could be attributed to block effects, environmental effects, and within-provenance differences which may reflect among-family variation. Although each provenance was made up of, on average, 4 to 5 wind-pollinated families, these were not tracked and therefore the actual amount of family variation can not be calculated. However, large family differences have been reported for many traits from multiple studies (Li *et al.* 1993), and are therefore a probable source of experimental error variation in this study as well.

A study utilizing 57 provenances of white spruce from Quebec and Ontario showed slightly lower levels to ours for among provenance variation (average 3.0%) for growth and phenological traits (Li *et al.* 1993). The same study showed no significant differentiation among provenances for budburst at year 3. Our results once again differed somewhat with more than half of the measured budflush variables being significant.

Another study on budflush timing of white spruce in Ontario showed no significant variation amongst provenances (Pollard and Ying 1979). That study dealt with a far more localized area than ours, dealing with only the south-eastern portion of

Ontario. Our study's results taken for the same geographic area showed that 6 of the 17 significant budflush variables were still significant within that area (results not shown), suggesting that fairly localized differentiation does occur for white spruce. In a study conducted in Maine, it was found that significant differences did occur amongst provenances in number of days until bud flush (Blum 1988). Results from that study showed a slight geographic trend with sources from higher latitudes flushing earliest. Similar geographic trends in budflush timing were expressed in our data, with northern sources generally flushing earlier than southern sources.

In another study conducted on a range-wide white spruce greenhouse trial, Khalil (1986) found significant differences amongst provenances for seed weight, germinative capacity, hypocotyl length, and 4-month seedling height. Regression analysis results showed both north-south and east-west trends were evident in the majority of these traits.

Regressions showed correlations to a mixture of temperature and precipitation related variables. Nienstaedt and Teich (1971) reported similar findings, stating that precipitation, temperature regime and photoperiod have all acted as important selective pressures on white spruce. Overall, regressions point to clear geographic trends for patterns of adaptation within the study area. Height and diameter growth are greatest from south-eastern areas and decrease with movement north and west. Figure 3 showing 2004 mean height at Kakabeka and Figure 4 showing 2004 root collar diameter at Petawawa are both examples of this trend. In contrast to this trend, Figure 6 shows greenhouse shoot elongation to be greatest in the northwest and smallest in the east. This reversal of the trend shown in Figures 3 and 4 could be attributed to northwest sources flushing earlier, therefore allowing more growing time in the 26 days from the start of the greenhouse growing session. When later greenhouse shoot elongation grids are examined we see that south-eastern sources have surpassed northwestern sources by the last measurement on day 70. In terms of phenological variables, sources from more northern locations flushed and set buds earliest, while southern sources flushed later and set bud later in the fall.

Top performing provenances in terms of 2003 and 2004 height growth were generally from the southeast region of the study area. Many of the top performing provenances were located on the Quebec side of the Ottawa River valley. Only two of the top performing provenances in our study were 410 Series sources (101 and 115), neither of which were in the top performing provenances reported by Morgenstern and Copis (1999). However, many were in close proximity, and general trends are in keeping with previous studies where it was found that Ottawa River valley sources showed superior growth at many trial locations (Morgenstern and Copis 1999). It was also possible to compare our top performing provenances to the 410 Series measurements made in 2001 (Cherry and Parker 2003). These comparisons provided further support for trends being observed in our data and also serve to strengthen previous findings.

Morgenstern and Copis (1999) looked at 410 Series provenance performance at trial locations by Hills' site regions (Hills 1961). Although our test locations were not identical, with the exception of Chalk River/Petawawa, we did have trials in 6 of the same site regions as 410 series tests, and comparisons could be made. Tree ages at the 410 series trials, at the time of measurement reported by Morgenstern and Copis (1999), ranged between 10 at Chalk River, to 18 at Kenora. Tree ages at the time of measurement in 2001 averaged 24 years (Cherry and Parker 2003).

Top performing provenances for the Petawawa/Chalk River trial, located in site region 5E, are shown in Figure 10. The top 5 provenances at age 10 for the 410 Series were all local or from similar latitudes (Morgenstern and Copis 1999) with the exception of provenance 8131, located in Manitoba. The 2001 measurements of the 410 tests show similar results, with 2 of the top 5 provenances being relatively local, and one being the same (8029). One provenance, 8086, however, is located west of Thunder Bay, while the final provenance, 8227, is from British Columbia (not shown in figure). Provenance 8227, given its source location may be of hybrid origin (white x Engelmann). The overall trend of local provenances performing best is generally the case and corroborates our 2004 height results (referred to as LLT Series in Figures 9-13), where all five top provenances were located in southern Ontario or adjacent Quebec.

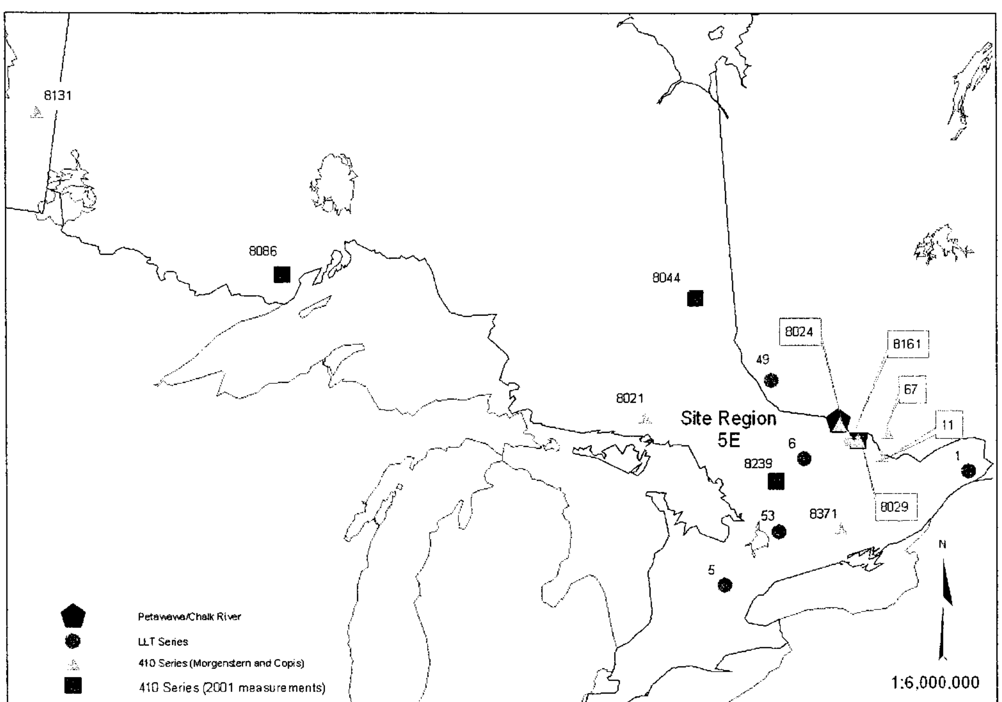

Figure 10. Comparison between LLT and 410 Series of top performing provenances in terms of height growth for the site region 5E field trial location (Petawawa/Chalk River)

The 410 Series Owen Sound trial is in the same site region (6E) as our Angus field trial. Top performing provenances for these two trials are shown in Figure 11. Top performing 410 Series provenances are tightly clustered in eastern Ontario. The one exception to this is provenance 8271 which was in the top five based on 2001 measurements, but is located in north-eastern Quebec (not shown in figure). LLT provenances are from the same area, but are more northern and are all located on the Quebec side of the Ottawa Valley. Morgenstern and Copis (1999) point out that the Owen Sound trial site is located on limestone soil type (as is the Angus trial), which could have consequences to adaptation based on Teich and Holst's 1974 study. A more current study investigating limestone ecotypic variation showed results contradictory to Teich and Holst's and indicated that soil type is not a factor in patterns of white spruce adaptation (Lesser *et al.* 2004).

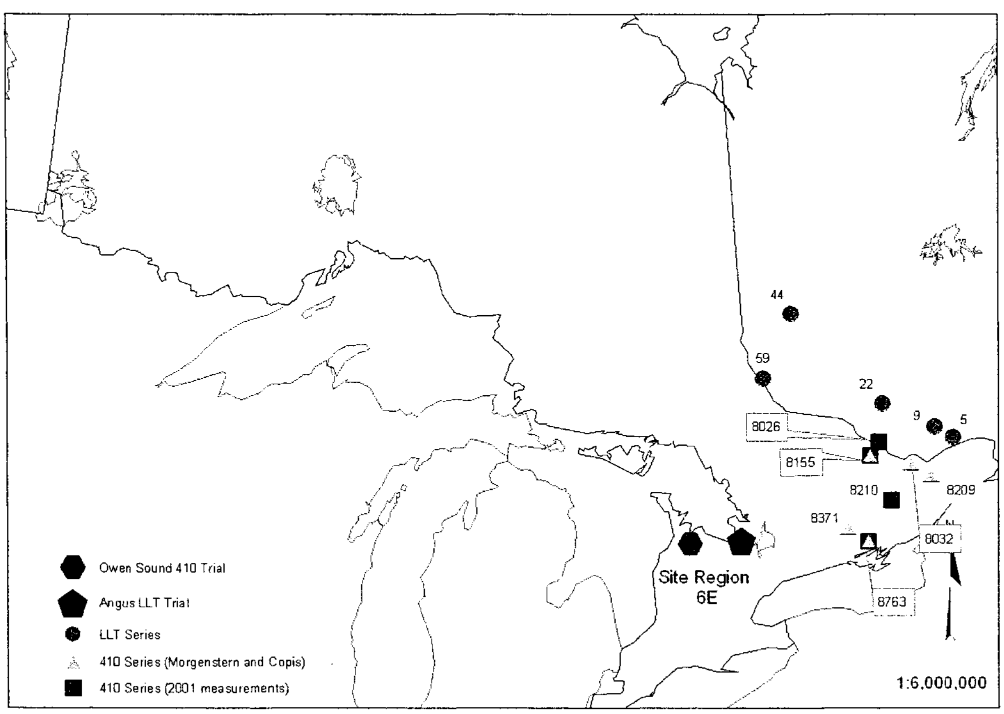

Figure 11. Comparison between LLT and 410 Series of top performing provenances in terms of height growth for the site region 6E field trial locations (Angus and Owen Sound)

The 410 series Hearst trial and our Englehart trial are both located in site region 3E. Top performing provenances are shown in Figure 12. Provenances from both 410 Series measurements range from Manitoba to Quebec. However, in our study provenances were far more local, with all 5 occurring in a narrow north-south band along the Quebec-Ontario border. For the Hearst trial there is only one local provenance, 8085 based on 2001 measurements (Cherry and Parker 2003), and no local provenances based on age 11 measurements.

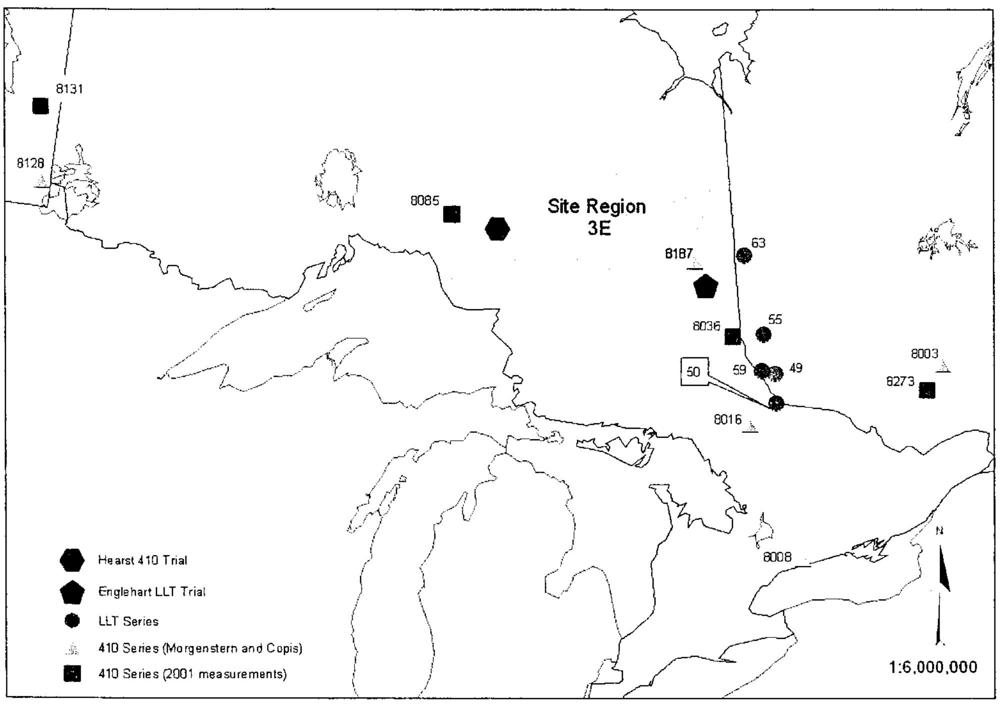

Figure 12. Comparison between LLT and 410 Series of top performing provenances in terms of height growth for the site region 3E field trial locations (Englehart and Hearst)

The 3W site region is represented by the Nipigon 410 series trial and by the Longlac trial in our study (Figure 13). Morgenstern and Copis (1999) reported that all 5 of the best performing provenances at the Nipigon site were boreal in origin extending across a broad, but narrow, east-west band. 2001 measurements of the Nipigon 410 trial showed similar results with three of the five provenances being the same as those at age

16. Provenance 8005, in the top five from 2001 was located in eastern Quebec (not shown in figure) but was within the same latitudinal band. Our study shows different results, with all five of the top provenances in 2004 being from more southern origins. Best performing provenance locations are in keeping with best performing sources at the Englehart, Petawawa, and Angus trials strengthening the evidence that south-eastern Ontario, and adjacent Quebec, sources are not only the best performing sources in a local environment, but will outperform local sources at more northern sites.

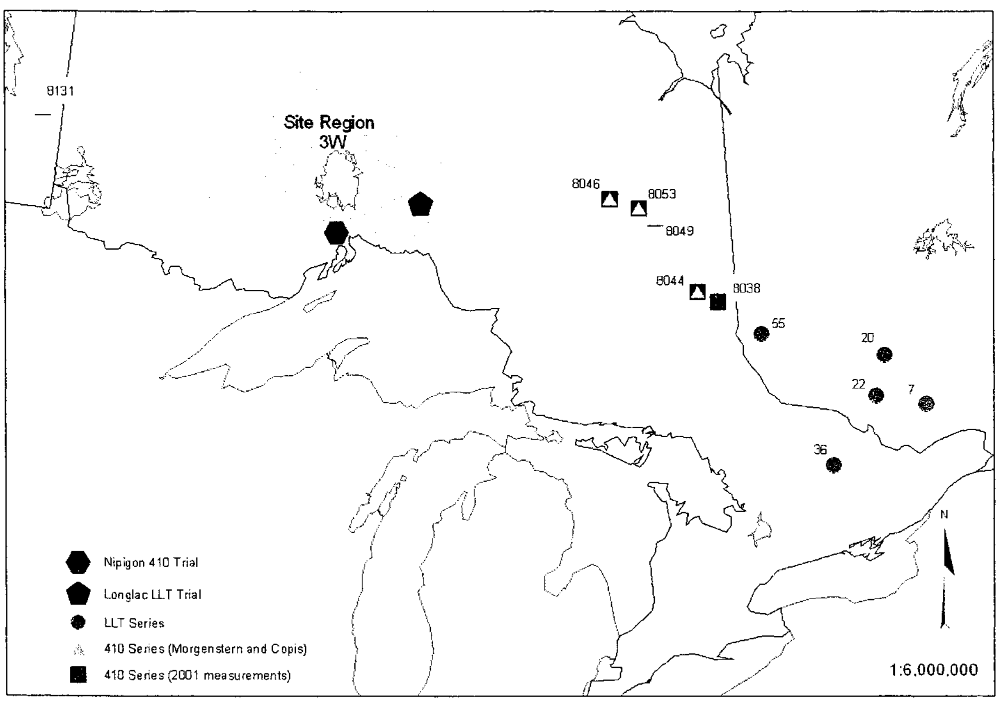

Figure 13. Comparison between LLT and 410 Series of top performing provenances in terms of height growth for the site region 3W field trial locations (Longlac and Nipigon)

The 4S site region contains three 410 series trials, Dryden, Kenora, and Red Lake. All three of these trials showed similar results with top provenances being from the same general north-west area or being from eastern Ontario (Morgenstern and Copis 1999). Figure 14 shows top provenances from the 410 Dryden trial, the closest in geographic proximity to our trial location. Our Dryden trial showed similar geographic results, however only 1 provenance was from the northwest (120) and the other 4 were all from the east and southeast regions of the study area. 2001 measurements for the Dryden 410 trial show top provenances all being from the northwest area, with 8052 being the most removed to the east. Figures 13 and 14 both indicate that growing conditions in northwestern Ontario have become more favourable for southern sources over the course of the last 20 years. This finding may be directly attributable to temperature increases associated with climate change.

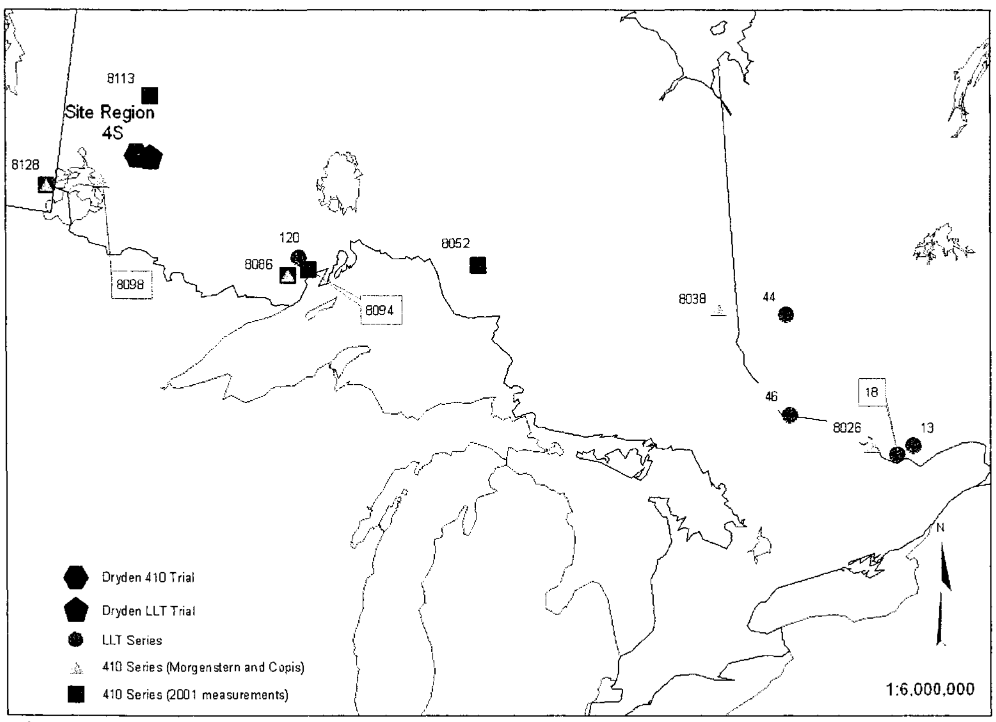

Figure 14. Comparison between LLT and 410 Series of top performing provenances in terms of height growth for the site region 4S field trial locations (Dryden)

While not as useful as the 410 Series, in terms of statistical reliability coupled with less than optimal site maintenance (Morgenstern and Copis 1999), results from the 194 and 93 Series of white spruce provenance tests also show the same trend as the 410 Series and our results (Nicholson 1970, Nienstaedt and Teich 1972, Teich 1973, Teich *et al.* 1975). Focken (1992) reports that provenances from the Beachburg area of the

Ottawa Valley in the 410, 194 and 93 Series of provenances tests all showed consistently superior height growth throughout the central region of Ontario. A 2001 study utilizing the 194 Series test in Pearson Township, 50 km southwest of Thunder Bay, found that southern sources on average outperformed local sources (Brown 2001). This result is further supported by a second 2001 study utilizing the two 194 Series tests located at the Petawawa Research Forest (Sarazin 2001). Overall, our results strengthen the conclusion that southern sources are outgrowing local sources in many cases thus suggesting the possibility of northward shifts to increase growth potential.

Maternal effects, most notably seed weight, can have a significant impact on seedling performance at early ages (Perry 1976); however, the high degree of similarity between our results and those from older previous studies suggests that maternal effects are having a minimal influence on our results. Furthermore, these similarities indicate that despite the early age of the seedlings, our results are demonstrating true patterns of adaptive variation.

Later flushing in white spruce can be a useful strategy in avoiding spruce budworm predation (Pollard and Ying 1979, Blum 1988). Early flushing in white spruce is also a source of spring frost damage, with later flushing being used as a strategy to avoid this (Blum 1988). Coupled with greater growth performance and later budset timing in the fall giving a longer growing season, sources from south-eastern Ontario and western Quebec should yield greater productivity when planted throughout the study area. Although this strategy may be advisable to optimize fibre production it goes against the philosophy that local sources are better adapted to their environment. Planting of non-local sources may result in maladaptation, but resulting losses have not been demonstrated in numerous provenance trials.

Grids produced for Longlac-2004 height and survival show that while best height growth comes from south-eastern Ontario and western Quebec, local sources have the greatest survival (Appendix IV). The same trend is seen in grids for Petawawa-2004 height and survival (Appendix IV); sources from the south-east, in this case local, have the best height growth, but sources from the northwest show higher survival levels.

In both cases, however, survival levels show a very narrow range (<10% difference) that indicates this is not a major concern. Also anticipated temperature increases resulting from climate change may lower the risks of northward transfers.

CHAPTER III
REGRESSION BASED FOCAL POINT SEED ZONES

INTRODUCTION

The previous chapter demonstrated that genetic variation in growth, survival and phenological traits is associated with variation in climatic factors, thus showing the existence of adaptive variation for white spruce across the study area. This chapter will build on that foundation to model multivariate patterns of adaptation, attempting to represent overall patterns of variation in relationship to the environment. Using these models continuous, or focal point, seed zones can be developed for any given point across the study area.

Building on work done by Rehfeldt (1984) and Campbell (1986) the focal point approach originally developed by Parker (1991) for black spruce and Parker and van Niejenhuis (1996a, 1996b) for black spruce and jack pine added a GIS component to seed zone development that allowed a unique seed zone to be delineated for any given point. Rather than a series of set polygons as are currently used in Ontario for seed zone delineation (OMNR 1997), the focal point approach creates an infinite number of zones, each of which is specific to a single planting location (Parker 1991).

While the focal point approach, as with any continuous zone method, creates far more administrative work than traditional generic discrete seed zones, it also offers several valuable benefits (Morgenstern 1996). First, seed zones should be developed based on species specific information obtained from provenance, or other genetic testing where possible in order to truly capture that species unique pattern of variation (Morgenstern 1996, OMNR 1997); and second, where patterns of adaptation have been shown to be clinal, discrete zone boundaries become artificial and transfer across zone boundaries is warranted (Morgenstern 1996).

The principal component multiple regression methodology used in this chapter is the same as the methodology previously employed by Parker and van Niejenhuis (1996a, 1996b) to develop focal point seed zones. This methodology first summarizes variation found in the measured biological variables through principal components analysis; and then models the summarized patterns of variation on climatic factors using multiple regression analysis. The resulting models are converted to spatial patterns of variation for each individual principal component axis and, when intersected using GIS tools, show individual patterns of variation standardized to any given point, thus creating a seed zone for that planting location.

The objective of this chapter was to map multivariate patterns of adaptation for white spruce across Ontario and western Quebec and to use this information to create focal point seed zone procedures that may be used for white spruce at any point within the study area. Resulting example seed zones were compared to generic seed zones currently in use in Ontario, and to previous focal point seed zone efforts for black spruce and jack pine in northwestern Ontario.

METHODS AND MATERIALS

The first step in determining focal point seed zones was to select which of the 94 measured variables would be used in the analysis. Two criteria were used for this selection process. First, variables had to demonstrate significant differences between sources meaning that some level of genetic variation had to be present. Second, the observed variation had to correspond to a climatic or geographic variable.

The first criterion is important in that variables which exhibit no between-source variation are not useful in determining seed zones; the second criterion ensures that there is a strong correlation between the components of variation and the local climate of the seed source (Parker and Van Niejenhuis 1996a). If both criteria are satisfied then the observed variation can be considered adaptive. This screening process coincides with the analysis that was conducted in Chapter II. ANOVA was used to detect significant differences and ICC was calculated to determine how much of the variation expressed could be attributed to genetic variation expressed among seed sources. Simple linear regressions were run on provenance mean values against climatic and geographic variables to determine if differences were attributable to climatic or geographic factors.

Following the screening process, provenance mean values of the retained variables were analyzed using principal components analysis (PCA). PCA summarized the main components of variation in the data set. PCA was run using the Princomp procedure in SAS (SAS Institute 2000). Eigenvalues were used to determine which of the PC axes would be retained, and analysis of the eigenvectors showed which variables were contributing to each axis.

Normalized provenance factor scores were calculated for the 3 main axes of variation. These factor scores were then used as new summary variables in multiple linear regressions against climate variables. The same sixty-seven climate variables that were used in the screening process regressions (Chapter II) were used here. Multiple regressions were run using the regression procedure in SAS (SAS Institute 2000). The r-square method was used to determine the model with the highest predictive power (highest r^2). To avoid over fitting the model predictor variables with tolerances less than 0.1 and non-significant t values were eliminated, and the model refitted (Parker and van Niejenhuis 1996a). Models were checked to ensure regression assumptions were met by graphing 1) the normal probability plot of the standardized residuals, 2) scatter plots of the standardized residual against each predictor variable, and 3) scatter plots of the standardized residual against the predicted values (Chatterjee *et al.* 2000).

The regression equations were then used to model the 3 main PCA axes. The regression models were converted to spatial data using GIS. Predicted scores for each axis were reproduced as contoured grids using grid algebra in the Grid sub package of ArcGIS (ESRI 2002). These grids summarize the spatial pattern of adaptive variation.

The final stage of the focal point seed zone procedure involved the adaptation of the focal point seed zone computer program to produce a unique seed zone for white spruce at any given point within the study area based on data from the 127 seed source locations. The computer program is shown in Appendix VI. For the purpose of this thesis, representative seed zones were determined for 23 points chosen at an even distribution across Ontario and western Quebec. Figure 15 demonstrates graphically how seed zones are constructed. For any selected point, new contour grids were produced for each of the 3 main PCA axes, with the scores standardized to that of the focal point (Figure 15a). Scores of the derived grid then represented deviations from that selected point. The derived grids for each axis were overlaid and intersected (Figure 15b). The resulting grid identified areas of similarity in terms of standard deviations from the source location (Figure 15c). Zones of decreasing similarity were identified by lighter shading patterns. All grids were produced in ARC 8.3 (ESRI, 2002).

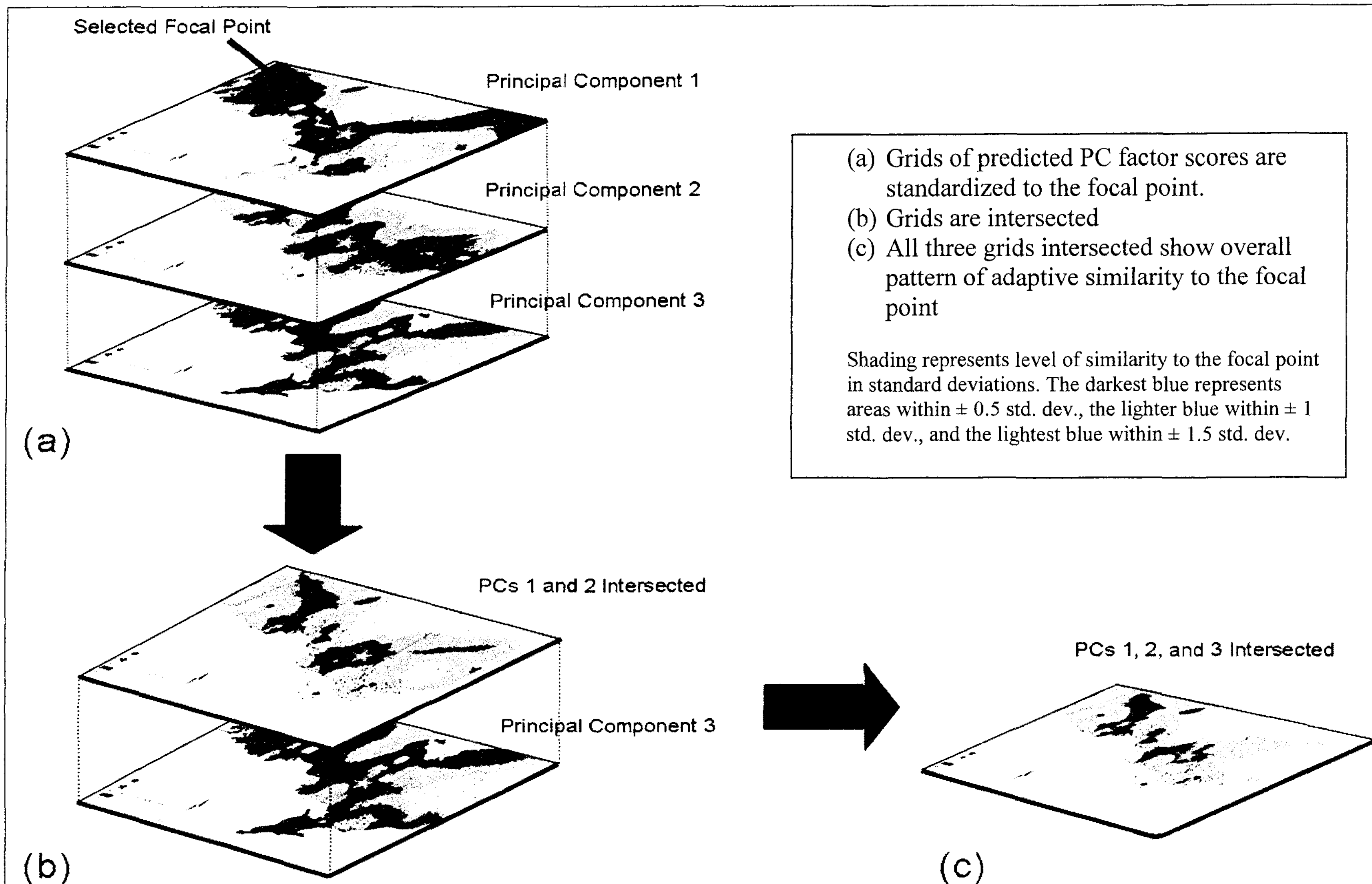

Figure 15. Flow chart outlining process of constructing focal point seed zones for a selected point

RESULTS

PRINCIPAL COMPONENTS ANALYSIS

Fifty-seven of the original 94 variables passed the double screening process and were retained in focal point seed zone development (Table 10). These variables included all growth variables, with the exception of 2003 root collar diameter at the Kakabeka trial. Four survival variables were retained: 2002 Petawawa, 2003 and 2004 Englehart, and 2004 Longlac. Fifteen budflush variables were retained; however, only three trials, Dryden, Longlac and the greenhouse, are represented by these 15 variables. The 11 budset variables that were retained came from all five 2003 field trials. All five greenhouse elongation variables were retained.

Results of principal components analysis (PCA) on these 57 variables are summarized in Table 10. Eigenvalues, the percentage of total variation attributed to each component, and the associated eigenvectors are shown for the first three PC axes. The first PC explains 34 percent of the total variation. The second and third PCs explain an additional 12.5 and 8 percent respectively. The cumulative amount of variation explained by the three PC axes is 54.5 percent of the total variation. The remaining 54 additional PC axes (results not shown) showed low eigenvalues (less than 3.5) and individually contributed little to the explained variation (less than 5.5 percent) and therefore were not considered for modelling patterns of adaptive variation.

Table 10. Summary of principal components analysis results for PCs 1-3

PCA Axis	1	2	3
Eigenvalue	19.37	7.10	4.63
Percent Variaton	33.98	12.46	8.13
Cumulative Variation	33.98	46.44	54.56
Eigenvectors			
Dryden budflush stage2	0.06	0.16	0.05
Dryden budflush stage3	0.07	0.17	0.04
Dryden budflush stage4	0.06	0.21	-0.02
Dryden budflush stage5	0.05	0.17	-0.01
Dryden budflush stage6	0.04	0.18	0.05
Longlac budflush stage2	0.11	0.13	-0.13
Longlac budflush stage3	0.13	0.11	-0.15
Longlac budflush stage4	0.14	0.09	-0.17
Longlac budflush stage5	0.12	0.03	-0.21
Longlac budflush stage6	0.10	0.00	-0.17
greenhouse budflush stage2	0.14	-0.01	-0.19
greenhouse budflush stage3	0.17	-0.02	-0.21
greenhouse budflush stage4	0.17	-0.02	-0.19
greenhouse budflush stage5	0.11	0.00	-0.20
greenhouse budflush stage6	0.10	0.02	-0.28
Dryden budset stage 5	0.06	0.26	0.12
Kakabeka budset stage3	0.05	0.24	0.07
Kakabeka budset stage4	0.11	0.24	0.13
Kakabeka budset stage5	0.10	0.21	0.14
Longlac budset stage4	-0.02	0.22	0.10
Longlac budset stage5	0.03	0.20	0.18
Englehart budset stage3	0.02	0.20	0.15
Englehart budset stage4	0.09	0.21	0.14
Englehart budset stage5	0.04	0.16	0.12
Petawawa budset stage3	0.01	0.17	0.06
Petawawa budset stage4	0.05	0.25	0.13
ht2002	0.19	-0.15	0.06
Dryden ht2003	0.10	-0.04	-0.12
Kakabeka ht2003	0.17	-0.11	0.09
Longlac ht2003	0.19	-0.07	0.02
Englehart ht2003	0.18	-0.12	0.10
Petawawa ht2003	0.19	-0.05	0.09
Dryden ht2004	0.15	-0.07	-0.03
Kakabeka ht2004	0.18	-0.08	0.10
Longlac ht2004	0.17	-0.08	0.00
Englehart ht2004	0.19	-0.08	0.13
Petawawa ht2004	0.18	-0.03	0.07
Angus ht2004	0.17	-0.09	0.02
Dryden dia2003	0.11	0.00	-0.04
Longlac dia2003	0.18	0.01	0.06
Englehart dia2003	0.19	-0.07	0.13
Petawawa dia2003	0.17	-0.06	0.07
Dryden dia2004	0.16	-0.06	-0.05
Kakabeka dia2004	0.18	-0.11	0.08
Longlac dia2004	0.17	-0.02	0.05
Englehart dia2004	0.19	-0.03	0.16
Petawawa dia2004	0.17	-0.02	0.09
Angus dia2004	0.18	-0.05	0.07
Petawawa surv2002	0.08	-0.09	0.00
Englehart surv2003	0.13	0.00	0.11
Englehart surv2004	0.14	0.00	0.11
Longlac surv2004	0.02	-0.13	-0.03
greenhouse elong. day 18	-0.11	-0.13	0.25
greenhouse elong. day 22	-0.12	-0.14	0.29
greenhouse elong. day 26	-0.11	-0.19	0.25
greenhouse elong. day 30	-0.06	-0.24	0.20
greenhouse elong. day 70	0.18	-0.11	0.09

Principal components are uncorrelated (orthogonal) by definition, and in this case reflect the influence of different categories of variables with different biological significance. PC 1 mainly represents growth potential, as seen by the relatively high positive eigenvectors associated with growth variables (Table 10). PC 1 is also strongly determined by Englehart survival variables, the final greenhouse elongation variable (day 70), and greenhouse budflush variables. There is a weaker positive correspondence to other survival, budflush, and budset variables. The first 4 greenhouse elongation variables show a negative relationship, indicating that the opposite of growth potential is being expressed in the early stages of greenhouse growth. This may reflect maternal effects from higher vigour seeds showing up as differences between recent collections and those obtained from the CFS seed bank that have been in storage for over 30 years. However, this explanation is not consistent with height measurements or the final elongation measurement. This result is likely indicative of budflush timing. Since northern sources flush earlier they begin elongation earlier, before eventually being surpassed by faster growing, but later flushing, southern sources. This hypothesis is further supported by the final elongation measurement having a positive correlation in the same magnitude as field trial growth variables.

PC 2 is strongly determined by phenological traits from the five field trials. Budset and budflush variables show relatively high positive relationships, with the exception of later stage budflush variables at the Longlac trial which are weaker, but still positive. Greenhouse phenology shows a much different pattern with all variables showing a negative or extremely weak relationship. Perhaps this result is attributable to the greenhouse trial receiving cold storage treatment instead of actual over-wintering field conditions. All growth variables show a negative relationship that is most strongly expressed by greenhouse elongation patterns which no longer have opposite polarity on this axis (Table 10).

PC 3 shows a relatively high negative relationship to greenhouse budflush variables. PC 3 also shows a strong positive relationship to the first four greenhouse elongation variables. The day 70 elongation variable shows a much weaker correspondence. This result, coupled with the high positive correspondence of the day 70 elongation variable to PC 1 suggests that the pattern of growth initiation in the greenhouse is essentially uncorrelated to the two main components of variation, growth and phenology in the field. PC 3 does not show a strong relationship to any of the field trial variables, with the exception of later stage budflush variables at the Longlac trial, which are in the same magnitude as the correspondence to the greenhouse budflush variables (Table 10). Once again, this result is most likely attributable to cold storage versus actual over-wintering field conditions. Other factors associated with greenhouse conditions such as temperature, water, fertilizer or daylength could also be responsible.

REGRESSION ANALYSIS

Results from multiple regressions run on the provenance factor scores for each of the first three principal components are shown in Table 11. Factor scores for the 3 PCs are given in Appendix VII. All three of the models are highly significant ($p<0.0001$) and all predictor variables in each of the models had tolerances above 0.1 and significant t values at $p<0.05$.

PC 1 factor scores were fit to a model containing precipitation in the wettest period, which coincides with the growing season, August maximum temperature and August precipitation. The selection of two summer precipitation variables, one being late summer, along with a late summer temperature variable suggests the importance of moisture conditions during bud development for the following year's growth potential. The coefficient of determination (r^2) for this model was 27.1 percent.

The best model for predicting PC 2 factor scores contained only June minimum temperature. The r^2 for this model was 48.45 percent showing the importance of late spring, early summer temperatures for phenological characteristics, especially budflush timing. PC 3 factor scores were predicted by annual precipitation, March maximum temperature and October precipitation. The r^2 for this model was 27.96 percent. This model is the most complex of the three with late winter temperature interacting with fall and annual precipitation amounts to explain greenhouse budflush timing and elongation patterns.

Table 11. Multiple regression models of principal component analysis factor scores against climate variables

Dependant Variable	p>F	Independent Variables	Coefficient	Tolerance	p>t
Principal component 1	<0.0001	constant	-8.572	\	<0.0001
R^2 = 27.1%		precipwp	-0.043	0.348	0.0078
		augmaxtemp	0.287	0.882	<0.0001
		augprecip	0.068	0.376	<0.0001
Principle component 2	<0.0001	constant	-3.393	\	<0.0001
R^2 =48.45%		junmintemp	0.400	1	<0.0001
Principle component 3	<0.0001	constant	2.986	\	0.0005
R^2 = 27.96%		annprecip	-0.011	0.165	<0.0001
		marmaxtemp	0.427	0.541	<0.0001
		octprecip	0.080	0.219	<0.0001

Figures 16, 17, and 18 show contour intervals for grids generated from the PC regression models representing the predicted factor scores, respectively, for each of the 3 principal components. Figure 16 can be interpreted as the pattern of adaptive variation in terms of growth potential across the study area with higher factor scores signifying greater growth potential. There is a strong southeast to northwest trend in eastern Ontario evident in the grid, with greater growth potential occurring in the southeast portion of the study area and decreasing through central Ontario and into northern areas. Growth potential increases again to the west of Lake Nipigon, showing values similar to south-central Ontario. A similar trend of diminishing growth potential moving east across northwestern Ontario was reported for a regional study of jack pine (Parker and van Niejenhuis 1996a).

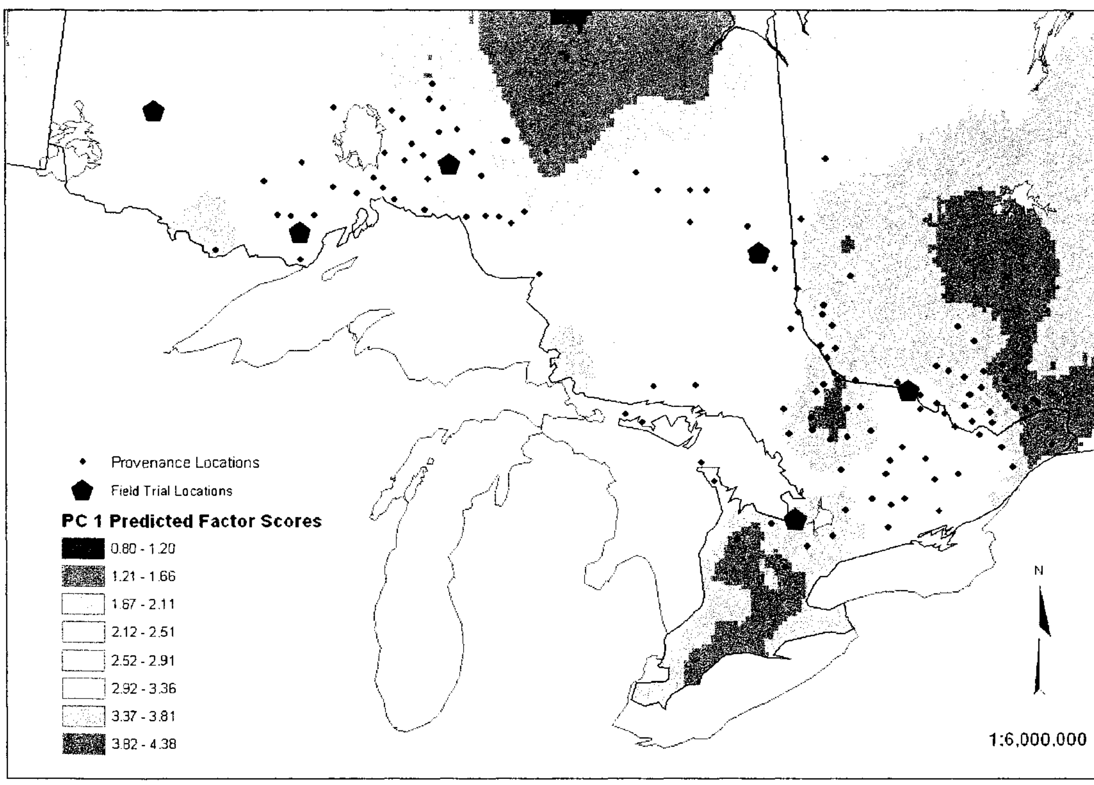

Figure 16. Predicted factor scores from PC 1 regression model

Figure 17 shows the pattern of adaptive variation for the study area in terms of phenological timing. The same general trend that was evident in Figure 16 can also be seen in Figure 17. The main contrast between the two grids is in western Quebec with the pattern in Ontario being very similar. Higher scores which correspond to later budflush timing in the spring along with later budset timing in the late summer–early fall are located predominantly in the southern portions of the study area. Scores decrease with movement north and west, but increase again to the west of Lake Nipigon. The influence of the Algonquin highlands in creating an environment similar to more northern areas can be seen on the grid in south-central Ontario.

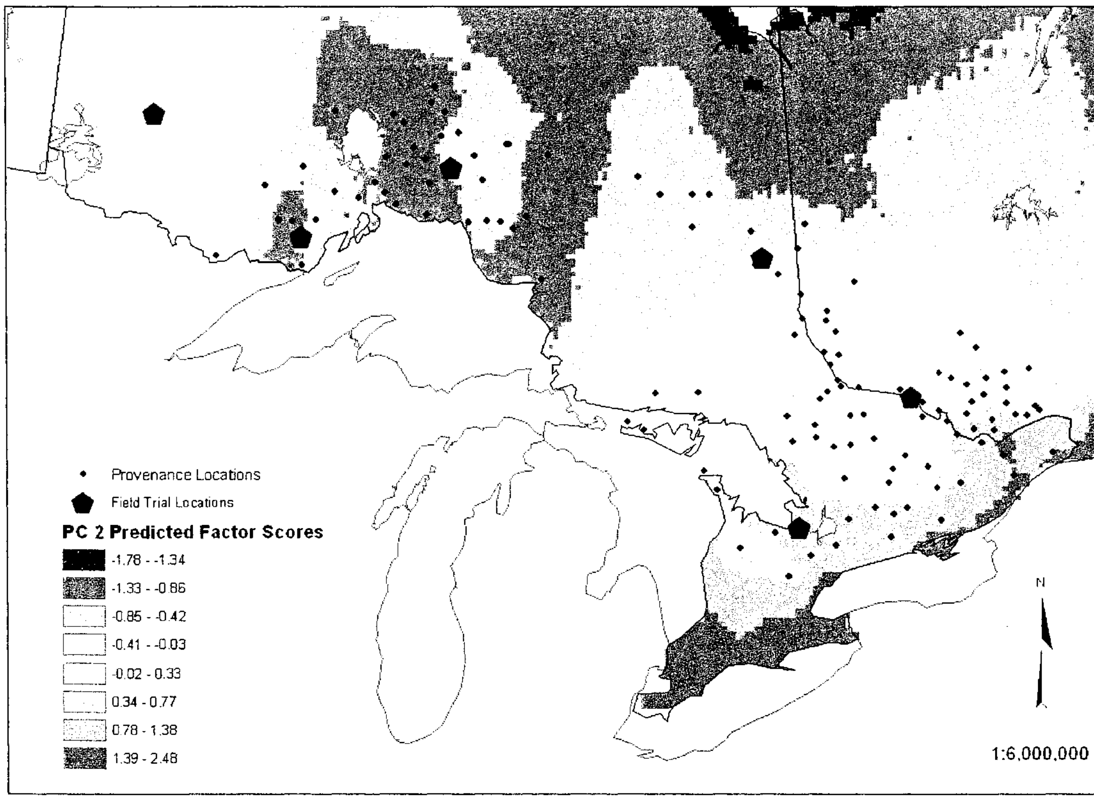

Figure 17. Predicted factor scores from PC 2 regression model

The predicted factor scores for PC 3 (Figure 18) show the pattern of variation expressed by greenhouse elongation and budflush timing. As with the other grids there is a strong north-south trend in the factor scores. This trend closely resembles winter temperature patterns seen in Appendix V. Higher factor scores are located across the southern region of the study area, but unlike the other grids relatively high scores extend continuously across northern areas along the shoreline of Lake Superior. The highest scores (darkest green) are located in pockets along the eastern shores of Lake Superior, and Lake Huron. Scores decrease rapidly with movement north away from the lakeshore with the lowest scores occurring northeast of Lake Nipigon.

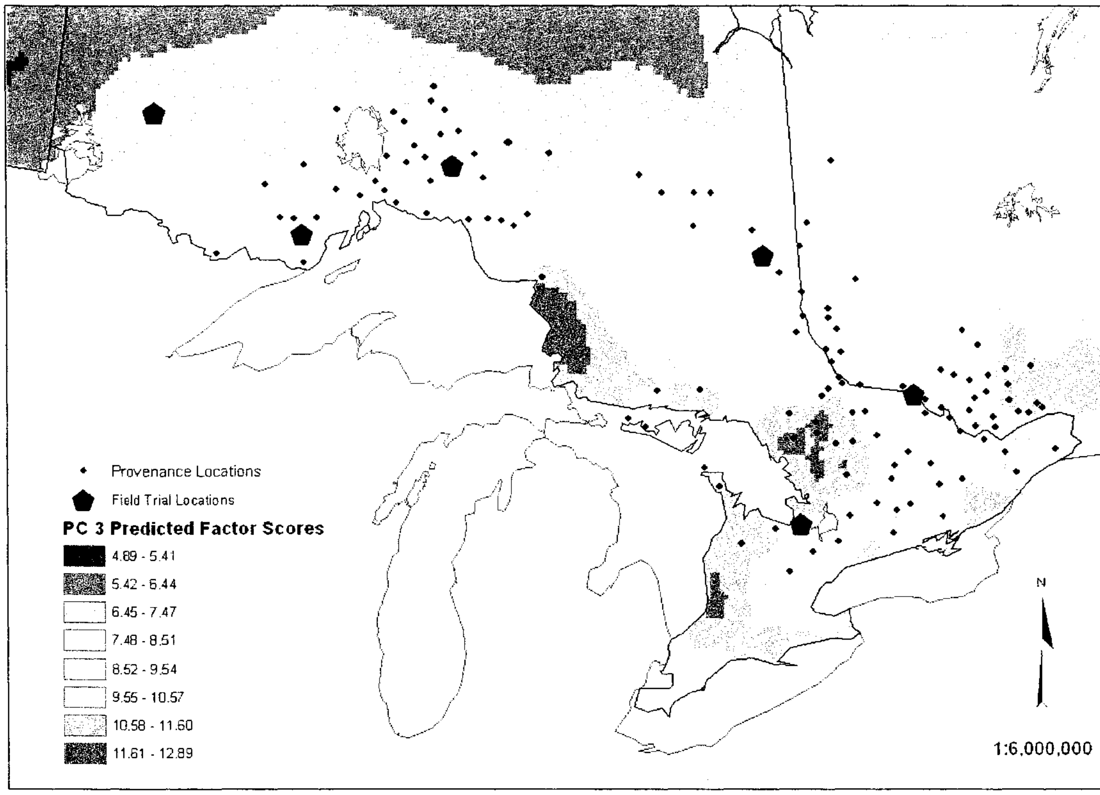

Figure 18. Predicted factor scores from PC 3 regression model

FOCAL POINT SEED ZONE EXAMPLES

Although focal point seed zones are meant to be determined on an 'as needed basis' a series of examples has been constructed for the purpose of this thesis. These sample zones illustrate the potential of the method, and serve to demonstrate overall trends in adaptive patterns across the study area. The sample zones will also provide the basis for comparison of the regression based methodology to the canonical correlation approach given in the following chapter. Figures 19 through 41 depict focal point seed zones for 23 points distributed evenly across the study area starting with the most westerly and moving systematically eastwards. In each of these figures the focal point is represented by a red star. Shading depicts levels of adaptive similarity to the focal point in terms of standard deviations. The darkest green shading represents areas of greatest similarity, or within ± 0.5 standard deviations. The slightly lighter green represents areas within ± 1 standard deviation, and the lightest green represents areas within ± 1.5 standard deviations. Areas not shaded (white) are outside of what is considered the level of adaptive similarity; or in more practical terms, probably beyond the acceptable range for seed transfer.

Figure 19, located in the far northwest of the study area, shows a localized area for the zone of most similarity. Acceptable areas extend across the northern limit of the study area in a fairly narrow latitudinal band that does not extend south of approximately 50 degrees, except for two dips in north-eastern Ontario. Figure 20, which is at the same longitude, but 2 degrees south of the point in Figure 19, shows areas of acceptable similarity extending across most of the province, but generally not above 50 degrees latitude. The lightest green shading, representing the lowest level of acceptability, coincides with the same level of shading in Figure 19, showing that a strong north-south differentiation is occurring in adaptation at approximately 50 degrees in terms of suitability to northwest locations. Figure 20 also shows significant lakeshore effects off the eastern shore of Lake Superior and Georgian Bay. Much of southeastern Ontario is considered to have the same level of similarity as more local areas in the northwest.

In Figure 21 the focal point has been moved east to the western shore of Lake Nipigon. The zone of greatest similarity extends on either side of Lake Nipigon and also as a significant disjunct zone covering much of eastern Ontario into Quebec. Lakeshore effects are once again evident; however, southern areas shown as acceptable in Figure

20 for the more western point are no longer included. One small disjunct area in the Ottawa Valley region is still shaded, but at the lowest acceptable level.

Moving east of Lake Nipigon, Figure 22 shows the same strong north-south trend seen in Figures 19 and 20. While areas of acceptable similarity extend across the entire northern section of the study area, essentially no areas south of approximately 50 degrees are considered acceptable. Once again, the exception is the two dips in the acceptable range seen in northeastern Ontario. Figure 23, in which the focal point is located at 50 degrees latitude, clearly shows the same transition taking place at this latitude. The zones of similarity extend broadly in an east-west direction, but are fairly narrow in a north-south orientation. Staying at the same longitude, but moving to the south of this transition, Figure 24 shows almost no areas of acceptable similarity extending north of 50 degrees latitude. With the exception of an area centered around the Petawawa trial, in the Ottawa Valley, no areas south of approximately 46 degrees north are considered acceptable. The zone of greatest similarity for this point is very small, compared to other northern points. This may reflect the unique climatic conditions of Lake Superior's north shore.

Figure 25 shows the same general trend as more western points at the same latitude; however, areas of acceptable similarity extend south more broadly through eastern Ontario. Also, areas to the west of Lake Nipigon are becoming less acceptable for transfer. Figure 27 continues this trend. As the focal point moves east at nearly the same latitude (49^{o}-50^{o}) areas of similarity extend further to the south then western points. However, Figure 29 shows a retraction of similar areas to the south, and a return to a narrower latitudinal band across the northern extent of the study area.

Figure 26 shows a strong lakeshore effect off the east shore of Lake Superior. The highest level of similarity is confined to a very narrow strip, with acceptable areas extending only through the Algonquin Highlands and southern Quebec. Figures 28 and 31 show a similar geographic pattern, but illustrate that even a small shift away from the eastern shore of Lake Superior creates a comparatively much broader level of similarity to surrounding areas. Figure 31 also shows a small area of similarity in the Quetico area in Northwest Ontario.

The effect of lakeshore and the Algonquin Highlands is shown in Figure 30. Zones of similarity extend across most of the northern study area and south into parts of the Ottawa Valley, but do not encompass any area off the east shore of Lake Superior or the central highlands.

Figures 32 and 33 show the two most southern selected points. The zones for both these points are fairly similar, with little area above approximately 46 degrees latitude being considered acceptable. Conversely, Figure 34, which has the focal point located on the Quebec border at 49 degrees latitude, shows almost no area as acceptable below 46 degrees. North of this latitude, however, zones of similarity extend across most of the study area. Figure 35 shows a very similar trend, but with a slight southward shift of the zones corresponding to the southward movement of the focal point from 49 degrees to 47 degrees latitude.

The focal point in Figure 36, located in the Algonquin region, shows very little area as being within acceptable limits of adaptability. Only immediate surrounding areas along with the eastern shore of Lake Superior and the northern shores of Lake Ontario and Lake Erie into southern Quebec are acceptable. Figures 37, 38 and 39 show almost the exact opposite pattern, with the areas found acceptable in Figure 36 being conspicuously white, or filled with the lightest shading. This clearly shows the influence the Algonquin Highlands and of lakeshore effects on sites in the same latitudinal range.

The focal points in Figures 40 and 41 do not show the same strong exclusion of the Algonquin region, and show zones of similarity covering all of southern Ontario and adjacent Quebec. Figure 40 does show a lakeshore influence along the eastern shore of Lake Superior.

Overall there are several clear trends evident across the study area. South-eastern points (Figures 39, 40, and 41) all show relatively small zones the darkest green, or highest level of similarity, in comparison to more western and northern points. The exception to this pattern is that points located along the shoreline of Lake Superior or in the Algonquin Highland region also show similarly small restrictive areas. In these cases, however, not just the darkest green, but all shaded areas are limited. The lakeshore effect is a result of the PC 1 and PC 3 grids which both show these areas as being dissimilar from surrounding areas. The effect of the Algonquin Highlands is evident in all three PC grids (Figures 16, 17, and 18).

Across the northern extent of the study area 50 degrees latitude seems to be the transition line for areas of similarity. Points located to the north of this latitude do not have similar areas extending south of it, and for points to the south the converse is true. This rule generally applies to points above 48 degrees. For points below this range a similar effect seems to be occurring with the 46th parallel. Points below 46 degrees show little or no areas acceptable north of this limit and points selected in the 46 to 48 degree range do not show acceptable areas extending southwards.

A final noteworthy trend is the similarity between points in the Fort Frances area of the Northwest (Figure 20) and areas in southern Ontario and eastern Quebec, most notably the Ottawa Valley region. This trend is seen to a lesser extent in other northwest points (Figures 21, 23, and 24), but is clearly the strongest with the point shown in Figure 20. The trend of northwestern sources being similar to eastern and southern sources is further strengthened by Figures 31, 34, and 35 which all show areas in the Fort Frances vicinity as being within acceptable limits. Principal component grids (Figures 16, 17, and 18) all show this same pattern, with the northwest being similar to areas in the south and east to varying degrees.

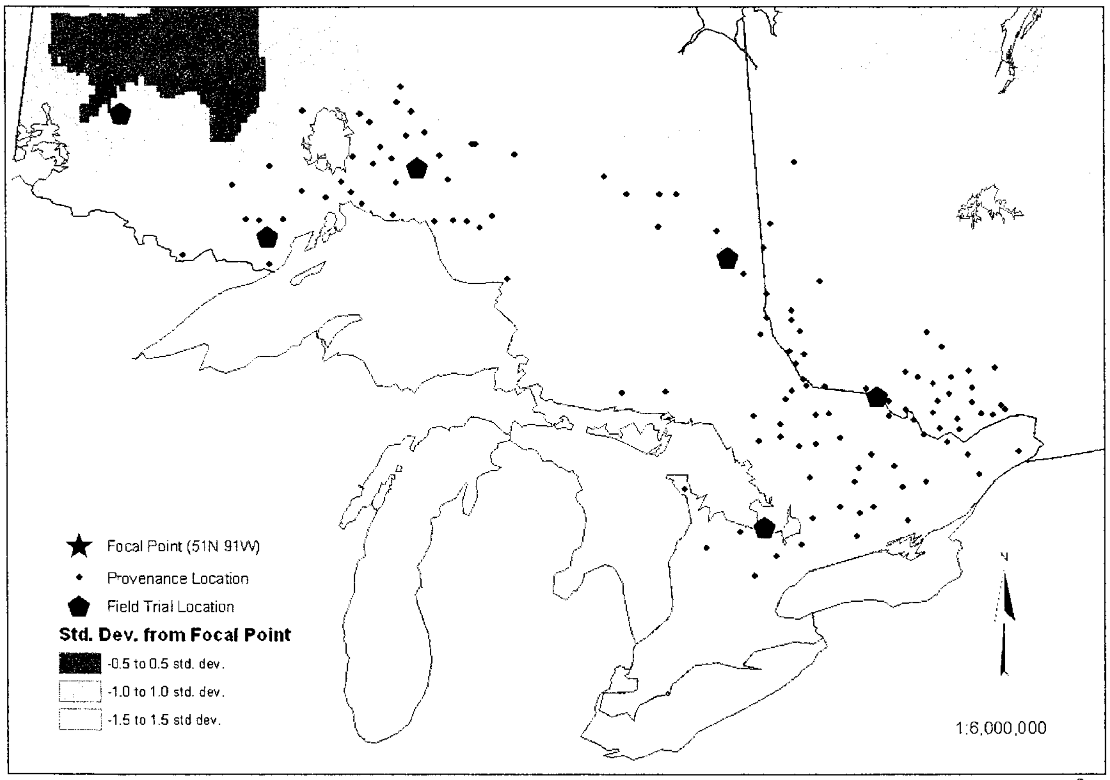

Figure 19. White spruce regression based focal point seed zones for coordinates 51°N 91°W

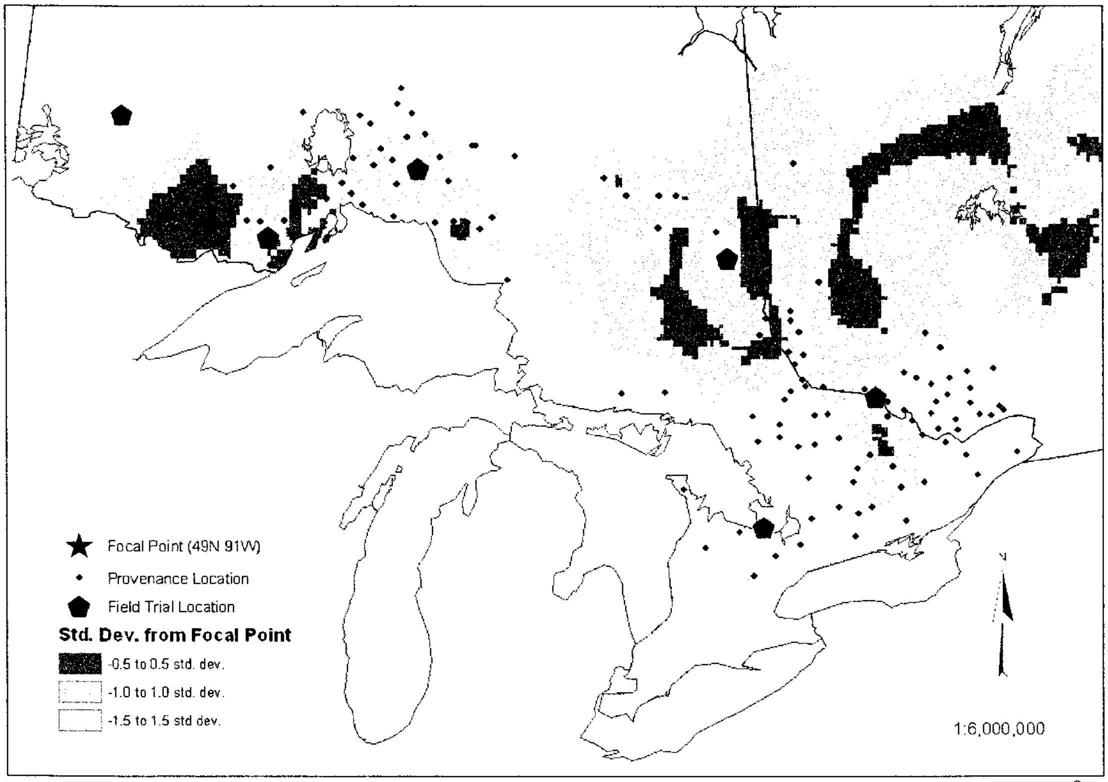

Figure 20. White spruce regression based focal point seed zones for coordinates 49°N 91°W

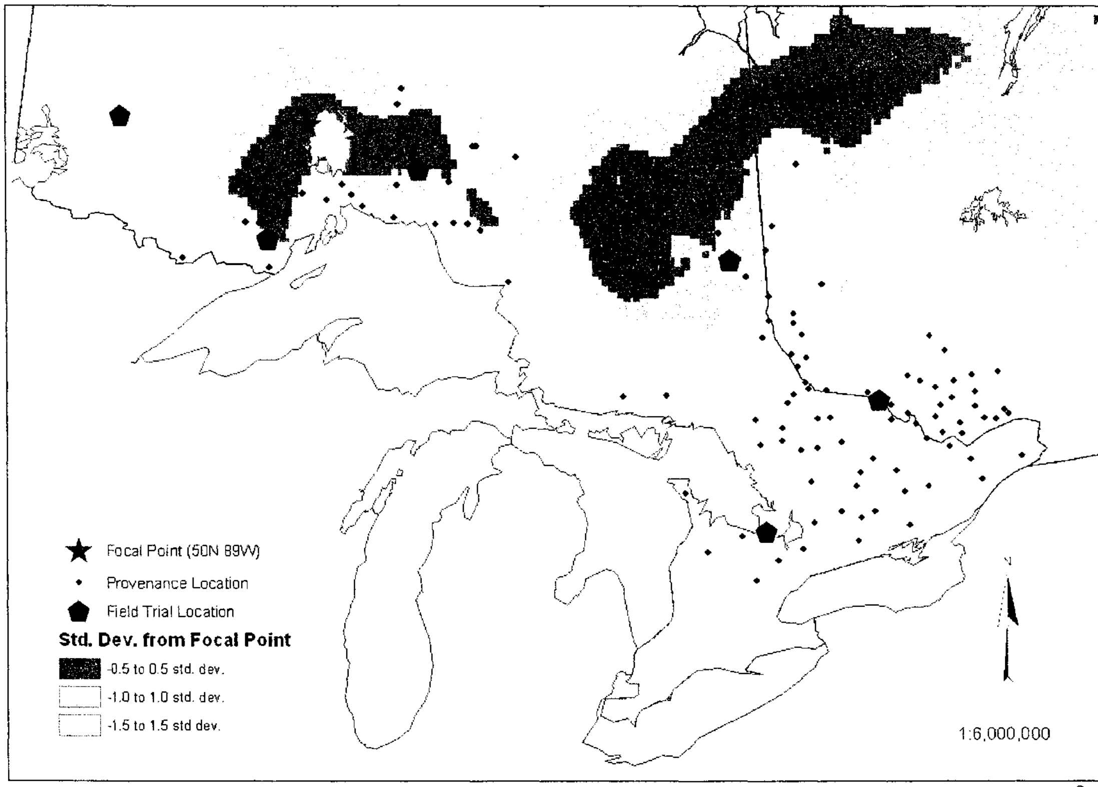

Figure 21. White spruce regression based focal point seed zones for coordinates 50°N 89°W

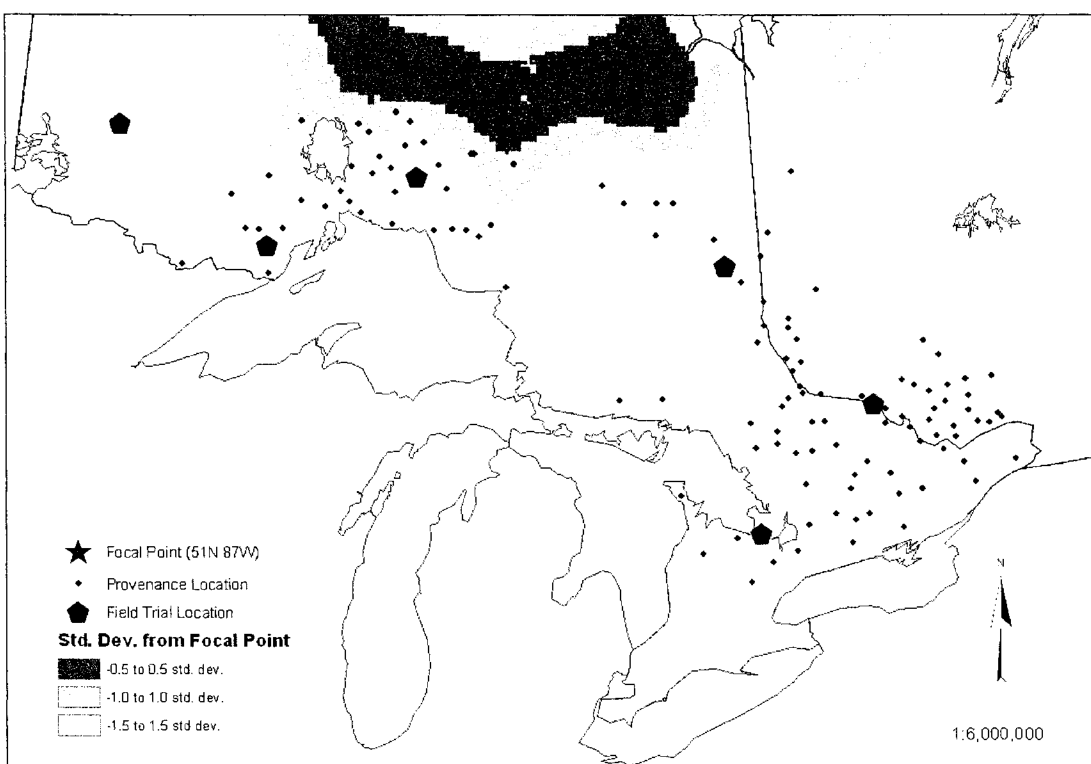

Figure 22. White spruce regression based focal point seed zones for coordinates 51°N 87°W

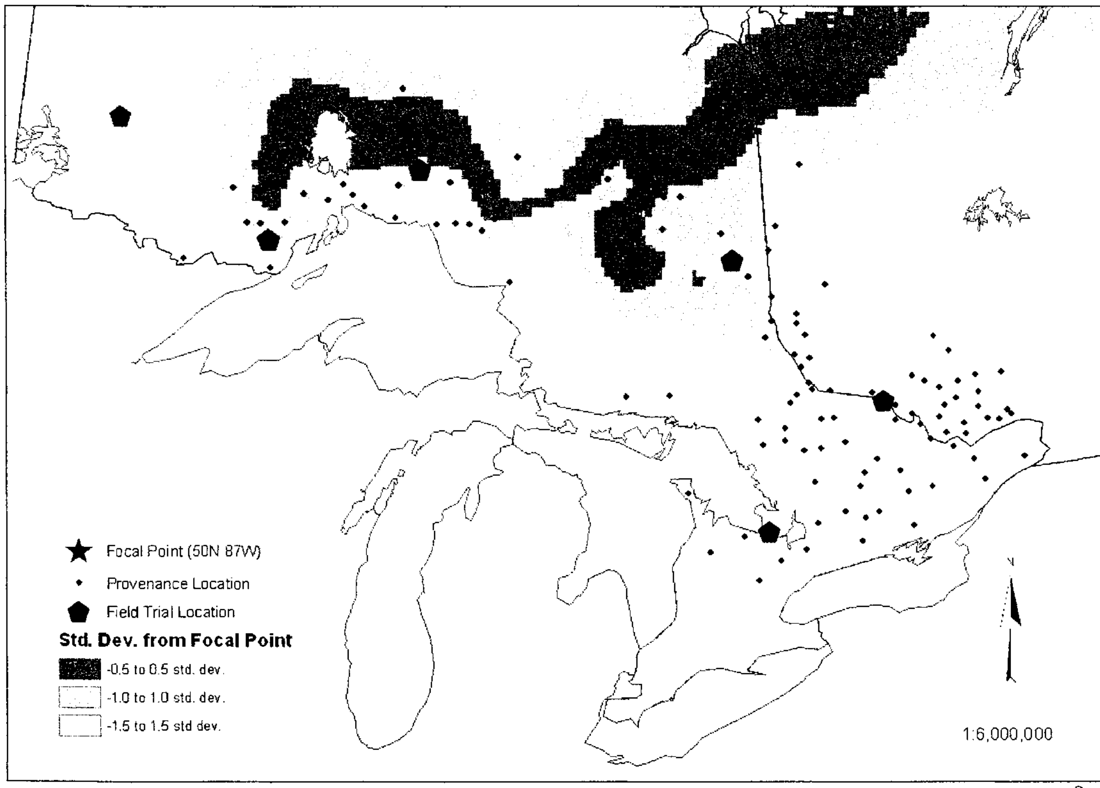

Figure 23. White spruce regression based focal point seed zones for coordinates 50°N 87°W

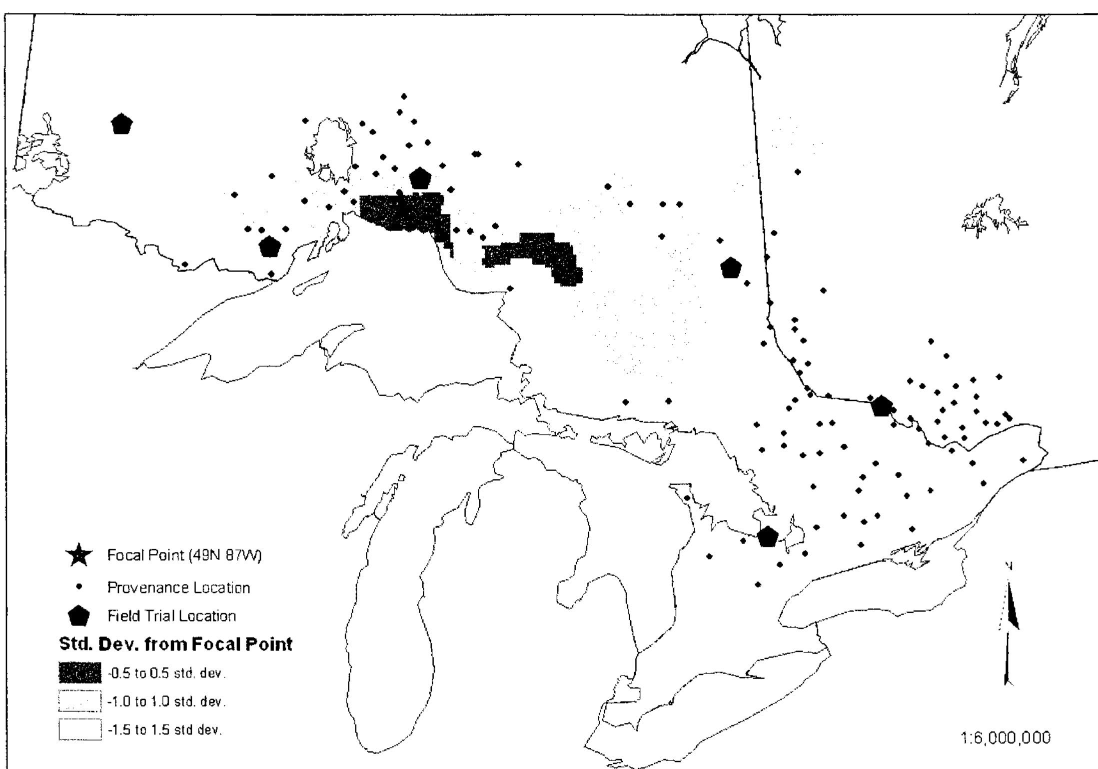

Figure 24. White spruce regression based focal point seed zones for coordinates 49°N 87°W

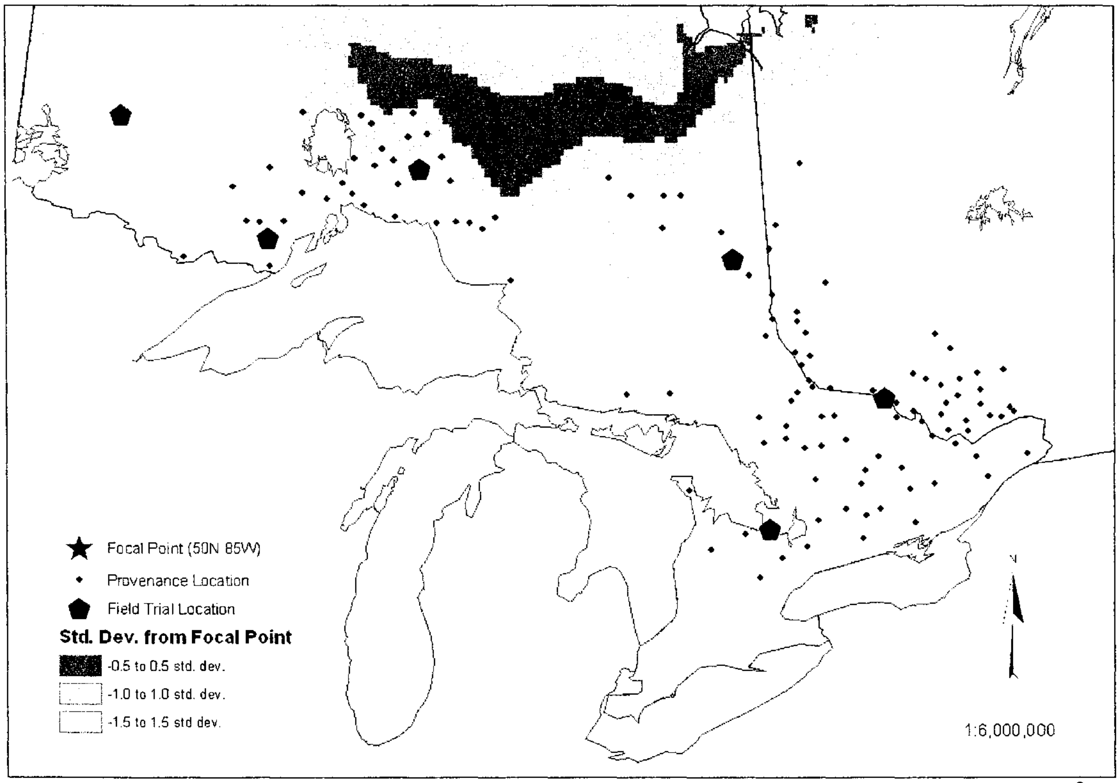

Figure 25. White spruce regression based focal point seed zones for coordinates 50°N 85°W

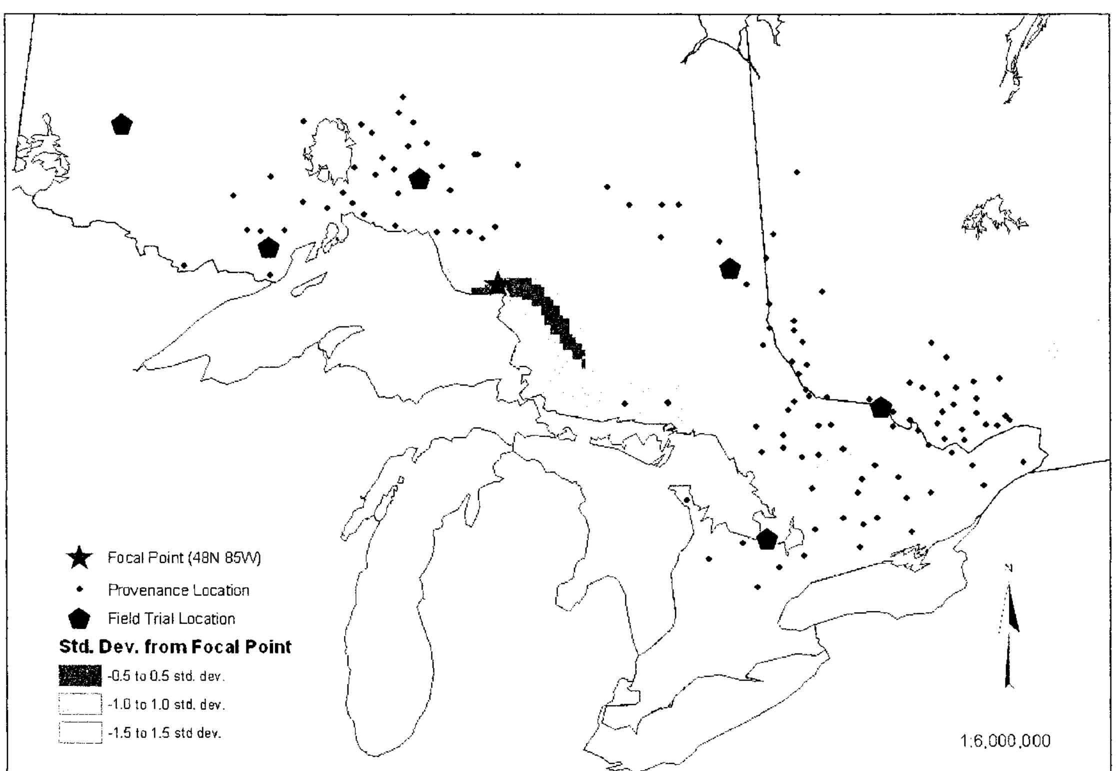

Figure 26. White spruce regression based focal point seed zones for coordinates 48°N 85°W

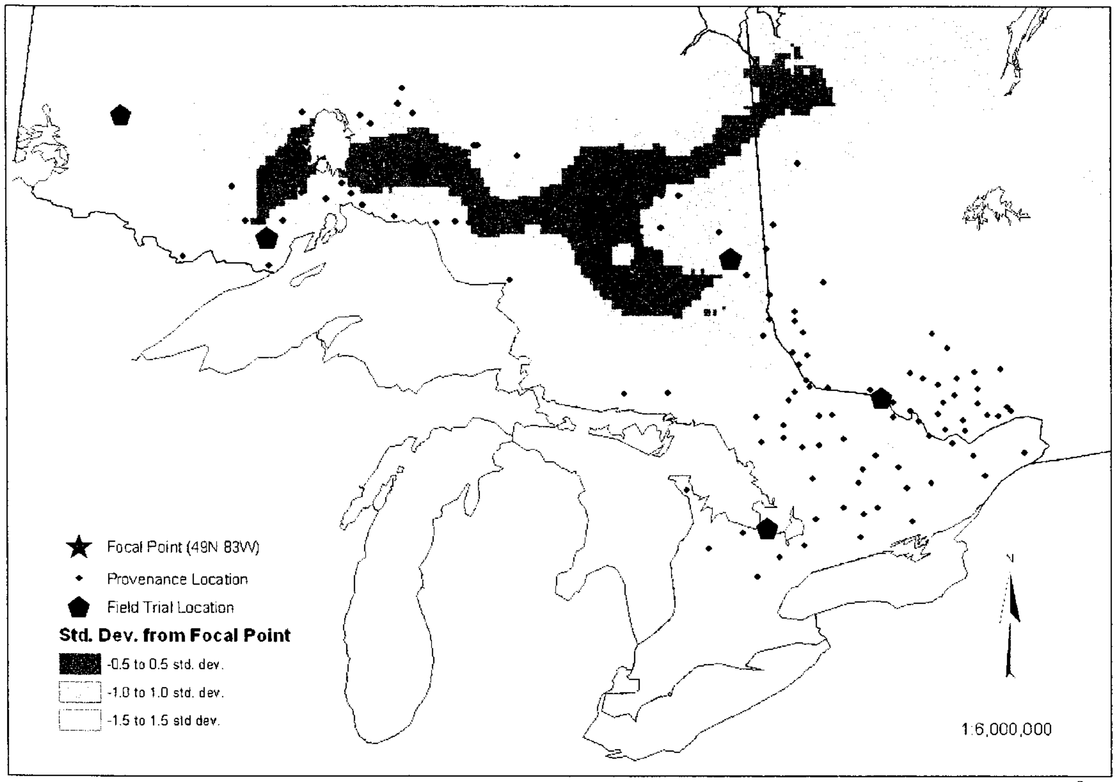

Figure 27. White spruce regression based focal point seed zones for coordinates 49°N 83°W

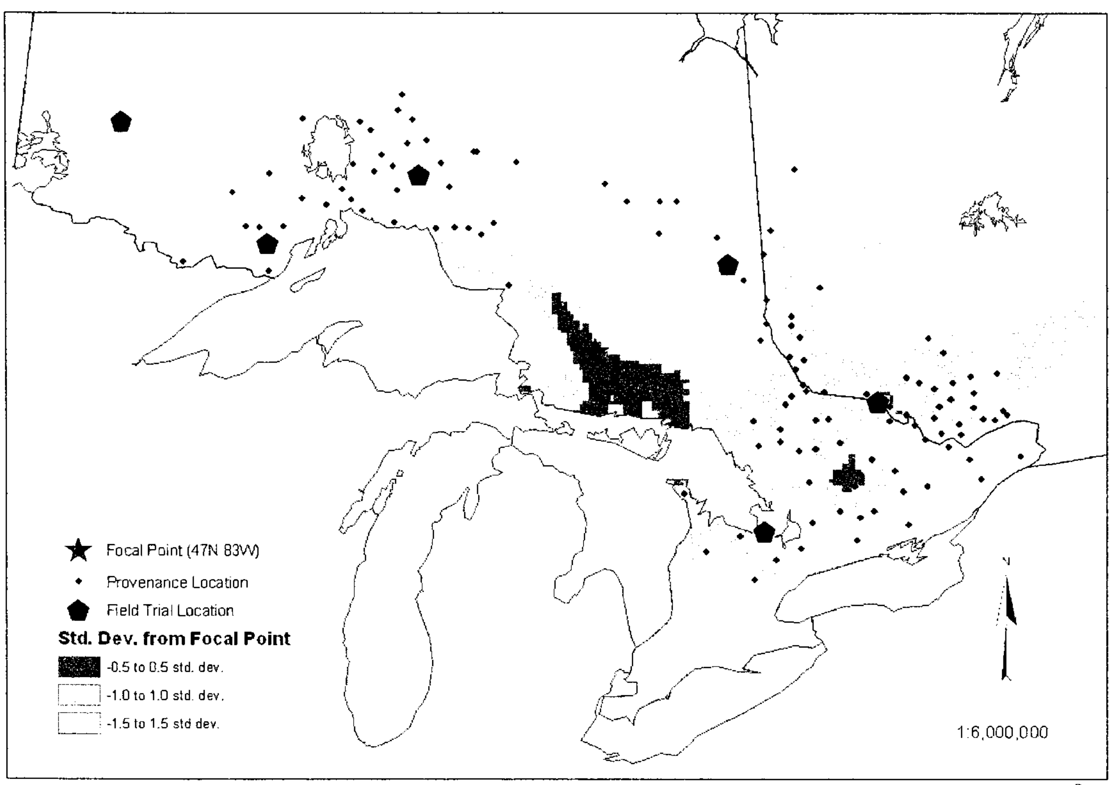

Figure 28. White spruce regression based focal point seed zones for coordinates 47°N 83°W

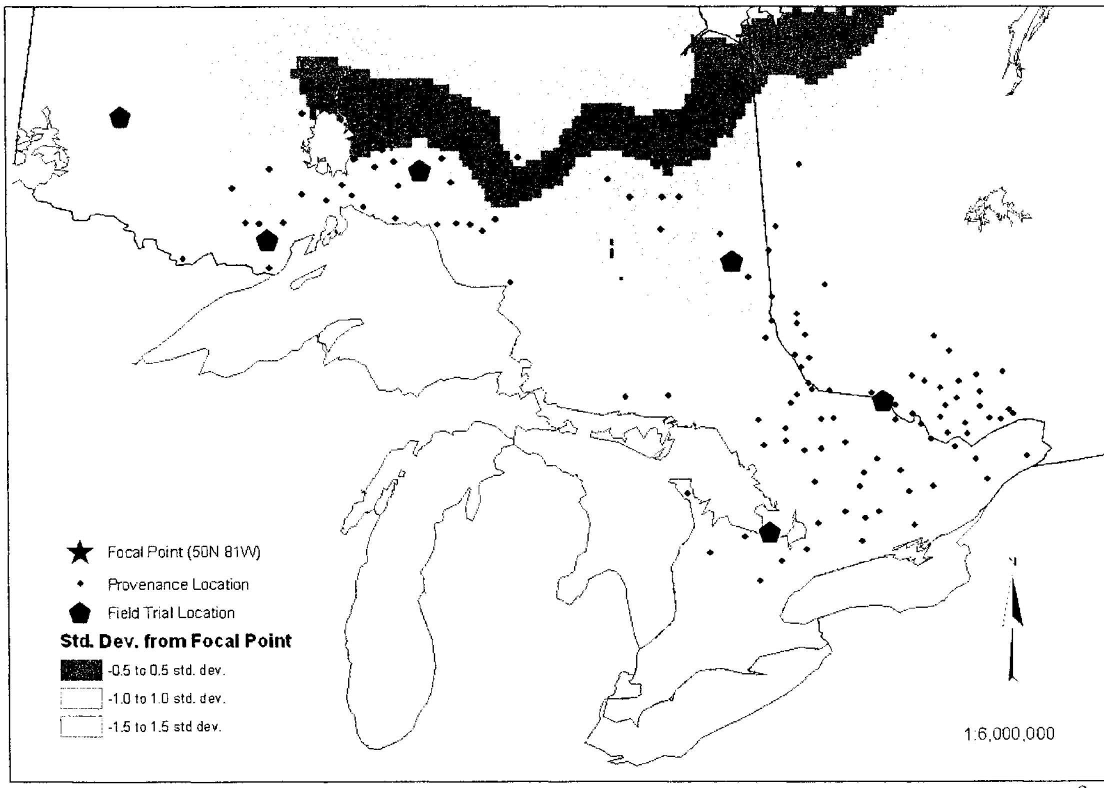

Figure 29. White spruce regression based focal point seed zones for coordinates 50°N 81°W

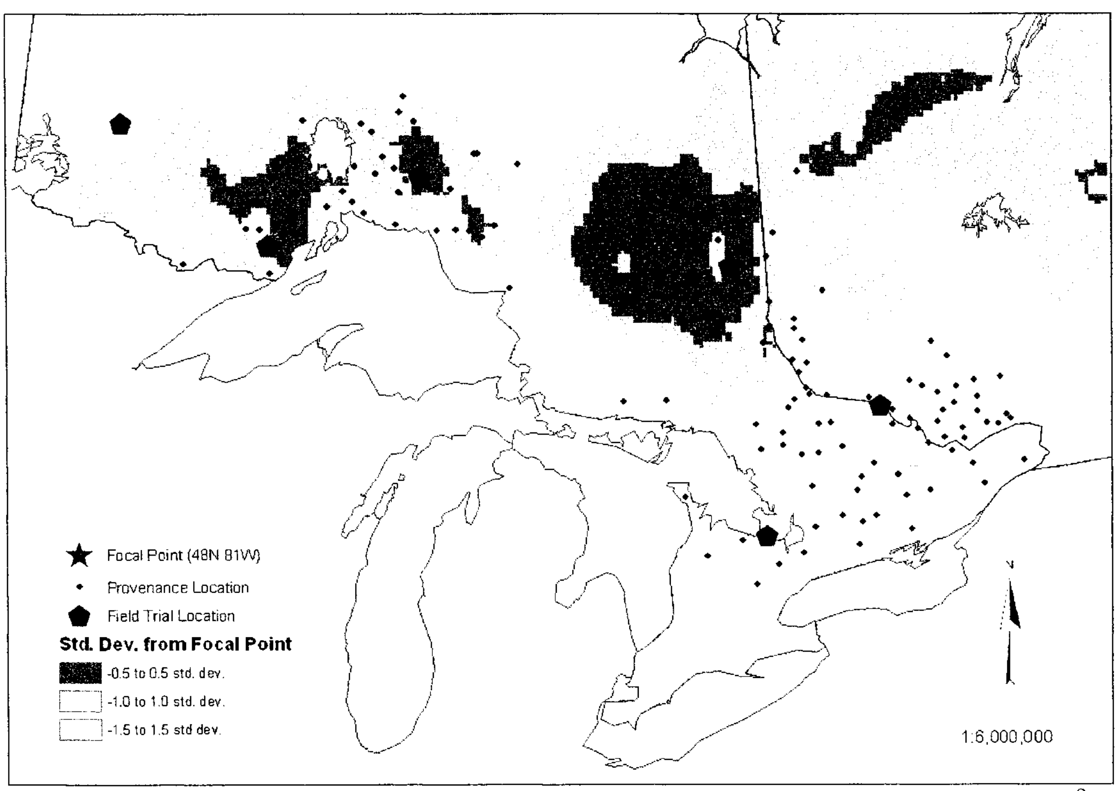

Figure 30. White spruce regression based focal point seed zones for coordinates 48°N 81°W

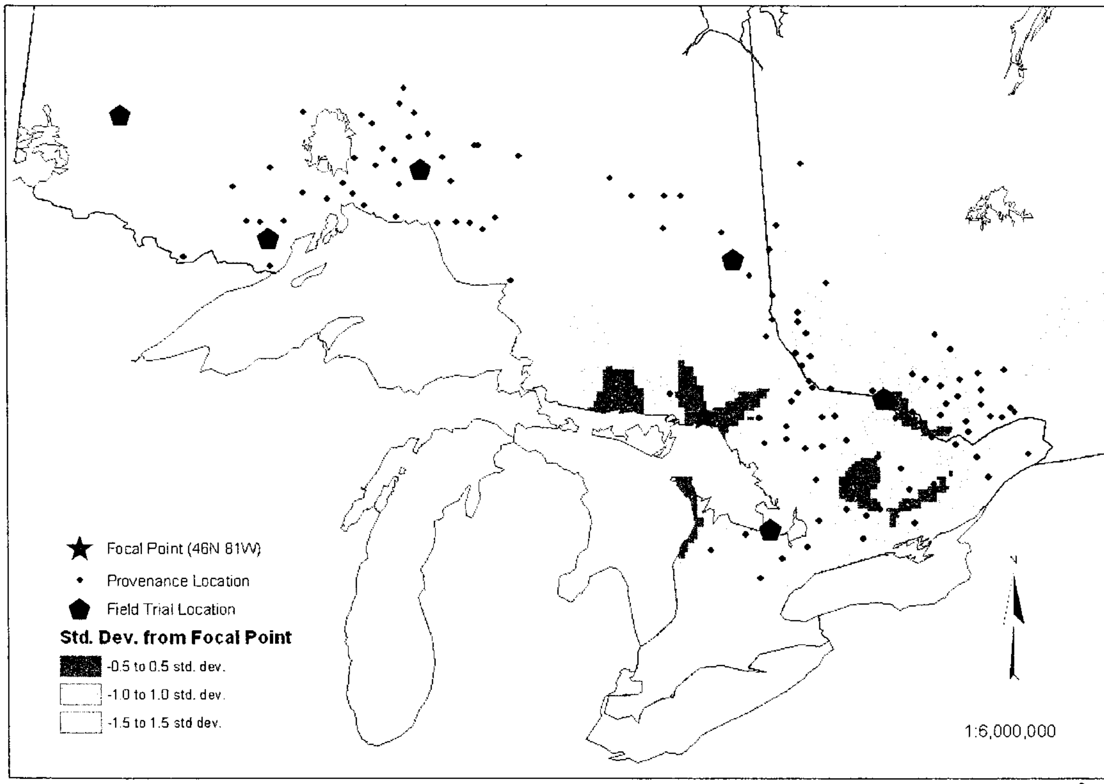

Figure 31. White spruce regression based focal point seed zones for coordinates 46°N 81°W

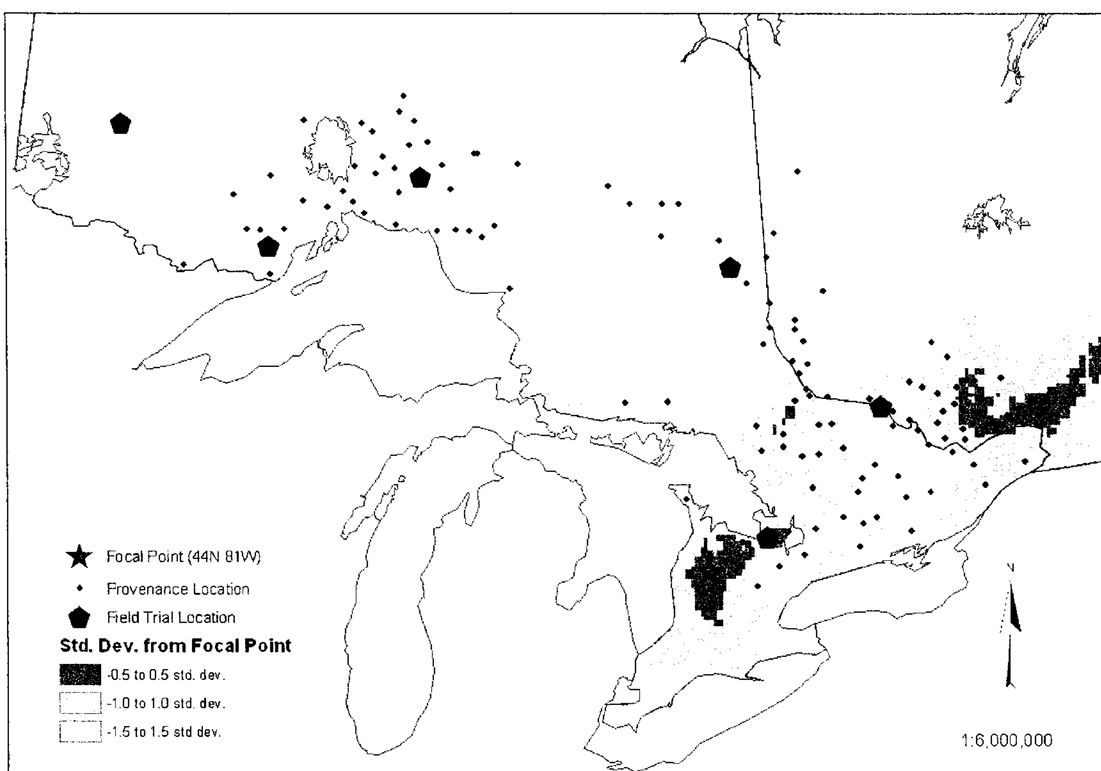

Figure 32. White spruce regression based focal point seed zones for coordinates 44°N 81°W

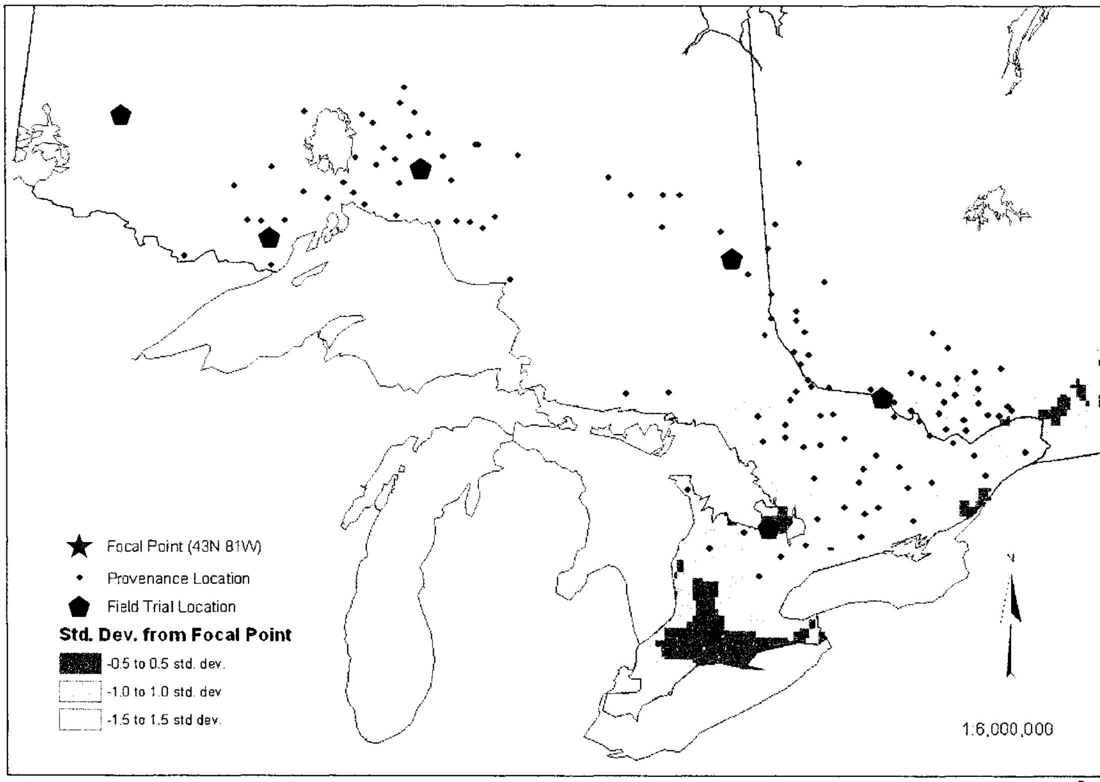

Figure 33. White spruce regression based focal point seed zones for coordinates 43°N 81°W

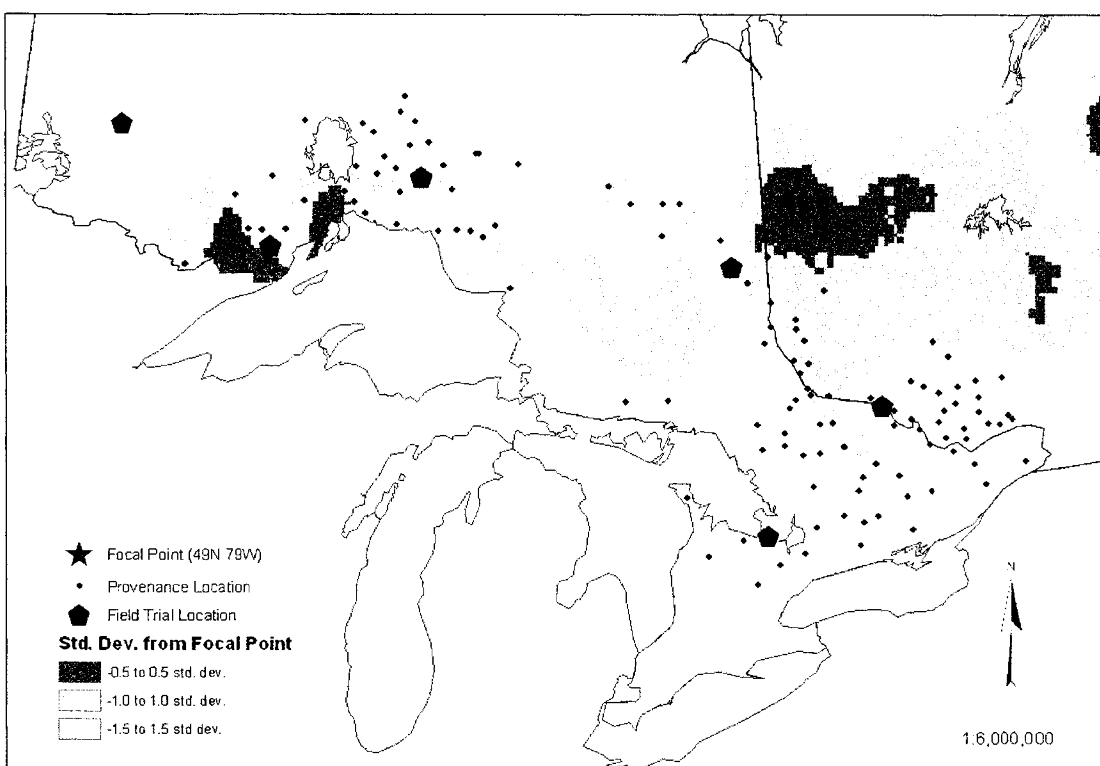

Figure 34. White spruce regression based focal point seed zones for coordinates 49°N 79°W

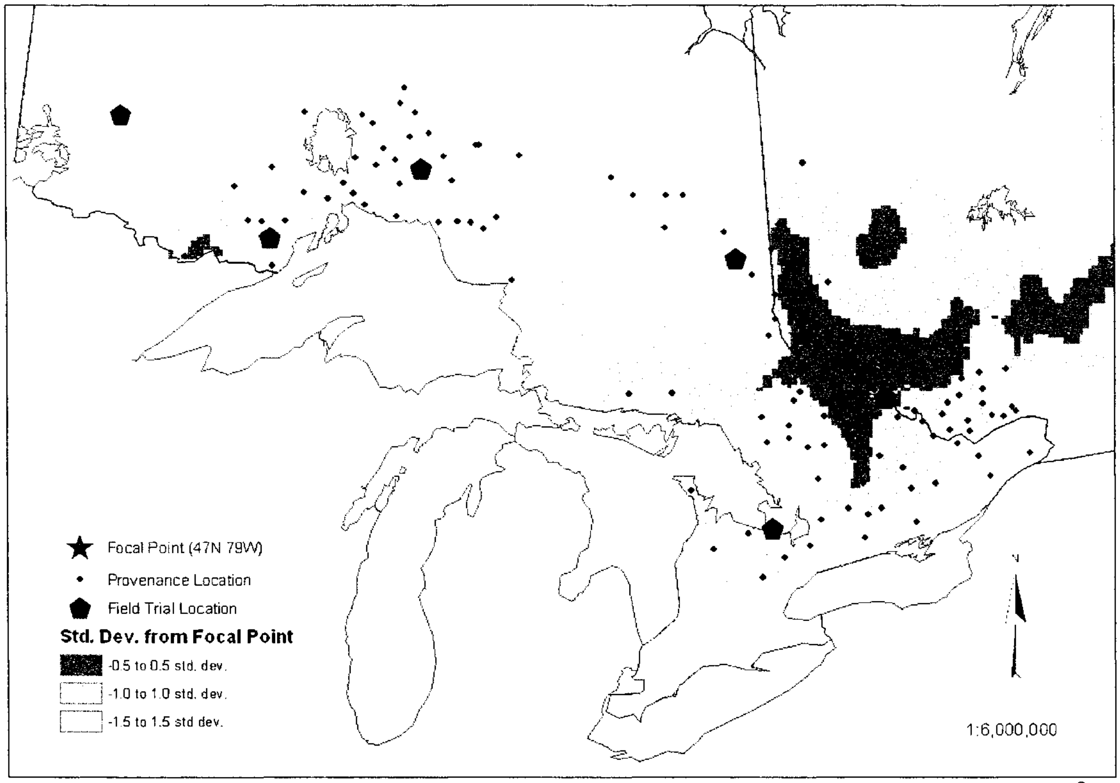

Figure 35. White spruce regression based focal point seed zones for coordinates 47°N 79°W

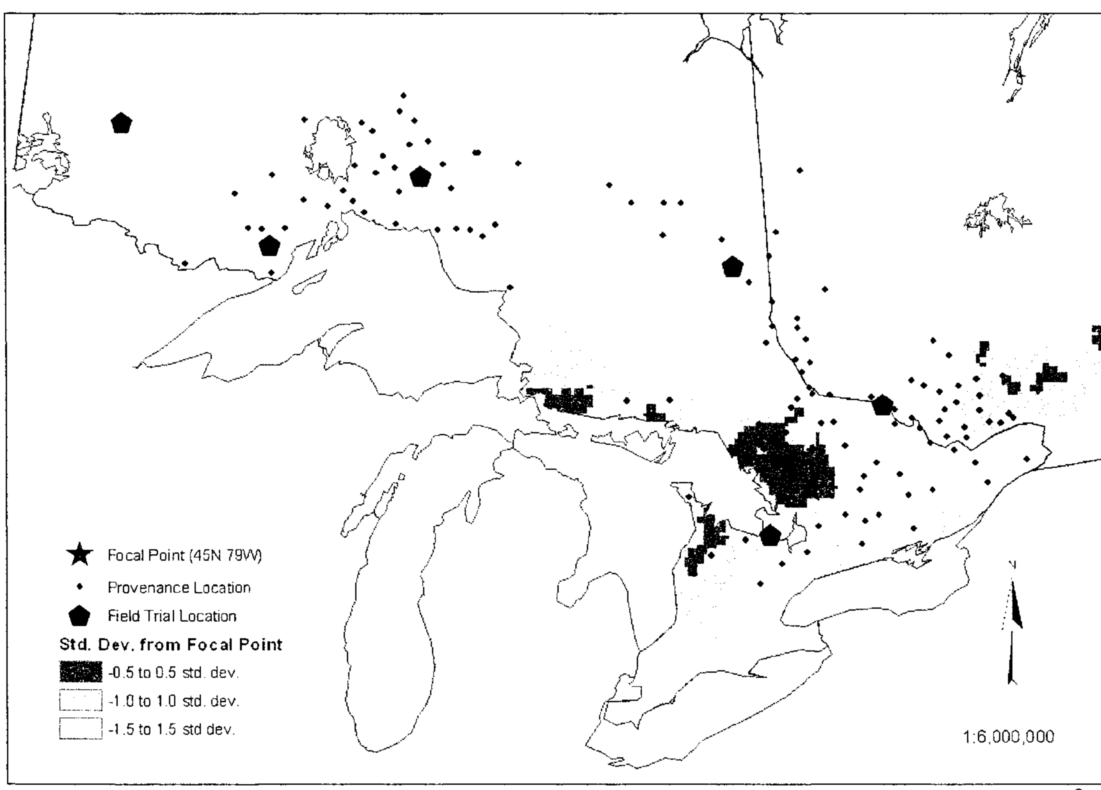

Figure 36. White spruce regression based focal point seed zones for coordinates 45°N 79°W

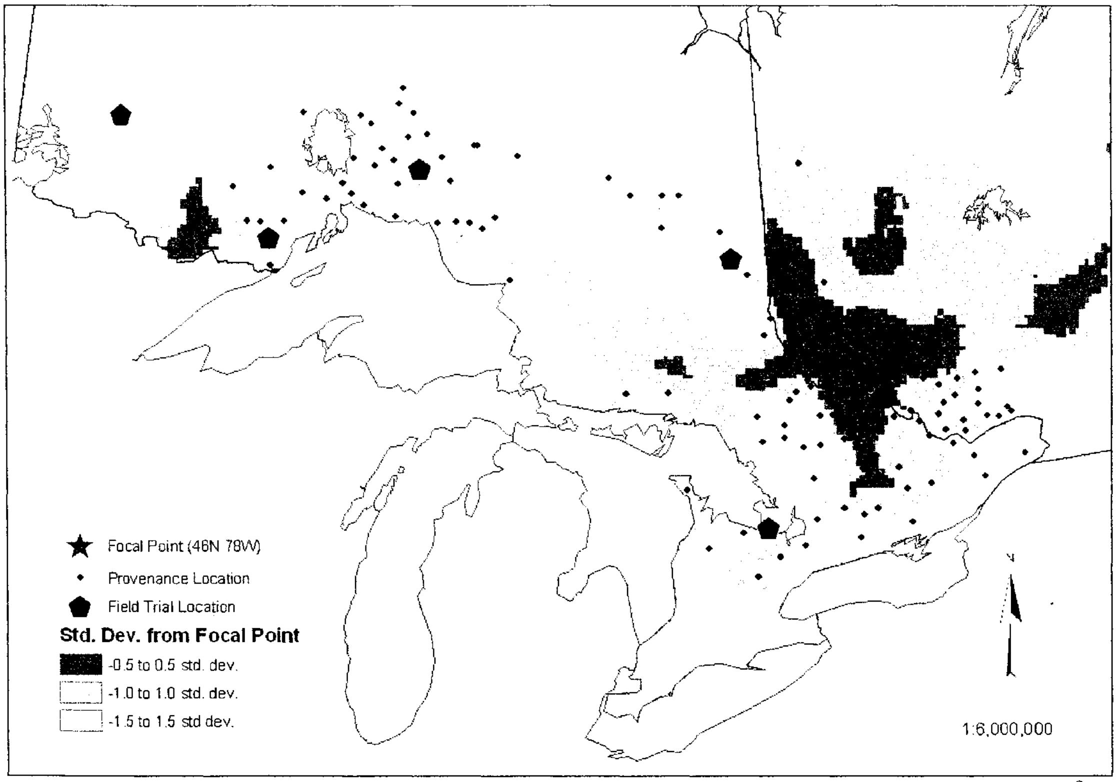

Figure 37. White spruce regression based focal point seed zones for coordinates 46°N 78°W

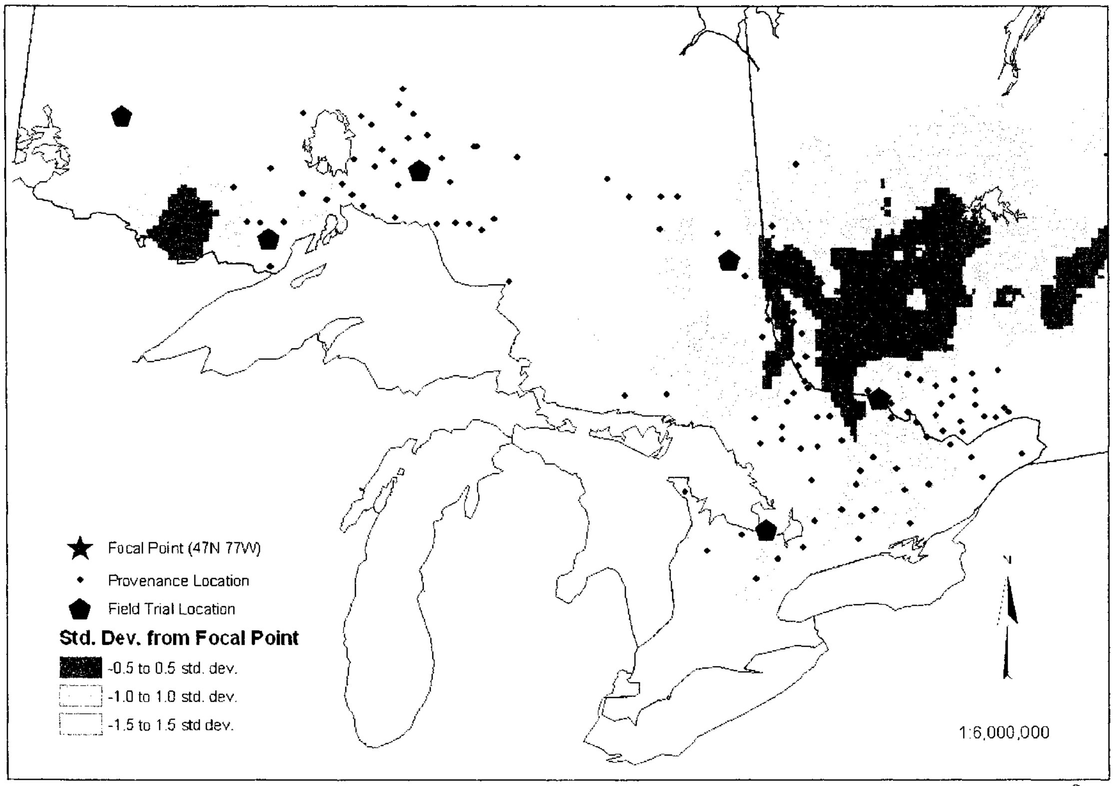

Figure 38. White spruce regression based focal point seed zones for coordinates 47°N 77°W

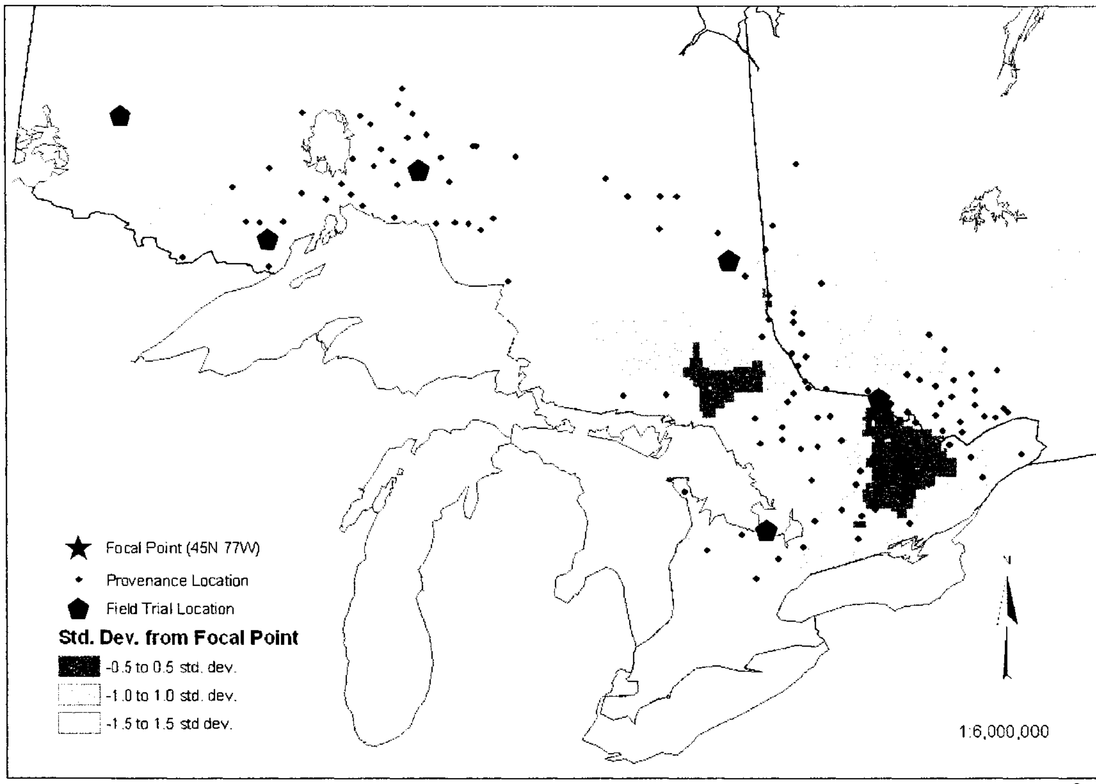

Figure 39. White spruce regression based focal point seed zones for coordinates 45°N 77°W

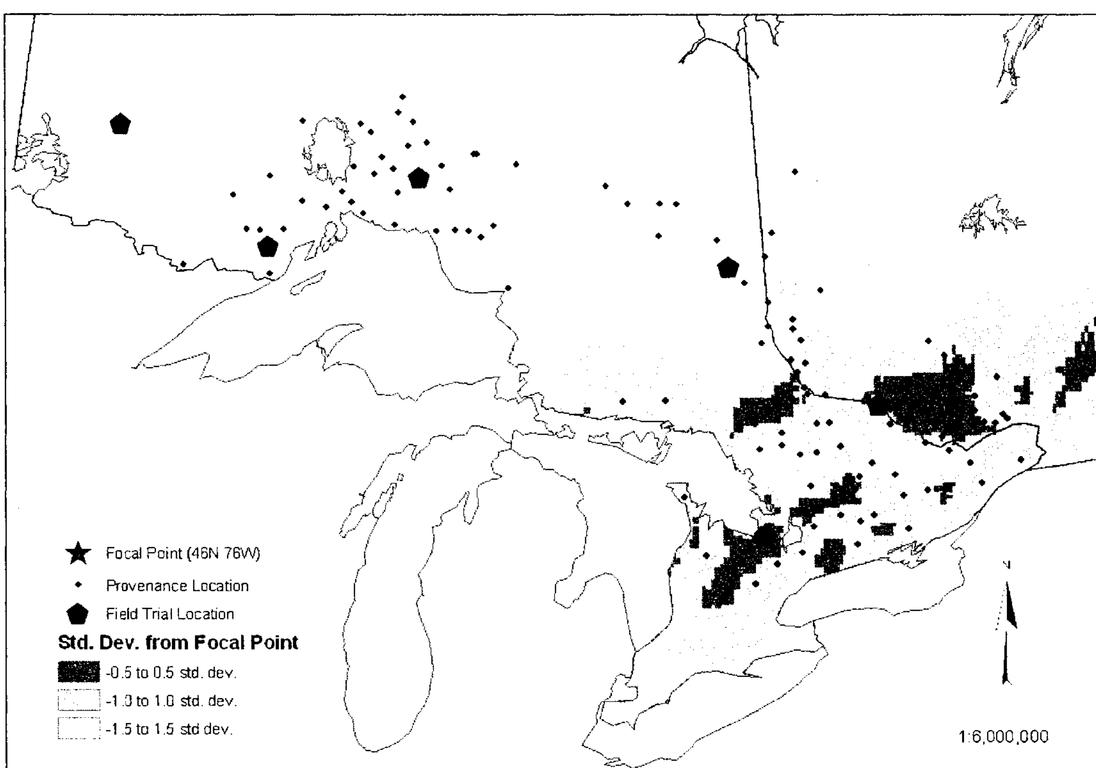

Figure 40. White spruce regression based focal point seed zones for coordinates 46°N 76°W

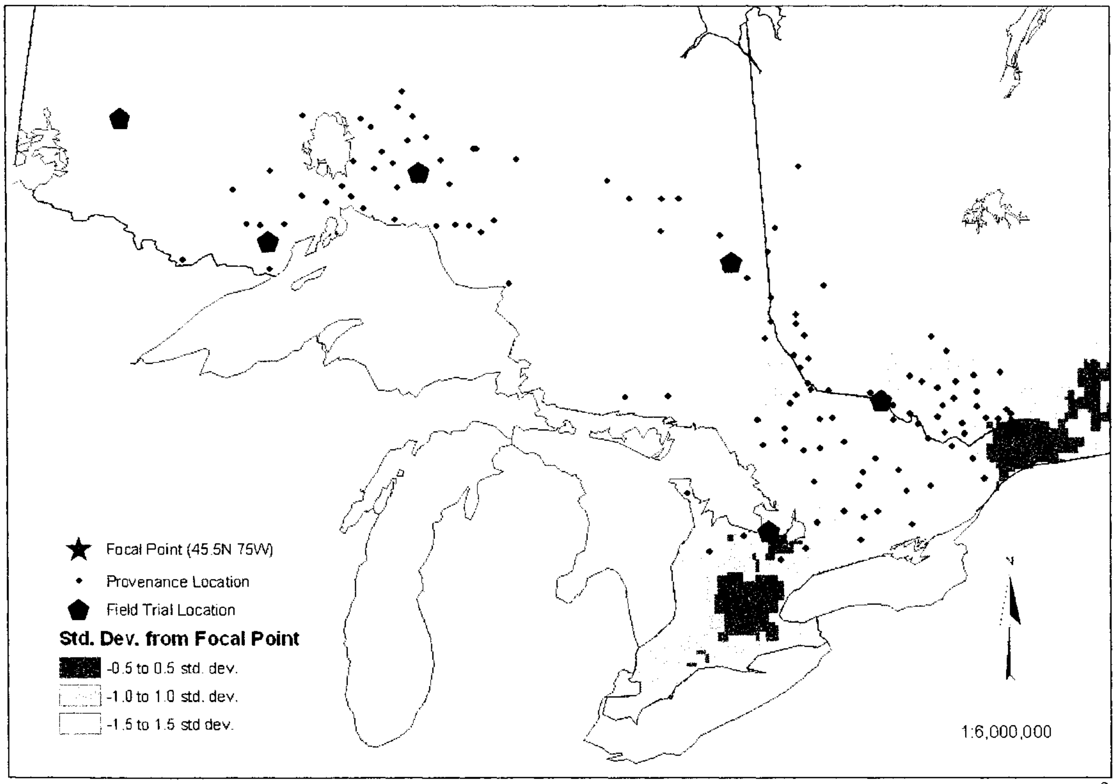

Figure 41. White spruce regression based focal point seed zones for coordinates 45.5°N 75°W

DISCUSSION

Existing white spruce provenance tests in Ontario provide little help in establishing focal point seed zones. The majority of the work done in studying adaptive variation has been through three test series that have been initiated over the course of the last 50 years. Of these three provenance test series (Experiment 93, Experiment 194, and Experiment 410), the 410 series was the most comprehensive. This test series was initiated in 1972 with the purpose of studying genetic variation across the entire range of the species and also to study within-region variability (Morgenstern and Copis 1999). Sixteen tests were established in Ontario as part of the 410 series, 10 through the Canadian Forest Service (CFS), and 6 through the Ontario Ministry of Natural Resources (OMNR). While this layout provided a comprehensive coverage of test locations across the province, the primary emphasis was on planting provenances that occurred at similar latitudes to any given test location, with only a few representatives of the entire range. Furthermore, no effort was made to replicate provenances between tests (Lesser 2003). While this arrangement suited the original purpose of the experiment, it renders it virtually unusable for the development of focal point seed zones where representation of each source is required at each site. This issue may be surmountable however, using scaling and joining techniques to connect disparate data sets (Rehfeldt 2004).

A key criterion of the focal point methodology is complete replication of all provenances at all test locations; and, it was to meet this criterion that the new series of tests was initiated for this study. Without this criterion being met, principal component analysis could not be run to summarize biological variables and subsequent steps in the process could not be developed. However, the 410 Series data (Cherry and Parker 2003) was used to provide complementary evidence and reference for the results shown by this study.

Seed zones for white spruce in Ontario have depended largely on the site region framework developed by Hills (1961) with divisions based mainly on landform, climate, and vegetation Site regions have been subdivided into site districts based on geology and soils, and these have been further refined through climate analysis (Mackey *et al.* 1996).

Focal point seed zones follow the approach that each individual tree species will have a unique pattern of adaptive variation within its range and within specific areas of that range. While these patterns will generally follow climatic, geological, and geographic trends in the landscape, a level of uncertainty is imposed in using such generalizations without knowing the specific patterns of adaptation for a given species.

Focal point seed zones represent the areas of greatest similarity to the selected focal point. This condition is in keeping with current practice in Ontario, where local seed is considered best for reforestation efforts. The focal point method indicates an indeterminate range of climatically similar locations corresponding to the selected focal point. This range can be refined by narrowing the mapped contour intervals, thus creating narrower, more specific zones from which to obtain seed collections (Parker and Van Niejenhuis 1996a). However, it is important to understand that while the identified sources are the most well adapted, focal point zones do not identify seed sources that will maximize growth potential at a given point.

Response functions developed for white spruce (based on 410 provenance series) by Cherry and Parker (2003) show that increased growth will generally be achieved in northwestern Ontario by moving southern sources north. Although this approach acts to produce maximum yield for a given site, care must be taken to avoid planting maladapted seed. Hence, the use of focal point zones to delineate areas of similar adaptation, combined with response and transfer functions to identify the sources that will produce the greatest growth from within these zones becomes a powerful strategy.

Generalized seed zones based on Hills site regions and climate, when compared to the focal seed zones, create zones that are too specific in many cases, while in individual instances are not nearly specific enough. Figures 19 through 41 show that, much of the northwest and northeast is equally suitable for seed transfer. There was a fairly strong restriction on movement north and south of 50° N Latitude, and areas directly along the eastern shore of Lake Superior and the Algonquin Highlands were generally less suitable. Furthermore, for most of the selected points in the northern area of the province much of the south was deemed similar in adaptation. This finding is fortuitous as best performing provenances in terms of height growth were generally from more southern areas and since findings from our results and 410 series measurements showed that the best growing provenances at tests in the northwest came predominately from more temperate southern regions (Morgenstern and Copis 1999).

Southern points do not show the same broad zones of similarity that more northern points do. As focal points move south (Figures 19-41) zones become more specialized and distinct. This trend is also supported by both our results and results from the 410 series that showed best growing provenances at more southern test sites were generally local, or at least regional, sources (Morgenstern and Copis 1999).

The implications of these findings is that there may not be the need for seed zones on a site region scale in the northern sections of the province, while this same scale is not adequate in southern regions. Furthermore, within regions lake and other geographic effects definitely need to be considered when selecting seed. Trends in adaptation facilitate movement of seed north, but movement of northern sources south is generally not acceptable.

Caution should be exercised in applying the focal point model to areas of the province that are not well represented by seed sources. While the model creates a surface for the entire study area, regions that are not well represented have more chance of not accurately reflecting true patterns, as the surface has been extrapolated from the growth of seed sources from surrounding points. Areas east of Sault Ste. Marie and west of Fort Frances are regions most lacking in complete representation. It is not certain, however, to what extent the patterns of adaptation for these areas are affected by poor representation, or if true patterns are being shown. Further study with sources collected from these regions would be needed to clarify this issue. Without further clarification some caution should be used when producing zones in either of these poorly sampled regions.

The regression models used to predict each of the PC axes, while all significant, have relatively low r^2 values, ranging from 27.1 to 48.45 percent (Table 11). This is probably a function of other environmental factors, not considered in this study, shaping patterns of variation in white spruce. Factors not considered could include soil type and vegetation type. Another potential issue is that the first three PC axes account for only 54 percent of the total amount of variation expressed. However, it is felt that the level of variation explained by the models is sufficient to delineate seed zones for two reasons:

1) that only the adaptive variation expressed between provenances is modeled; and 2) the amount of variation explained is actually much higher when compared to levels of variation expressed for individual variables (Table 6) (Parker and van Niejenhuis 1996a).

The final point that should be made when using the focal point model is that disjunct areas having greatest similarity as seen in many of the figures (19-41) should be considered with caution, particularly when they occur across a great geographic distance. While these areas may be true representations of adaptive patterns, it is also possible that they are anomalies expressed due to incomplete accounting of adaptive variation. While the focal point seed zone method attempts to account for all adaptive variation present in white spruce within Ontario, this goal was realistically not possible hence, incomplete seed source sampling may affect the outcome.

Comparisons with focal point seed zones developed for black spruce and jack pine in north-western Ontario are somewhat difficult to make, due to the difference in geographic scale and more intense seed source representation from that area. For both the black spruce and jack pine studies, the Northwest was sampled extensively, while for this project the Northwest is represented poorly in comparison. However, similarities do exist for points centered around Lake Nipigon (Figures 19-24) compared to black spruce results. Black spruce focal point seed zones were found to change most rapidly over short distances in the southern part of the study area and along the shores of Lake Superior and Lake Nipigon (Parker and Van Niejenhuis 1996b). White spruce results show a similar trend for zones in these areas, however, only the effect of Lake Superior appears significant (Figure 24), as zones wrap around Lake Nipigon, extending to both the east and west. Figure 19 does show a relatively confined area of greatest similarity in the southern area of the Northwest; however acceptable zones extend across almost the entire study area. Jack pine focal point zones show a somewhat similar trend to our results in that for northern points zones of similarity are strongly limited by latitude (Parker and Van Niejenhuis 1996a). The sinusoid east-west pattern reported for the jack pine zones (Parker and Van Niejenhuis 1996a) is also evident in our results to a degree in Figures 19-24.

Another point of interest is the correspondence between areas in northwestern Ontario, centered on the Fort Frances area, and south-eastern areas, most notably around the Ottawa Valley. This trend is seen in all three of the predicted PC factor score grids (Figures 16-18), and is also seen in many of the focal point figures (Figures 19-41). One explanation for this genetic similarity between extremely geographically disjunct areas is that the same correspondence is seen for these geographic areas when Rowe's forest regions of Canada are considered (Rowe 1972). The Great Lakes-St. Lawrence forest region which covers most of central and eastern Ontario and southern Quebec, also occurs in western Ontario extending from the U.S. border north to approximately 49° latitude, running east-west between the Thunder Bay area and the Manitoba border. The north-south divide at approx. 50° latitude seen for focal points across the northern extent of the study area also corresponds to this forest region transition in northwestern Ontario. The sharp latitudinal divide also shows similarities to site region boundaries (Hills 1961), which show a similar divide across northern Ontario. Furthermore, the second divide seen in the focal point seed zone maps at approx. 47° latitude in central Ontario, also corresponds to the eastern transition from boreal to Great Lakes-St. Lawrence forest region (Rowe 1972). The connection to Rowe's forest regions and

Hill's site regions gives ecological significance and plausibility to our findings for white spruce.

While focal point seed zones represent the best adapted seed sources for a given location, they are based on current climatic conditions. Predicted climate change scenarios suggest that temperature and precipitation amounts and patterns in Ontario will change drastically over the next 50 years. The focal point methodology can be adapted to predict areas of best adaptation based on these scenarios, and allow forest managers to obtain seed that will be best suited for the future. While this approach could have repercussions if climate change predictions are not realized, gains could also be substantial if predictions do hold true.

CHAPTER IV
CANONICAL CORRELATION BASED FOCAL POINT SEED ZONES

INTRODUCTION

The previous chapter dealt with the development of focal point seed zones following the same methodology developed by Parker and van Niejenhuis (1996a, 1996b) for black spruce and jack pine in northwestern Ontario. While that approach produced good results for both previous studies, and for this current study, canonical correlation analysis (cancorr) offers an alternative statistical methodology for developing seed zones. Canonical correlation analysis is, statistically speaking, a better tool for addressing ecological issues dealing with two multi-variable data sets and the relationships between them (Gittins 1985). Cancorr maximizes the covariance between the two data sets utilizing the information from all variables. While other approaches to problems of this nature use multiple statistical tools such as principal components analysis and multiple regression to reach the end goal, cancorr both summarizes and relates data sets in one step, resulting in less loss of information and providing a potentially more ecologically sound interpretation of the relationships between data sets.

While cancorr is statistically appealing it has previously been met with limited enthusiasm in ecological applications (Gittins 1985). Parker and van Niejenhuis (1996b) found it less satisfactory than the principal component–regression based approach on a number of fronts, and other studies have shown similar dissatisfaction (Austin 1968, Gauch and Wentworth 1976). Westfall (1992) however, successfully used cancorr procedures to develop seed zones for white fir in California, and other studies have also shown that cancorr provides an effective means of analyzing ecological data (Gimaret-Carpentier *et al.* 2003, Pélissier *et al.* 2001).

The purpose of this chapter was to develop a procedure to produce focal point seed zones using canonical correlation analysis. Resulting examples were compared to seed zones developed in the preceding chapter using the principal component-regression based methodology.

METHODS AND MATERIALS

The same screening process used to select variables for the regression based focal point seed zones was used for the canonical correlation approach. As before, 57 of the original variables were retained for further analysis. These variables all demonstrated significant between-provenance variation with some level of genetic variation that could be attributed to a climatic or geographic variable (refer to Tables 6 and 7). The screening process ensured that only variables that demonstrated adaptive variation across the study area were used to construct seed zones.

The provenance means for the 57 retained biological variables, along with the provenance values for the 67 climatic variables (refer to Chapter II for details on climate variables) that were used in the screening process were entered into canonical correlation analysis (cancorr). Cancorr was run using the cancorr procedure in SAS (SAS Institute 2000). A sample of the program written to perform this procedure is given in Appendix VIII.

Cancorr considers both sets of data (biological and climatic) simultaneously and selects linear functions that maximize the covariance between the variable sets. By this procedure cancorr identifies the components of one set of variables that are most linearly related to the components of the second variable set. As in principal components analysis the successive pairs of canonical variates are uncorrelated, or orthogonal, to each other (Thompson 1984).

Canonical variates were assessed for level of significance using an F test ($p<0.05$). Significant variates were retained for further analysis. Correlations of variables from each variable set and each canonical variate were calculated to determine which variables were contributing the most to each of the canonical variates. For each of the significant variates the standardized canonical coefficients for the climate variable set were calculated. The canonical coefficients are essentially equivalent to partial regression coefficients in multiple linear regressions (Gittins 1985). Canonical coefficients from one variable set can therefore be used to predict values of the other variable set for each of the canonical variates in question.

The climatic canonical coefficients were used to model the biological scores for the three significant canonical variates. Models were converted to spatial data using GIS. Using the Grid sub-package of ARC 8.3 (ESRI 2002) each of the 67 supplied climate variable grids (McKenney 2004) was multiplied by its respective coefficient. The 67 grids were then stacked, or added, to each other producing one single grid that represented predicted biological variable scores for the respective canonical variate.

To facilitate comparison with conventional focal point seed zones, provenance point data were extracted from each of the grids and the mean and standard deviation of the 127 points was calculated. Grids were then standardized using the provenance point mean and standard deviation. The program written to perform this function is shown in Appendix IX. The resulting standardized grids summarize the spatial pattern of adaptive variation in relation to the 67 climate variables.

Using the standardized grids, focal point seed zones were built using the same protocol as used in the regression based method. The computer program developed for the regression based method was altered to accommodate the new canonical based grids.

For any selected point within the study area this program standardized the 3 canonical grids to that focal point and intersected them. The resulting single grid identified areas of adaptive similarity in terms of standard deviations from the focal point. Zones of decreasing similarity were identified by shading patterns. All grids were produced in ARC 8.3 (ESRI 2002). For a more complete description of this process refer to Methods in Chapter III.

Seed zones were constructed for the same 23 focal points used to illustrate the regression based methodology in Chapter III. This procedure enabled a visual comparison between the techniques.

RESULTS

CANONICAL CORRELATION ANALYSIS

The first three canonical variates were significant ($p<0.05$) (Table 12). Canonical variate 1 explained 44 percent of the covariance in the two variable sets. The second canonical variate explained a further 18 percent of the covariance, and the third canonical variate a further 10 percent. The total amount of covariance in the data sets explained by the 3 variates is 72 percent.

Table 12. Correlations, eigenvalues, proportions and significance levels for canonical variates 1 to 3

Canonical Variate	Canonical Correlation	Eigenvalue	Proportion Covariance	Cumulative Proportion	Approx. F Value	Pr > F
1	0.999	754.446	0.443	0.443	1.360	<.0001
2	0.998	300.067	0.176	0.620	1.230	<.0001
3	0.997	172.887	0.102	0.721	1.140	0.008

Absolute correlation values of the biological variables to canonical variate 1 range from 0.31 to 0 (Table 13). The highest correlations were with the 2003 and 2004 Englehart survival variables (0.31 and 0.29, respectively). Budset variables all have relatively high positive correlations ranging from 0.28 for Petawawa stage 3 to 0.13 for Englehart stage 3. Although budset variables show the most similarity, other variable categories show a mixture of results that ranges above and below budset values. Budflush variables show a mixture of positive and negative correlations that are all relatively weak. Dryden budflush stages and early to middle stages at Longlac are all positive and range from 0.12 for Dryden stage 6 to 0.004 for Dryden stage 2. With the exception of stage 2, that shows a weak positive correlation; greenhouse budflush stages all show negative correlations ranging from -0.039 for stage 4 up to -0.12 for stage 6. Growth variables show a wide range of both positive and negative correlations. 2004 diameter at Petawawa has the highest growth variable correlation at 0.21. The lowest correlation was 0 for 2004 diameter at Longlac. Nine growth variables show relatively weak negative correlations.

Correlations of the biological variables to the second canonical variate show a similar pattern in terms of there being no identifiable trend in variable categories that would give the canonical variate a clear biological interpretation (Table 13). Of the 57 variables, only 4 show positive relationships to canonical variate 2. While the highest 12 negative correlations are all growth variables, other growth variables are lower and the range of correlation values from 0 to -0.39 shows all variable groups at the same general level of correlation.

Correlations of the biological variables to canonical variate 3 are approximately half positive and half negative (Table 13). Correlations range from a high of negative 0.28 (2004 Longlac survival) to almost zero (-0.007 for greenhouse budflush stage 2). Canonical variate 3 shows a relatively strong positive relationship to the budset variable category with values ranging from 0.23 for Kakabeka stage 3 to 0.055 for Petawawa stage 3. However, Englehart stage 5 shows a negative correlation of 0.13. Budflush and growth variable categories show a range of both positive and negative correlations with no clear trend evident.

Table 13. Correlations of the biological variables to canonical variates 1 to 3

Biological Variable	Canonical Variate 1	2	3	Biological Variable	Canonical Variate 1	2	3
drbf2	0.004	-0.280	-0.118	enht03	0.002	-0.297	-0.129
drbf3	0.093	-0.266	-0.091	enht04	0.110	-0.339	-0.103
drbf4	0.026	-0.169	0.054	ht02	-0.036	-0.227	-0.183
drbf5	0.120	-0.120	0.053	kbht03	-0.096	-0.299	-0.033
drbf6	0.102	-0.141	0.094	kbht04	-0.032	-0.328	0.065
ghbf2	0.032	-0.082	-0.002	lcht03	0.017	-0.217	-0.089
ghbf3	-0.091	-0.086	0.015	lcht04	-0.062	-0.217	-0.052
ghbf4	-0.039	-0.128	-0.040	pwht03	0.103	-0.328	0.007
ghbf5	-0.070	-0.121	-0.031	pwht04	0.155	-0.320	-0.037
ghbf6	-0.120	-0.124	0.020	andia04	0.107	-0.180	0.023
lcbf2	0.017	-0.028	0.159	drdia03	0.033	-0.248	0.128
lcbf3	0.017	-0.095	0.184	drdia04	0.055	-0.017	-0.027
lcbf4	0.032	-0.094	0.110	endia03	0.134	-0.348	-0.010
lcbf5	-0.058	-0.023	0.063	endia04	0.162	-0.367	0.009
lcbf6	-0.004	0.040	0.046	kbdia04	-0.026	-0.398	0.048
drbs5	0.164	0.087	0.176	lcdia03	-0.035	-0.374	0.044
enbs3	0.135	0.000	0.185	lcdia04	0.000	-0.263	0.017
enbs4	0.138	-0.156	0.214	pwdia03	0.162	-0.279	0.023
enbs5	0.233	-0.242	-0.127	pwdia04	0.211	-0.345	0.032
kbbs3	0.156	-0.081	0.235	ensurv03	0.308	-0.237	-0.011
kbbs4	0.232	-0.294	0.214	ensurv04	0.290	-0.222	0.031
kbbs5	0.264	-0.157	0.212	lcsurv04	-0.098	-0.054	-0.289
lcbs4	0.230	-0.121	0.223	pwsurv02	-0.115	-0.137	-0.066
lcbs5	*0.191*	*-0.116*	*0.214*	ghelong1	*0.020*	*-0.186*	*-0.133*
pwbs3	0.281	0.073	0.055	ghelong2	-0.060	-0.091	-0.107
pwbs4	0.224	0.074	0.116	ghelong3	-0.103	-0.024	-0.103
anht04	0.061	-0.169	-0.156	ghelong4	-0.080	-0.016	-0.072
drht03	0.022	-0.035	-0.102	ghelong5	0.075	-0.174	-0.096
drht04	0.053	-0.025	-0.235				

Canonical variate 1 reflects mainly the influence of temperature related variables (Table 14). Correlations of the climate variables to canonical variate 1 range from 0.34 for April minimum temperature to 0.02 for the isotherm variable. Monthly temperature variables all show relatively high positive correlations ranging from 0.34 for April minimum temperature to 0.21 for July maximum temperature. Overall, precipitation related variables show lower correlations ranging from 0.22 for April to 0.02 for October. Precipitation variables also show a mixture of positive and negative correlations, with variables from the summer months and those associated with the growing season generally being negative.

Table 14. Correlations of the climatic variables to canonical variates 1 to 3

Climate Variable	Canonical Variate 1	2	3	Climate Variable	Canonical Variate 1	2	3
diurnran	-0.284	0.119	-0.281	aprmintemp	0.342	-0.135	0.369
isotherm	0.021	0.034	0.109	maymintemp	0.321	-0.116	0.369
tempseas	-0.289	0.113	-0.362	junmintemp	0.317	-0.132	0.327
maxtempwp	0.206	-0.093	0.258	julmintemp	0.317	-0.124	0.295
mintempcp	0.317	-0.118	0.373	augmintemp	0.327	-0.127	0.326
tempanran	-0.298	0.105	-0.347	sepmintemp	0.308	-0.120	0.327
mtempwetq	-0.111	-0.091	0.014	octmintemp	0.315	-0.123	0.306
mtempdryq	0.141	-0.012	0.382	novmintemp	0.306	-0.139	0.346
mtempwarmq	0.302	-0.122	0.310	decmintemp	0.311	-0.131	0.362
mtempcoldq	0.320	-0.120	0.374	janmaxtemp	0.310	-0.116	0.385
annprecip	0.105	-0.101	0.171	febmaxtemp	0.322	-0.119	0.371
precipwp	-0.072	-0.072	-0.149	marmaxtemp	0.314	-0.127	0.349
precipdp	0.219	-0.070	0.320	aprmaxtemp	0.302	-0.122	0.362
precipseas	-0.212	0.098	-0.430	maymaxtemp	0.236	-0.106	0.293
precipwettq	-0.104	-0.044	-0.234	junmaxtemp	0.223	-0.100	0.212
precipdryq	0.209	-0.094	0.322	julmaxtemp	0.210	-0.088	0.253
precipwarmq	-0.170	-0.058	-0.300	augmaxtemp	0.301	-0.088	0.339
precipcoldq	0.189	-0.056	0.325	sepmaxtemp	0.316	-0.116	0.348
daystart	-0.310	0.131	-0.358	octmaxtemp	0.322	-0.133	0.335
dayend	0.327	-0.093	0.334	novmaxtemp	0.310	-0.126	0.367
daygrow	0.329	-0.116	0.357	decmaxtemp	0.304	-0.118	0.382
tprecipp1	0.218	-0.076	0.292	janprecip	0.113	-0.021	0.315
tprecipp2	-0.142	-0.060	-0.290	febprecip	0.235	-0.054	0.326
tprecipp3	0.191	-0.162	0.135	marprecip	0.208	-0.079	0.302
tprecipp4	0.216	-0.155	0.183	aprprecip	0.221	-0.128	0.265
ggdp3	0.315	-0.120	0.331	mayprecip	0.184	-0.147	0.113
annmtemp	0.326	-0.128	0.366	junprecip	-0.137	-0.093	-0.318
annmintemp	0.329	-0.129	0.362	julprecip	-0.200	0.033	-0.351
annmaxtemp	0.312	-0.122	0.363	augprecip	-0.111	-0.126	-0.122
mtempp3	0.273	-0.120	0.274	sepprecip	-0.172	-0.024	-0.162
tempranp3	0.197	-0.095	0.245	octprecip	0.023	-0.107	0.038
janmintemp	0.321	-0.115	0.372	novprecip	0.104	-0.108	0.259
febmintemp	0.330	-0.121	0.365	decprecip	0.207	-0.081	0.312
marmintemp	0.336	-0.130	0.378				

Correlations to canonical variate 2 are overall much weaker with the highest correlation being negative 0.16 for the total precipitation in period 3 variable. Only seven of the 67 variables show a positive relationship. As with canonical variate 1, temperature variables show the highest correlations, but the relationship is much weaker and in this case negative. Also, precipitation variables are well within the same range of correlation values, and in fact have the three highest correlations with May precipitation at -0.147, total precipitation in period 4 at -0.155, and total precipitation in period 3 at -0.16.

Correlations for canonical variate 3 range from -0.43 for precipitation seasonality to 0.014 for mean temperature in the wettest quarter. Monthly temperature variables all show relatively high positive correlations ranging from 0.38 for January maximum temperature to 0.21 for June maximum temperature. Monthly precipitation variables are relatively lower than temperature variables, ranging from 0.32 for February down to 0.04 for October. The summer month precipitation variables (June – September) all show negative correlations. Derived variables show a range of values both positive and negative.

Overall, correlations do not give any clear interpretation of how any given ‘set’ of climate variables interacts with a set, or category, of biological variables. This result points to the complexity of the relationship between climate and both growth and phenological variables.

Canonical coefficients for the climate variables were used to model the biological variable scores for each canonical variate. Climate coefficients for the first three canonical variates are shown in Table 15. These coefficients, or weights, reflect the association of that variable after the influence of all other variables in the set have been removed (Gittins 1985). While in principle the coefficients can be used as an indication of the effects and direction that variables have, interpretation is more difficult and not as reliable as using the correlation values for such purposes. This issue is a result of the drastically different magnitudes of scale between climate variables (Gittins 1985).

Table 15. Canonical coefficients of the climate variables for canonical variates 1 to 3

Climate Variable	Canonical Variate 1	2	3	Climate Variable	Canonical Variate 1	2	3
diurnran	4.228	3.453	-1.927	aprmintemp	21.829	-22.697	-4.845
isotherm	-0.177	-0.129	-0.275	maymintemp	13.026	-5.604	4.770
tempseas	4.025	20.148	-21.006	junmintemp	5.562	-8.430	12.621
maxtempwp	-4.386	-15.764	0.520	julmintemp	8.148	-0.661	0.471
mintempcp	-22.893	-28.163	-8.075	augmintemp	13.121	-9.833	8.757
tempanran	-17.028	-25.207	5.015	sepmintemp	3.489	-1.916	13.018
mtempwetq	0.471	0.187	1.027	octmintemp	-0.603	-8.868	3.185
mtempdryq	0.064	0.224	-0.110	novmintemp	20.362	-27.895	-3.162
mtempwarmq	-4.325	-14.530	-3.257	decmintemp	28.929	-25.008	7.174
mtempcoldq	13.547	35.783	-9.971	janmaxtemp	-2.144	-21.441	6.346
annprecip	48.387	22.723	44.688	febmaxtemp	-2.517	-8.087	1.969
precipwp	0.354	-3.555	1.995	marmaxtemp	2.931	-8.148	-1.202
precipdp	-0.934	1.856	2.716	aprmaxtemp	1.694	-4.512	7.737
precipseas	0.325	0.146	0.119	maymaxtemp	-5.127	-8.420	-0.477
precipwettq	0.177	3.425	-2.666	junmaxtemp	2.906	-0.981	8.298
precipdryq	1.548	-5.594	0.116	julmaxtemp	-0.058	29.984	8.375
precipwarmq	-3.106	3.195	-4.921	augmaxtemp	7.601	2.919	6.646
precipcoldq	-6.587	11.946	-20.531	sepmaxtemp	-16.579	-4.107	1.112
daystart	-0.079	6.072	-0.270	octmaxtemp	0.793	-12.904	3.509
dayend	12.252	-6.163	-1.860	novmaxtemp	-0.586	1.589	6.249
daygrow	0.000	0.000	0.000	decmaxtemp	-4.815	-15.453	5.618
tprecipp1	8.675	-2.257	5.071	janprecip	-9.068	-7.024	0.823
tprecipp2	10.857	24.640	15.736	febprecip	-5.726	-3.486	-2.910
tprecipp3	-86.704	-172.558	-90.247	marprecip	-7.442	0.417	-5.128
tprecipp4	82.597	165.984	90.025	aprprecip	-9.428	-0.342	-7.368
ggdp3	3.655	-15.661	-6.801	mayprecip	-1.477	1.371	-5.043
annmtemp	34.531	43.267	-65.649	junprecip	-1.747	-1.431	-1.758
annmintemp	-197.859	185.517	-27.117	julprecip	-4.792	-2.968	-3.888
annmaxtemp	-13.611	80.375	-7.650	augprecip	-2.465	-2.488	-2.273
mtempp3	15.825	-17.163	-4.443	sepprecip	-2.785	0.817	-3.116
tempranp3	-1.206	-9.056	-2.938	octprecip	-2.751	-2.451	-4.680
janmintemp	31.731	-29.726	13.073	novprecip	-8.025	-4.570	-7.384
febmintemp	20.369	-29.420	2.410	decprecip	-6.103	-8.724	-1.277
marmintemp	13.249	-22.137	16.507				

While the coefficients are individually not interpretable to any great degree, the standardized grids developed by modeling the climate variables based on their coefficients show meaningful trends. Figure 42 shows standardized predicted scores for canonical variate 1. A clear north-south trend is shown in the grid with scores generally decreasing with movement northwards. Lakeshore effects are also apparent off the east coast of Lake Superior, and the effect of the Algonquin Highlands can also be seen in central Ontario. This grid shows a strong resemblance to the grid for PC 3 (Figure 18) with both grids reflecting winter temperature patterns.

The grid for canonical variate 2 shows a clear north-south trend is once again evident in the eastern part of the study area, however higher scores are found in northern areas with scores decreasing with movement south (Figure 43). Northwestern Ontario shows similar scores to more southern areas. Lakeshore effects are evident along both the north and eastern shores of Lake Superior. There is also a noticeable effect, once again, in the central Ontario area caused by the highlands region. There is a strong parallel between the grid for canonical variate 2 and the grid for PC 2 (Figure 17). Both grids show similar trends in the southeast to north-central and the northwest to north-central regions, however the scores in the two grids show opposite polarity.

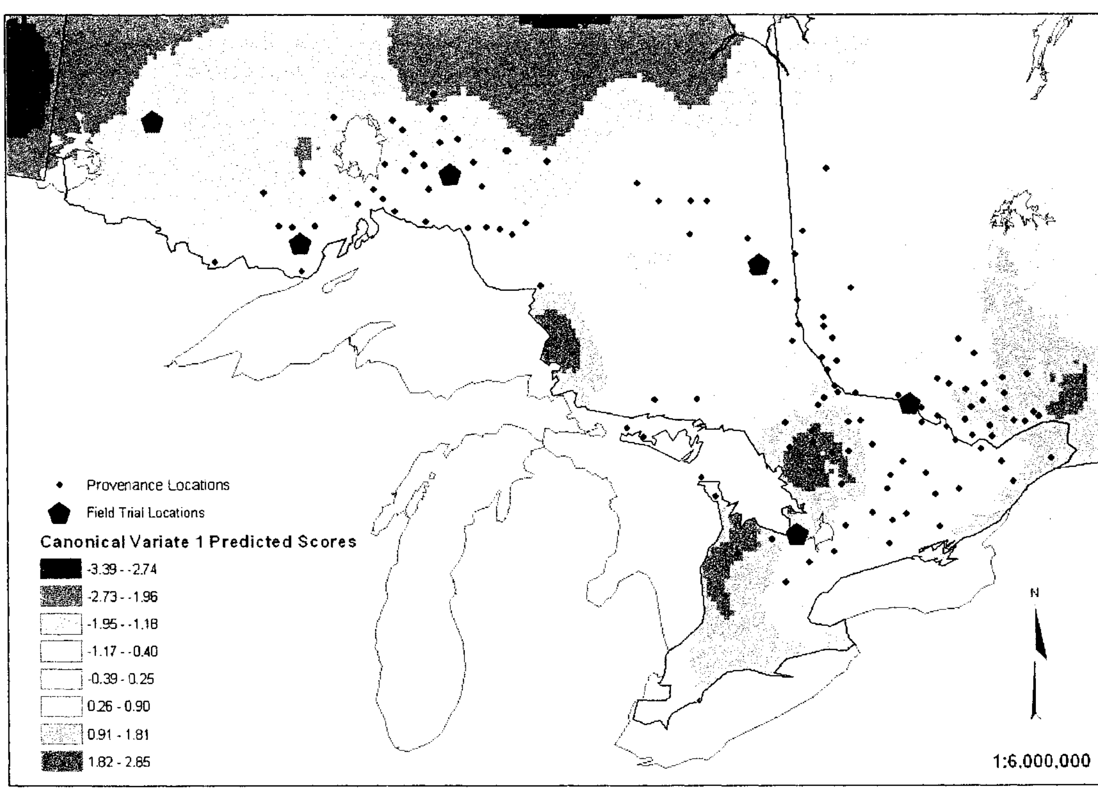

Figure 42. Standardized predicted scores derived from climatic coefficients for canonical variate 1

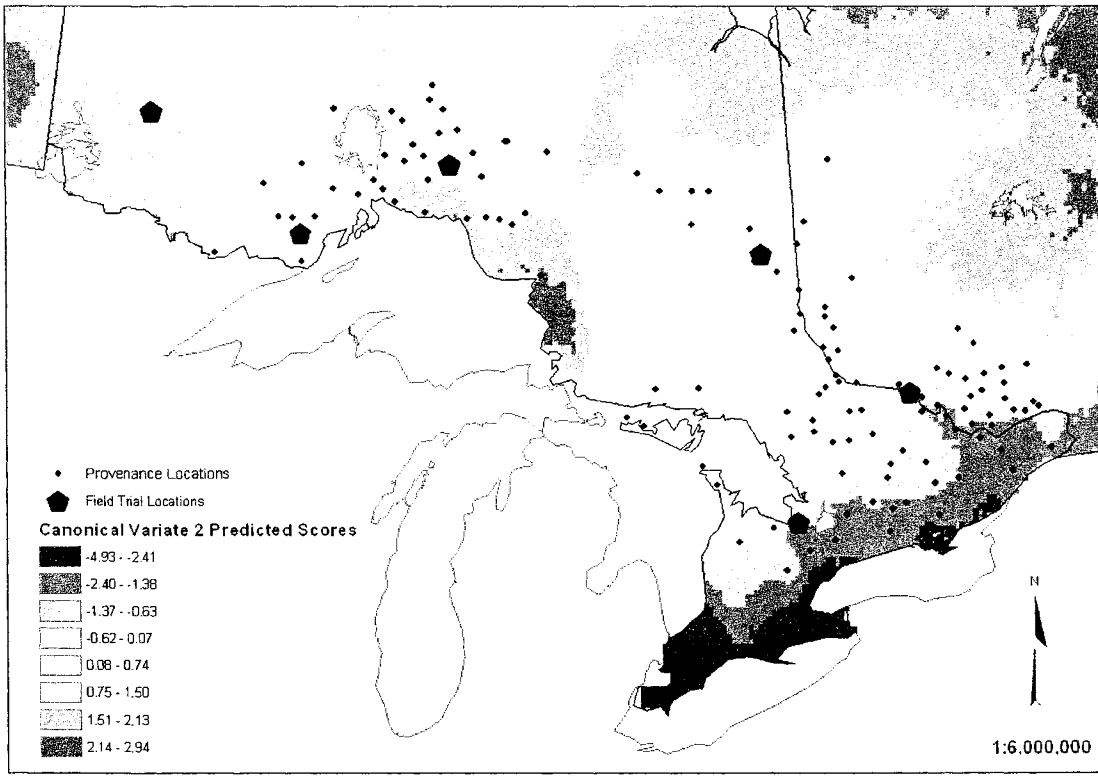

Figure 43. Standardized predicted scores derived from climatic coefficients for canonical variate 2

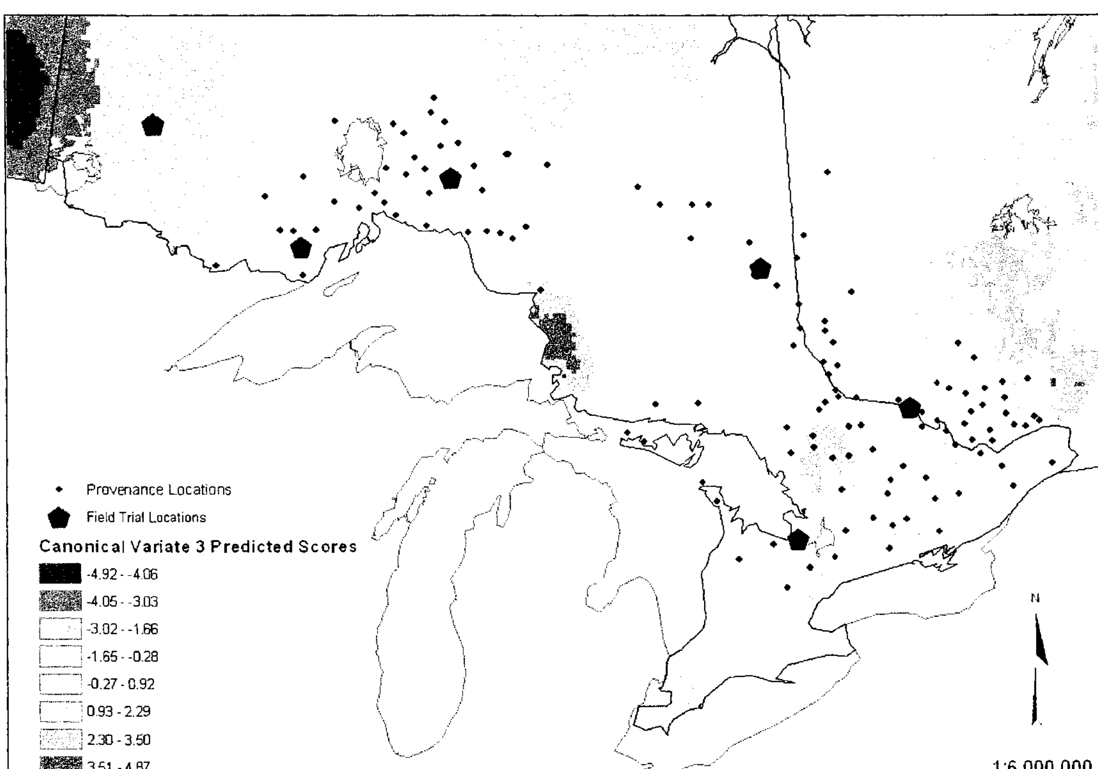

Figure 44. Standardized predicted scores derived from climatic coefficients for canonical variate 3

The grid for canonical variate 3 (Figure 44) emphasizes both the lakeshore effect of Lake Superior and the highland effect of the Algonquin area that were seen to a more limited extent in the first two variates. The similarities between the northwest portion of the study area and southern Ontario are also apparent in Figure 44, however much of north-eastern Ontario also shows scores similar to more southern areas. Overall the strong latitudinal trend seen in the first two variates is not as evident in the third.

FOCAL POINT SEED ZONE EXAMPLES

Figures 45 through 67 show focal point seed zones for 23 selected focal points across the study area. The same 23 points that were selected as examples of the regression based seed zone development in Chapter III are used here to facilitate visual comparisons. Figure 45 shows the most western selected point, with successive figures systematically moving eastwards across the study area. As with the seed zones in the previous chapter, levels of shading have been used to identify areas of similarity. The darkest green shading represents areas of greatest similarity (± 0.5 standard deviations). The slightly lighter green represents areas within ± 1 standard deviation; and the lightest green represents areas within ± 1.5 standard deviations from the focal point. The lightest green areas were considered the lowest acceptable level of similarity in terms of seed transfer decisions.

Figure 45 shows areas of greatest similarity contained to a relatively narrow east-west band, to the west of Lake Nipigon. Acceptable areas of similarity extend across all of the northwest and much of north-central Ontario, with the noticeable exception of the north shore of Lake Superior. This trend is also seen in Figure 46, although less of northern Ontario is found to be acceptable, and there are larger disjunct areas of similarity seen in south-east Ontario.

Moving eastwards the same trend is seen in Figures 47 through 49 and Figure 51. Large areas of northern Ontario are considered acceptable, but generally no areas south of 47 degrees latitude are within acceptable limits. Figure 50, in which the focal point is located on the north shore of Lake Superior clearly shows the lake effect of this area in making it dissimilar to the Northwest region. Areas of similarity do extend to the east across northern Ontario and over much of north-western Quebec. Zones of similarity do not extend south beyond approximately 47 degrees latitude.

Figure 52 clearly shows the lakeshore effect off of the eastern shore of Lake Superior. As with the focal point in Figure 50, very little of the surrounding area is found acceptable and the zone of greatest similarity is very small relative to other focal point locations. Similar areas are shown over much of western Quebec, but are all disjunct from the immediate zones. Figure 53 shows areas of similarity extending, once again over much of the northern study area; however suitable areas are beginning to extend further south, and less of northwest Ontario is being found acceptable. The lakeshore effect that contained the zones of similarity in Figure 52 is noticeable in Figure 53 as a relatively immediate area that is not considered acceptable. This trend can be seen clearly throughout the next several figures, where zones of similarity wrap around the eastern shore of Lake Superior leaving a conspicuous white area.

As the selected focal point moves east and south, the influence of the Algonquin Highlands can also be seen (Figure 54 and 56) and becomes strongly apparent in Figure 57. Figure 57 also clearly shows a transition in the overall pattern as the focal point is moved south of 47 degrees latitude. In preceding figures most of the northern portion of the study area was considered acceptable, but focal points located south of 47 degrees show little to no northern areas as acceptable. Figures 57 through 59 and 62 show relatively small areas of similarity contained to latitudes below 47 degrees and strongly influenced by the Algonquin Highlands and Lakeshore effects. The effect of the Algonquin area is especially evident in Figure 62, where the focal point is located in that geographic area, and zones of similarity are likewise confined.

Figures 60, 61, 63, and 64 all reinforce this trend. Zones of similarity for the focal points in these figures are confined to a north-south band between approximately 49 and 46 degrees latitude that does not extend significantly into either northern or southern portions of the study area. Figure 65 shows a relatively small area of local similarity, but has a conspicuous area of suitability in the northwest portion of the study area. Figures 66 and 67 show similar small local areas of similarity that do not extend northwards and are also limited by lakeshore effect along Lake Ontario and Lake Erie, and the Algonquin Highlands in south-central Ontario.

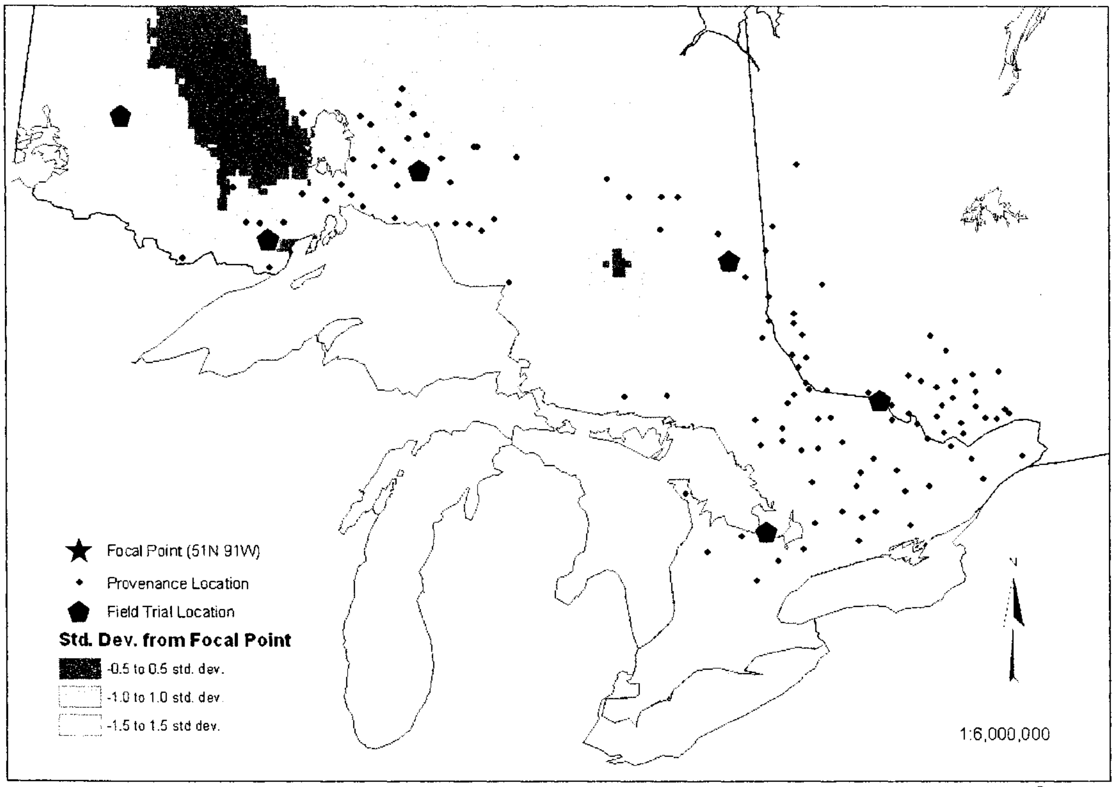

Figure 45. White spruce cancorr based focal point seed zones for coordinates 51°N 91°W

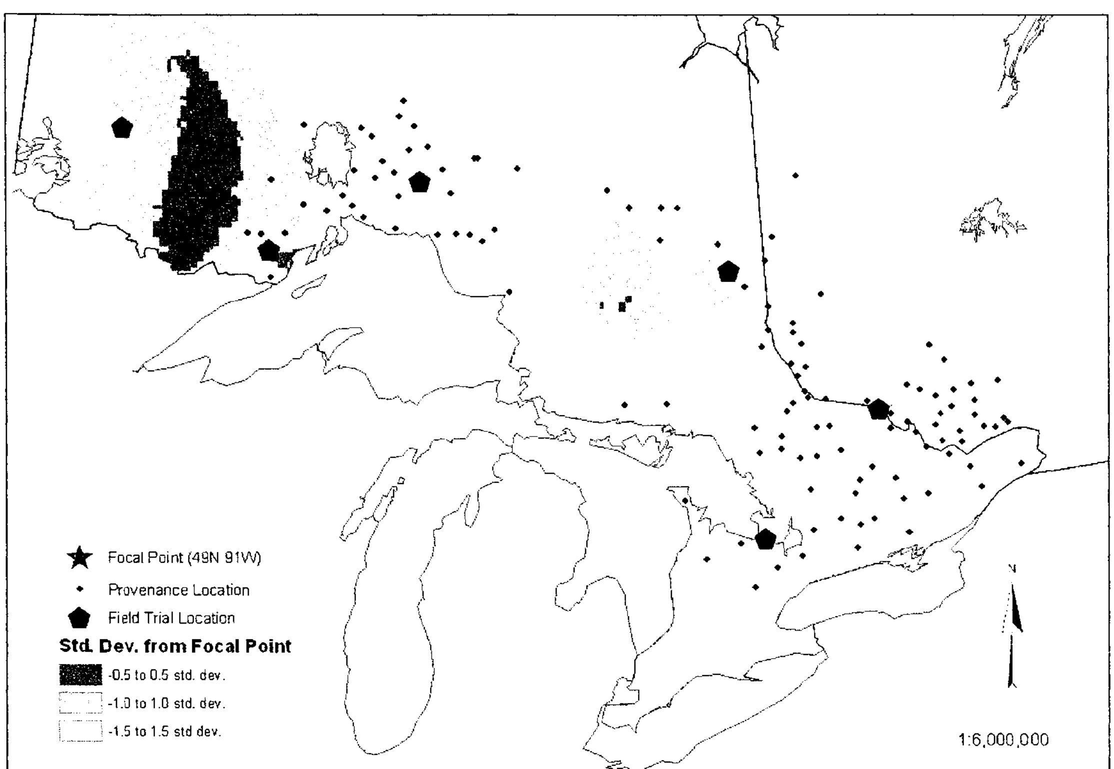

Figure 46. White spruce cancorr based focal point seed zones for coordinates 49°N 91°W

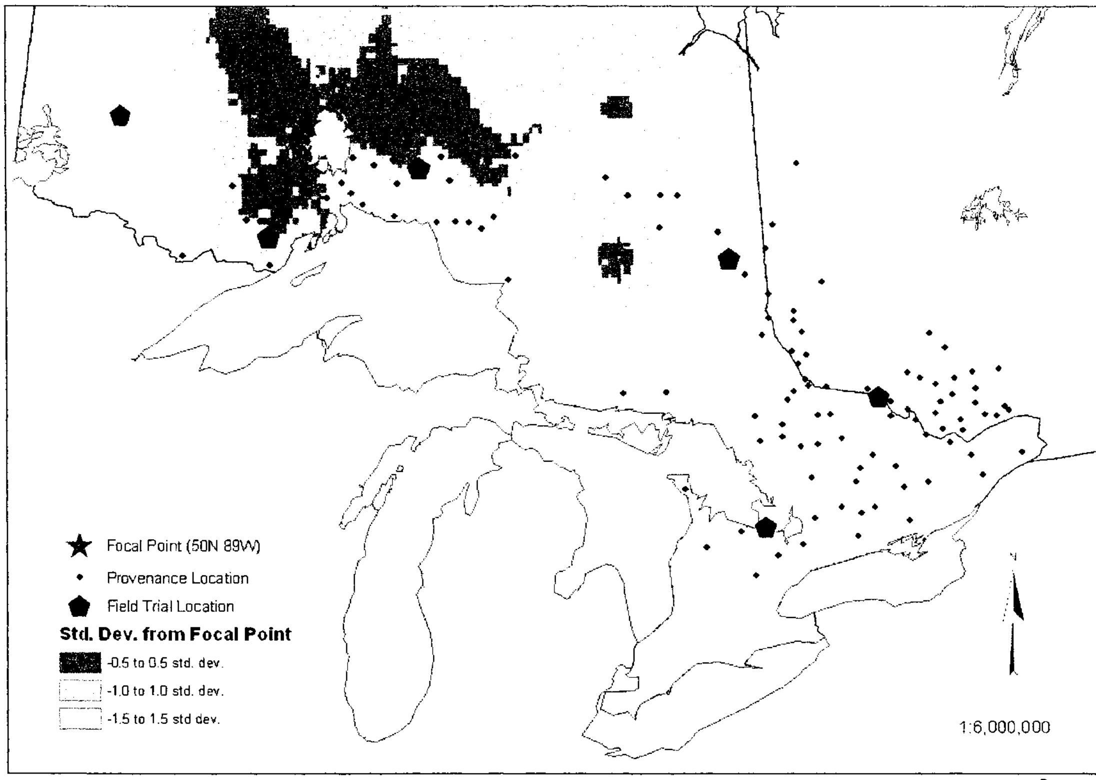

Figure 47. White spruce cancorr based focal point seed zones for coordinates 50°N 85°W

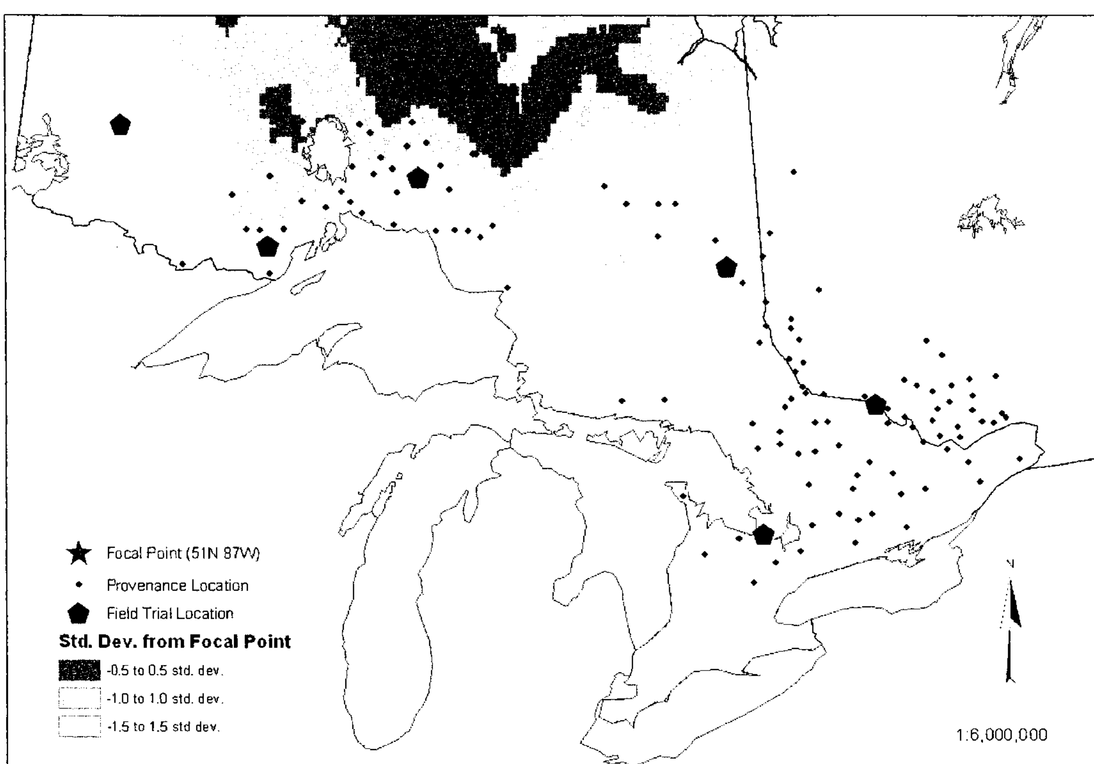

Figure 48. White spruce cancorr based focal point seed zones for coordinates 51°N 87°W

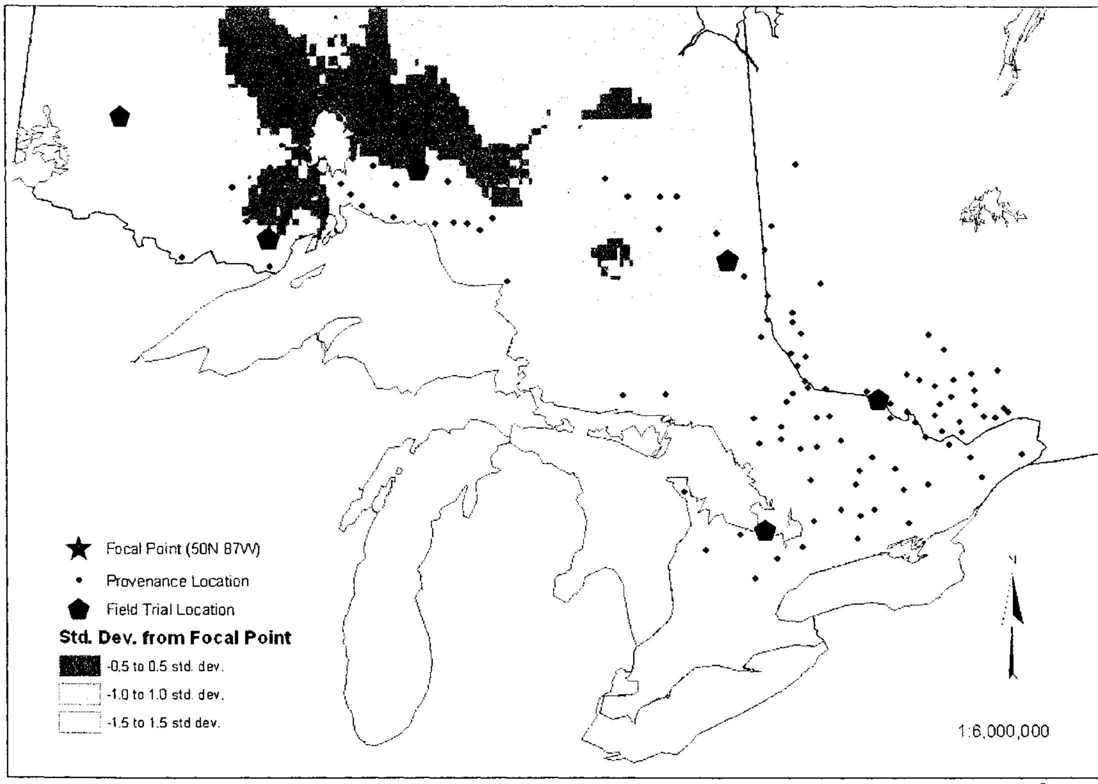

Figure 49. White spruce cancorr based focal point seed zones for coordinates 50°N 87°W

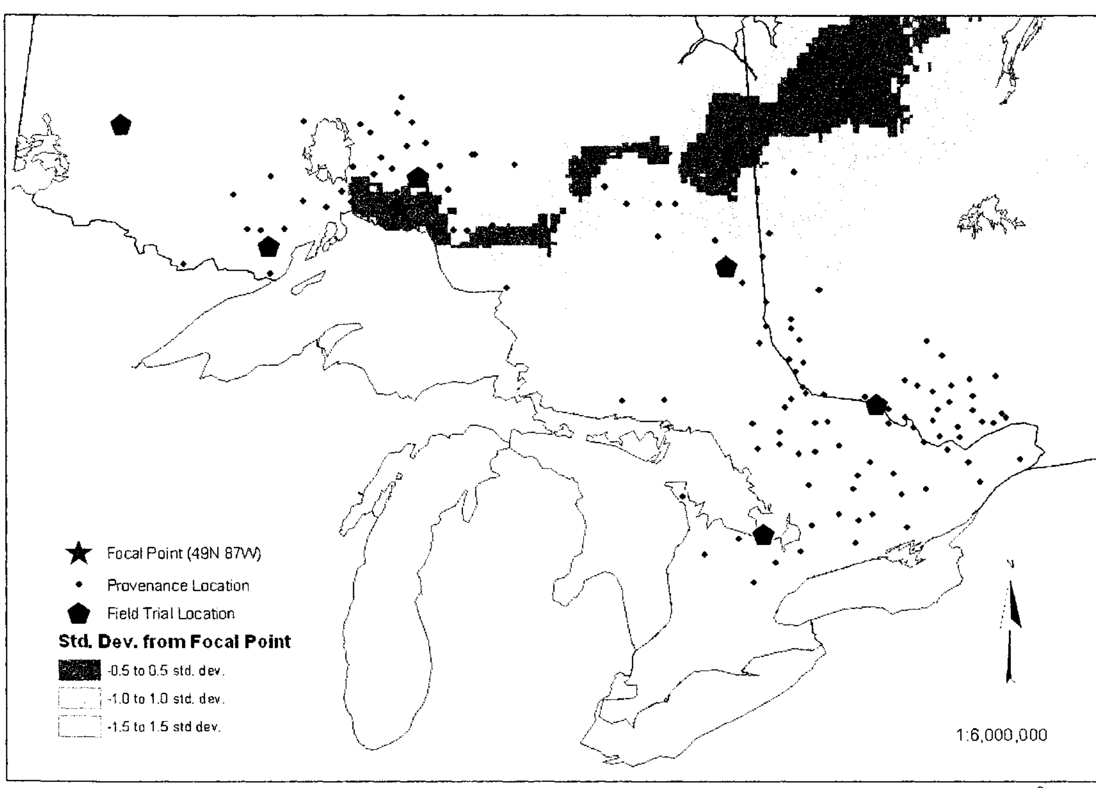

Figure 50. White spruce cancorr based focal point seed zones for coordinates 49°N 87°W

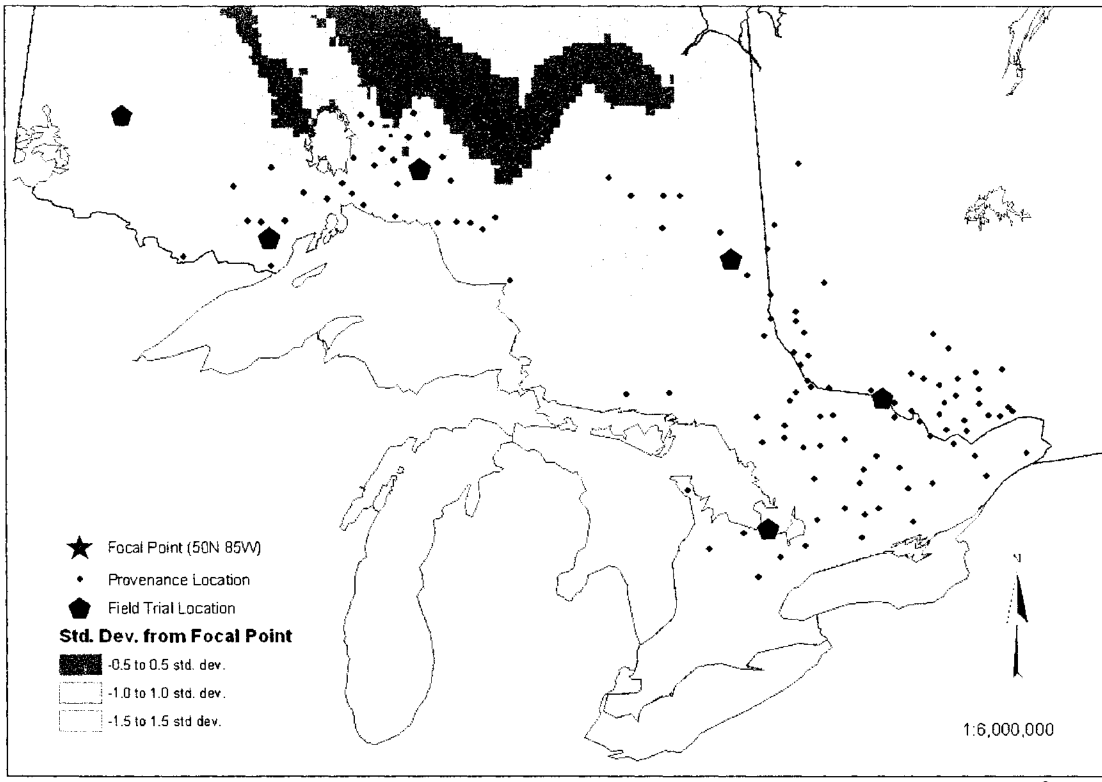

Figure 51. White spruce cancorr based focal point seed zones for coordinates 50°N 85°W

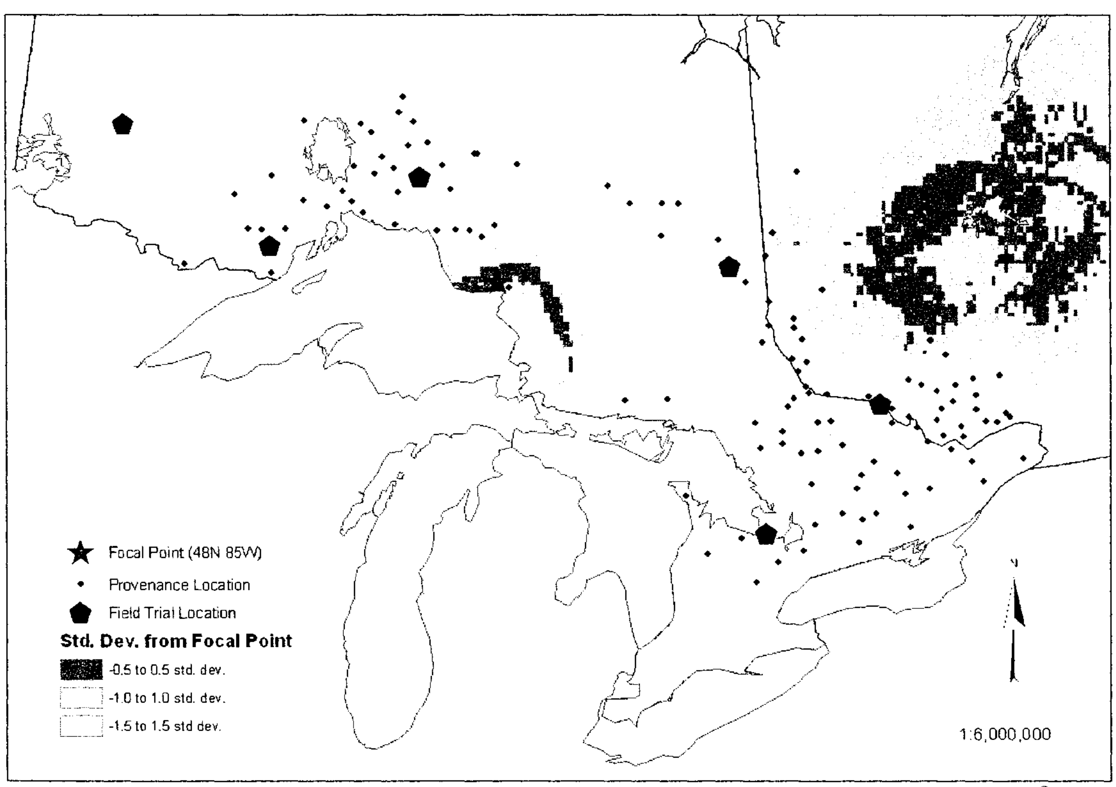

Figure 52. White spruce cancorr based focal point seed zones for coordinates 48°N 85°W

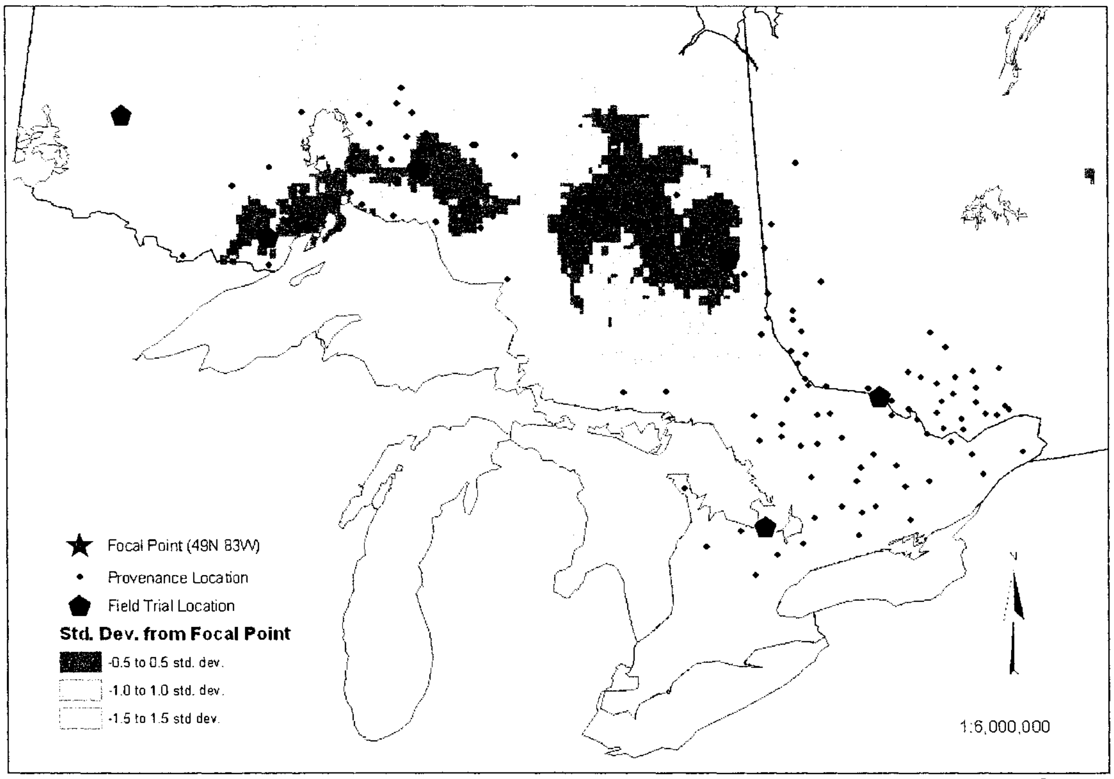

Figure 53. White spruce cancorr based focal point seed zones for coordinates 49°N 83°W

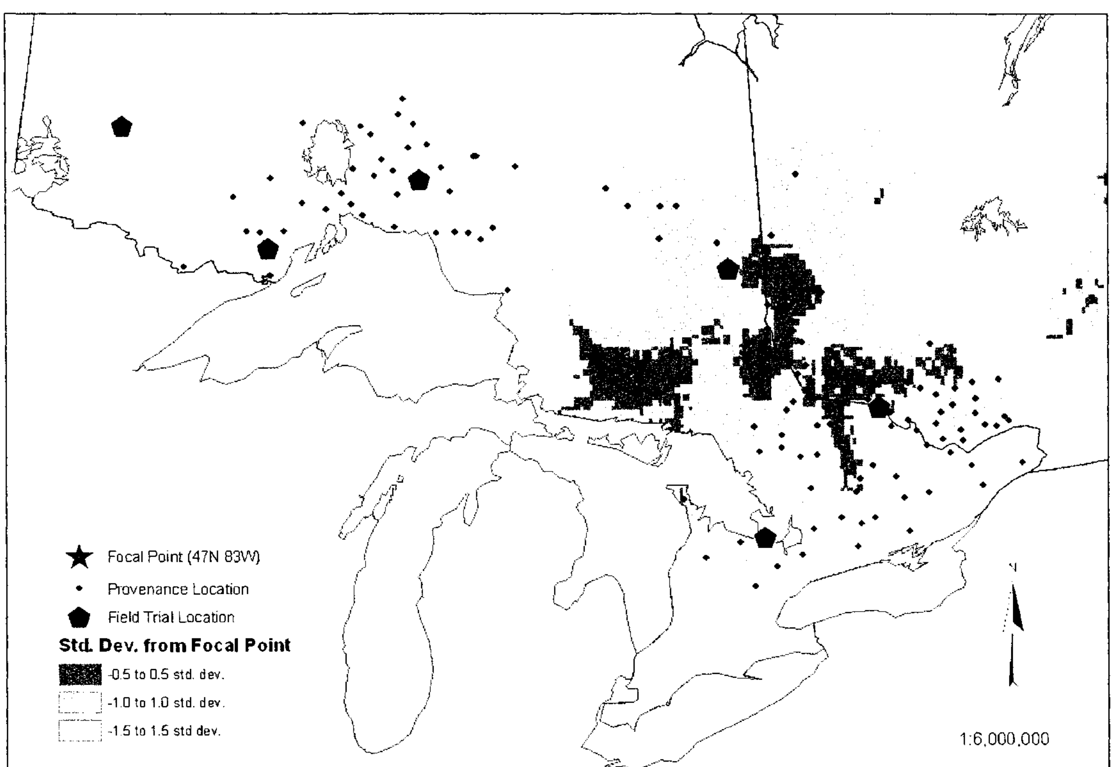

Figure 54. White spruce cancorr based focal point seed zones for coordinates 47°N 83°W

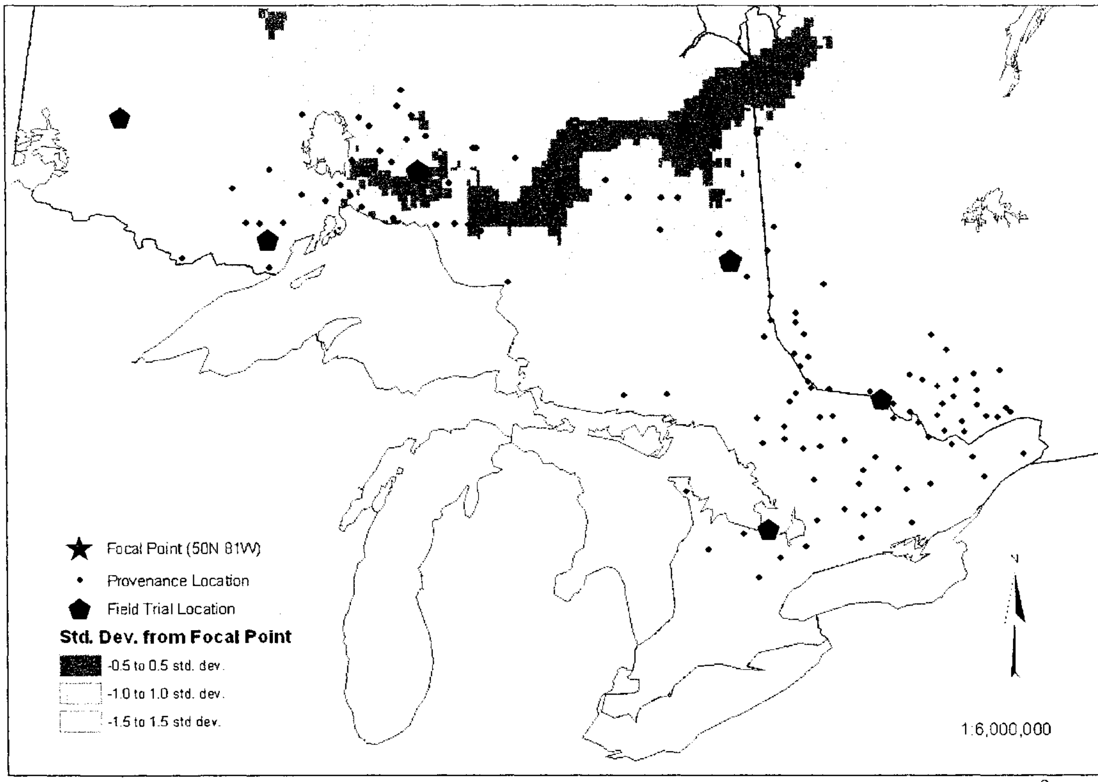

Figure 55. White spruce cancorr based focal point seed zones for coordinates 50°N 81°W

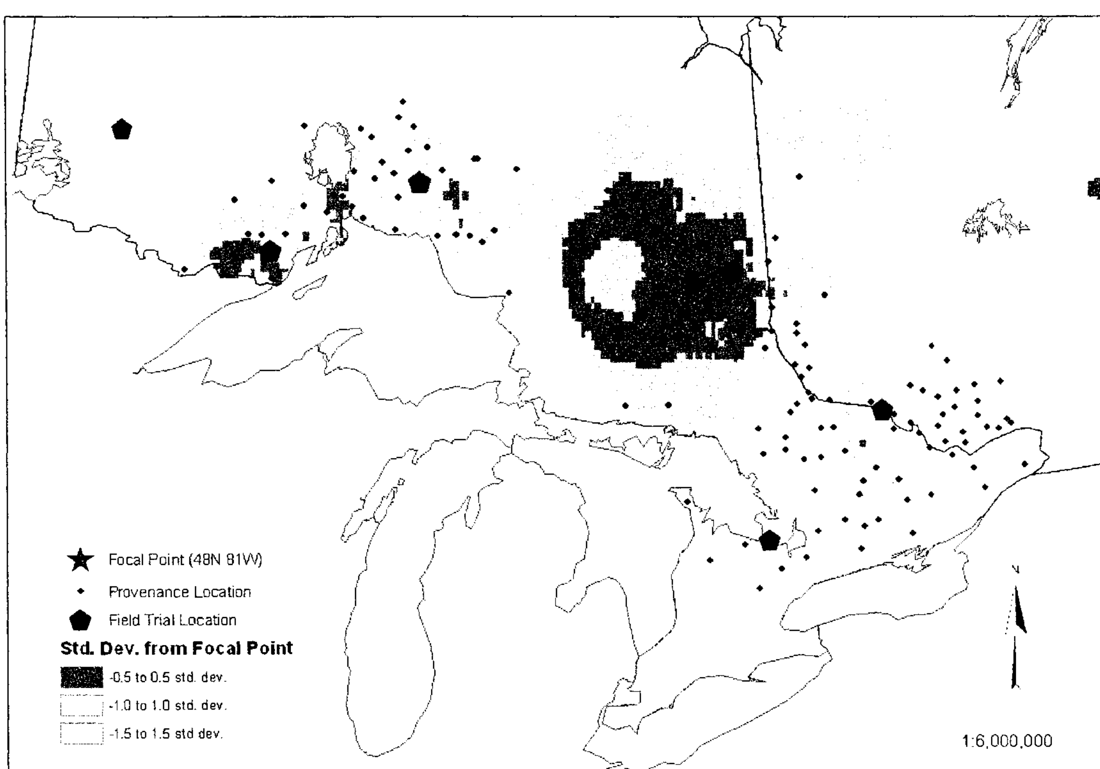

Figure 56. White spruce cancorr based focal point seed zones for coordinates 48°N 81°W

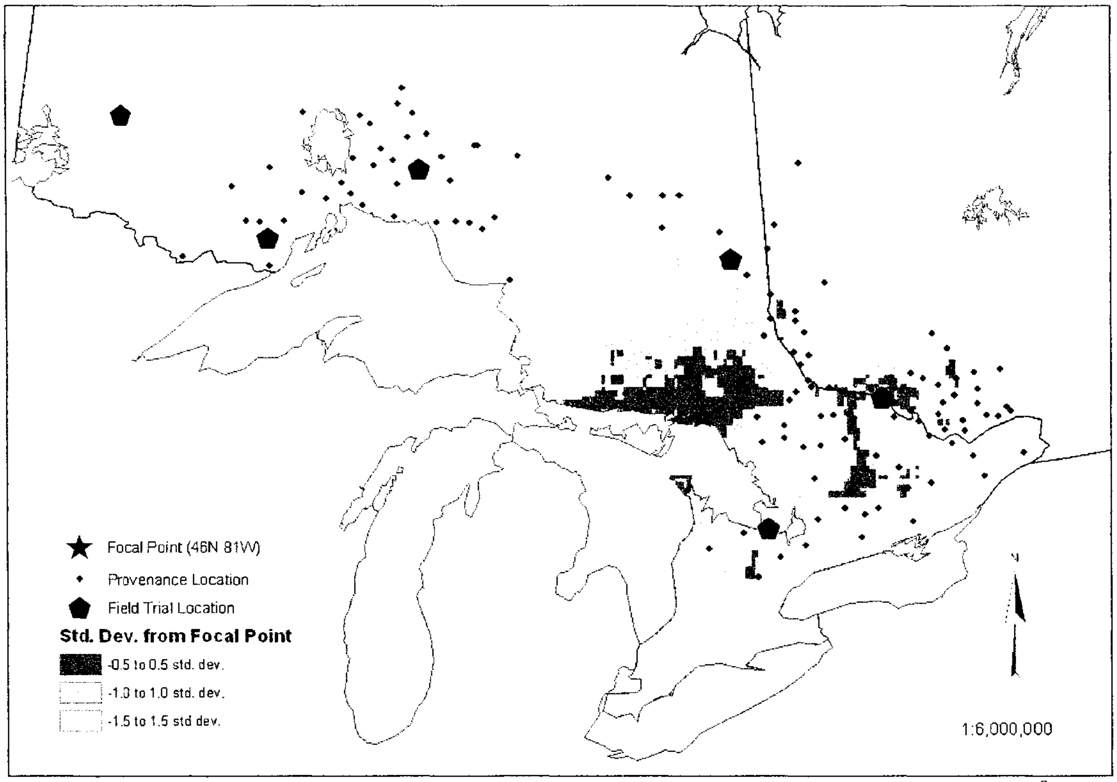

Figure 57. White spruce cancorr based focal point seed zones for coordinates 46°N 81°W

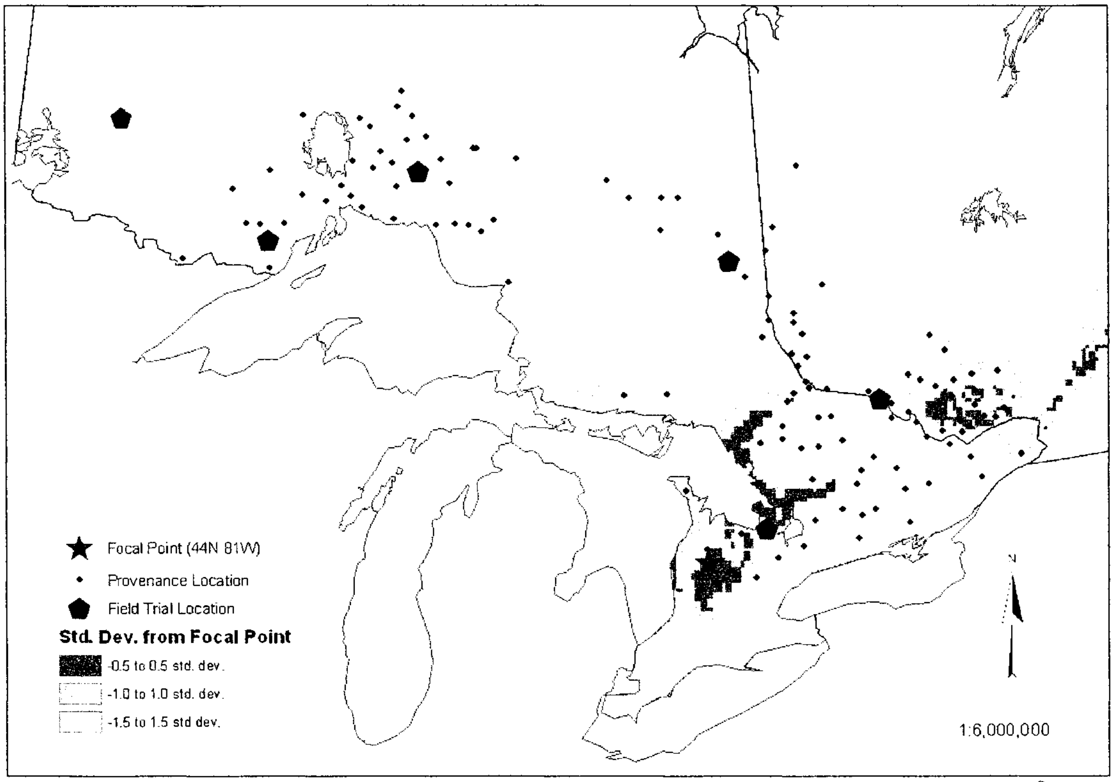

Figure 58. White spruce cancorr based focal point seed zones for coordinates 44°N 81°W

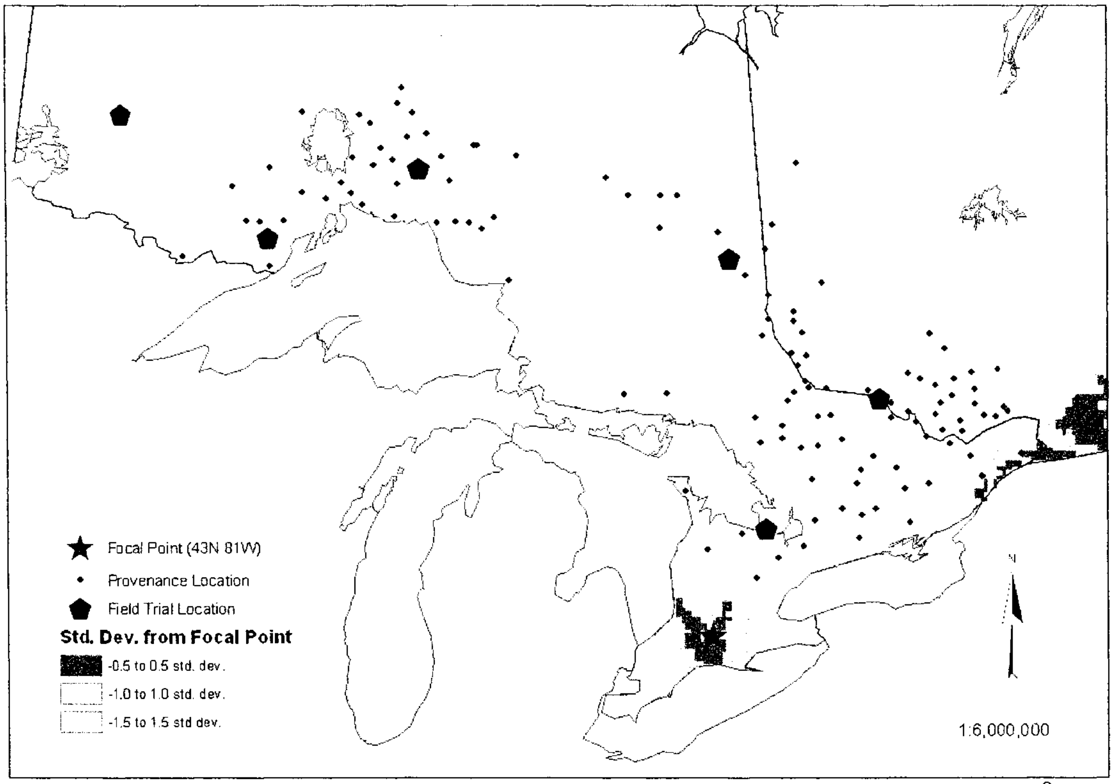

Figure 59. White spruce cancorr based focal point seed zones for coordinates 43°N 81°W

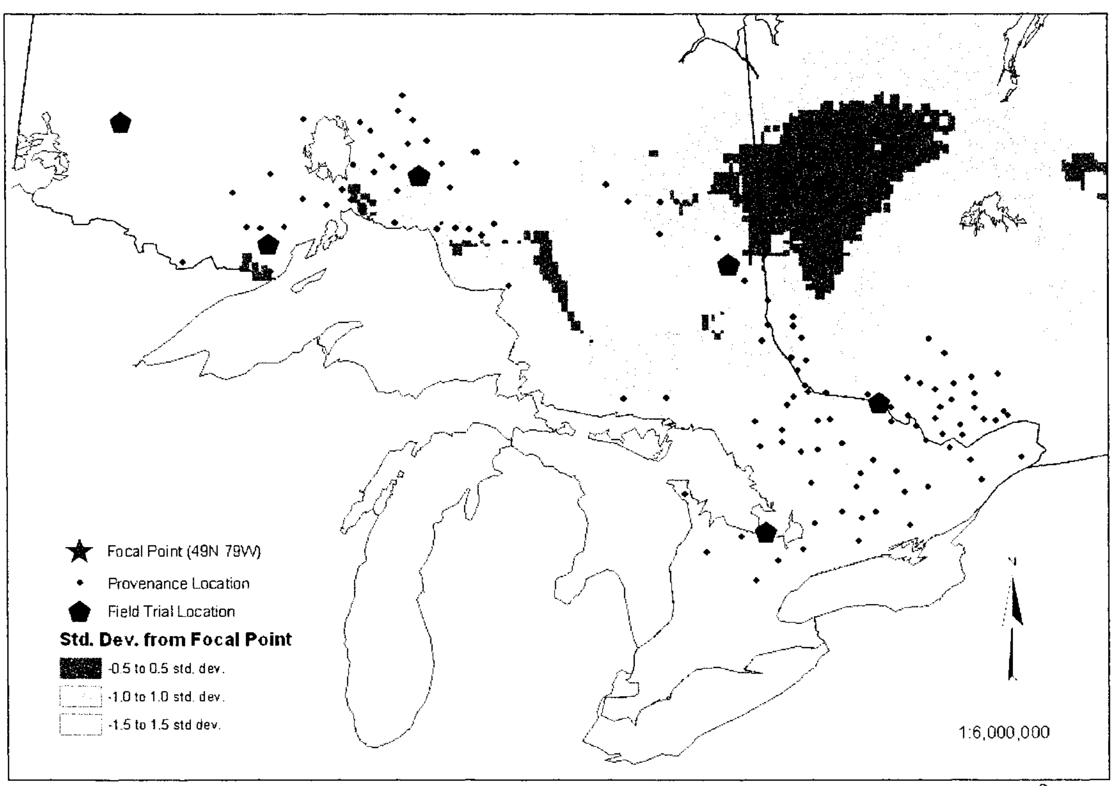

Figure 60. White spruce cancorr based focal point seed zones for coordinates 49°N 79°W

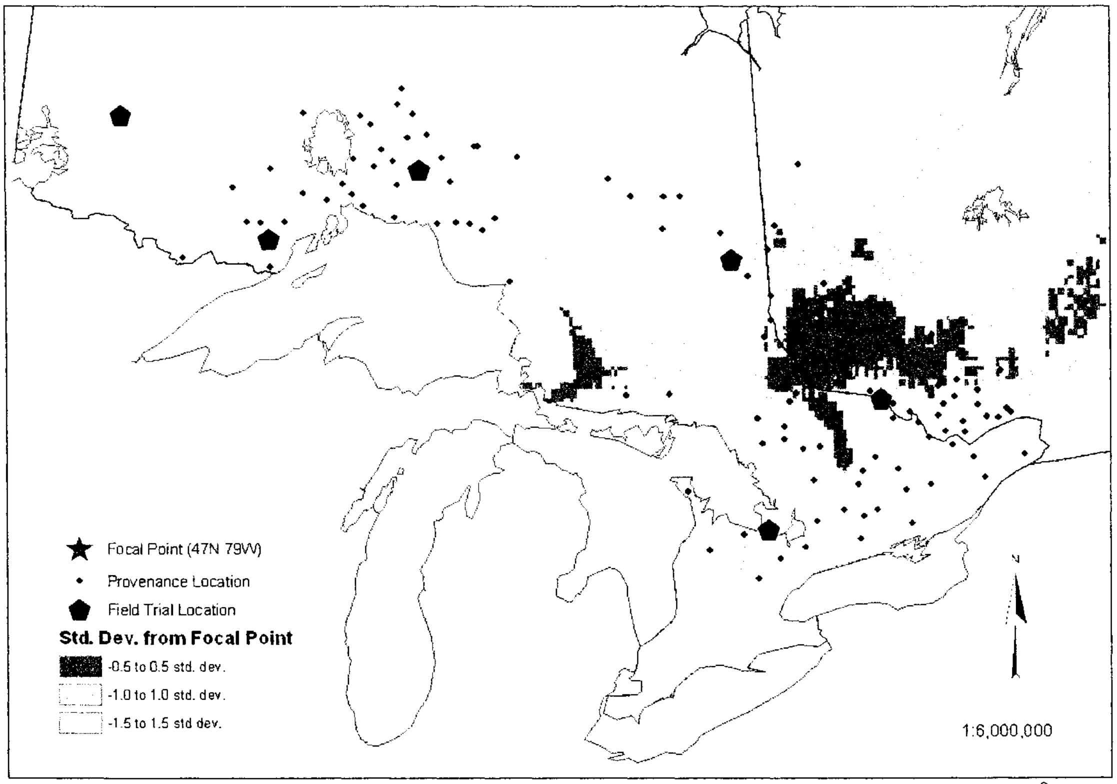

Figure 61. White spruce cancorr based focal point seed zones for coordinates 47°N 79°W

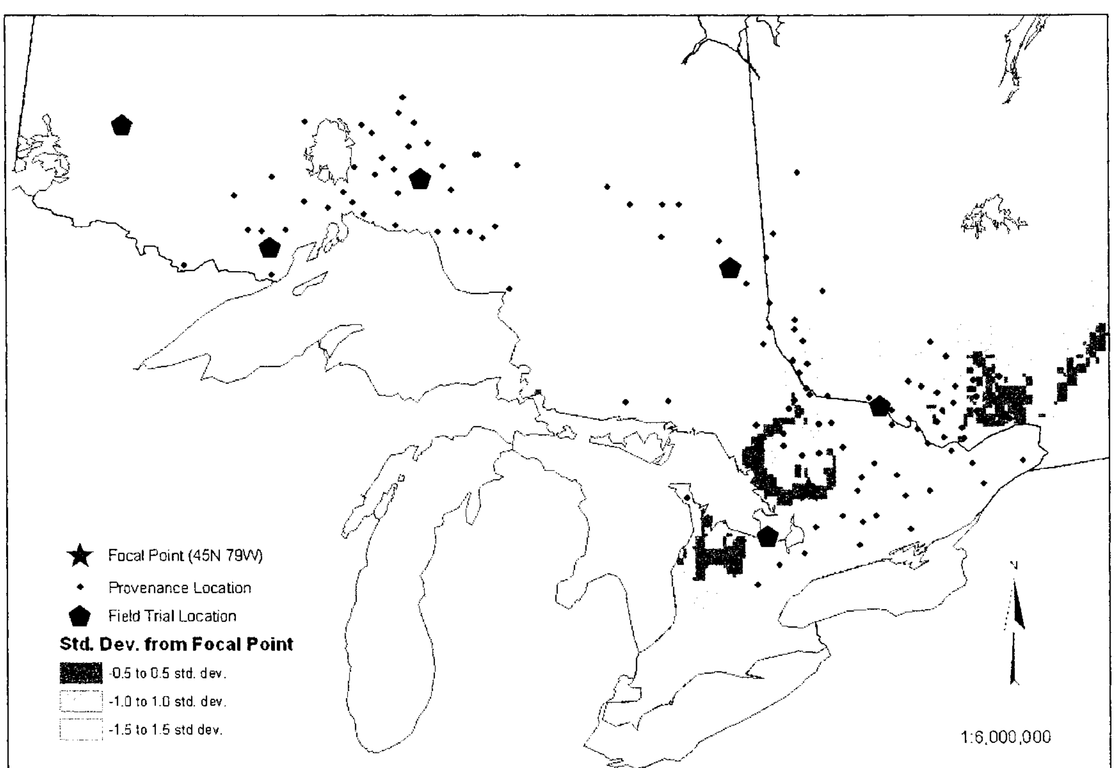

Figure 62. White spruce cancorr based focal point seed zones for coordinates 45°N 79°W

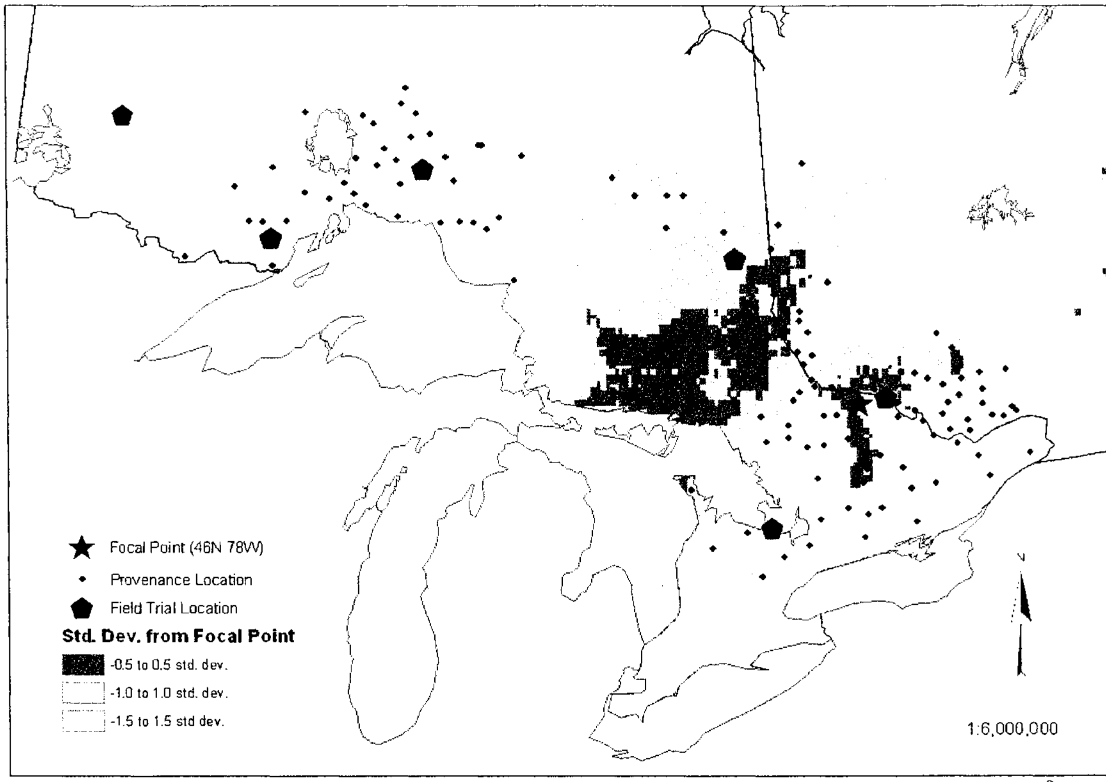

Figure 63. White spruce cancorr based focal point seed zones for coordinates 46°N 78°W

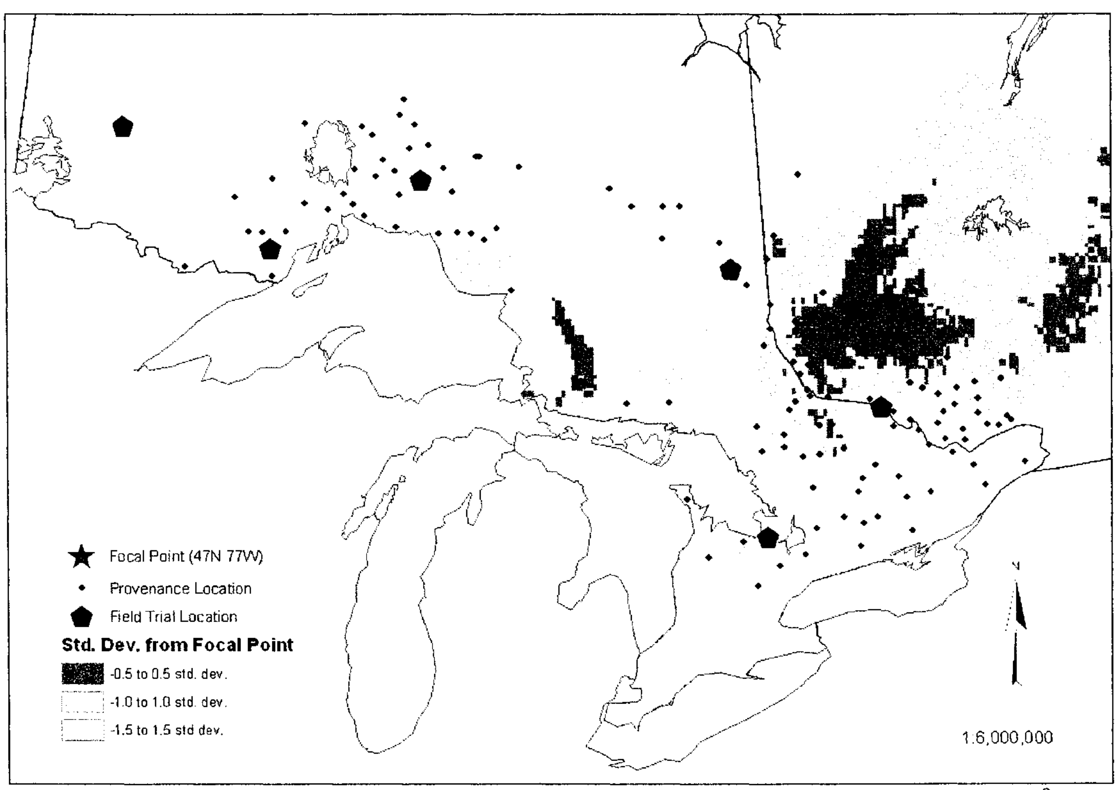

Figure 64. White spruce cancorr based focal point seed zones for coordinates 47°N 77°W

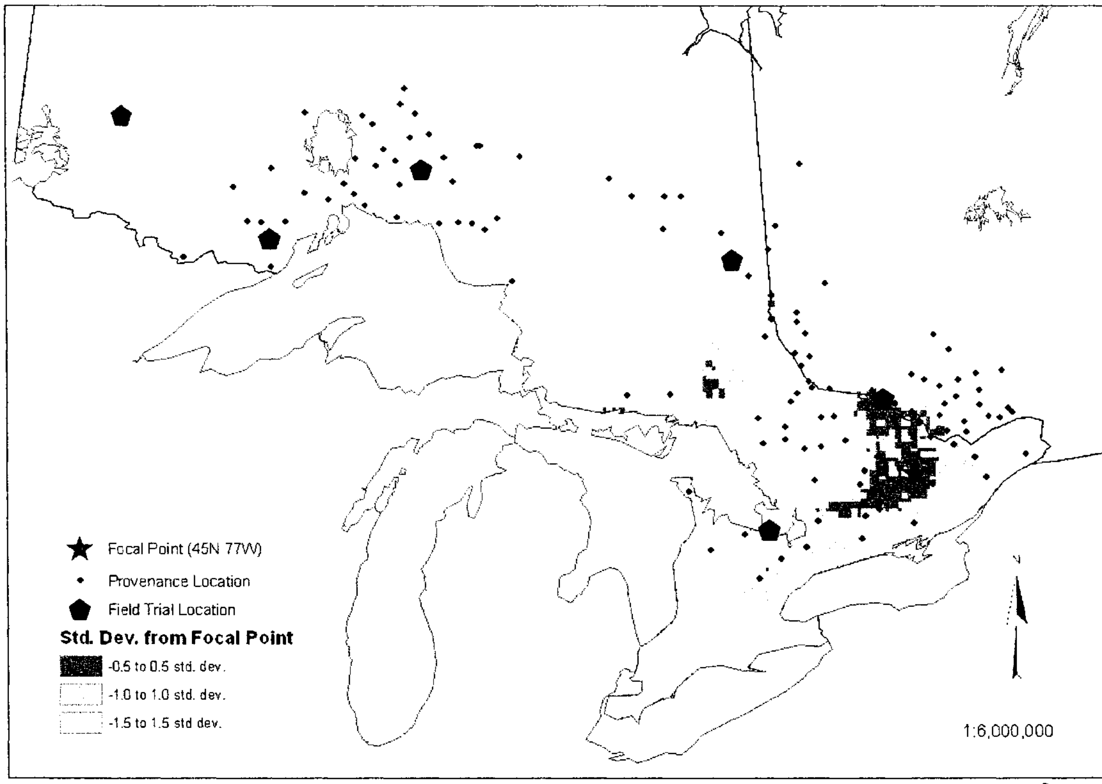

Figure 65. White spruce cancorr based focal point seed zones for coordinates 45°N 77°W

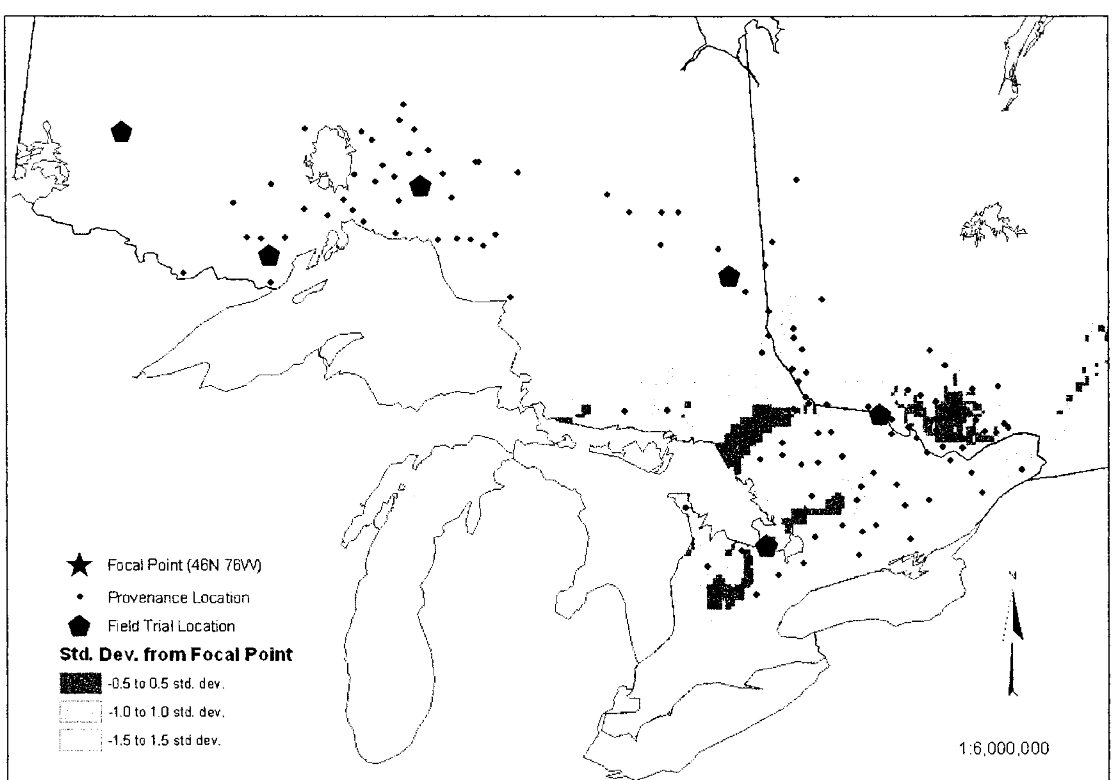

Figure 66. White spruce cancorr based focal point seed zones for coordinates 46°N 76°W

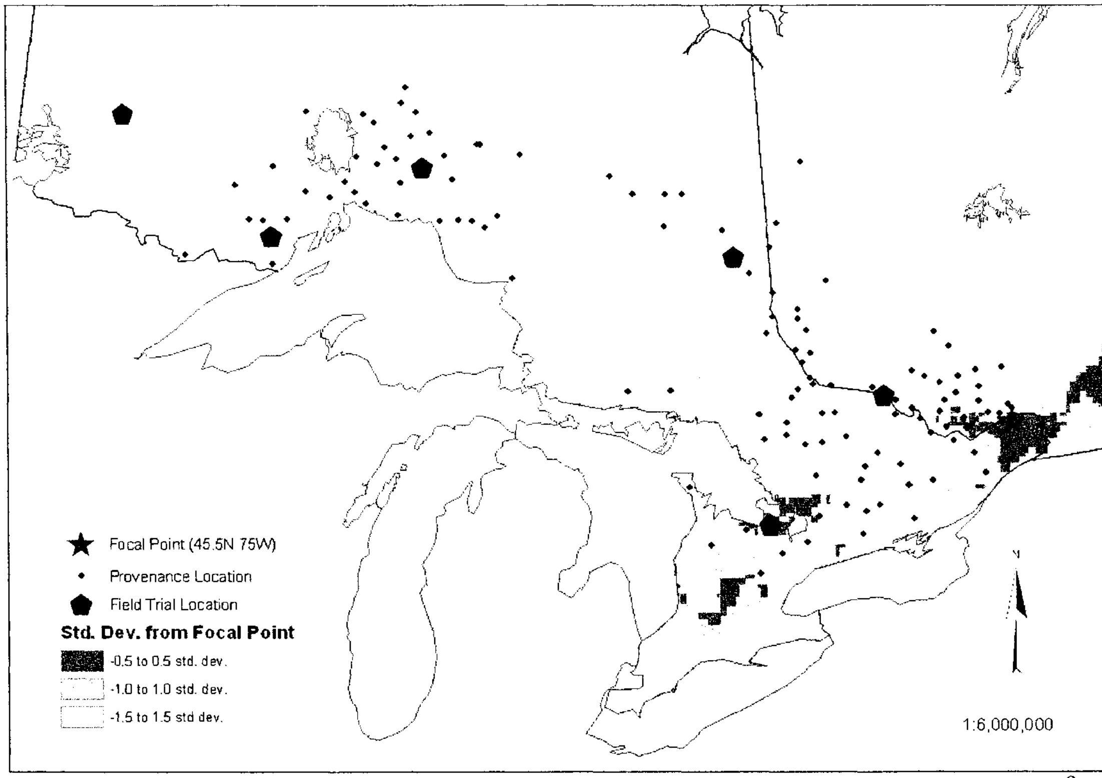

Figure 67. White spruce cancorr based focal point seed zones for coordinates 45.5°N 75°W

DISCUSSION

Canonical correlation analysis (cancorr) offers an appealing statistical alternative to the traditional principal component and regression based methodology (Parker 1991, Parker and Van Niejenhuis 1996a, 1996b) for developing focal point seed zones. In the traditional approach there are two distinct phases on the analysis. First of all, principal components analysis is used to summarize the variance in the biological variable data set. Secondly, the provenance factor scores from each of the significant PC axes are regressed against an array of climatic data to determine the relationship between the summarized biological data and the environment. Canonical correlation analysis, however, takes only one step to essentially reach the same end result. The canonical correlation analysis finds the axes through both the biological and climatic data sets that maximizes the covariance between the two data sets and simultaneously summarizes and relates the data sets to each other (Gittins 1985). Furthermore, canonical correlation analysis does not discard information on relationships as the multiple regression phase of the traditional approach does (Gittins 1985). The cancorr method retains all of the climate variables and the resulting seed zones are based on the weighted contributions of the full array. In the regression approach, suitable multiple regression equations are developed that, while seeking to explain the greatest amount of correlation between each PC axis and the climate array, are actually limiting the explanatory power of the model. Furthermore, the first step in the traditional approach, the principal components analysis, segregates the biological data set into its various components with no regard to their relationship to the climate data set. The separation of the biological variables into growth potential (PC1), phenological timing (PC2), and greenhouse effects (PC3) has high utility in that it allows a meaningful biological interpretation of the resulting patterns of variation; but is really an arbitrary mathematical determination that does not necessarily lend itself to explaining the true relationships between the biological and climate data sets (Gittins 1985).

While this method of relating two sets of variables would seem to have high appeal, canonical correlation analysis is often viewed sceptically by ecologists (Gittins 1985). Canonical correlation analysis was first used in an ecological application by Austin (1968) who found the results to be unsatisfactory in comparison to other ordination techniques. Gauch and Wentworth (1976) suggest that canonical correlation analysis is only useful to ecological situations when the problem is so trivial that cancorr simply repeats the structure that was already evident prior to any analysis; and that when the problem becomes more difficult cancorr is ineffective. Other studies however, have shown that cancorr can be used as an effective statistical tool in ecological applications (Pélissier *et al.* 2001, Gimaret-Carpentier *et al.* 2003). Westfall (1992) demonstrated the applicability of cancorr in seed zone development, using it as the basis in seed zones for white fir in California.

A previous attempt to use cancorr as the basis of building focal point seed zones for black spruce in northwestern Ontario was viewed as less satisfactory than the regression based approach, in that resulting zones contained more geographic discontinuities than the regression based counterparts, and that, as with results presented here, no biological interpretation of the axes was possible (Parker and van Neijenhuis 1996b).

Specific issues with canonical correlation analysis are that canonical weights tend to be highly unstable. Instability can be caused by inadequate sample size, measurement errors and collinearity of the variables in either data set (Gittins 1985). Furthermore, difficulties with interpretability of results can be an issue (Gittins 1985, Gimaret-Carpentier *et al.* 2003). Results from this study show no clear biological interpretation of the canonical axes, however, it is thought that this is at least partially due to the overly complex relationship between the biological and climatic variables. When considering the complexity of the relationship between these data sets, it seems understandable that there is no clear delineation between growth, phenology, and greenhouse effects that is seen when PCA is performed on just the biological variable set. While this does confound the interpretation of the patterns of adaptation by not allowing their breakdown into useful categories, this alone should not dissuade from the use of canonical correlation analysis. The end result (Figures 42-44), while being an intermingling of growth, phenology and greenhouse effects, still shows clear meaningful patterns of adaptation across the landscape. Each of these three grids can essentially be looked at as a significant portion of the overall pattern of adaptation. The fact that these three grids so closely resemble the PCA predicted factor score grids (Figures 16-18) strengthens the argument that the patterns are meaningful.

Overall, focal point seed zones developed from canonical correlation analysis appear quite similar to regression based seed zones. The same lake shore effects and the effect of the Algonquin Highlands are readily apparent in both sets of seed zone maps. Both methodologies show a transition at approximately 47 degrees latitude as focal points move from north-eastern Ontario into southern Ontario and Quebec. This transition corresponds to the boreal Great Lakes–St. Lawrence forest region transition in eastern Ontario (Rowe 1972). Focal points located north of 47 degrees generally show little acceptable area to the south, with southern points showing little to no acceptable area north of that latitude.

While broad patterns of similarity are the same, there are also notable differences in the produced zones. For northern points the clear 'boundary' at approximately 50 degrees latitude that is seen in the regression based zones is not apparent in the cancorr zones. The cancorr zones for the same northern points show zones extending north and south of 50 degrees but being more limited longitudinally. This effect is seen for all of the selected northern points (Figures 19-25 and 45-51). While this longitudinal effect does not follow the north-south divides seen in Hill's site regions and the regression based zones, there are still similarities to Hill's regions. Breaks between the 4S, 3W and 3E regions are all longitudinal and could be seen as more influential divides. The north-south break corresponding to the divide seen in regression based zones is predominately between districts within regions, not between major regions (Hills 1961).

Another point of difference between methodologies is that the lakeshore effect of the north shore of Lake Superior is seen much more strongly in the cancorr zones than in the regression based zones for focal points located across northern Ontario.

Generally, cancorr developed zones for southern focal points show less acceptable areas in the north-west as compared to regression based zones for the same points. Cancorr developed zones for southern points are also generally smaller than their regression based counterparts, and appear to be more heavily influenced by lakeshore effects and the Algonquin Highland area. Southern cancorr zones are also more fragmented than regression based zones within the local area of the focal point, but show fewer remote disjunct areas of similarity.

When only the zone of greatest similarity (±0.5 std. dev.) is considered, the degree of similarity between the two methods is very high. The fact that two independent statistical techniques produce such similar results strengthens the overall result, regardless of which approach is used. Even though both methods use the same data set to obtain the results, that they both produce such similar outcomes leads to the conclusion that true patterns of adaptive variation are being identified and mapped.

It is difficult to establish concretely which of the two methods should be preferred. While overall results are very similar, the scale of differences that do exist is large enough to have significant impacts on seed transfer decisions. This is particularly true for northern areas where the differences in latitudinal versus longitudinal breadth are most clearly seen. Various quantitative measures could be developed to compare the output of the two techniques such as measurement of dissimilar area, number and area of disjunct zones and areas of overlap to name just a few. However, while these measures will all provide terms of comparison, they will never establish which of the methods is actually better.

The only way to decisively prove which method is the better model of adaptive similarity would be to plant and monitor trials at locations throughout the study area based on both methodologies. While this would be the ideal solution to the issue at hand, it is well beyond the scope of this project. However, it is still possible to make observations regarding the choice of methodologies. First, canonical correlation analysis offers the better approach statistically; it reduces the number of steps, the loss of information, and ultimately describes a more complete real world picture than the regression based models.

Second, the longitudinal trend of the cancorr results throughout northern portions of the study area is considered more realistic, in regards to actual observed patterns of adaptation (Apendix IV), climatic trends (Appendix V) and patterns observed for black spruce and jack pine (Parker and van Niejenhuis 1996a, 199b). Third, cancorr results show overall less disjunct areas and more localized zones of similarity than the regression-based zones. The issue of fragmentation that is seen in southern cancorr zones could be solved through applying different standard deviation intervals in constructing the zones, subtly changing boundaries to amalgamate local areas more definitively. Finally, it is felt that the increased strength of lake shore and highland effects seen in the cancorr results is realistic. Although these effects are seen in the regression-based results as well, they are not as strong, and do not persist across the landscape in the same way that they do in the cancorr results (Figures 19-41 and 45-67).

All of these points lead to the conclusion that the canonical correlation analysis methodology is preferred. It should be noted, however, that this conclusion is based on observations and intuition as much as quantitative measures. It should also be cautioned, that, as discussed previously, canonical correlation analysis can be highly unstable. While a preferred result was obtained with this particular data set, using this particular set of biological measurements and climatic indicators, there is no surety that similar satisfactory results would be obtained from a different data set: for example, Parker and van Niejenhuis' (1996b) results where the regression-based methodology was considered superior to the cancorr approach.

CONCLUSION

Establishment of the 6 replicated white spruce field trials is a long-term investment for the future management of this species in Ontario. The models used to generate focal point seed zones for white spruce will continue to be refined in the future. The results gathered at the three year completion of this study will be enhanced by maintenance and periodic measurement of the 6 field tests over the next quarter century.

As the demands on artificial forest regeneration continues to grow and management practices become more ecologically based, genetic based species specific seed zone development will also grow in importance. The importance of seed in the reforestation process is being recognized by forest managers and awareness will continue to increase. Coupled with the fundamental importance of seed origin, is the use of improved seed from breeding programs (Morgenstern and Wang 2001). If forest management goals dictate, breeding zones for white spruce may be developed based on the patterns of adaptive variation observed across the province. The creation of these breeding zones would provide the basis for tree improvement programs. Using the focal point seed zone growth models as a basis, the Differential Systematic Coefficient (DFC) can be used as an indicator of breeding zone boundaries (Parker 2000). This approach identifies areas where patterns of adaptation show the greatest rate of change and therefore is also a useful tool in assessing biodiversity and development of a conservation strategy for white spruce.

In addition to breeding zones, response and transfer functions can be developed. This will be a continuation and strengthening of the work done in this area on white spruce by Cherry and Parker (2003). Their work dealt with the 410 series of range-wide white spruce provenance tests, looking specifically at the 15 test locations in Ontario. Data from the six newly established tests for this project will provide complementary information to that study and strengthen findings. This approach will explore the possibilities of moving seed in order to optimize growth potential. While this approach goes against the philosophy of local is best zones, it creates the potential of higher realized fibre gain for industrial forestry purposes.

The feasibility of utilizing seed from outside of what is prescribed by the focal seed zone delineation will be considered in conjunction with climate change scenarios that will inevitably cause shifts, most likely northwards, in focal point seed zones. The combination of climate change moving regions of adaptability, and the potential of southern sources to grow better in more northern locations, has serious implications for forest management practices now and in the future.

To conclusively determine which of the two approaches to focal point seed zone development is preferable, the recommendation would be to establish a quantitative means by which the methodologies can be compared. This could be accomplished through further field trial testing, or by utilizing another data set for comparison purposes. While the main issue with the first choice is the cost of funding such trials, the issue with the second choice is that no other data set currently exists for the study area that can be used for developing focal point seed zones. The difficulty remains in using an existing data set such as the 410 Series data as a comparison when the same methodologies can not be performed. The potential, however, does exist and may yet provide the basis of a quantitative comparison between these techniques.

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APPENDICES

APPENDIX I
PROVENANCE NUMBER, SOURCE, AND LOCATION

Source No.	Source	SourceID	Location	Lat	Long	Elev (m)
1	ofri	22	Cornwall	45.07	74.83	80
2	que	3178	St-Andre Avellin	45.67	74.97	155
3	que	3179	St-Andre Avellin	45.73	75.05	152
4	que	3148	Camp 27	46.25	75.08	259
5	que	3180	Thurso	45.62	75.23	100
6	que	3173	Poupee	45.65	75.45	15
7	que	3163	Lac Iroquois	46.03	75.57	213
8	que	3176	Ruisseau Murphy	46.25	75.58	304
9	que	3181	Val-Des-Bois	45.82	75.60	168
10	ofri	4	Augusta	44.83	75.63	100
11	cfs	8209	Marlborough Tp	45.12	75.80	90
12	que	3147	Breckenridge	45.47	75.92	107
13	que	3182	Wakefield	45.62	75.93	244
14	que	3146	Bouchette	46.20	75.95	183
15	que	3144	Aylwin	45.97	76.03	152
16	que	3153	Grand-Remous	46.63	76.07	244
17	cfs	8032	Antrim	45.32	76.18	121
18	que	3183	Wyman	45.52	76.30	91
19	que	3156	Lac Cayamant	46.15	76.33	274
20	que	3159	Lac Du Faucard	46.85	76.35	305
21	que	3170	Ladysmith	45.75	76.40	213
22	que	3168	Lac Usborne	46.25	76.63	274
23	cfs	8028	Renfrew	45.47	76.63	121
24	cfs	8210	Silver Lk	44.82	76.68	180
25	cfs	8026	Beachburg	45.68	76.80	137
26	que	3154	Grove Creek	45.90	76.27	244
27	que	3174	Riviere-Coulonge	46.35	76.87	274
28	que	3157	Lac Cranson	45.83	76.95	122
29	ofri	92	Tyendinaga	44.33	77.13	107
30	ofri	5	Barrie	44.78	77.15	274
31	que	3177	Sheenboro	45.97	77.25	152
32	ofri	25	Denbigh	45.08	77.28	305
33	cfs	8161	Alice	45.77	77.28	150
34	cfs	8024	PNF!	45.98	77.45	160
35	que	3175	Rolphton	46.17	77.67	183
36	ofri	18	Carlow	45.27	77.70	366
37	ofri	52	Marmora	44.55	77.75	229
38	cfs	8025	Bancroft	45.10	77.97	396
39	ofri	28	Dummer	44.48	78.02	236
40	cfs	8211	Anstruther Tp	44.92	78.07	365
41	ofri	41	Haldimand	44.17	78.12	274
42	cfs	8015	Whitney	45.53	78.27	396
43	ofri	42	Harvey	44.60	78.38	300
44	que	3152	Canton Sebille	47.70	78.40	305
45	ofri	50	Lister	45.87	78.45	442

Source No.	Source	SourceID	Location	Lat	Long	Elev (m)
46	que	3149	Canton Cameron	46.25	78.50	183
47	ofri	65	Osler	45.87	78.70	442
48	que	3169	Lac Wawagosis	49.35	78.70	289
49	que	3167	Lac Smith	46.72	78.83	335
50	cfs	8019	Rutherglen	46.28	78.85	229
51	que	3145	Baie Kelly	47.03	78.87	335
52	cfs	8157	Mattawan Tp	46.38	78.90	305
53	ofri	30	Eldon	44.47	78.92	280
54	cfs	8164	Hindon Tp	45.03	78.93	335
55	que	3150	Canton Gaboury	47.33	79.00	305
56	cfs	8153	Jocko Tp	46.60	79.02	306
57	que	3161	Lac Guay	47.20	79.03	305
58	cfs	8166	Sinclair Tp	45.47	79.08	370
59	que	3151	Canton Mercier	46.78	79.12	305
60	cfs	8186	Bonfield Tp	46.23	79.13	245
61	ofri	81	Scott	44.12	79.18	290
62	cfs	8168	Chisholm	46.13	79.27	275
63	que	3162	Lac Hebecourt	48.53	79.30	224
64	ofri	89	Strong	45.78	79.42	381
65	cfs	8167	Armour Tp	45.62	79.42	300
66	que	3165	Lac Labyrinthe	48.22	79.48	289
67	que	3172	N.Dame des Quinze	47.58	79.50	213
68	cfs	8163	Lorrain Tp	47.25	79.52	240
69	cfs	8165	Peck Tp	45.48	78.75	460
70	cfs	8036	Cobalt	47.03	79.68	306
71	cfs	8152	McKellar	45.58	79.87	275
72	cfs	8038	Englehart	47.87	79.92	215
73	cfs	8189	East Mills	45.92	79.93	245
74	ofri	32	Erin	43.75	80.12	427
75	ofri	67	Osprey	44.35	80.33	503
76	cfs	8044	Kirkland Lk	48.03	80.37	304
77	cfs	8187	Bowman Tp	48.48	80.42	290
78	ofri	7	Bentinck	44.17	81.00	305
79	cfs	8049	Clute 2	49.02	81.23	289
80	cfs	8043	Pagwa	49.77	85.42	245
81	cfs	8053	Fraserdale	49.03	81.58	215
82	cfs	8188	Robb Tp	48.58	81.62	290
83	ofri	90	St. Edmunds	45.25	81.63	206
84	cfs	8021	Nairn Tp	46.32	81.65	243
85	cfs	8046	Gurney Tp	49.05	82.25	215
86	ofri	74	Proctor	46.33	82.50	249
87	cfs	8236	Cargill	49.30	82.70	289
88	ofri	31	Elizabeth Bay	45.83	82.75	191
89	ofri	55	Meldrum Bay	45.95	83.08	183
90	cfs	8047	Arnott Tp	49.62	84.58	275
91	cfs	8039	Wawa	47.92	84.75	306
92	cfs	8045	Bouchard	48.78	85.05	457
93	cfs	8052	White R	48.62	85.32	305
94	kc	012-16-344-01	Highway 11	49.77	85.47	236

Source No.	Source	SourceID	Location	Lat	Long	Elev (m)
95	cfs	8051	Mobert Tp	48.70	85.58	305
96	cfs	8067	Strathearn	48.72	85.87	335
97	cfs	8066	Manitouwadge	49.28	85.97	305
98	cfs	8061	Caramat	49.60	86.15	305
99	cfs	8063	Pic R	48.70	86.25	240
100	cfs	8083	Kenogami	49.92	86.48	305
101	cfs	8075	Nakina	50.20	86.78	335
102	cfs	8081	False Crk	49.87	86.87	365
103	cfs	8065	O'Sullivan	50.53	87.02	335
104	cfs	8076	Long Lake	49.22	87.07	335
105	kc	012-15-342-08	Maun/Anaconda Rd	50.32	87.09	328
106	ofri	29	Eastnor	44.98	81.37	191
107	cfs	8064	Terrace B	48.78	87.12	200
108	kc	012-15-343-07	Grandpa Rd	49.55	87.18	404
109	cfs	8079	Jellicoe	49.70	87.42	365
110	cfs	8240	Parks Lk	49.47	87.57	460
111	cfs	8077	S Onaman R	50.03	87.65	305
112	lu	2001.3	Mountain Bay	48.91	87.77	195
113	cfs	8078	Auden	50.15	87.88	335
114	cfs	8082	Beardmore	49.55	88.00	365
115	cfs	8074	Limestone	49.07	88.02	245
116	cfs	8056	Nipigon	49.20	88.22	229
117	lu	2001.2	Stewart Lake	48.98	88.54	267
118	cfs	8057	Chief Bay	49.05	89.05	275
119	cfs	8060	Waweig L	50.15	89.12	305
120	lu	2001.1	Lakehead U Woodlot	48.65	89.41	457
121	cfs	8087	Pigeon R	48.02	89.65	306
122	cfs	8069	Twist L	49.37	89.75	425
123	cfs	8084	Shabaqua	48.62	89.90	410
124	cfs	8088	Shebandowan	48.62	90.18	459
125	cfs	8068	Upsala	49.07	90.52	489
126	cfs	8089	Eva L	48.07	91.42	428
130	ofri	47	King	44.00	79.67	240

APPENDIX II
PROVENANCE MEAN VALUES FOR ALL BIOLOGICAL VARIABLES

Prov	2004 Heights (mm)						2003 Heights (mm)					2002 Ht. (mm)	2004 Root Collar Diameters (mm)					
	drht04	kbht04	lcht04	enht04	pwht04	anht04	drht03	kbht03	lcht03	enht03	pwht03		drdia04	kbdia04	lcdia04	endia04	pwdia04	andia04
1	278.759	337.800	214.857	268.417	321.000	361.828	171.78	163.73	173.82	172.79	205.74	128.22	5.473	5.392	5.415	6.119	7.027	6.502
2	249.929	280.138	199.429	224.913	273.222	289.552	147.70	135.79	163.56	147.57	164.56	111.57	5.679	4.159	4.539	5.526	6.231	5.282
3	268.262	278.967	186.238	268.250	235.316	339.828	146.00	144.60	156.76	166.05	165.21	114.08	5.226	4.788	4.534	5.996	6.031	6.190
4	259.767	274.867	193.813	213.500	286.750	331.107	133.60	138.50	147.39	133.42	184.64	110.40	4.850	4.130	4.633	5.143	6.874	5.598
5	229.690	248.185	225.500	247.409	238.435	375.000	176.90	112.59	159.79	166.30	160.78	108.82	4.986	4.063	5.343	5.591	6.579	6.868
6	214.214	310.621	186.583	257.591	272.077	344.100	122.88	158.10	141.79	162.78	171.15	113.87	4.878	5.139	4.511	5.937	6.509	6.202
7	276.571	303.240	233.100	294.708	270.136	359.800	175.44	146.04	182.41	194.21	183.09	129.61	5.476	5.156	5.151	6.326	7.203	6.342
8	266.750	298.000	160.063	277.316	222.800	344.897	156.90	146.31	128.26	174.05	147.80	109.92	5.219	4.622	3.469	5.899	5.559	5.929
9	261.828	292.448	166.938	271.063	250.636	380.000	143.10	139.77	138.85	178.50	168.61	118.62	5.220	4.614	4.034	6.173	7.164	6.196
10	251.034	294.533	208.250	277.440	256.348	329.567	159.30	149.07	156.00	183.00	169.09	120.19	5.523	4.813	4.878	6.267	6.605	6.248
11	255.071	229.143	165.583	230.952	222.368	304.103	159.89	110.81	135.00	145.24	141.75	102.76	4.943	3.575	3.874	5.042	5.717	5.532
12	281.241	242.172	174.429	211.048	197.063	303.679	204.20	128.24	144.94	138.52	136.31	101.32	5.558	3.986	5.203	5.395	5.092	5.580
13	291.633	306.333	226.100	271.000	255.316	333.867	175.50	149.23	174.14	177.13	175.58	121.32	5.573	4.646	5.185	6.147	6.476	6.069
14	234.700	248.767	160.417	208.240	274.625	288.586	164.60	118.03	122.06	131.68	174.19	98.64	4.420	3.958	4.420	4.875	6.424	5.469
15	281.833	271.138	170.455	232.333	232.150	287.267	190.40	130.79	132.24	136.67	157.80	95.31	5.275	4.026	4.420	5.177	5.568	4.998
16	250.207	302.621	216.750	282.040	269.731	338.167	178.20	162.86	171.22	176.60	177.77	124.95	5.782	5.464	5.437	6.486	7.163	6.138
17	259.074	323.690	173.417	259.600	249.750	304.310	139.90	157.79	148.95	174.60	160.24	114.56	5.735	4.969	4.515	6.141	6.149	5.679
18	310.464	293.107	185.273	266.440	228.842	331.276	213.90	144.11	148.50	165.20	156.74	112.63	5.952	4.076	4.643	5.724	5.976	5.961
19	273.069	310.862	211.750	294.307	266.333	332.467	164.89	147.45	165.90	185.29	182.63	125.94	5.618	4.694	4.741	6.706	6.951	5.863
20	234.276	265.172	231.278	242.100	264.958	343.467	165.10	133.66	169.52	164.33	164.21	122.92	5.394	4.973	5.281	5.635	7.333	5.993
21	265.034	301.567	214.143	279.174	240.870	328.103	202.60	149.20	177.53	182.74	158.87	122.65	5.449	4.500	4.974	6.176	5.727	5.660
22	267.333	315.300	239.875	287.400	258.667	366.267	170.50	158.27	168.50	193.30	183.50	135.93	4.902	5.099	5.436	6.546	5.570	6.407
23	242.769	245.000	177.818	238.400	251.393	326.033	157.50	126.41	163.00	150.80	163.48	112.00	5.407	3.993	4.106	5.287	5.768	6.141
24	215.733	231.517	144.286	203.722	196.412	284.654	150.30	111.10	98.60	135.72	126.72	87.66	4.261	4.034	3.241	4.971	5.222	5.230
25	244.448	324.893	200.412	222.278	233.474	326.967	155.30	164.79	156.90	146.11	150.14	114.55	5.149	5.398	4.922	5.246	6.491	5.832
26	231.690	289.379	151.154	218.000	219.000	326.867	186.70	138.90	132.44	140.88	141.06	105.63	4.712	4.463	3.704	4.681	4.999	5.758
27	259.519	285.148	202.118	263.292	284.053	347.433	139.10	144.64	156.76	169.63	188.58	124.42	5.398	4.875	4.966	6.464	7.629	6.233
28	273.379	306.767	196.000	279.000	293.474	359.233	172.78	157.73	159.68	186.50	192.58	125.86	5.602	4.846	4.844	6.438	8.044	6.220
29	242.367	247.321	198.417	214.857	220.000	265.633	143.40	119.38	141.29	140.38	135.41	93.51	5.169	3.770	4.461	5.134	6.052	5.016
30	242.414	260.833	164.400	256.000	265.882	337.567	148.11	128.90	131.38	155.58	162.18	106.81	5.491	4.490	4.254	6.112	7.091	6.336
31	274.310	252.552	182.714	216.263	193.000	299.552	184.20	116.69	148.72	139.11	131.74	102.68	5.435	4.029	4.854	4.915	5.301	5.321
32	260.000	300.357	226.083	281.348	247.400	315.704	167.60	157.14	179.59	178.35	169.48	125.26	5.401	4.992	5.292	6.206	6.192	6.421
33	232.643	287.200	179.833	264.944	234.000	295.433	139.44	153.67	153.50	157.47	153.23	103.59	4.818	4.524	4.581	6.383	5.896	5.641
34	251.704	274.448	192.583	246.632	233.190	307.133	148.00	130.24	142.79	153.74	159.35	98.37	5.134	4.345	4.245	5.250	5.163	5.538
35	249.700	295.033	230.833	263.952	240.632	352.900	162.10	149.90	167.87	169.95	167.79	120.48	5.067	4.393	4.788	5.521	6.285	6.455
36	267.654	280.448	236.632	249.409	240.667	316.759	107.00	142.48	158.36	153.55	158.77	107.31	6.011	4.481	5.529	5.865	6.359	5.946
37	237.036	299.036	207.222	219.750	191.045	314.067	161.50	138.93	162.80	147.88	132.41	110.41	4.877	5.102	4.887	4.922	4.402	5.580
38	242.821	274.250	152.188	201.750	229.727	316.433	154.60	147.11	134.22	129.82	152.95	102.64	5.122	4.317	4.034	4.632	5.366	5.888
39	273.556	308.357	200.667	254.957	256.417	328.571	167.44	163.79	157.06	158.35	178.25	120.22	5.344	4.519	4.689	5.979	6.224	6.285
40	219.483	245.333	182.778	235.667	240.391	299.467	134.78	118.83	137.53	163.48	167.61	102.39	4.439	4.061	4.696	5.404	6.171	5.586
41	261.167	296.067	198.154	226.409	199.632	308.571	158.40	150.73	151.55	132.73	132.37	102.57	5.089	4.433	4.675	5.293	5.218	5.640
42	271.321	302.310	209.417	236.800	298.682	325.167	177.10	148.03	159.25	156.04	191.27	120.46	6.014	5.068	4.782	5.540	6.622	5.776

Prov	2004 Heights (mm)						2003 Heights (mm)					2002 Ht.	2004 Root Collar Diameters (mm)					
	drht04	kbht04	lcht04	enht04	pwht04	anht04	drht03	kbht03	lcht03	enht03	pwht03	(mm)	drdia04	kbdia04	lcdia04	endia04	pwdia04	andia04
43	248.552	298.037	186.000	288.172	244.600	331.828	147.38	153.00	148.71	187.24	171.60	125.77	4.976	4.819	4.441	6.380	6.089	5.897
44	286.643	294.767	218.786	279.520	230.583	379.857	200.22	146.20	167.29	181.64	166.88	129.87	5.913	4.884	5.430	6.455	5.155	6.749
45	207.400	248.000	168.933	231.136	206.320	288.414	149.30	127.03	140.83	150.09	138.31	98.94	4.662	4.320	3.759	5.071	5.105	5.161
46	283.931	315.933	189.111	253.960	265.917	315.700	172.33	165.87	158.05	165.00	173.00	120.08	5.224	4.956	4.897	5.576	6.477	6.031
47	212.586	248.571	157.222	225.300	174.952	333.276	115.33	128.61	124.67	148.10	122.55	99.61	4.735	3.868	3.777	5.043	4.467	6.210
48	248.036	242.931	209.294	202.227	188.278	339.000	184.67	124.64	165.10	139.32	129.10	118.31	5.219	3.884	4.896	4.673	4.363	5.889
49	283.500	306.276	210.316	324.480	297.826	318.800	159.40	162.14	170.00	200.16	197.25	132.37	5.613	5.224	5.450	6.649	7.344	6.189
50	274.000	327.310	213.125	298.348	262.875	342.600	182.50	166.69	165.52	187.52	182.46	134.08	5.744	5.324	5.056	6.243	6.431	6.049
51	235.643	208.542	136.333	190.600	196.400	290.778	137.89	98.29	105.10	119.60	101.42	75.41	4.163	3.390	3.451	4.208	5.373	5.287
52	241.846	259.852	166.188	211.750	189.579	314.200	122.88	135.07	115.00	128.00	122.85	92.69	4.975	4.170	4.406	4.666	4.552	5.484
53	259.407	325.033	175.455	264.550	296.091	318.875	171.00	175.03	151.17	174.00	202.86	123.16	4.746	5.001	4.881	6.303	7.792	6.081
54	177.667	221.240	173.933	198.313	209.389	265.379	120.50	113.77	133.44	135.00	135.00	89.65	4.027	3.833	3.935	4.053	5.007	5.261
55	246.569	334.233	238.353	323.136	274.913	345.000	148.60	170.73	189.95	212.64	194.43	138.08	5.261	5.577	5.595	6.759	6.472	6.283
56	241.621	262.621	207.063	220.000	220.650	301.536	164.78	133.52	151.82	142.00	145.45	105.18	4.818	4.094	4.619	5.335	5.845	5.382
57	268.241	276.600	220.824	234.727	220.444	331.833	184.56	144.13	159.76	154.23	151.89	120.87	5.690	4.455	5.290	5.409	5.695	5.622
58	233.345	286.793	188.917	225.385	242.222	329.500	149.90	146.07	137.83	149.23	148.94	112.76	4.574	4.937	4.124	5.332	5.941	5.906
59	280.033	307.667	230.167	308.762	236.095	385.733	159.20	154.97	171.84	203.38	156.71	132.04	5.733	4.962	5.015	6.703	6.130	6.446
60	194.138	243.929	169.800	204.409	214.545	312.214	115.80	123.10	127.44	131.41	137.83	91.81	3.636	4.021	3.890	4.458	5.595	5.691
61	253.407	254.897	178.636	243.545	257.273	287.483	149.11	129.38	138.20	158.32	173.27	118.97	5.158	4.177	5.292	5.629	6.935	6.012
62	242.821	246.481	165.250	224.294	208.118	297.133	140.40	115.28	124.26	148.41	134.44	99.68	5.137	3.995	3.380	4.504	5.539	5.546
63	270.655	301.448	224.929	300.269	282.286	365.533	193.20	155.20	188.18	194.00	187.77	139.28	5.397	5.041	4.891	6.436	6.855	6.651
64	245.482	282.069	212.300	219.952	190.550	308.700	174.44	140.80	159.78	144.52	120.62	106.91	5.040	4.630	5.508	5.175	5.051	5.758
65	262.172	268.067	140.273	224.958	214.762	341.862	156.50	140.83	127.40	140.04	156.71	102.32	5.025	4.293	3.821	5.266	4.846	5.807
66	272.500	307.857	206.313	296.700	286.609	343.833	202.00	166.36	171.87	197.95	192.91	132.77	5.555	5.127	4.561	6.268	6.644	6.228
67	275.200	290.034	181.375	251.957	275.714	351.733	177.50	140.23	167.05	155.07	181.29	123.77	5.373	4.869	4.199	5.733	5.990	6.029
68	273.704	283.033	192.556	235.190	215.842	314.467	166.50	143.30	137.62	152.33	143.74	103.54	5.096	4.433	4.226	5.431	5.964	5.594
69	254.345	287.172	198.125	216.652	247.696	288.310	159.90	147.34	138.72	145.22	167.87	104.31	5.079	4.443	4.008	4.870	5.808	5.477
70	211.185	240.321	165.667	220.667	219.727	280.467	125.00	119.54	115.65	134.44	142.82	87.72	4.505	3.927	3.926	4.752	5.599	5.279
71	224.857	237.276	159.929	212.950	209.360	340.567	135.44	123.41	128.24	140.25	138.42	108.37	4.832	4.172	4.115	4.847	5.134	6.263
72	249.500	287.345	161.118	225.824	202.682	329.667	136.00	141.17	140.24	146.53	128.59	111.57	5.178	4.696	3.969	4.562	4.902	5.682
73	240.241	313.448	207.643	226.880	234.261	318.333	156.80	150.72	154.94	148.80	156.25	109.53	5.374	5.266	4.855	5.401	6.049	6.150
74	230.900	304.448	220.824	226.500	295.650	344.429	152.40	159.93	159.14	145.77	219.48	121.86	4.886	5.174	5.409	6.056	7.609	6.002
75	213.536	223.367	169.714	211.875	218.667	289.138	164.44	116.33	127.23	135.92	141.17	101.91	4.438	3.894	4.391	4.857	5.595	5.467
76	209.889	228.000	173.200	184.450	182.059	285.931	157.63	116.33	142.29	127.00	119.56	89.12	4.454	3.850	3.845	4.073	4.406	4.743
77	234.367	236.867	163.357	207.737	199.857	286.414	144.90	122.70	131.71	139.16	122.86	99.14	5.010	4.056	3.690	4.371	4.760	5.163
78	207.423	256.433	180.538	216.808	255.385	344.667	107.70	123.90	146.13	138.85	157.77	103.66	4.219	4.652	4.948	5.876	6.469	6.209
79	250.069	240.767	199.688	199.889	211.591	322.933	159.00	122.83	142.95	139.50	151.23	108.47	5.009	3.678	4.477	4.468	4.660	5.583
80	192.148	226.615	143.467	198.417	188.909	280.138	124.13	110.81	102.88	116.77	124.45	85.78	3.745	3.496	3.255	4.712	4.794	4.764
81	262.643	240.897	204.750	251.875	232.000	332.690	166.40	118.14	143.00	167.94	150.36	113.83	5.672	4.262	5.079	5.256	5.999	5.702
82	229.148	248.862	165.000	209.000	209.611	292.931	152.56	122.70	127.56	140.52	127.15	100.75	4.632	3.762	3.796	4.677	5.275	5.386
83	209.750	217.621	156.250	226.182	222.762	315.379	141.20	109.20	119.00	135.59	139.38	90.24	4.198	3.469	3.688	4.862	5.718	5.611
84	235.172	272.000	158.667	211.724	239.053	316.000	138.40	133.50	126.65	147.06	160.10	103.24	4.634	4.290	3.855	5.051	6.106	5.674
85	235.233	241.414	176.765	196.438	214.875	300.074	156.80	128.93	134.65	132.75	138.13	95.77	4.737	3.948	4.005	4.808	6.052	5.607
86	235.133	291.967	225.650	296.654	270.579	336.800	181.10	150.90	170.35	187.85	185.68	134.06	4.777	5.046	5.529	7.045	7.061	6.269
87	214.500	222.821	176.100	200.000	231.600	283.900	129.50	109.96	144.90	137.08	151.60	100.38	4.304	3.584	3.847	3.693	5.123	4.866

Prov	2004 Heights (mm)						2003 Heights (mm)					2002 Ht.	2004 Root Collar Diameters (mm)					
	drht04	kbht04	lcht04	enht04	pwht04	anht04	drht03	kbht03	lcht03	enht03	pwht03	(mm)	drdia04	kbdia04	lcdia04	endia04	pwdia04	andia04
88	245.931	279.100	180.556	226.316	225.667	301.367	172.90	150.40	141.85	150.95	153.11	114.22	4.762	5.032	4.453	5.161	6.430	5.968
89	218.185	269.179	190.889	216.000	244.087	296.345	143.56	136.68	141.90	141.50	162.91	108.77	4.094	4.461	4.907	5.586	6.144	5.781
90	247.200	228.429	167.526	186.706	195.000	311.333	153.30	112.61	117.26	132.11	136.00	95.72	4.792	3.630	3.724	4.100	5.604	5.473
91	252.655	233.828	163.647	202.727	230.000	265.724	159.00	118.97	125.35	138.41	148.32	99.41	5.367	4.161	3.829	4.705	5.472	5.109
92	247.778	244.655	179.389	208.063	230.762	319.724	163.75	132.93	146.13	145.94	158.41	109.63	4.573	4.424	4.389	5.214	5.655	5.655
93	238.885	263.700	188.000	222.563	216.364	302.233	187.50	135.90	137.00	136.31	153.68	104.95	4.944	4.323	4.159	4.616	5.992	5.852
94	255.192	310.655	211.000	238.158	260.286	348.276	158.44	152.13	168.21	166.60	177.55	128.22	5.360	4.764	4.310	5.310	6.267	6.104
95	243.556	264.467	202.071	218.235	223.050	339.033	151.70	131.97	151.47	143.94	145.86	105.88	5.173	4.236	4.138	5.154	5.556	5.829
96	212.778	242.233	145.333	171.200	199.391	272.267	187.67	123.10	101.23	116.50	138.25	91.78	4.518	4.256	3.913	4.018	5.121	4.779
97	216.900	228.700	179.700	203.688	177.824	279.400	131.10	115.07	127.09	141.71	131.00	94.42	4.373	3.930	4.151	4.338	4.295	5.086
98	235.379	249.967	167.450	200.100	206.762	299.897	177.00	130.00	126.90	131.10	141.09	101.77	4.179	3.896	3.723	4.794	4.804	5.479
99	245.414	268.714	185.913	215.727	223.136	313.143	150.50	130.43	144.71	145.64	140.39	108.18	4.709	4.711	4.510	4.888	5.792	5.813
100	232.897	178.241	160.294	173.118	174.667	237.933	159.10	93.68	105.94	122.00	102.82	80.87	4.603	3.179	3.865	3.961	4.188	4.408
101	283.414	328.276	201.250	260.792	266.304	361.103	177.00	180.59	167.38	186.96	185.43	152.28	5.506	5.489	4.546	5.525	6.867	5.941
102	261.345	257.778	168.643	227.833	217.130	318.433	174.30	138.33	129.84	150.11	137.68	109.19	5.053	4.273	3.821	4.847	5.343	5.299
103	231.379	245.897	179.471	219.435	198.889	313.250	122.70	121.55	142.21	156.96	136.85	112.97	4.398	4.414	4.044	5.043	5.507	5.371
104	213.690	267.621	198.438	218.120	215.647	311.200	128.40	131.23	142.32	148.36	155.79	120.09	4.929	4.117	5.035	5.106	5.376	5.750
105	238.448	267.724	184.118	257.048	240.545	337.700	156.80	146.34	153.45	172.00	159.83	128.41	4.792	4.774	4.852	5.559	6.368	5.857
106	245.607	254.926	156.200	231.765	212.045	266.000	142.00	125.45	121.75	142.18	152.09	80.81	4.497	3.778	4.095	5.628	5.477	5.474
107	197.893	246.185	155.643	241.583	207.833	283.192	117.22	118.74	111.29	146.42	134.61	91.17	4.163	4.216	3.515	5.382	5.201	5.249
108	227.143	270.067	191.211	228.444	234.250	299.074	147.67	131.57	146.65	148.33	149.74	106.53	4.751	4.146	4.632	5.133	5.495	5.786
109	220.370	246.233	169.909	235.667	211.955	300.900	134.44	133.48	148.25	159.74	145.18	116.61	4.518	3.898	4.139	5.092	5.050	5.393
110	211.192	218.280	151.643	182.467	185.158	301.241	121.50	116.52	106.25	130.07	131.74	89.27	4.522	3.414	3.351	3.861	5.118	5.303
111	230.600	260.423	152.200	232.368	213.920	307.900	182.80	139.59	133.00	159.68	147.85	120.10	4.537	4.246	3.807	4.902	5.232	5.805
112	266.172	316.900	209.250	276.182	232.565	318.367	144.11	168.90	160.27	189.77	163.30	136.87	5.486	5.510	5.327	6.084	6.130	6.049
113	227.759	274.500	172.563	221.688	236.063	324.167	156.44	147.69	131.67	158.69	152.47	122.29	4.416	4.198	4.306	4.550	5.663	5.307
114	248.931	265.379	164.235	225.813	222.550	301.000	159.44	139.52	137.11	158.50	148.43	107.96	4.925	4.615	3.744	4.731	5.676	5.775
115	268.033	323.241	206.429	267.136	245.263	325.000	183.00	173.72	178.76	181.77	172.63	131.84	5.473	5.387	5.063	5.970	6.587	5.905
116	232.448	269.276	158.625	220.583	201.800	304.000	120.11	148.03	117.83	149.88	135.25	107.92	5.070	4.298	3.738	5.128	5.135	5.488
117	280.633	331.067	213.222	259.556	293.909	364.900	210.40	179.87	175.33	174.48	191.55	136.19	5.656	5.892	4.869	5.701	7.290	6.220
118	274.897	272.967	174.471	209.474	218.136	341.067	164.60	138.60	140.50	142.21	150.14	119.06	5.069	4.217	4.067	4.302	5.282	5.838
119	232.533	251.500	151.667	195.769	188.455	292.103	182.10	118.27	96.62	133.69	129.30	94.60	4.373	3.903	3.232	4.602	4.735	5.164
120	285.429	303.286	203.722	254.682	236.050	344.552	148.80	161.50	159.80	174.00	155.05	118.56	5.555	4.631	4.902	5.382	5.912	5.944
121	231.310	258.967	178.692	216.667	255.333	303.300	151.00	130.93	149.72	150.78	168.57	115.59	4.588	4.263	3.760	4.626	6.118	5.930
122	239.077	280.741	162.316	230.842	210.727	331.700	134.11	145.96	138.19	158.68	147.22	111.95	4.715	4.058	4.040	5.148	4.749	5.982
123	243.033	257.214	178.938	241.964	245.429	330.967	149.60	125.52	138.32	162.68	164.71	119.74	5.106	4.370	4.258	5.242	6.647	5.829
124	223.071	261.926	179.333	243.833	206.278	303.433	157.20	136.29	121.78	151.33	142.94	110.14	4.611	4.449	4.553	5.663	5.306	5.477
125	238.692	261.536	192.300	227.850	243.412	334.448	121.63	132.82	141.48	145.10	154.89	111.31	4.698	4.383	4.721	5.069	5.685	5.620
126	261.552	233.655	166.563	241.294	226.857	344.655	168.50	115.37	145.67	149.71	154.96	107.87	4.755	3.755	3.673	5.006	5.452	5.912
130	192.690	231.103	190.500	240.333	213.778	275.276	109.80	106.79	136.25	155.00	154.78	93.46	4.299	3.855	4.828	5.638	5.879	5.444

Prov	2003 Root Collar Diameters (mm)					2004 Survival (%)						2003 survival (%)				
	drdia03	kbdia03	lcdia03	endia03	pwdia03	drsurv04	kbsurv04	lcsurv04	ensurv04	pwsurv04	ansurv04	drsurv03	ensurv03	kbsurv03	lcsurv03	pwsurv03
1	4.22	4.29	5.00	4.57	4.60	83.855	90.000	56.998	63.435	51.640	83.855	83.86	63.44	90.00	68.86	53.86
2	3.75	3.16	4.00	4.13	4.56	81.145	83.855	42.993	61.923	51.145	83.855	81.15	61.93	83.86	61.92	51.15
3	3.90	3.56	4.06	4.58	4.00	83.855	90.000	57.701	55.778	53.360	83.855	83.86	53.07	90.00	75.00	53.36
4	3.54	3.29	3.87	3.73	4.47	90.000	90.000	47.007	51.145	50.769	77.710	90.00	53.86	90.00	66.15	50.85
5	4.43	3.47	4.16	4.34	4.16	83.855	75.000	39.148	59.708	65.853	78.930	83.86	61.72	77.71	57.00	65.85
6	3.33	3.82	3.90	4.43	4.52	81.145	83.855	39.148	59.708	72.785	90.000	81.15	56.79	83.86	77.71	72.79
7	4.24	3.85	4.52	4.72	4.59	77.710	70.075	54.991	63.435	64.222	90.000	77.71	63.44	75.00	68.86	66.15
8	3.82	3.18	3.37	4.19	3.67	77.710	83.855	46.923	52.775	55.075	83.855	83.86	54.78	83.86	75.00	55.08
9	3.75	3.52	4.16	4.46	4.52	83.855	83.855	46.923	46.714	60.787	90.000	83.86	46.72	90.00	68.86	60.79
10	4.00	3.80	3.81	5.03	4.10	83.855	90.000	46.923	70.075	66.932	90.000	90.00	70.08	90.00	77.71	66.93
11	3.99	2.72	3.57	3.53	3.76	77.710	81.145	39.148	57.701	53.855	83.855	77.71	57.70	78.93	54.99	53.86
12	4.64	3.29	4.37	3.77	3.60	83.855	83.855	43.077	56.998	47.215	81.145	83.86	55.08	83.86	63.44	47.22
13	4.18	3.73	4.04	4.24	4.20	90.000	90.000	35.218	59.004	53.855	90.000	90.00	63.93	90.00	57.70	53.86
14	3.46	2.98	3.75	3.74	4.30	90.000	90.000	39.232	66.640	46.923	83.855	90.00	68.86	90.00	68.07	46.92
15	4.43	3.31	3.31	3.48	3.77	90.000	83.855	37.225	45.000	60.000	90.000	90.00	45.00	83.86	68.86	60.00
16	4.89	4.31	4.54	4.90	4.98	83.855	83.855	54.991	66.640	68.855	90.000	90.00	66.64	83.86	81.15	68.86
17	3.74	3.81	3.76	4.39	3.88	71.565	83.855	39.148	54.782	56.070	83.855	77.71	57.00	83.86	71.57	58.78
18	4.33	3.42	3.89	4.44	3.98	77.710	81.145	36.932	66.640	53.360	83.855	83.86	66.64	81.15	66.15	53.36
19	3.74	3.51	4.34	4.91	4.43	83.855	83.855	46.923	77.710	68.068	90.000	83.86	77.71	83.86	77.71	68.07
20	3.33	3.88	4.21	4.20	4.88	83.855	83.855	50.853	54.782	64.633	90.000	90.00	56.79	83.86	70.08	64.64
21	4.75	3.56	4.32	4.37	3.52	83.855	90.000	43.077	66.145	61.923	83.855	83.86	57.29	90.00	63.93	61.93
22	4.62	4.07	4.65	4.94	3.74	90.000	90.000	46.923	55.778	57.785	90.000	90.00	53.07	90.00	90.00	57.79
23	3.55	3.56	4.29	3.62	3.91	72.785	83.855	36.145	56.070	77.710	90.000	75.00	56.07	90.00	70.08	77.71
24	3.52	2.72	2.95	3.35	3.35	90.000	83.855	28.780	50.853	49.138	68.855	90.00	50.85	83.86	59.22	51.15
25	3.39	4.10	4.35	3.80	3.96	83.855	81.145	48.930	51.145	57.993	90.000	83.86	53.86	78.93	71.57	60.00
26	3.94	3.15	3.36	3.39	3.42	83.855	83.855	41.070	63.930	46.220	90.000	83.86	66.15	90.00	64.64	60.00
27	3.22	3.86	4.28	4.56	4.78	75.000	75.000	48.846	68.068	53.855	90.000	83.86	70.08	77.71	83.86	53.86
28	3.71	3.96	4.48	4.86	4.78	83.855	90.000	46.923	63.930	53.855	90.000	90.00	63.93	90.00	83.86	53.86
29	3.30	3.24	4.28	3.77	3.56	90.000	81.145	38.855	58.077	48.930	90.000	90.00	58.08	83.86	57.79	48.93
30	4.02	3.51	3.54	4.66	4.20	83.855	90.000	34.633	63.930	48.930	90.000	83.86	63.93	90.00	55.08	48.93
31	4.17	2.99	4.19	3.39	3.31	83.855	83.855	43.077	52.775	53.068	83.855	90.00	52.78	83.86	75.00	53.07
32	3.86	3.99	4.29	4.44	4.06	90.000	77.710	39.232	61.220	55.075	75.000	90.00	57.00	77.71	67.86	57.00
33	3.75	3.72	4.20	4.27	3.90	77.710	90.000	39.148	50.937	57.290	90.000	77.71	53.15	90.00	63.93	57.29
34	3.18	2.97	3.65	3.57	3.25	71.565	83.855	39.063	53.855	57.785	90.000	71.57	55.78	83.86	59.22	63.93
35	3.60	3.41	4.10	4.42	4.10	90.000	90.000	39.232	58.780	53.152	90.000	90.00	58.78	90.00	68.86	53.15
36	2.96	3.44	4.41	4.47	4.43	76.923	83.855	52.775	59.004	57.785	83.855	81.15	59.01	83.86	83.86	57.79
37	3.88	3.64	4.18	3.48	3.25	81.145	77.710	50.853	64.633	59.213	90.000	81.15	66.64	83.86	70.08	59.22
38	3.55	3.52	4.16	3.57	3.84	77.710	77.710	46.923	46.923	60.787	90.000	83.86	50.77	77.71	75.00	60.79
39	3.81	3.57	4.08	4.52	3.94	75.000	77.710	45.000	61.923	73.077	81.145	77.71	61.93	77.71	66.15	73.08
40	3.36	3.19	4.51	3.94	3.98	83.855	90.000	50.853	56.789	66.145	90.000	83.86	52.86	90.00	63.44	66.15
41	3.80	3.96	4.16	3.73	3.28	90.000	90.000	41.070	59.213	53.068	81.145	90.00	61.93	90.00	68.07	53.07
42	3.87	3.81	3.96	4.12	4.15	77.710	83.855	39.148	70.075	60.000	90.000	83.86	70.08	90.00	59.01	60.00

Prov	2003 Root Collar Diameters (mm)					2004 Survival (%)						2003 survival (%)				
	drdia03	kbdia03	lcdia03	endia03	pwdia03	drsurv04	kbsurv04	lcsurv04	ensurv04	pwsurv04	ansurv04	drsurv03	ensurv03	kbsurv03	lcsurv03	pwsurv03
43	3.22	4.04	4.08	4.65	4.07	83.855	78.930	46.923	83.855	70.075	83.855	81.15	83.86	78.93	59.71	70.08
44	4.14	3.90	4.23	4.88	3.82	77.710	90.000	43.077	75.000	68.855	77.710	83.86	75.00	90.00	72.79	68.86
45	3.44	3.56	3.69	3.76	3.30	90.000	83.855	45.000	60.787	66.640	83.855	90.00	60.79	83.86	68.86	72.79
46	3.73	3.95	4.09	4.22	3.95	83.855	90.000	51.145	70.075	68.068	90.000	83.86	70.08	90.00	61.93	68.07
47	3.66	2.92	3.50	3.57	3.13	83.855	77.710	51.848	55.367	62.215	83.855	83.86	60.00	77.71	62.71	62.22
48	4.18	3.60	4.17	3.48	3.30	77.710	83.855	48.930	60.000	51.145	83.855	77.71	60.79	83.86	68.86	57.79
49	3.85	4.19	4.56	4.57	4.76	77.710	83.855	52.775	66.145	66.145	90.000	90.00	66.15	83.86	81.15	68.86
50	4.72	4.26	3.76	4.66	4.47	83.855	83.855	47.007	61.220	68.855	90.000	90.00	61.22	83.86	63.44	68.86
51	3.05	2.50	2.67	3.58	3.15	77.710	64.633	32.215	34.925	30.000	71.565	77.71	39.15	64.64	44.92	63.93
52	3.98	3.53	3.87	3.63	3.12	68.855	75.000	46.923	46.923	52.859	90.000	68.86	48.85	75.00	63.93	52.86
53	3.48	3.92	4.02	4.60	4.69	75.000	90.000	37.141	54.782	60.000	68.855	77.71	54.78	90.00	66.15	60.00
54	3.02	2.94	3.75	3.26	3.00	78.930	66.145	45.000	46.923	55.075	83.855	81.15	46.92	72.29	70.78	55.07
55	3.48	4.55	4.66	4.89	4.43	83.855	90.000	48.930	59.708	61.714	83.855	83.86	59.71	90.00	66.15	61.72
56	3.71	3.42	3.97	3.94	3.79	83.855	83.855	46.923	53.068	56.070	81.145	83.86	53.07	83.86	61.72	56.07
57	4.04	3.51	4.57	4.02	3.97	83.855	90.000	48.846	60.000	50.853	90.000	83.86	57.00	90.00	75.00	52.78
58	3.82	3.74	3.65	3.92	3.90	83.855	83.855	38.152	68.855	51.145	90.000	83.86	68.86	83.86	63.93	51.15
59	4.45	4.12	4.15	4.91	4.16	90.000	90.000	50.853	56.789	62.215	90.000	90.00	56.79	90.00	75.00	62.22
60	2.37	3.16	3.54	3.19	3.61	83.855	77.710	45.000	63.846	60.000	81.145	83.86	63.85	83.86	63.93	66.15
61	4.51	3.58	4.28	4.00	4.45	75.000	83.855	36.848	59.004	59.708	83.855	77.71	59.71	83.86	63.93	59.71
62	3.76	3.15	3.30	3.42	3.47	77.710	75.000	46.923	49.222	49.633	90.000	77.71	49.22	83.86	68.86	51.64
63	4.13	4.10	4.51	4.79	4.46	83.855	83.855	42.993	72.785	57.701	90.000	83.86	72.79	90.00	72.79	63.85
64	3.78	3.62	4.21	4.11	3.49	77.710	83.855	60.000	57.785	55.367	90.000	77.71	53.86	90.00	75.00	58.08
65	3.53	3.22	3.38	3.91	3.54	83.855	90.000	37.225	63.930	61.923	83.855	81.15	63.93	90.00	62.71	61.92
66	4.39	4.05	4.14	4.43	4.38	81.145	77.710	46.714	54.782	66.932	90.000	81.15	54.78	77.71	76.92	66.93
67	4.04	3.60	4.55	4.33	4.35	90.000	83.855	46.923	61.923	58.780	90.000	90.00	68.07	90.00	72.79	58.78
68	3.59	3.39	3.67	3.79	3.78	75.000	90.000	50.853	57.290	52.775	90.000	81.15	59.22	90.00	83.86	52.78
69	3.34	4.09	3.96	3.74	4.03	83.855	83.855	46.923	61.923	66.145	83.855	90.00	59.22	83.86	63.44	66.15
70	2.68	3.19	3.06	3.77	3.63	78.930	77.710	45.000	50.853	60.000	90.000	78.93	50.85	77.71	63.85	60.00
71	3.31	3.21	3.73	3.61	3.38	77.710	83.855	42.993	55.075	70.778	90.000	77.71	55.08	83.86	63.93	70.78
72	3.39	3.59	3.62	3.36	3.43	77.710	83.855	48.930	48.930	59.708	90.000	83.86	55.86	83.86	70.08	59.71
73	4.44	3.64	4.18	4.15	4.10	83.855	83.855	42.993	66.145	65.853	90.000	83.86	66.15	83.86	68.86	68.07
74	3.87	4.03	4.53	4.20	4.71	90.000	83.855	49.222	68.855	55.367	81.145	90.00	68.86	83.86	68.86	55.37
75	3.37	3.32	3.79	3.70	3.73	81.145	90.000	56.998	63.930	56.998	83.855	83.86	61.22	90.00	66.15	59.71
76	3.66	3.05	3.28	3.21	3.10	75.000	90.000	45.000	55.075	45.000	83.855	75.00	53.15	90.00	57.00	67.51
77	3.20	3.14	3.67	3.35	3.00	90.000	90.000	42.993	53.068	57.785	83.855	83.86	53.07	90.00	66.15	57.79
78	2.81	3.68	4.14	4.41	3.94	72.290	90.000	41.070	68.855	68.855	90.000	81.15	66.15	83.86	70.08	68.86
79	3.51	3.28	3.71	3.72	3.57	83.855	90.000	46.923	51.848	64.222	90.000	83.86	51.85	90.00	70.08	64.22
80	2.85	2.60	2.83	3.62	3.15	75.000	71.565	45.000	39.232	60.000	83.855	75.00	41.15	71.57	60.00	60.00
81	3.97	3.55	3.89	4.19	3.69	77.710	83.855	38.855	46.923	59.708	83.855	75.00	46.92	83.86	62.71	59.71
82	3.12	3.22	3.28	3.50	3.39	75.000	83.855	46.923	55.778	51.932	83.855	77.71	61.92	90.00	68.07	51.93
83	3.19	2.97	2.97	3.69	3.96	77.710	83.855	39.148	59.213	56.789	83.855	83.86	59.22	90.00	57.29	56.79
84	3.54	3.27	3.38	3.30	4.08	83.855	77.710	45.000	49.138	53.855	90.000	83.86	51.15	77.71	63.93	60.00
85	3.63	3.00	3.50	3.73	3.94	90.000	83.855	48.930	47.007	47.215	75.000	90.00	47.01	77.71	70.08	47.22
86	4.37	3.90	4.50	5.00	4.31	90.000	90.000	55.778	72.785	53.855	90.000	90.00	70.08	90.00	77.71	53.86
87	3.41	2.81	3.78	3.20	3.50	72.290	81.145	55.367	39.148	55.367	90.000	75.00	41.15	81.15	72.29	55.37

Prov	2003 Root Collar Diameters (mm)					2004 Survival (%)						2003 survival (%)				
	drdia03	kbdia03	lcdia03	endia03	pwdia03	drsurv04	kbsurv04	lcsurv04	ensurv04	pwsurv04	ansurv04	drsurv03	ensurv03	kbsurv03	lcsurv03	pwsurv03
88	3.53	3.90	3.73	3.73	4.12	83.855	90.000	50.853	53.068	51.145	90.000	83.86	53.07	90.00	67.86	51.15
89	3.79	3.48	4.24	4.02	4.06	71.565	77.710	51.145	54.782	62.710	83.855	77.71	56.79	77.71	66.15	62.71
90	3.25	3.03	3.27	3.24	3.90	90.000	77.710	52.775	48.930	40.778	90.000	90.00	51.15	77.71	63.93	61.17
91	3.21	3.41	3.27	3.55	3.92	83.855	83.855	48.930	59.004	53.855	83.855	90.00	63.93	83.86	53.15	53.86
92	4.06	3.25	3.44	3.94	3.40	75.000	83.855	50.769	47.007	57.785	83.855	81.15	47.01	81.15	66.15	60.00
93	4.34	3.83	3.33	3.70	4.00	72.785	90.000	43.077	46.923	64.925	90.000	75.00	46.92	90.00	63.44	64.93
94	3.21	3.55	4.07	4.22	4.34	68.855	83.855	43.077	52.859	58.077	83.855	77.71	57.00	90.00	70.08	58.08
95	4.23	3.53	3.69	3.60	3.53	75.000	90.000	43.077	49.138	56.070	90.000	75.00	48.93	90.00	57.79	58.08
96	3.82	3.17	3.13	3.11	3.40	71.565	90.000	38.360	54.991	66.932	90.000	71.57	53.07	90.00	53.15	73.08
97	3.30	3.05	3.38	3.41	2.90	90.000	90.000	54.782	46.923	49.222	90.000	90.00	48.93	90.00	72.79	49.22
98	3.95	3.22	3.34	3.36	3.31	83.855	83.855	55.778	55.367	56.998	83.855	77.71	58.08	80.79	75.00	61.22
99	3.42	3.77	4.06	3.81	3.52	83.855	77.710	61.923	59.213	60.000	81.145	83.86	57.00	77.71	66.15	61.93
100	3.59	2.60	3.16	3.03	2.78	83.855	83.855	48.846	48.930	44.708	90.000	83.86	51.15	77.71	61.72	48.93
101	3.29	4.17	3.54	4.16	4.70	83.855	83.855	39.148	63.435	66.932	83.855	90.00	63.93	83.86	72.29	66.93
102	4.05	3.78	3.32	3.58	3.57	83.855	75.000	42.993	50.853	66.145	90.000	83.86	50.85	75.00	61.93	70.78
103	2.94	3.36	3.66	3.80	3.43	83.855	83.855	48.930	61.714	51.932	77.710	83.86	63.93	83.86	66.15	58.08
104	3.17	3.40	4.01	3.79	3.71	83.855	83.855	46.923	70.075	49.222	90.000	90.00	70.08	90.00	77.71	58.08
105	3.43	3.67	3.88	4.30	3.92	83.855	83.855	48.846	56.998	63.930	90.000	83.86	57.00	83.86	66.15	63.93
106	3.42	3.04	3.66	4.00	3.63	77.710	71.565	44.916	48.930	60.000	83.855	77.71	50.85	83.86	63.44	60.00
107	3.53	3.50	3.77	3.99	3.75	77.710	75.000	43.077	39.063	51.848	72.785	77.71	45.08	75.00	61.72	59.71
108	3.79	3.19	3.62	3.82	3.46	77.710	90.000	52.859	51.932	56.070	75.000	77.71	51.93	90.00	66.15	58.08
109	3.20	3.08	3.10	3.91	3.79	71.565	90.000	36.932	50.937	63.846	90.000	77.71	53.15	90.00	68.86	63.85
110	3.09	3.22	2.92	3.06	3.26	72.290	70.075	43.077	45.000	53.068	83.855	75.00	46.92	70.08	61.22	53.07
111	3.41	3.38	3.45	3.73	3.43	90.000	72.290	45.084	52.775	70.778	90.000	90.00	50.85	75.00	68.86	72.79
112	3.83	4.51	4.34	4.72	4.19	83.855	90.000	46.923	59.708	61.923	90.000	83.86	59.71	90.00	77.71	61.93
113	4.28	3.40	3.34	3.63	3.97	83.855	90.000	46.923	47.007	46.220	90.000	77.71	48.93	83.86	61.22	48.44
114	3.85	3.51	3.20	3.50	3.84	83.855	83.855	48.930	46.923	56.070	90.000	83.86	48.93	83.86	66.15	56.07
115	3.67	3.96	4.60	4.47	4.43	90.000	83.855	42.701	59.708	57.290	90.000	90.00	61.72	83.86	81.15	57.29
116	3.34	3.27	3.43	3.64	3.50	83.855	83.855	46.923	63.435	45.000	77.710	83.86	59.22	90.00	66.64	46.92
117	4.08	4.43	4.33	4.32	4.92	90.000	90.000	50.937	75.000	59.708	90.000	90.00	75.00	90.00	70.78	59.71
118	3.47	3.61	3.39	3.64	3.86	83.855	90.000	48.930	52.859	60.000	90.000	90.00	52.86	90.00	68.86	60.00
119	3.48	2.96	2.87	3.26	3.12	90.000	90.000	33.003	41.154	59.708	83.855	90.00	39.15	90.00	59.01	61.93
120	3.81	3.72	4.21	3.95	4.01	77.710	77.710	50.853	59.708	55.367	83.855	83.86	59.71	77.71	64.64	55.37
121	3.65	3.44	3.77	3.63	4.24	83.855	90.000	39.991	50.853	57.785	90.000	83.86	50.85	90.00	59.71	57.79
122	3.05	3.68	3.59	4.08	3.40	72.290	75.000	52.859	53.152	64.222	90.000	77.71	53.15	75.00	63.93	66.15
123	3.69	3.54	3.77	4.08	4.17	90.000	77.710	46.923	81.145	57.290	90.000	90.00	83.86	83.86	83.86	57.29
124	3.81	3.26	3.45	4.06	3.39	77.710	75.000	50.853	67.859	51.932	90.000	83.86	67.86	81.15	66.15	51.93
125	2.81	3.11	3.77	3.67	4.23	76.923	81.145	55.367	54.991	48.930	83.855	78.93	57.00	81.15	68.86	48.93
126	3.61	3.01	3.26	3.56	3.70	83.855	83.855	47.299	49.222	58.077	83.855	90.00	49.22	90.00	78.93	60.00
130	3.01	2.94	4.09	4.17	3.97	83.855	83.855	35.218	63.930	51.848	83.855	83.86	63.44	81.15	61.93	51.85

Prov	2002 survival (%)					Dryden Budset				Kakabeka Budset				Longlac Budset			
	drsurv02	ensurv02	kbsurv02	lcsurv02	pwsurv02	drbs2	drbs3	drbs4	drbs5	kbbs2	kbbs3	kbbs4	kbbs5	lcbs2	lcbs3	lcbs4	lcbs5
1	90.00	77.71	90.00	90.00	53.86	221.00	221.87	223.83	225.31	219.24	221.54	225.21	228.28	222.12	224.76	227.19	229.00
2	90.00	72.29	90.00	90.00	48.44	221.00	221.50	222.60	222.33	219.00	219.90	223.74	227.74	222.18	224.04	226.78	228.11
3	90.00	65.85	90.00	90.00	64.93	225.00	222.33	222.40	222.69	219.24	221.26	224.95	228.04	222.91	225.17	226.85	228.37
4	83.86	75.00	90.00	90.00	60.12	.	221.00	221.71	223.07	219.12	220.45	223.42	227.15	221.67	224.50	228.05	228.58
5	83.86	68.07	90.00	90.00	56.07	221.00	222.50	224.14	222.29	219.00	220.25	222.93	227.00	222.08	224.30	226.79	230.00
6	83.86	77.71	90.00	90.00	56.07	221.80	222.67	223.20	222.45	219.10	221.06	223.46	228.57	223.10	225.44	227.49	228.53
7	90.00	90.00	77.71	90.00	62.22	221.00	222.20	223.33	223.00	219.29	220.87	225.05	228.22	222.20	223.90	225.48	228.20
8	90.00	66.64	83.86	90.00	44.21	.	221.00	222.78	222.71	219.10	220.30	222.30	227.64	222.42	224.09	226.55	227.61
9	90.00	75.00	90.00	90.00	71.07	221.00	221.55	222.91	222.92	219.00	220.42	223.00	228.04	222.33	224.81	226.75	227.86
10	90.00	77.71	90.00	90.00	68.86	221.67	222.24	223.46	223.22	219.31	221.08	225.07	229.72	222.38	224.56	226.25	228.62
11	90.00	63.93	83.86	83.86	53.86	221.67	221.66	222.84	225.15	219.19	221.96	224.80	228.90	222.41	225.22	227.45	229.67
12	90.00	75.00	83.86	83.86	49.14	224.00	223.41	222.76	223.62	219.29	221.52	223.76	229.09	222.60	224.12	226.93	229.21
13	90.00	71.57	83.86	90.00	48.93	221.00	221.44	223.00	224.07	219.27	221.05	225.07	229.96	221.63	224.63	226.46	229.86
14	90.00	81.15	77.71	83.86	48.93	221.00	221.80	223.00	223.07	219.33	221.19	224.91	228.57	222.38	223.73	226.94	229.47
15	77.71	68.86	83.86	90.00	56.07	221.00	221.37	222.81	222.92	219.61	220.64	223.83	228.83	222.61	224.73	227.30	228.43
16	90.00	83.86	90.00	90.00	62.01	.	221.00	221.46	222.73	219.00	219.53	222.98	226.85	221.93	224.04	224.97	226.91
17	83.86	83.86	90.00	90.00	55.86	221.33	223.10	225.22	222.60	219.00	220.84	222.56	227.77	222.83	225.23	226.82	228.11
18	83.86	68.86	83.86	83.86	62.71	221.00	223.29	223.87	223.56	219.00	220.22	223.36	228.44	221.53	224.96	227.98	228.64
19	83.86	75.00	83.86	90.00	48.93	.	221.00	222.45	222.54	219.33	220.11	224.31	228.33	222.02	225.03	226.38	227.00
20	90.00	81.15	90.00	90.00	66.93	.	.	221.00	221.67	219.09	220.52	222.20	227.69	221.33	224.53	225.40	228.11
21	90.00	77.71	90.00	90.00	47.71	221.00	226.00	221.80	222.14	219.00	220.68	224.10	228.08	221.92	223.96	227.15	227.53
22	90.00	83.86	83.86	90.00	57.29	221.00	221.67	222.11	222.52	219.12	220.11	223.48	228.19	222.55	223.05	226.25	228.50
23	83.86	75.00	83.86	90.00	51.85	221.00	222.00	223.00	224.83	219.18	220.60	223.86	229.62	223.37	225.30	227.51	229.53
24	90.00	61.93	83.86	90.00	42.79	221.73	224.40	224.47	224.09	219.41	221.49	224.66	228.50	221.95	224.90	228.22	230.33
25	90.00	75.00	90.00	90.00	53.15	.	221.00	222.14	223.48	219.20	220.31	223.84	227.73	222.81	223.73	226.16	228.80
26	83.86	77.71	90.00	83.86	50.90	221.00	225.00	221.50	222.33	219.00	220.76	223.05	227.31	223.32	226.55	229.18	230.33
27	81.15	90.00	90.00	90.00	68.86	221.00	222.50	222.43	222.48	219.00	219.86	222.71	228.23	222.74	225.54	226.31	227.48
28	83.86	90.00	90.00	90.00	58.78	221.20	222.40	223.11	223.73	219.10	220.54	225.34	229.09	221.94	225.12	227.45	228.24
29	90.00	75.00	77.71	90.00	46.92	221.00	222.60	223.00	223.72	219.33	220.86	224.43	227.70	222.29	225.10	227.95	230.50
30	77.71	83.86	90.00	90.00	60.00	221.00	221.83	222.81	222.00	219.00	220.38	224.59	228.76	222.08	224.73	228.33	229.53
31	90.00	66.15	83.86	90.00	53.07	221.00	222.06	222.90	223.00	219.25	220.82	222.83	227.59	222.63	224.94	228.04	227.46
32	90.00	90.00	90.00	83.86	55.08	221.00	222.90	222.90	223.37	219.00	220.30	223.52	228.76	222.43	225.00	226.70	228.73
33	90.00	75.00	90.00	90.00	44.21	221.00	224.20	222.54	223.26	219.00	220.54	224.20	228.82	222.06	225.00	228.05	229.44
34	83.86	66.64	83.86	83.86	48.93	221.00	222.60	222.00	223.72	219.00	220.62	223.51	228.08	221.73	223.96	225.98	228.47
35	90.00	77.71	90.00	90.00	49.64	.	221.00	221.60	222.73	219.00	220.09	222.82	228.14	222.67	223.92	226.82	228.40
36	90.00	75.00	83.86	90.00	53.15	221.00	225.00	221.33	221.89	219.00	221.03	222.68	226.68	221.96	224.67	225.88	227.09
37	90.00	77.71	90.00	90.00	42.70	223.00	221.80	223.14	223.56	219.00	220.47	224.17	228.67	222.20	223.53	225.73	228.45
38	77.71	60.00	75.00	83.86	46.72	221.00	222.72	222.46	223.71	219.15	220.49	223.48	229.08	223.22	225.76	227.40	227.89
39	90.00	83.86	83.86	90.00	53.86	221.00	221.57	224.33	222.92	219.00	220.64	224.41	228.64	221.83	224.48	227.12	229.00
40	90.00	83.86	90.00	83.86	64.22	221.00	221.50	222.27	223.07	219.07	220.71	222.34	227.80	222.09	225.46	226.41	226.78
41	90.00	81.15	90.00	90.00	51.15	221.67	222.78	222.69	223.31	219.00	220.78	224.33	229.22	222.71	225.14	227.30	229.00
42	83.86	83.86	90.00	90.00	59.71	221.00	223.00	223.22	222.08	219.48	220.90	224.03	227.00	221.93	224.88	227.58	227.40

Prov	2002 survival (%)					Dryden Budset				Kakabeka Budset				Longlac Budset			
	drsurv02	ensurv02	kbsurv02	lcsurv02	pwsurv02	drbs2	drbs3	drbs4	drbs5	kbbs2	kbbs3	kbbs4	kbbs5	lcbs2	lcbs3	lcbs4	lcbs5
43	90.00	83.86	90.00	83.86	53.86	222.00	221.40	222.38	223.31	219.46	221.25	224.51	228.80	221.80	225.63	228.15	230.33
44	83.86	90.00	90.00	90.00	57.99	.	221.00	221.40	221.83	219.00	219.95	224.08	228.14	222.70	223.56	224.73	227.96
45	90.00	75.00	90.00	90.00	57.79	221.00	221.00	221.91	223.00	219.00	220.51	223.87	229.08	223.00	225.88	226.17	228.53
46	83.86	81.15	90.00	90.00	60.00	221.00	221.76	222.72	223.14	219.00	220.09	223.36	227.74	222.00	223.76	224.71	226.26
47	90.00	66.15	77.71	90.00	51.15	221.00	222.67	223.20	223.07	219.00	219.63	222.38	228.04	222.58	224.47	227.16	227.57
48	90.00	81.15	90.00	83.86	58.29	.	221.00	221.80	221.86	219.00	220.07	221.81	226.59	221.89	223.51	226.27	224.79
49	90.00	83.86	90.00	90.00	62.01	225.00	221.67	221.80	222.66	219.10	220.49	223.46	227.50	222.83	225.13	226.00	227.44
50	90.00	83.86	83.86	90.00	44.00	221.00	225.00	221.89	222.14	219.12	219.93	223.05	227.15	222.33	224.07	226.33	227.74
51	90.00	61.93	72.79	77.71	42.29	221.00	222.67	223.40	222.33	219.00	220.51	221.75	226.27	223.22	225.73	227.67	227.00
52	90.00	68.86	90.00	83.86	51.85	221.00	222.00	222.14	222.44	219.00	220.33	222.95	228.08	223.08	224.46	225.08	227.44
53	72.29	83.86	83.86	90.00	57.79	221.00	221.86	223.27	224.00	219.00	220.70	226.42	229.22	222.46	224.85	227.07	228.50
54	90.00	57.00	90.00	90.00	44.00	223.00	222.00	222.33	222.23	219.39	220.56	223.28	227.00	222.15	226.00	228.23	226.75
55	90.00	81.15	90.00	90.00	63.93	221.00	221.67	222.43	222.00	219.13	220.01	222.38	228.38	221.83	222.44	224.87	226.67
56	90.00	83.86	83.86	90.00	58.78	.	221.00	221.80	222.86	219.00	220.31	223.64	226.85	221.63	223.44	226.38	228.37
57	90.00	83.86	90.00	90.00	48.93	.	221.00	222.27	222.93	219.00	219.91	223.55	227.15	223.47	224.45	225.85	228.56
58	90.00	71.57	90.00	90.00	49.93	225.00	223.67	222.00	222.14	219.00	220.22	222.95	227.14	222.31	225.14	227.11	228.37
59	90.00	83.86	90.00	90.00	64.93	221.00	221.67	221.83	223.40	219.10	220.54	223.12	227.55	223.48	224.33	225.97	227.20
60	83.86	81.15	90.00	90.00	64.22	227.00	223.00	222.09	222.93	219.00	221.11	223.76	228.29	222.78	224.38	226.82	226.50
61	83.86	75.00	83.86	90.00	56.07	221.00	222.93	223.71	223.61	219.00	221.44	225.46	228.91	223.37	225.95	228.59	230.14
62	90.00	75.00	77.71	90.00	39.06	.	.	221.00	222.43	219.80	220.39	222.83	226.56	222.13	224.58	227.15	227.29
63	83.86	77.71	90.00	90.00	60.00	221.00	223.00	224.20	221.86	219.00	219.54	221.92	226.45	221.29	223.40	225.80	227.10
64	90.00	83.86	90.00	90.00	49.64	221.00	223.00	222.09	222.93	219.14	219.73	221.98	226.47	221.00	223.00	225.00	227.48
65	90.00	83.86	83.86	90.00	43.78	221.00	222.25	223.62	223.81	220.11	220.59	222.56	227.15	222.45	225.10	226.63	229.86
66	90.00	83.86	83.86	90.00	51.14	.	.	221.00	222.00	219.00	219.86	221.21	225.43	224.33	223.36	224.00	226.74
67	90.00	83.86	90.00	90.00	57.00	221.00	222.00	222.00	221.86	219.36	220.97	222.95	227.44	221.67	223.24	227.67	229.38
68	90.00	77.71	83.86	75.00	46.72	221.00	222.00	222.78	222.63	219.00	220.08	221.84	227.69	222.73	225.46	226.52	227.91
69	90.00	77.71	83.86	90.00	50.90	.	221.00	221.80	221.83	219.00	220.73	223.44	228.23	222.03	224.88	225.67	226.33
70	90.00	71.57	83.86	90.00	49.22	.	221.00	221.86	222.19	219.00	219.74	221.20	226.85	222.42	225.07	227.07	229.27
71	90.00	75.00	77.71	90.00	42.70	221.00	221.50	222.50	223.15	219.11	219.85	223.66	227.89	221.81	224.76	225.67	227.60
72	90.00	70.08	83.86	90.00	45.29	.	221.00	221.80	221.83	219.00	220.33	222.82	228.19	221.92	223.67	225.90	227.86
73	90.00	81.15	83.86	90.00	48.93	221.00	222.71	223.77	223.46	219.31	221.59	225.07	228.64	223.16	225.22	227.57	229.00
74	90.00	90.00	90.00	90.00	54.99	222.00	222.00	223.67	222.71	219.14	220.89	224.54	229.00	221.44	223.64	227.38	228.62
75	90.00	68.86	83.86	90.00	50.77	.	221.00	222.11	222.43	219.00	220.36	222.27	227.80	222.07	224.57	226.37	227.80
76	90.00	66.64	83.86	90.00	49.22	223.00	222.33	222.75	222.63	219.00	219.87	221.89	226.72	224.04	224.17	225.59	227.00
77	90.00	66.64	90.00	90.00	43.08	.	221.00	222.00	221.69	219.00	219.56	222.18	227.57	222.08	224.60	225.43	227.36
78	83.86	83.86	83.86	90.00	56.57	221.00	221.29	222.69	223.46	219.00	220.45	223.17	229.14	222.00	225.38	227.55	229.00
79	90.00	90.00	90.00	90.00	64.22	.	221.00	221.67	221.41	219.00	219.63	221.97	225.27	222.14	225.81	224.93	226.05
80	83.86	66.15	90.00	90.00	57.11	221.00	221.65	221.74	222.48	219.23	219.82	222.05	226.85	221.67	225.14	226.38	228.29
81	90.00	60.00	90.00	90.00	53.86	.	221.00	221.50	221.59	219.88	220.09	221.24	224.43	222.53	224.83	225.71	225.50
82	90.00	66.15	83.86	83.86	48.44	221.00	223.00	222.75	222.19	219.00	219.74	221.49	226.07	222.69	224.89	227.93	227.00
83	83.86	83.86	90.00	75.00	53.36	221.00	222.03	224.11	223.24	219.27	220.84	224.17	227.33	223.33	225.08	227.71	227.55
84	90.00	64.64	83.86	90.00	51.64	223.00	222.67	223.17	222.28	219.00	221.00	223.57	228.00	222.52	224.97	227.49	228.50
85	90.00	77.71	90.00	90.00	49.14	225.00	223.00	222.71	221.83	219.28	220.50	223.32	227.74	223.33	223.74	225.32	226.47
86	83.86	90.00	75.00	90.00	60.00	222.00	223.66	224.73	221.86	219.00	220.23	223.64	227.53	222.63	224.51	226.08	229.17
87	77.71	72.79	83.86	90.00	42.00	.	221.00	221.80	221.89	219.00	220.53	222.69	226.70	221.92	224.42	226.37	226.40

Prov	2002 survival (%)					Dryden Budset				Kakabeka Budset				Longlac Budset			
	drsurv02	ensurv02	kbsurv02	lcsurv02	pwsurv02	drbs2	drbs3	drbs4	drbs5	kbbs2	kbbs3	kbbs4	kbbs5	lcbs2	lcbs3	lcbs4	lcbs5
88	90.00	90.00	90.00	90.00	60.00	221.00	222.33	222.23	223.00	219.00	220.65	223.84	228.86	222.42	224.25	226.32	226.20
89	83.86	77.71	90.00	90.00	60.79	221.00	222.50	222.20	222.85	219.00	220.63	222.62	227.74	222.06	224.11	227.07	229.00
90	90.00	64.64	81.15	90.00	80.79	.	221.00	221.29	221.93	219.00	220.22	222.46	227.62	222.13	224.64	225.04	226.90
91	83.86	68.86	77.71	83.86	51.85	.	.	221.00	221.40	219.00	220.24	220.88	224.93	222.50	224.50	225.85	225.00
92	90.00	77.71	83.86	90.00	45.00	.	221.00	222.67	222.04	219.17	219.78	221.61	225.96	221.89	223.81	226.06	227.61
93	83.86	68.86	90.00	90.00	57.29	.	.	221.00	222.19	219.50	220.33	222.06	226.07	222.00	223.67	226.25	228.43
94	77.71	75.00	90.00	90.00	55.07	.	221.00	222.43	222.33	219.19	220.43	222.05	228.19	221.42	224.17	224.92	226.60
95	90.00	75.00	83.86	90.00	60.12	.	221.00	221.67	221.44	219.00	220.00	222.19	226.47	221.80	223.86	225.00	225.71
96	90.00	66.64	83.86	90.00	48.93	.	.	.	221.00	219.00	220.50	221.29	225.27	222.69	225.48	227.81	229.00
97	83.86	75.00	83.86	90.00	46.92	.	.	221.00	221.40	219.00	219.91	222.45	226.85	222.54	224.17	226.75	227.12
98	83.86	72.29	90.00	90.00	53.07	.	221.00	221.40	222.14	219.09	220.19	222.06	225.07	222.85	225.00	226.68	227.32
99	90.00	83.86	90.00	90.00	48.93	.	221.00	222.33	221.55	219.00	219.85	221.91	225.81	221.40	223.57	224.29	225.16
100	90.00	53.86	90.00	83.86	50.90	.	.	221.00	221.69	219.00	220.02	221.47	225.86	222.60	224.93	227.47	228.14
101	90.00	90.00	81.15	90.00	73.08	.	221.00	221.67	221.40	219.00	219.92	221.85	227.55	222.79	224.30	226.65	228.45
102	90.00	75.00	83.86	90.00	73.40	221.33	222.83	222.67	222.57	219.00	219.90	221.80	225.72	221.67	223.63	226.82	229.00
103	90.00	77.71	90.00	90.00	46.22	.	221.00	223.00	221.41	219.00	219.89	222.81	227.29	221.76	224.33	225.20	226.60
104	90.00	81.15	90.00	90.00	65.85	.	221.00	225.00	221.27	219.14	219.77	221.68	225.27	222.31	225.13	225.51	227.62
105	90.00	83.86	90.00	90.00	51.85	221.00	223.00	222.67	221.71	219.55	220.43	222.93	226.85	221.67	223.14	225.38	226.90
106	90.00	72.29	90.00	90.00	53.86	223.00	224.33	223.00	223.09	219.00	220.48	223.45	226.04	222.70	225.06	228.47	228.69
107	83.86	57.00	83.86	90.00	51.15	.	221.00	221.00	221.30	219.00	219.19	219.99	224.48	222.73	225.27	227.06	226.25
108	90.00	70.08	90.00	90.00	56.07	222.33	225.00	223.29	221.96	219.13	219.67	221.88	225.07	222.62	224.70	225.42	227.11
109	83.86	77.71	90.00	90.00	56.07	.	221.00	222.00	222.43	219.00	219.88	222.02	227.14	222.42	224.06	226.68	229.95
110	90.00	52.78	90.00	90.00	55.07	221.00	221.50	222.50	222.23	219.00	219.94	222.25	227.48	221.18	223.39	226.12	226.90
111	90.00	68.86	90.00	90.00	43.08	221.00	222.46	223.33	222.38	219.13	220.22	221.62	227.31	222.08	224.49	226.53	228.24
112	90.00	90.00	81.15	90.00	66.15	.	221.00	222.50	221.69	219.00	219.62	221.17	225.43	222.64	224.56	226.17	225.36
113	90.00	75.00	90.00	90.00	60.00	221.00	221.67	222.20	222.86	219.12	220.03	222.38	227.30	222.69	224.51	225.05	227.80
114	83.86	75.00	90.00	90.00	57.29	.	221.00	221.40	222.52	219.11	219.88	222.02	226.56	223.45	224.25	225.45	227.55
115	90.00	77.71	90.00	90.00	62.71	221.00	224.10	222.33	221.46	219.27	220.17	223.14	226.70	222.40	225.03	225.45	227.48
116	90.00	75.00	90.00	90.00	44.92	.	.	221.00	221.55	219.00	219.61	222.20	226.73	222.27	224.77	227.28	228.50
117	83.86	83.86	83.86	83.86	61.93	.	221.00	221.50	222.33	219.15	220.15	222.51	227.43	221.30	223.14	225.73	228.24
118	90.00	68.86	90.00	90.00	51.15	.	221.00	222.00	222.24	219.00	219.91	222.57	227.28	223.25	224.54	226.32	228.83
119	83.86	75.00	77.71	83.86	60.00	.	221.00	223.00	222.24	219.13	219.96	221.35	225.40	222.36	225.04	226.65	229.24
120	90.00	83.86	90.00	90.00	64.22	221.00	221.43	221.79	222.79	219.00	220.00	222.79	228.28	221.61	224.33	226.75	229.20
121	90.00	81.15	83.86	90.00	62.22	221.00	224.00	223.00	222.00	219.00	219.41	222.29	226.71	222.22	223.67	225.38	227.59
122	90.00	83.86	90.00	90.00	56.07	221.00	222.50	223.29	221.77	220.00	220.49	222.18	227.00	221.44	224.02	225.59	229.00
123	83.86	75.00	90.00	90.00	51.15	.	221.00	221.67	221.93	219.00	220.19	222.89	228.08	222.76	225.24	227.11	228.56
124	83.86	77.71	81.15	90.00	49.64	221.00	223.00	221.33	222.00	220.00	219.78	221.72	227.89	222.96	225.39	226.47	227.67
125	90.00	81.15	83.86	90.00	48.93	.	221.00	222.80	222.69	219.17	219.94	222.71	227.46	222.12	225.10	227.13	228.62
126	83.86	75.00	90.00	83.86	44.00	221.00	221.50	223.22	222.79	219.00	220.00	222.24	227.14	222.44	223.67	225.83	227.73
130	81.15	75.00	75.00	83.86	49.14	221.00	222.11	223.17	223.26	219.00	220.45	223.77	227.77	223.10	224.92	225.67	229.47

Prov	Englehart Budset				Petawawa Budset				Dryden Budflush					Kakabeka Budflush				
	enbs2	enbs3	enbs4	enbs5	pwbs2	pwbs3	pwbs4	pwbs5	drbf2	drbf3	drbf4	drbf5	drbf6	kbbf2	kbbf3	kbbf4	kbbf5	kbbf6
1	220.15	224.97	227.57	228.89	222.00	222.74	228.33	229.00	126.54	130.78	131.58	134.55	140.61	123.44	126.63	129.97	133.96	142.77
2	221.00	222.73	223.68	228.07	222.00	222.62	226.35	233.00	119.73	125.51	128.53	132.23	139.17	123.84	126.82	129.43	133.41	143.67
3	220.00	223.13	227.82	226.50	222.00	223.82	225.28	230.29	121.22	124.37	127.55	132.67	139.10	122.59	126.10	128.66	132.58	142.96
4	220.00	222.00	224.95	229.93	222.00	223.21	226.58	230.80	123.29	128.87	131.84	134.48	139.00	123.68	128.37	130.38	134.20	143.43
5	220.00	222.39	223.61	228.71	222.00	224.67	225.48	231.00	124.64	129.52	132.42	135.61	140.43	124.29	126.30	129.59	134.00	143.50
6	220.00	220.88	225.09	230.13	222.50	223.31	227.00	229.88	123.84	127.45	130.96	133.64	140.84	124.16	127.24	128.15	132.52	141.70
7	221.00	224.27	225.29	230.46	.	222.00	227.22	228.25	126.58	131.78	134.91	139.00	141.58	123.39	126.82	129.60	134.12	142.30
8	220.00	220.91	223.67	228.33	233.00	222.00	226.05	229.38	123.50	126.98	129.55	132.77	139.78	122.17	126.09	127.95	132.48	142.39
9	220.00	222.20	224.67	227.88	222.00	223.31	226.27	228.60	121.33	126.26	128.96	133.21	139.55	123.61	125.60	128.39	133.37	143.08
10	220.00	223.17	225.12	229.42	223.38	223.84	227.45	227.80	123.85	129.91	133.46	136.83	141.00	124.23	128.32	131.13	134.64	144.04
11	220.00	222.43	227.00	230.00	222.00	223.83	226.95	230.67	124.04	128.01	132.70	135.32	139.06	124.70	127.55	129.40	132.52	142.43
12	220.00	222.13	225.15	228.30	222.00	223.73	227.08	231.00	121.81	127.81	130.42	133.04	139.05	125.11	128.87	130.43	134.25	142.78
13	220.00	223.17	226.38	229.86	222.00	224.16	227.94	231.67	123.36	128.14	130.94	133.80	140.68	123.78	126.44	128.28	132.29	143.32
14	220.00	221.57	224.08	229.79	222.00	223.17	227.60	233.00	121.83	125.94	129.63	134.54	140.04	123.14	126.59	128.67	132.96	142.46
15	220.00	222.29	224.21	229.89	222.00	222.80	225.33	228.29	120.36	124.63	128.04	134.43	140.00	124.57	127.66	129.33	133.56	143.57
16	220.00	221.60	224.88	229.80	222.00	222.31	225.33	228.33	121.76	126.81	127.72	132.96	140.54	123.12	126.09	129.22	133.58	141.24
17	220.40	223.91	224.67	226.67	222.00	222.71	226.90	231.40	121.66	128.45	130.25	133.43	141.10	123.47	126.13	128.77	132.44	142.20
18	220.00	221.78	223.70	227.80	222.29	223.83	226.87	231.67	119.36	124.11	127.80	132.56	138.88	124.02	126.66	130.00	133.24	144.72
19	220.00	221.20	224.70	229.00	222.00	223.83	227.06	230.00	124.94	129.31	131.96	134.16	140.48	124.55	127.32	130.09	134.11	145.27
20	220.00	220.62	224.20	228.27	222.00	222.44	224.56	230.40	124.40	129.47	132.30	134.58	141.23	122.55	125.80	128.45	132.68	142.86
21	220.00	221.45	226.09	228.67	222.00	223.53	227.87	229.33	121.31	126.00	127.96	132.68	140.08	124.25	127.26	129.86	133.86	143.92
22	220.00	221.27	223.90	229.86	222.00	224.56	228.16	230.80	123.48	129.24	127.73	133.14	140.67	124.33	126.54	129.54	134.52	143.12
23	220.19	223.05	224.68	229.40	222.00	223.56	230.21	226.67	122.96	128.56	131.63	134.73	140.85	122.85	125.85	128.64	132.73	142.58
24	220.33	224.56	229.00	231.00	222.00	223.60	230.50	231.67	122.41	128.00	129.38	133.23	143.05	122.83	127.08	129.85	134.24	143.32
25	220.00	221.33	223.21	230.13	222.80	224.07	226.83	227.50	124.13	128.24	130.60	133.87	141.14	123.69	127.02	130.52	134.75	142.86
26	220.75	224.64	223.88	229.87	222.00	223.73	225.69	229.83	123.05	127.44	129.85	134.34	140.24	124.34	126.32	128.79	133.54	142.73
27	220.00	220.71	224.72	231.20	226.00	222.00	224.44	229.91	123.09	128.39	130.88	134.84	140.00	122.90	125.53	127.54	132.07	142.48
28	220.00	222.47	226.20	230.91	222.00	223.23	228.00	227.80	127.93	131.79	129.78	133.56	138.92	125.53	128.84	130.23	133.91	144.05
29	220.00	223.08	224.83	231.18	222.00	224.30	226.23	230.25	122.64	127.33	129.88	134.54	140.79	122.72	128.14	130.61	134.15	144.43
30	220.00	220.83	223.26	231.06	222.00	223.31	226.43	231.00	123.73	129.18	132.33	136.50	140.24	124.25	128.36	130.88	135.26	145.00
31	220.00	224.50	225.18	228.09	223.00	224.25	226.33	229.20	123.36	128.80	131.91	135.45	141.75	122.74	125.11	127.91	132.96	143.08
32	220.00	222.25	224.91	227.91	222.00	224.21	226.11	229.40	121.96	127.97	130.88	134.35	140.72	124.09	128.09	129.89	133.70	144.19
33	220.75	222.80	226.75	229.67	223.00	222.76	227.98	231.33	123.81	126.49	131.54	133.96	142.67	124.09	127.29	130.04	133.69	142.32
34	220.00	220.57	222.30	230.00	222.00	223.54	226.14	228.17	122.47	126.80	128.30	132.55	140.10	124.48	126.61	128.47	132.22	141.22
35	220.00	221.83	224.65	229.29	223.57	223.40	228.00	228.60	122.81	127.37	130.01	132.80	139.75	123.16	125.50	128.64	132.88	141.56
36	220.00	221.33	224.86	229.33	.	222.00	225.05	229.40	119.96	124.74	128.73	133.17	138.90	126.03	128.96	131.97	135.57	143.83
37	222.27	223.40	228.00	232.00	222.70	225.71	228.35	229.50	123.67	127.23	128.65	134.26	141.30	123.89	126.70	128.45	132.41	141.80
38	220.80	223.36	224.38	227.70	222.00	223.69	225.59	228.83	124.28	127.96	128.71	132.62	140.28	123.74	127.19	129.45	133.45	142.30
39	220.00	222.78	225.57	230.15	222.00	224.10	228.75	229.00	123.05	126.66	129.35	133.96	141.08	123.74	126.48	128.84	132.72	141.74
40	220.00	222.38	224.75	228.55	222.00	223.54	225.39	229.38	122.52	126.80	129.30	133.87	141.87	122.52	126.44	127.57	132.27	143.16
41	221.69	222.76	225.71	231.30	222.00	224.84	227.79	233.00	124.54	128.15	129.54	132.85	141.00	123.46	126.52	129.04	132.85	142.50
42	220.00	221.17	223.38	228.95	222.00	223.04	225.05	227.80	123.12	126.33	130.60	133.71	139.14	123.82	126.96	130.00	134.50	143.70

Prov	Englehart Budset				Petawawa Budset				Dryden Budflush					Kakabeka Budflush				
	enbs2	enbs3	enbs4	enbs5	pwbs2	pwbs3	pwbs4	pwbs5	drbf2	drbf3	drbf4	drbf5	drbf6	kbbf2	kbbf3	kbbf4	kbbf5	kbbf6
43	220.00	221.83	228.09	231.60	222.00	223.17	227.50	231.67	123.25	127.57	129.92	134.52	141.83	123.92	128.14	130.74	133.65	144.73
44	220.00	222.55	224.30	227.43	222.00	223.61	226.10	229.83	121.26	125.34	128.89	132.04	138.58	124.66	127.17	129.11	133.52	143.25
45	220.80	223.93	226.42	232.00	224.25	223.53	227.17	230.29	123.67	126.31	129.10	134.42	140.24	122.47	125.52	127.47	132.12	142.00
46	220.00	221.59	224.17	228.27	224.25	223.28	226.45	230.50	123.32	127.57	128.83	132.10	139.20	123.37	126.72	129.21	133.36	143.15
47	220.00	222.33	225.23	228.73	224.00	223.64	226.58	230.00	124.54	129.64	132.21	136.83	141.81	124.70	127.61	129.37	133.50	144.04
48	220.00	220.89	222.27	228.42	222.00	223.25	226.94	229.20	123.76	127.99	130.27	132.83	140.86	123.13	126.21	129.28	133.93	144.00
49	220.00	221.11	227.28	227.50	222.00	222.25	226.17	226.00	122.44	125.43	128.28	131.61	139.32	122.76	125.26	128.85	133.70	143.28
50	220.00	222.50	224.32	229.07	222.00	223.45	225.21	231.42	123.87	127.24	130.49	133.73	139.52	124.30	126.79	129.62	133.96	142.88
51	220.00	220.67	224.42	228.00	222.00	224.63	224.60	229.33	120.75	124.74	127.44	130.75	138.30	123.94	127.67	128.45	133.42	142.63
52	220.00	220.57	223.56	229.38	222.00	223.00	225.89	231.00	123.72	130.33	132.56	135.50	140.50	124.02	128.21	128.61	133.58	142.88
53	220.57	222.09	226.05	231.56	222.00	224.18	226.53	231.00	122.92	127.74	131.54	136.67	142.52	124.84	128.10	129.53	133.19	142.62
54	222.00	225.42	223.21	226.55	.	222.00	225.50	229.50	122.66	126.46	128.99	132.92	139.89	123.14	127.76	130.04	133.65	142.56
55	220.00	220.79	224.23	229.85	222.00	223.25	225.14	229.88	121.93	128.05	130.24	135.04	142.05	124.22	127.01	129.56	133.78	144.04
56	220.00	221.44	224.80	230.30	222.00	222.93	226.40	230.00	122.26	126.61	129.28	134.64	140.68	126.25	130.00	130.17	135.08	142.41
57	220.00	221.40	223.90	227.29	223.00	223.75	226.67	231.17	124.14	128.80	131.77	135.47	140.86	124.48	126.84	129.45	133.58	143.96
58	220.00	221.56	223.09	227.45	223.00	224.40	225.81	227.50	121.82	125.90	130.72	132.52	141.14	123.64	126.39	129.63	132.63	142.78
59	220.00	222.55	224.79	227.08	222.00	223.00	224.74	230.63	122.32	125.88	128.21	132.88	139.05	124.27	128.44	129.95	133.24	142.00
60	220.00	222.11	223.33	228.35	222.00	223.77	225.33	228.55	123.84	127.66	129.33	134.68	144.00	122.92	128.03	130.70	134.50	143.65
61	221.57	222.06	226.11	227.56	222.88	223.75	229.29	231.67	128.33	132.97	135.61	138.05	145.00	124.28	126.86	129.21	133.46	144.16
62	220.00	222.00	224.21	231.75	223.83	223.92	223.44	228.44	122.23	127.45	130.81	134.65	140.74	124.33	126.58	128.63	133.17	144.32
63	220.00	220.80	225.12	228.00	222.00	223.73	225.26	226.13	123.73	127.73	129.48	133.74	140.09	123.05	125.77	129.13	133.31	142.88
64	220.00	221.33	223.58	227.46	222.00	223.29	227.10	227.50	123.08	127.38	129.09	133.64	139.61	123.42	126.53	129.60	134.17	142.59
65	220.00	222.94	224.07	228.91	222.00	224.11	226.37	229.00	120.41	124.45	129.68	132.00	138.25	121.95	127.99	129.95	134.51	141.91
66	220.00	220.18	223.00	227.81	222.00	222.79	225.45	228.17	122.02	127.42	130.22	135.00	140.24	123.99	126.58	129.50	134.50	144.42
67	220.00	223.00	225.65	228.67	222.00	222.91	225.55	230.63	127.10	130.63	132.48	133.64	139.62	124.54	126.95	128.83	133.07	142.00
68	220.00	221.57	224.55	228.20	222.00	224.20	225.53	229.70	123.36	127.98	129.87	133.42	140.17	125.38	129.16	131.46	134.74	143.26
69	220.00	221.80	222.43	228.00	222.00	222.33	225.39	230.63	120.43	124.90	126.73	129.87	137.50	124.12	127.18	129.44	133.27	142.19
70	220.00	220.50	223.53	227.77	222.00	222.31	225.23	229.27	121.83	125.94	129.07	134.55	141.43	123.11	126.06	128.57	132.72	142.00
71	220.00	221.85	224.07	227.91	222.00	222.47	226.08	230.36	122.57	126.66	129.84	133.58	140.05	123.97	127.14	129.10	133.11	145.17
72	225.00	220.75	223.42	230.15	222.00	223.00	225.32	228.88	123.80	127.80	130.50	135.08	141.82	125.95	127.72	129.60	133.68	144.63
73	220.00	221.63	224.58	228.80	222.00	222.25	226.10	229.70	122.10	126.93	131.64	134.17	138.55	123.42	126.74	129.25	132.78	143.92
74	220.00	221.47	223.77	228.93	222.00	223.27	226.47	231.40	123.76	129.60	130.86	134.31	142.10	123.10	125.85	128.56	133.63	142.65
75	220.00	221.43	222.82	228.47	222.00	224.82	225.68	227.00	123.96	127.95	130.83	134.63	139.83	123.00	125.76	128.75	133.93	143.96
76	220.00	220.60	224.03	226.17	222.00	223.23	225.71	230.67	123.54	127.87	129.95	133.79	139.65	124.22	128.29	130.27	135.63	144.24
77	220.00	220.75	222.00	228.36	.	222.00	225.29	229.70	123.24	128.02	131.67	136.64	142.18	123.77	127.22	128.88	133.62	144.36
78	220.44	223.81	226.24	227.85	223.63	224.68	227.09	229.20	122.39	128.09	128.47	132.83	140.56	124.43	127.75	130.93	134.21	145.52
79	220.00	220.86	222.33	228.21	222.00	222.44	224.36	227.67	123.22	129.07	131.95	135.12	140.58	125.46	128.00	131.42	136.17	144.76
80	220.00	220.67	222.77	228.44	222.00	222.67	225.18	231.40	121.96	125.56	128.08	132.57	139.35	124.58	128.57	131.19	135.30	145.40
81	220.00	220.57	223.00	227.09	222.00	222.40	224.34	228.31	120.74	123.72	126.97	133.03	139.27	122.61	125.36	128.18	133.78	142.44
82	220.00	220.57	222.35	228.31	222.00	224.50	224.44	229.10	122.46	128.47	131.30	135.00	139.82	124.42	127.66	129.57	133.22	143.00
83	220.00	223.40	225.80	227.00	222.00	223.36	227.00	227.86	123.09	126.94	129.18	131.89	140.47	122.99	126.03	127.64	132.44	144.19
84	220.00	221.85	223.54	228.55	222.00	222.67	226.53	228.83	121.41	126.19	128.92	132.91	138.62	122.38	126.92	129.67	133.00	141.95
85	220.00	220.40	224.40	229.18	222.00	223.60	223.63	228.90	118.64	122.22	126.77	131.15	138.54	124.73	128.84	130.70	135.54	144.00
86	220.00	222.25	223.26	229.83	223.33	223.80	225.76	228.60	124.12	129.58	129.68	134.05	140.90	123.14	125.91	128.22	133.43	142.86
87	220.00	221.00	222.25	227.36	.	222.00	224.30	229.75	124.54	129.67	130.39	134.00	138.19	124.60	126.98	130.06	134.32	146.43

Prov	Englehart Budset				Petawawa Budset				Dryden Budflush					Kakabeka Budflush				
	enbs2	enbs3	enbs4	enbs5	pwbs2	pwbs3	pwbs4	pwbs5	drbf2	drbf3	drbf4	drbf5	drbf6	kbbf2	kbbf3	kbbf4	kbbf5	kbbf6
88	220.00	221.43	222.24	227.92	222.00	222.80	224.88	228.50	121.50	125.51	128.79	133.29	139.65	123.31	126.72	129.34	133.75	143.14
89	220.00	222.92	225.28	227.27	222.00	223.60	225.10	230.10	123.54	127.18	129.64	134.12	141.38	123.48	126.49	128.27	133.36	144.00
90	220.00	220.44	222.84	228.00	222.00	222.50	225.20	230.25	121.25	125.84	129.45	133.71	139.79	124.42	127.91	130.88	134.48	143.21
91	220.00	222.50	221.68	226.28	223.33	223.63	225.11	228.11	119.47	123.97	128.15	133.08	139.17	124.32	128.14	131.48	135.80	143.23
92	220.00	221.07	221.62	227.14	222.00	223.83	225.67	228.67	122.91	126.64	128.35	133.05	140.10	124.12	126.10	128.44	132.91	142.79
93	220.00	221.07	222.84	226.83	222.00	223.55	225.10	231.50	123.64	127.72	129.50	133.68	141.25	125.15	127.42	129.03	132.83	142.33
94	220.00	222.11	223.24	226.35	222.00	222.50	225.30	229.75	120.59	124.61	128.73	133.46	138.75	123.20	126.54	128.38	133.14	141.89
95	220.00	220.40	223.19	226.50	.	222.00	223.60	228.42	122.59	126.43	128.99	133.57	140.52	124.77	127.06	129.21	134.38	143.70
96	.	220.00	222.63	226.92	222.00	222.29	223.61	229.19	120.82	125.30	129.24	134.23	139.35	123.39	126.27	129.78	133.33	142.67
97	220.00	221.82	224.82	229.00	222.00	222.89	226.40	228.00	121.40	126.42	130.96	135.41	139.95	124.07	126.74	129.29	132.97	143.12
98	220.00	221.50	223.15	228.33	222.00	223.36	224.82	228.89	118.81	124.43	128.64	132.88	136.09	124.28	128.18	129.45	133.86	141.06
99	220.00	221.05	221.78	227.94	224.33	222.67	225.85	228.64	123.50	129.03	129.93	133.54	140.81	123.36	127.24	129.31	134.31	144.18
100	220.00	221.50	221.71	228.08	222.00	223.92	227.53	231.00	123.44	127.66	131.92	135.45	139.68	126.15	130.48	130.18	134.05	141.22
101	220.00	220.48	223.11	229.67	222.00	223.11	225.61	228.14	121.15	126.08	129.43	133.72	140.63	123.25	124.71	127.06	132.63	142.85
102	220.00	221.25	223.88	229.91	222.00	222.71	225.60	230.70	122.64	126.22	128.76	133.20	140.17	122.91	125.25	127.92	132.41	141.73
103	223.00	221.71	222.39	226.75	222.00	222.00	223.79	227.60	121.56	127.01	128.69	133.24	139.67	124.58	127.32	128.73	132.81	141.92
104	220.00	221.14	222.86	227.44	222.00	223.69	225.67	227.78	121.85	125.28	128.54	133.04	140.88	123.37	126.05	128.08	133.48	141.42
105	.	220.00	223.00	228.73	222.00	222.22	223.81	227.67	122.57	126.94	127.20	130.64	138.35	124.21	126.15	128.93	133.56	143.20
106	220.00	222.45	226.00	231.75	222.00	223.83	227.59	231.00	122.02	126.22	129.29	131.71	139.35	124.26	128.45	130.09	134.95	141.35
107	220.00	223.00	223.40	228.40	223.33	224.63	224.80	229.33	122.25	123.12	126.52	132.96	139.83	122.87	126.15	128.43	132.64	142.39
108	.	220.00	221.94	229.14	223.00	223.38	225.55	228.88	124.48	127.75	131.70	134.96	141.77	123.52	127.71	128.64	132.68	143.35
109	220.00	222.70	221.63	227.88	222.00	222.57	223.95	229.38	121.99	127.59	129.04	133.06	138.76	123.27	125.29	126.71	133.04	140.59
110	220.00	221.00	222.50	229.27	.	222.00	224.89	229.25	124.14	126.70	129.52	132.65	139.26	124.01	127.27	128.77	134.33	143.40
111	220.00	221.11	223.21	230.18	222.00	222.59	225.72	226.75	120.44	124.83	128.24	130.92	138.83	124.70	128.24	130.20	133.46	144.71
112	.	220.00	221.48	226.95	.	222.00	224.60	226.85	122.01	126.31	127.70	132.40	138.50	125.61	128.63	131.70	136.17	146.45
113	220.00	221.60	222.35	227.38	224.00	223.40	224.93	231.63	126.87	131.32	131.78	135.26	140.28	123.28	125.57	127.55	132.66	142.08
114	220.00	222.33	222.44	228.14	222.00	222.79	224.00	229.60	120.66	123.80	127.30	130.90	138.30	124.43	127.31	129.96	133.81	143.67
115	220.00	220.67	224.35	227.93	.	222.00	223.11	229.00	121.50	126.13	129.29	132.65	140.16	124.43	127.36	129.44	133.40	141.21
116	.	220.00	222.52	228.94	.	222.00	225.09	228.44	121.48	126.04	128.68	131.67	139.15	122.69	124.98	128.16	132.64	142.21
117	220.00	220.31	224.60	227.27	.	222.00	224.02	228.90	119.80	123.46	126.93	131.85	138.12	124.44	127.49	129.55	134.46	143.12
118	220.00	222.25	222.50	228.79	.	222.00	223.55	229.58	120.95	125.10	127.75	131.37	137.96	124.71	127.52	130.44	134.52	143.59
119	220.00	220.80	222.92	227.56	222.00	222.55	225.04	230.23	121.88	125.81	126.75	129.91	136.50	122.86	125.46	127.89	132.39	142.04
120	220.00	220.89	223.73	229.55	222.00	224.50	224.95	230.33	122.77	125.79	127.73	132.59	137.96	123.83	126.32	129.63	133.45	142.70
121	220.00	221.14	224.31	228.62	222.00	222.29	226.48	229.25	121.48	126.25	127.67	131.33	138.96	122.74	126.18	127.70	132.39	142.21
122	220.00	221.45	224.11	228.25	223.17	223.86	226.58	229.88	124.20	128.10	129.35	133.40	139.44	125.01	127.72	130.20	134.04	145.18
123	220.67	221.00	223.85	225.36	.	222.00	223.71	230.63	122.46	126.33	128.00	132.14	138.15	124.30	126.31	128.69	133.42	143.04
124	220.00	220.36	222.92	228.28	224.00	222.57	225.25	226.71	121.57	126.13	129.04	133.61	140.11	124.35	126.73	129.97	134.60	142.96
125	220.00	220.67	223.37	228.56	222.00	223.57	224.65	229.17	123.13	128.31	129.70	134.48	141.35	124.94	127.84	130.48	134.93	143.59
126	220.00	221.11	224.44	229.36	222.00	223.23	226.90	227.78	120.68	125.56	127.08	131.04	137.19	123.44	126.59	129.96	132.67	141.62
130	220.00	222.16	228.05	229.14	222.00	223.36	227.59	230.67	121.82	126.51	129.42	132.17	140.33	123.41	127.49	128.95	132.67	141.39

Prov	Longlac Budflush					Englehart Budflush					Petawawa Budflush				
	lcbf2	lcbf3	lcbf4	lcbf5	lcbf6	enbf2	enbf3	enbf4	enbf5	enbf6	pwbf2	pwbf3	pwbf4	pwbf5	pwbf6
1	129.90	133.27	136.20	138.89	143.87	129.25	134.24	137.28	140.48	148.06	129.37	136.60	136.23	138.79	145.18
2	129.27	132.62	135.00	138.21	141.30	131.77	133.81	136.87	141.08	148.50	133.27	137.58	136.67	138.13	146.00
3	129.08	131.77	134.93	138.37	142.33	131.96	135.14	137.20	140.71	148.69	126.78	131.53	133.11	137.25	141.33
4	128.59	132.05	134.82	138.34	142.44	126.83	133.39	135.33	138.18	146.87	128.31	132.19	135.42	139.61	145.38
5	128.15	131.46	133.70	137.48	140.82	128.11	132.30	134.61	139.23	145.63	126.87	132.04	133.97	139.45	144.83
6	129.71	133.41	135.83	138.59	141.39	130.85	132.45	134.24	137.94	148.00	129.49	135.32	134.58	140.69	144.73
7	128.93	132.13	134.51	138.38	142.52	132.24	136.71	137.55	141.00	149.57	136.67	141.13	141.68	144.05	147.29
8	129.14	132.37	134.82	137.84	141.88	128.07	132.71	136.17	137.75	144.47	131.95	136.26	138.42	144.41	145.20
9	129.42	132.77	134.37	138.74	142.40	133.71	136.05	136.98	140.49	147.40	134.33	139.27	142.10	145.08	147.62
10	130.09	132.62	135.33	138.59	141.65	132.30	134.59	136.96	140.43	148.29	131.11	137.87	135.14	137.34	145.46
11	131.27	133.55	135.61	138.40	142.10	131.72	135.82	138.17	138.07	145.71	129.71	131.56	133.40	139.99	142.50
12	130.68	133.22	134.97	137.93	141.71	127.00	129.24	132.18	136.76	145.53	129.94	134.07	135.91	140.33	145.00
13	130.53	134.09	135.73	138.90	142.06	130.04	133.62	136.11	139.88	147.11	129.85	131.93	134.09	139.56	143.00
14	129.87	132.86	135.50	138.43	142.15	130.56	132.94	135.34	138.38	147.67	131.83	133.83	136.18	142.36	146.20
15	128.51	131.46	133.88	137.51	141.18	129.75	130.96	133.64	137.62	147.33	133.15	136.55	138.36	138.68	146.33
16	129.95	133.59	135.06	138.98	142.20	127.55	133.88	135.78	140.01	147.93	130.92	134.88	135.85	140.82	145.63
17	130.16	133.10	134.84	138.39	142.36	132.11	137.46	136.98	139.64	147.29	125.99	131.67	131.85	134.68	145.53
18	127.70	131.74	134.68	139.13	142.06	131.64	134.35	136.07	139.48	150.00	132.07	137.71	139.05	139.95	145.60
19	129.05	131.93	134.00	138.00	141.67	130.79	134.90	137.01	140.16	147.11	133.62	134.29	135.93	140.25	146.60
20	131.72	134.64	137.21	141.31	144.00	131.88	131.65	134.20	139.27	146.20	130.81	135.42	136.54	139.63	145.53
21	129.40	133.57	135.63	138.45	142.32	131.06	132.66	136.69	141.51	147.67	131.29	133.85	137.07	141.42	147.35
22	128.60	132.00	134.29	138.73	142.95	130.84	134.03	136.28	140.67	148.69	132.35	137.45	140.43	142.20	147.83
23	130.20	132.84	135.23	138.65	142.32	130.55	136.37	137.72	141.17	146.82	127.93	134.69	137.36	139.98	145.63
24	129.04	132.24	134.36	138.11	142.76	125.94	129.23	133.85	137.29	147.15	123.93	127.47	129.00	133.75	143.31
25	129.15	132.84	135.64	138.60	141.29	127.29	132.42	133.92	138.33	147.57	130.30	135.46	138.17	142.26	144.83
26	129.47	132.50	135.50	139.10	142.20	126.95	130.81	133.62	138.80	147.12	127.10	131.71	134.38	137.00	147.27
27	128.80	131.92	134.44	137.92	141.48	132.05	135.36	137.76	139.67	148.05	132.39	136.07	138.36	140.17	145.20
28	131.54	135.07	136.17	139.04	142.41	130.67	134.01	136.67	140.24	147.25	129.33	135.15	137.29	139.31	148.09
29	130.07	132.95	135.25	138.33	141.75	124.02	130.04	132.76	136.00	146.25	129.14	131.58	133.99	138.85	144.08
30	128.80	132.68	134.90	138.05	141.53	128.40	129.99	133.84	137.00	144.53	129.38	131.36	132.81	138.25	141.33
31	128.36	131.45	134.19	138.09	141.22	127.12	130.37	133.29	137.94	146.23	129.06	132.24	133.50	138.11	143.77
32	130.39	133.47	136.14	139.25	142.73	129.24	132.92	135.92	139.69	147.13	134.07	137.60	137.43	138.87	147.35
33	129.72	132.03	134.51	137.69	142.10	131.09	134.05	136.51	139.87	146.50	127.73	130.78	134.84	139.26	144.54
34	127.65	131.38	134.46	137.62	141.05	127.88	132.77	136.10	138.79	146.75	124.95	129.13	131.40	137.67	145.50
35	130.14	133.18	135.31	139.14	142.16	135.73	135.43	138.31	141.05	146.71	133.64	139.61	140.61	144.95	143.44
36	129.62	132.61	134.93	137.79	141.33	127.39	131.12	133.13	137.62	146.11	131.37	134.95	137.10	140.96	145.77
37	129.44	132.81	134.05	138.27	141.95	129.75	132.44	134.92	138.72	147.82	132.94	136.21	138.69	140.31	147.43
38	129.34	132.58	135.36	139.49	142.69	132.68	133.75	135.06	140.03	146.78	131.50	133.34	136.39	141.73	143.67
39	128.42	131.59	135.21	138.58	141.71	127.37	131.53	135.28	138.81	146.78	132.83	138.30	139.39	142.67	147.38
40	127.81	131.75	134.21	137.83	141.55	130.28	132.88	135.11	138.79	147.40	127.10	131.34	134.93	138.70	145.42
41	129.16	132.45	135.19	138.01	141.70	129.92	133.70	136.00	138.65	148.47	133.07	134.18	136.18	138.60	145.25
42	128.64	132.56	136.07	139.61	143.78	130.13	132.26	135.38	139.15	145.67	126.64	130.33	134.33	137.54	141.59

Prov	Longlac Budflush					Englehart Budflush					Petawawa Budflush				
	lcbf2	lcbf3	lcbf4	lcbf5	lcbf6	enbf2	enbf3	enbf4	enbf5	enbf6	pwbf2	pwbf3	pwbf4	pwbf5	pwbf6
43	129.64	132.45	135.64	138.51	141.83	133.17	136.42	139.26	141.83	147.60	133.65	138.20	140.79	143.91	145.15
44	130.27	134.07	136.97	139.61	143.27	134.71	135.87	138.35	141.46	149.47	127.95	131.64	133.38	137.80	143.53
45	128.67	131.41	134.26	137.55	141.57	126.40	129.84	131.38	135.57	143.00	132.37	134.25	135.48	140.14	145.31
46	128.29	131.58	134.03	137.90	142.10	129.97	133.14	136.26	140.08	147.53	135.68	135.18	136.99	141.11	144.83
47	130.03	133.17	135.14	138.55	141.67	130.31	133.71	136.52	140.02	147.44	131.60	134.07	134.91	139.85	145.31
48	131.10	133.65	136.35	139.63	143.13	129.67	131.41	134.18	139.06	146.25	130.27	134.34	136.23	141.88	150.73
49	129.68	133.14	135.42	138.55	142.07	130.42	134.52	137.31	140.86	145.50	131.13	134.20	135.64	135.19	145.35
50	129.47	132.30	134.47	138.49	142.23	130.59	132.59	135.81	139.51	146.33	131.90	134.78	135.41	137.93	143.33
51	129.98	132.68	134.54	139.09	141.80	126.26	133.36	135.96	139.71	145.40	124.78	127.68	129.99	137.71	144.05
52	129.30	131.73	134.20	137.91	141.50	127.64	133.62	136.05	139.65	146.14	128.30	132.55	134.97	137.47	145.29
53	130.12	134.37	136.98	140.19	142.71	130.39	134.23	136.29	139.80	148.67	130.79	135.31	136.65	140.33	144.23
54	128.55	131.60	134.36	138.09	141.50	130.04	131.55	134.35	139.35	147.00	127.02	131.73	134.59	138.93	144.79
55	129.28	132.92	135.96	139.83	143.59	129.36	131.16	134.56	138.88	147.00	126.58	131.47	133.86	138.40	144.60
56	128.61	131.42	133.64	137.96	141.81	132.58	134.19	136.20	139.74	146.00	130.64	135.33	138.65	139.18	146.14
57	128.76	132.13	133.68	137.13	140.95	129.70	134.15	136.54	140.67	148.29	132.91	136.75	139.48	144.68	149.50
58	130.62	133.65	135.30	138.03	141.18	129.46	134.04	134.89	139.40	147.00	130.20	135.59	135.67	138.60	141.00
59	129.29	132.35	134.25	138.50	142.11	134.66	138.46	138.98	142.46	148.14	132.76	138.86	143.24	146.33	149.00
60	129.50	132.95	135.36	138.64	142.74	128.72	131.72	134.12	138.36	147.60	127.49	129.83	132.23	136.14	143.00
61	130.14	134.17	135.87	138.52	141.80	127.48	131.46	134.05	138.89	148.76	129.84	131.75	134.00	138.22	144.87
62	129.08	133.01	134.64	137.65	142.16	125.66	129.76	133.00	136.43	145.00	139.19	142.34	144.51	144.40	147.60
63	130.34	133.83	136.89	140.63	144.09	130.73	134.95	137.76	140.20	148.30	129.77	135.56	138.13	142.12	148.18
64	128.87	132.09	134.53	138.29	141.95	133.65	134.06	135.09	140.14	149.00	130.97	134.30	135.32	139.98	149.00
65	129.45	133.29	135.68	139.09	143.61	128.37	131.47	134.39	138.22	147.00	126.25	129.81	132.60	135.89	143.27
66	129.80	133.56	136.22	139.70	142.94	130.31	134.47	137.04	141.55	148.06	129.46	132.13	135.04	139.42	146.33
67	128.83	132.92	134.51	137.79	141.42	128.84	133.70	135.71	138.28	145.84	135.11	134.71	136.96	140.95	147.46
68	130.23	134.06	135.60	138.87	142.58	129.55	133.02	135.65	140.33	148.56	129.54	134.00	135.00	140.60	146.38
69	127.22	130.54	133.32	138.38	141.70	127.65	131.32	134.97	137.91	146.40	131.42	134.66	137.25	140.27	145.22
70	128.26	131.69	134.04	137.80	141.50	130.35	133.51	135.78	139.62	145.94	131.83	134.43	137.35	139.88	144.87
71	128.45	132.06	134.17	138.78	141.65	129.13	132.86	135.32	139.80	146.07	128.62	131.73	134.32	139.19	143.82
72	128.64	132.76	134.99	138.45	141.65	130.83	134.36	136.00	139.69	147.29	129.66	130.16	132.06	136.64	144.50
73	129.58	132.41	134.49	137.53	141.83	128.03	131.81	135.00	137.44	144.75	128.42	132.73	135.65	140.09	143.71
74	129.19	132.44	134.09	138.15	142.73	133.40	135.06	137.11	141.23	147.75	128.45	132.61	133.74	138.06	142.85
75	129.94	133.52	134.98	138.89	141.50	128.64	132.57	135.51	140.38	147.50	135.02	138.63	139.45	144.80	151.83
76	129.63	131.95	134.37	137.62	141.11	130.37	135.29	136.91	140.56	148.25	129.85	134.88	136.06	140.21	147.13
77	129.44	132.01	134.35	138.15	141.95	129.59	134.21	136.69	141.62	148.71	126.45	131.99	133.91	137.83	149.33
78	129.51	132.80	134.30	137.71	141.59	132.15	137.36	139.80	141.94	149.89	129.04	132.32	134.59	139.31	144.69
79	128.59	132.46	135.20	138.69	142.48	137.54	139.01	140.95	142.97	150.45	131.02	134.62	134.91	139.09	143.47
80	128.09	130.75	133.46	137.80	142.60	131.71	135.61	137.65	140.87	147.33	127.02	133.50	136.81	141.45	147.73
81	128.34	131.76	134.42	139.48	143.63	124.73	129.62	131.62	137.00	146.14	128.06	131.34	133.97	138.81	142.89
82	129.34	131.09	133.53	138.01	142.61	127.19	130.91	134.26	137.89	146.88	127.91	132.04	135.09	139.07	145.83
83	128.68	132.30	135.22	138.12	141.96	126.14	132.13	135.35	136.72	145.71	129.45	132.00	134.70	139.08	146.33
84	128.35	131.37	134.34	138.36	141.95	125.35	128.28	131.33	137.62	145.44	125.15	130.16	133.23	139.12	144.33
85	128.70	131.82	134.63	138.10	141.68	128.14	130.76	133.64	137.72	145.00	126.62	129.37	131.81	136.71	145.50
86	128.29	131.22	133.84	137.70	141.21	129.66	131.63	135.00	137.47	147.25	133.51	137.41	138.54	141.82	146.54
87	129.62	132.63	135.01	138.38	142.00	130.67	133.00	135.20	138.20	147.67	129.15	133.76	135.82	139.12	144.07

Prov	Longlac Budflush					Englehart Budflush					Petawawa Budflush				
	lcbf2	lcbf3	lcbf4	lcbf5	lcbf6	enbf2	enbf3	enbf4	enbf5	enbf6	pwbf2	pwbf3	pwbf4	pwbf5	pwbf6
88	129.03	131.56	134.09	138.35	141.77	130.07	130.93	133.53	136.94	146.00	130.48	134.79	136.26	138.37	144.40
89	127.91	130.54	133.30	137.87	141.21	132.08	135.87	136.90	139.77	146.33	133.73	136.53	138.70	143.34	145.55
90	129.31	132.81	134.92	138.82	141.71	130.57	133.82	136.72	140.50	148.00	135.47	138.94	143.24	144.48	149.25
91	127.84	130.35	132.93	137.40	142.00	130.38	134.32	135.85	139.91	147.67	125.32	128.96	130.44	136.60	141.46
92	128.09	131.15	134.07	137.79	141.47	128.28	132.71	135.24	138.90	147.75	130.20	132.69	136.17	143.08	147.17
93	128.46	131.49	134.08	137.87	141.90	127.66	133.53	134.38	140.38	143.50	125.36	131.62	134.75	141.06	144.54
94	129.40	131.86	135.58	139.02	142.63	128.25	132.42	134.76	139.00	148.47	133.53	135.44	137.62	141.59	146.06
95	129.70	133.27	135.56	138.56	142.88	128.46	132.98	134.91	139.31	147.40	127.71	131.84	133.77	139.80	147.25
96	129.07	131.70	134.01	138.03	141.53	129.47	135.79	135.34	139.95	151.15	127.79	133.75	136.34	140.51	143.62
97	128.88	132.14	134.41	138.40	141.68	128.47	133.53	136.87	141.60	146.78	125.24	129.71	133.16	136.87	144.33
98	128.42	131.66	134.51	138.74	142.38	127.61	130.96	134.94	139.65	146.88	128.51	133.57	136.20	140.02	144.06
99	128.36	132.00	134.37	138.09	141.95	128.52	133.30	136.34	140.22	147.29	125.40	129.39	133.10	139.50	144.83
100	128.45	131.27	132.94	137.36	141.00	128.42	131.29	134.27	139.26	146.33	127.78	129.41	131.88	135.50	141.33
101	129.92	132.35	135.11	138.23	142.35	128.73	132.74	135.83	139.80	145.60	137.40	138.40	138.74	139.58	147.59
102	128.98	131.61	134.17	137.73	141.52	131.23	133.98	135.18	138.90	147.93	131.22	134.20	134.40	139.90	143.93
103	127.95	130.97	133.60	137.23	140.57	131.07	133.96	136.26	139.61	147.29	129.07	132.38	135.02	139.91	144.33
104	128.25	131.13	133.39	137.25	141.24	130.60	132.32	134.78	138.73	146.33	133.13	135.25	136.88	139.78	145.46
105	128.52	132.21	134.11	137.99	142.17	131.92	134.62	137.20	140.70	148.08	128.34	131.24	134.81	137.22	144.89
106	129.10	132.25	134.60	138.33	140.82	128.25	133.55	135.64	139.03	147.93	128.31	132.99	132.64	137.37	143.91
107	127.60	130.83	132.55	137.22	141.38	127.76	131.18	132.80	136.43	145.57	126.33	129.33	130.52	138.18	141.71
108	129.18	132.19	135.01	138.28	142.28	130.30	132.73	136.07	139.35	148.14	126.39	128.39	131.27	138.09	145.12
109	128.69	131.14	133.35	137.79	142.00	131.75	135.15	137.69	140.62	147.57	131.67	137.78	138.82	140.84	144.09
110	128.60	131.41	133.84	137.88	141.59	125.29	129.04	131.89	137.50	145.00	124.77	127.58	131.50	136.71	144.44
111	129.17	132.05	134.91	139.24	142.29	128.11	131.29	133.69	137.21	146.33	131.17	134.00	135.86	139.31	146.00
112	129.99	133.08	135.31	137.62	141.30	127.94	132.21	134.77	138.60	145.19	126.55	131.02	133.88	137.38	146.76
113	128.58	131.74	133.76	137.53	141.14	132.26	136.68	137.09	140.67	147.86	137.04	140.93	142.16	143.98	148.60
114	128.94	131.98	133.58	138.04	141.61	129.81	132.49	135.43	139.73	146.87	133.20	138.93	140.01	142.45	147.77
115	129.97	134.12	136.07	139.32	142.11	129.46	132.37	135.09	139.72	146.65	127.74	134.57	137.07	138.14	144.09
116	128.00	130.09	132.70	136.82	141.65	128.57	131.84	133.96	138.03	143.95	133.00	132.69	133.25	140.26	147.60
117	130.84	134.16	136.55	139.63	142.95	132.21	136.29	138.40	142.27	149.00	131.45	133.27	136.99	140.44	147.40
118	129.30	132.24	134.52	138.34	142.69	128.37	130.85	133.71	137.47	148.50	128.48	128.81	129.89	133.78	142.47
119	128.14	131.90	133.87	136.95	141.31	127.47	132.10	135.03	137.29	146.45	127.66	132.23	133.96	138.98	141.92
120	128.55	132.15	135.08	138.18	141.65	133.75	136.31	138.12	140.87	147.00	125.94	129.84	131.79	137.10	144.83
121	127.73	130.68	133.26	137.36	140.79	133.52	134.39	135.88	140.57	147.00	131.07	132.75	133.79	137.98	143.00
122	127.66	130.02	133.09	137.15	141.70	129.55	133.72	135.70	139.60	147.00	130.69	133.57	135.45	138.73	144.67
123	128.77	131.76	134.58	138.05	142.14	130.48	134.56	136.49	138.97	147.89	132.39	136.04	137.99	138.91	146.69
124	127.24	129.69	132.72	136.48	140.60	132.66	135.53	137.61	140.19	147.25	128.97	131.61	132.94	134.09	141.18
125	127.60	130.01	132.82	137.55	141.29	128.20	130.56	133.02	137.76	145.27	131.07	133.39	134.40	136.37	145.67
126	129.15	132.92	134.96	137.40	141.33	126.44	129.72	132.50	137.50	146.33	128.35	132.10	133.28	137.68	145.12
130	130.12	133.41	135.38	137.94	141.52	129.50	133.88	134.01	136.95	145.00	128.47	131.43	133.74	138.84	144.54

Prov	Greenhouse Budflush					Greenhouse Elongation (mm)				
	ghbf2	ghbf3	ghbf4	ghbf5	ghbf6	day18	day22	day26	day30	day70
1	8.67	10.76	12.83	15.48	18.57	19.90	36.13	47.54	63.33	303.50
2	7.67	10.39	11.82	14.62	17.43	18.97	34.85	51.92	71.23	267.70
3	7.96	10.59	12.76	15.48	17.97	18.52	37.06	52.50	73.23	283.03
4	7.94	10.38	12.42	14.72	17.38	19.11	36.05	51.05	70.29	265.59
5	7.81	10.12	12.33	15.18	17.93	20.27	38.68	55.05	75.03	291.70
6	8.14	10.95	13.20	14.80	17.40	16.92	33.17	49.21	68.70	279.90
7	7.38	10.22	12.42	14.47	17.33	19.80	37.52	53.64	73.84	303.17
8	8.22	10.61	12.70	15.14	17.60	21.09	39.55	55.56	73.20	274.17
9	8.20	10.22	12.55	14.98	17.87	19.11	37.16	52.10	72.20	293.57
10	7.70	10.68	12.98	15.05	17.83	19.90	36.93	53.23	71.67	287.40
11	7.29	9.83	12.00	14.68	17.50	20.69	38.18	53.70	70.33	270.83
12	7.60	8.74	10.88	14.29	17.28	22.37	38.86	57.18	72.47	257.27
13	7.80	10.79	12.76	14.86	17.53	18.36	34.76	51.46	70.49	292.77
14	7.98	9.69	11.95	14.52	17.40	19.86	37.23	50.93	66.44	233.03
15	7.26	9.20	11.17	15.20	17.57	19.60	36.99	52.52	67.94	227.23
16	8.25	11.23	13.21	15.09	18.07	19.59	34.11	49.22	68.44	269.27
17	7.36	9.84	12.30	14.14	16.60	20.63	39.62	56.20	76.10	272.97
18	7.69	9.95	12.37	14.70	17.28	19.35	37.68	56.01	75.48	293.50
19	7.86	10.76	12.98	15.17	17.66	17.15	34.66	53.89	73.46	295.70
20	8.45	10.90	13.22	15.35	18.77	19.59	32.88	47.66	66.25	286.40
21	8.17	10.63	13.03	15.45	17.80	17.28	33.29	50.72	71.18	279.57
22	8.33	10.91	12.99	14.88	17.90	19.86	36.82	52.96	71.86	324.13
23	8.18	10.54	12.72	15.16	17.83	19.51	36.41	52.47	71.89	286.63
24	7.31	9.24	11.03	14.57	17.31	20.72	40.25	54.73	69.32	220.30
25	7.67	10.59	12.30	14.73	18.17	20.51	36.00	49.97	68.30	276.27
26	7.61	10.58	12.82	15.22	18.00	18.79	35.92	52.13	69.80	278.50
27	7.43	10.18	12.23	14.48	16.53	20.34	41.17	57.16	75.92	296.17
28	8.02	10.62	12.87	14.92	18.43	19.32	36.41	52.11	69.07	296.63
29	7.46	9.78	12.03	14.60	17.53	20.15	36.94	52.33	69.87	243.07
30	7.72	10.40	12.84	15.01	17.53	18.87	37.46	54.91	74.14	290.00
31	7.23	9.94	12.29	15.04	17.57	18.92	37.45	53.39	71.02	248.50
32	8.00	10.38	12.53	14.97	17.10	19.81	35.24	49.47	65.72	276.00
33	7.00	9.63	12.20	14.75	16.97	21.36	40.36	56.27	71.36	248.97
34	7.46	9.79	12.05	14.88	17.07	19.93	37.58	53.20	68.54	247.40
35	7.80	10.58	12.81	14.78	17.10	20.65	38.62	55.98	75.26	300.27
36	7.67	10.71	13.30	15.04	17.76	18.15	35.48	52.07	73.12	263.57
37	7.17	9.93	12.58	14.68	16.90	18.18	35.93	52.83	70.84	280.07
38	7.32	10.30	12.72	15.03	18.10	18.04	35.01	49.15	66.04	252.43
39	8.00	10.20	12.50	14.70	17.60	20.76	40.04	55.54	74.71	313.53
40	7.64	9.56	11.68	14.88	17.67	19.31	37.28	53.22	70.64	249.63
41	7.14	9.28	11.74	14.44	16.63	21.05	37.99	51.75	67.67	256.57
42	7.65	11.23	13.42	15.13	17.77	17.64	35.14	52.12	69.99	282.67

Prov	Greenhouse Budflush					Greenhouse Elongation (mm)				
	ghbf2	ghbf3	ghbf4	ghbf5	ghbf6	day18	day22	day26	day30	day70
43	7.33	10.33	12.67	14.80	17.03	19.10	38.52	56.36	72.58	284.23
44	7.78	10.48	12.78	15.37	17.93	19.98	37.35	53.13	71.32	292.30
45	7.23	9.68	12.07	14.87	17.20	19.71	39.33	55.42	72.15	254.63
46	7.61	10.45	12.57	14.76	17.53	21.77	38.78	57.06	75.72	293.57
47	7.40	10.00	12.48	14.72	16.97	20.71	40.57	57.34	76.10	261.10
48	8.00	10.90	12.79	14.92	18.37	17.04	32.01	48.78	69.11	286.93
49	7.76	10.37	12.73	14.65	17.43	20.52	36.82	53.64	71.53	304.07
50	7.75	10.40	12.72	15.05	17.57	17.35	36.13	54.11	74.01	316.07
51	7.45	9.65	12.07	14.68	17.71	20.27	37.63	55.73	70.91	227.71
52	7.33	9.95	12.31	14.59	17.03	21.02	39.82	54.62	71.40	255.33
53	7.54	10.67	12.95	15.23	18.17	16.97	31.71	48.15	64.03	280.37
54	7.55	9.28	11.48	14.65	16.90	22.42	40.70	55.17	68.76	221.27
55	8.28	11.07	13.28	14.97	17.83	17.62	34.46	51.47	69.52	301.13
56	7.92	10.71	13.03	15.80	18.40	18.96	36.82	55.08	69.18	260.37
57	7.78	9.95	12.50	15.02	17.30	19.53	38.20	56.06	74.69	277.33
58	7.80	10.65	12.82	14.77	17.23	19.08	40.81	57.86	77.04	279.00
59	8.39	11.25	12.73	15.12	18.57	18.53	33.73	51.77	71.31	311.63
60	7.13	9.22	11.82	14.65	17.30	22.80	42.04	58.50	76.40	256.60
61	7.95	9.83	12.82	15.25	18.53	18.63	36.09	48.90	62.90	283.20
62	7.29	9.98	12.60	14.77	17.77	21.52	40.02	56.91	74.93	240.97
63	8.20	11.08	13.03	15.15	18.23	19.38	35.47	52.62	71.91	311.80
64	7.75	9.88	12.30	14.67	17.63	19.83	36.53	52.32	69.67	256.63
65	7.86	10.81	12.75	14.67	17.97	18.86	37.81	55.20	73.28	274.07
66	8.53	11.27	13.51	15.94	18.77	18.51	35.55	52.16	74.42	301.60
67	8.43	10.83	13.08	15.72	18.83	19.43	35.59	52.57	73.07	304.93
68	7.78	10.31	12.41	15.00	18.13	20.03	39.05	57.24	76.46	271.30
69	7.29	9.95	12.17	14.75	17.60	20.27	38.81	54.75	71.37	252.03
70	7.61	9.20	11.58	14.68	17.67	23.13	42.25	57.69	72.72	219.17
71	7.52	10.40	12.72	14.83	17.20	18.88	35.96	51.19	68.46	271.93
72	7.72	10.12	12.27	15.18	18.17	22.00	42.25	59.88	78.27	276.77
73	7.98	10.34	12.22	15.00	18.03	19.94	36.96	53.25	70.52	271.17
74	8.04	10.50	12.77	15.42	18.43	17.95	33.26	48.79	68.40	282.70
75	7.80	10.78	12.92	14.83	18.03	16.21	31.40	46.28	62.34	235.77
76	7.66	9.84	12.03	14.92	17.80	19.29	35.49	51.75	66.48	231.23
77	8.00	10.48	12.72	15.23	18.41	16.98	33.55	50.43	69.70	242.37
78	7.41	9.33	12.02	14.42	16.33	20.46	39.48	55.91	73.67	280.80
79	7.72	11.00	13.10	15.02	18.13	18.41	35.96	52.97	71.71	262.43
80	7.14	9.20	11.35	14.85	17.30	20.70	40.34	57.85	75.10	227.73
81	7.46	10.03	12.48	14.97	17.00	19.25	37.85	55.73	75.17	269.30
82	7.65	9.72	12.07	14.70	17.60	19.40	37.30	53.63	69.58	244.13
83	7.59	9.93	12.23	14.57	17.80	21.49	37.42	53.86	70.13	268.67
84	7.35	9.17	11.80	14.73	17.63	22.96	41.51	57.54	74.62	258.40
85	7.59	10.10	12.33	15.00	18.37	18.95	35.24	50.61	67.33	237.77
86	7.48	10.25	12.87	14.87	17.63	21.34	41.32	57.61	75.40	298.20
87	7.56	9.70	12.12	14.61	17.47	20.31	38.42	56.87	76.03	248.83

Prov	Greenhouse Budflush					Greenhouse Elongation (mm)				
	ghbf2	ghbf3	ghbf4	ghbf5	ghbf6	day18	day22	day26	day30	day70
88	7.20	9.70	11.90	14.81	17.00	20.81	41.10	56.72	74.81	284.60
89	7.36	9.84	12.27	14.36	16.77	19.90	38.64	55.45	71.97	268.27
90	7.79	10.43	12.60	14.85	17.77	18.36	36.97	54.18	74.98	266.07
91	7.78	9.79	12.20	14.52	17.30	19.89	38.13	53.74	70.68	222.60
92	7.34	9.42	11.68	14.47	16.87	20.84	41.09	59.30	79.40	257.70
93	7.98	10.70	13.06	15.09	17.87	19.03	37.44	55.42	76.25	262.43
94	8.02	9.98	12.22	14.65	17.37	20.70	38.19	55.18	73.05	284.67
95	7.50	10.35	12.85	14.45	17.63	19.79	37.27	54.77	74.47	279.73
96	7.20	9.48	11.75	14.58	17.60	19.48	37.74	54.70	72.71	218.33
97	7.42	9.81	11.84	14.68	17.13	21.19	40.90	57.66	74.42	238.87
98	7.19	9.43	11.67	14.57	17.10	21.84	42.83	59.49	77.41	252.50
99	7.75	10.10	12.52	15.08	17.80	19.72	38.50	58.78	79.26	274.43
100	7.19	8.96	10.97	14.45	17.13	20.52	39.53	51.98	66.74	192.47
101	7.70	10.25	12.88	15.22	17.90	19.97	37.25	54.45	73.65	321.20
102	8.14	10.15	12.38	15.37	18.17	22.78	38.09	54.12	73.01	266.87
103	7.73	9.66	11.80	14.42	17.40	21.80	41.93	59.97	78.73	265.30
104	7.46	9.91	11.99	14.74	17.57	23.07	42.21	59.52	76.98	269.63
105	7.30	9.50	11.88	14.43	16.93	23.76	44.12	61.89	80.42	288.80
106	7.36	9.41	11.60	14.28	16.67	20.53	38.62	52.83	68.59	247.93
107	7.56	8.83	10.74	14.43	17.14	27.40	50.18	68.99	86.76	248.54
108	7.48	9.34	12.10	14.45	16.87	20.40	40.08	56.39	74.78	248.13
109	7.16	8.71	11.18	14.43	16.97	24.80	46.07	62.37	79.46	279.63
110	7.62	9.54	11.53	15.15	17.77	22.31	40.63	56.81	73.33	230.90
111	7.78	9.58	11.72	14.45	17.03	21.34	41.30	57.90	77.17	279.33
112	7.75	10.30	12.68	14.93	17.83	21.04	39.02	57.12	76.12	283.60
113	7.19	9.57	11.87	14.23	16.50	21.77	42.64	59.62	77.11	283.87
114	7.11	9.30	11.80	14.90	16.97	21.16	40.70	56.70	73.71	254.47
115	7.61	10.32	12.85	15.27	18.20	24.69	42.94	60.06	80.15	300.13
116	7.25	9.06	11.12	14.27	16.97	25.44	49.35	66.62	83.53	267.43
117	7.43	10.35	12.80	14.93	17.27	20.35	39.83	58.05	77.28	302.83
118	7.60	10.30	12.40	14.72	17.57	20.46	37.93	55.40	75.58	303.50
119	7.34	9.54	11.27	14.77	17.83	20.48	39.51	56.33	73.71	235.43
120	7.75	10.70	12.87	14.92	18.13	19.56	34.88	52.27	70.21	279.30
121	7.16	10.08	12.48	14.52	17.00	22.58	43.80	61.84	81.48	276.07
122	7.43	9.35	11.72	14.87	17.10	23.33	45.39	61.88	81.03	295.10
123	7.70	10.12	12.67	15.38	18.33	20.83	37.65	51.35	66.94	273.17
124	7.90	10.13	12.47	15.16	17.33	21.61	39.74	56.66	74.49	264.70
125	7.39	9.33	11.67	15.02	17.28	21.99	42.20	58.77	76.33	263.00
126	7.42	9.52	11.57	15.03	17.30	21.32	42.84	61.19	80.31	283.57
130	7.43	9.46	11.25	14.33	17.07	20.87	40.38	55.30	71.18	222.97

APPENDIX III
PROVENANCE VALUES FOR 67 CLIMATE VARIABLES

Prov	Climate Variables													
	diurnran	isotherm	tempseas	maxtempwp	mintempcp	tempanran	mtempwetq	mtempdryq	mtempwarmq	mtempcoldq	annprecip	precipwp	precipdp	precipseas
1	10.1	0.24	4.02	26.4	-14.8	41.1	18.1	-7.1	19.2	-8.6	941	98	59	17
2	11	0.25	4.12	25.6	-17.5	43.1	18	-8.7	18	-10.3	1006	100	61	15
3	11.1	0.26	4.13	25.6	-17.7	43.4	18	-8.9	18	-10.5	1002	99	60	15
4	12	0.27	4.18	24.7	-19.8	44.5	16.8	-10.2	16.8	-11.9	1017	107	58	19
5	10.9	0.25	4.15	26.1	-17.3	43.3	18.4	-8.6	18.4	-10.2	973	95	59	14
6	11	0.25	4.19	26.6	-17.1	43.7	19	-8.3	19	-10	937	89	57	14
7	11.6	0.26	4.19	25.2	-19.1	44.3	17.4	-9.7	17.4	-11.4	996	97	60	15
8	11.8	0.27	4.21	24.5	-20.1	44.6	16.7	-10.5	16.7	-12.2	1022	102	61	17
9	11.3	0.26	4.18	25.6	-18.3	43.9	17.9	-9.2	17.9	-10.9	991	94	60	14
10	10.3	0.25	3.95	26.5	-14.5	41.1	18.2	-6.8	19.2	-8.2	896	88	56	15
11	10.4	0.25	4.05	26.5	-15.3	41.9	18.1	-7.4	19.1	-8.9	875	83	57	14
12	10.8	0.25	4.14	26.3	-16.7	43	17.6	-8.2	18.8	-9.8	895	84	58	13
13	10.9	0.25	4.16	25.4	-17.8	43.2	17.9	-9.1	17.9	-10.7	963	90	62	12
14	11.7	0.26	4.23	25.3	-19.3	44.7	17.5	-9.9	17.5	-11.5	931	95	56	17
15	11.4	0.26	4.21	25.7	-18.5	44.3	18	-9.3	18	-11	928	90	58	14
16	11.9	0.26	4.28	24.5	-20.5	45.1	16.8	-10.8	16.8	-12.6	950	101	56	20
17	10.8	0.25	4.09	26.4	-16.3	42.7	17.7	-7.9	18.8	-9.5	862	81	57	13
18	11.1	0.26	4.13	26.5	-16.9	43.4	17.7	-8.2	18.8	-9.7	860	79	56	12
19	11.4	0.26	4.22	24.9	-19.4	44.3	17.2	-10.1	17.2	-11.7	946	94	59	15
20	11.6	0.26	4.31	23.9	-21.1	44.9	15.1	-5.7	16.3	-13.1	959	105	56	22
21	11.3	0.26	4.17	25.7	-18.1	43.8	18	-9.1	18	-10.7	920	86	61	12
22	11.4	0.26	4.23	24.9	-19.5	44.4	17.2	-10.2	17.2	-11.8	929	94	56	17
23	11.4	0.26	4.12	26.5	-17.1	43.6	17.5	-8.3	18.6	-9.8	827	78	53	14
24	10.7	0.26	3.96	26.3	-14.9	41.3	7.8	-7.3	18.6	-8.7	840	83	56	13
25	11.6	0.26	4.15	26.4	-17.8	44.2	18.4	-8.7	18.4	-10.2	837	83	51	16
26	11.3	0.26	4.19	25.3	-18.6	44	17.6	-9.6	17.6	-11.1	945	90	62	13
27	11.4	0.26	4.24	24.8	-19.7	44.5	17.1	-10.3	17.1	-11.9	917	94	53	19
28	11.7	0.26	4.17	26.3	-18.1	44.5	18.3	-8.8	18.3	-10.4	838	86	47	18
29	10	0.26	3.75	26.3	-12.6	38.9	2	19.1	19.1	-6.8	894	93	58	14
30	11.2	0.27	4.01	26.2	-15.8	41.9	-0.1	-8	18.1	-9.5	898	92	64	12
31	11.6	0.26	4.17	26	-18.4	44.4	17.9	-9.1	17.9	-10.8	841	88	48	19
32	11.8	0.27	4.06	25.9	-17.2	43.1	17.6	-8.7	17.6	-10.3	816	81	50	15
33	12	0.27	4.15	26.2	-18.5	44.7	17.9	-9	17.9	-10.7	808	86	47	19
34	11.5	0.26	4.16	25.9	-18.2	44.1	17.9	-9	17.9	-10.7	841	88	49	18
35	11.8	0.26	4.18	25.7	-19	44.6	17.5	-9.5	17.5	-11.2	848	88	49	20
36	12.3	0.28	4.03	25.3	-18.3	43.7	15.9	-9	17	-10.6	827	83	49	18
37	10.8	0.27	3.82	25.9	-14.4	40.3	1	-6.7	18.3	-8.1	854	82	58	12
38	12	0.28	3.96	25.2	-17.6	42.8	12	-8.6	17.1	-10.1	877	87	54	15
39	10.7	0.27	3.81	25.9	-14.1	40	1.2	-6.5	18.5	-7.8	846	82	57	12
40	11.7	0.28	3.93	25.4	-16.7	42.1	12.4	-8.1	17.4	-9.6	885	86	56	14
41	9.8	0.26	3.66	25.3	-12.7	38	1.7	-5.8	18.3	-7	856	83	58	12
42	12.2	0.28	4.02	24.9	-18.7	43.5	15.6	-4.1	16.6	-10.9	927	94	55	17

Prov	Climate Variables													
	diurnran	isotherm	tempseas	maxtempwp	mintempcp	tempanran	mtempwetq	mtempdryq	mtempwarmq	mtempcoldq	annprecip	precipwp	precipdp	precipseas
43	11	0.27	3.89	26	-15.1	41	0.8	-2.3	18.2	-8.5	884	86	58	13
44	12.1	0.26	4.44	23.9	-22.5	46.5	14.8	-12.6	15.9	-14.2	952	105	50	25
45	12	0.28	4.07	24.4	-19.2	43.6	15.1	-4.8	16.2	-11.6	973	101	57	18
46	12.3	0.28	4.14	25.7	-18.7	44.4	16.3	-9.6	17.3	-11	899	96	50	21
47	11.8	0.27	4.05	24.3	-18.9	43.2	15.1	-4.7	16.1	-11.4	1023	107	60	18
48	12.2	0.25	4.69	22.9	-25.4	48.3	13.4	-9.1	14.5	-17	883	113	33	37
49	11.7	0.26	4.24	24.4	-20	44.5	15.4	-11	16.4	-12.5	966	103	53	22
50	11.9	0.27	4.13	25.4	-18.5	43.8	16.2	-9.7	17.1	-11.1	942	102	51	21
51	11.7	0.26	4.31	24.1	-21	45.1	15.1	-11.7	16.2	-13.1	965	103	54	21
52	11.6	0.27	4.16	24.9	-18.9	43.8	15.8	-10.2	16.7	-11.6	962	105	52	22
53	10.5	0.26	3.79	25.8	-14.2	39.9	7.8	-2	18.2	-7.8	912	90	58	13
54	11.4	0.27	3.88	25	-16.5	41.4	-5.9	-3.1	17.2	-9.4	1049	107	68	15
55	11.7	0.26	4.39	24.1	-21.8	45.9	15.1	-12.1	16.2	-13.6	936	101	51	22
56	11.4	0.26	4.22	24.6	-19.5	44.1	15.7	-10.6	16.7	-12	958	104	52	22
57	11.7	0.26	4.36	24.1	-21.4	45.6	15.2	-11.9	16.2	-13.4	938	100	52	21
58	11.6	0.28	3.93	24.6	-17.5	42.1	6	-3.8	16.5	-10.3	1118	116	72	16
59	11.4	0.26	4.26	24.4	-20.1	44.5	15.6	-11	16.6	-12.5	951	102	53	21
60	11.3	0.26	4.13	25.1	-18.3	43.4	16.2	-9.6	17.2	-11	955	107	50	22
61	9.9	0.26	3.69	25.8	-12.7	38.5	17.6	-5.9	18.5	-6.9	853	89	51	16
62	11.1	0.26	4.1	24.9	-18.2	43.1	16.2	-9.5	17.2	-10.9	972	110	51	23
63	12.3	0.26	4.6	24	-24.2	48.2	14.5	-7.4	15.6	-15.6	882	110	38	32
64	11.5	0.27	3.99	24.4	-18.2	42.6	5.8	-4.2	16.4	-10.8	1092	113	67	16
65	11.7	0.28	3.94	24.9	-17.7	42.6	-0.7	-3.6	16.8	-10.2	1102	112	71	16
66	12.1	0.25	4.59	23.8	-24	47.8	14.5	-7.4	15.7	-15.4	881	103	44	28
67	11.5	0.25	4.51	24.5	-22.3	46.8	15.6	-12.3	16.9	-13.9	830	90	43	24
68	11.2	0.24	4.43	24.5	-21.5	45.9	15.8	-11.8	16.9	-13.3	844	92	45	23
69	11.7	0.28	3.96	24.2	-18.1	42.3	5.6	-4.3	16.2	-10.8	1091	113	69	15
70	11	0.24	4.38	24.3	-21	45.2	15.6	-11.6	16.8	-13.1	879	96	50	20
71	11	0.26	3.91	24.9	-16.8	41.7	-6.1	-3.3	17.2	-9.6	1087	116	66	20
72	12.1	0.25	4.58	24.5	-23.2	47.7	15.3	-6.7	16.5	-14.7	825	90	47	22
73	10.9	0.26	4.02	25	-17.6	42.6	6.7	-3.6	17.4	-10.2	1005	107	63	16
74	10.1	0.26	3.67	25.2	-12.9	38.1	16.9	-6.5	17.7	-7.4	895	96	54	15
75	9.1	0.25	3.65	24.1	-12.8	36.9	0.9	-2.7	17.2	-7.6	1007	99	66	16
76	12.1	0.25	4.61	24.1	-23.7	47.8	14.9	-7.2	16.1	-15.2	850	95	48	23
77	12.3	0.25	4.65	24	-24.4	48.3	14.5	-7.7	15.7	-15.8	844	98	43	28
78	9.4	0.26	3.53	25.1	-11.3	36.4	-2.9	4.8	18	-6.1	1041	109	67	16
79	12.6	0.26	4.7	23.8	-24.9	48.7	14.1	-8.4	15.3	-16.5	844	99	41	28
80	12.9	0.26	4.8	23.6	-25.8	49.4	13.9	-8.9	15.2	-17.2	721	84	36	28
81	12.6	0.26	4.72	24.1	-24.8	49	14.5	-8.1	15.7	-16.2	831	97	41	27
82	12.7	0.26	4.65	24	-24.6	48.6	15.7	-7.8	15.7	-15.8	851	95	45	25
83	8.3	0.24	3.35	22.6	-11.6	34.2	-2.6	-2.1	16.6	-6	892	96	55	20
84	12	0.27	4.04	25.8	-18.3	44.1	12	-3.9	17	-10.6	866	97	47	20
85	12.6	0.26	4.71	24	-25	48.9	14.5	-8.2	15.7	-16.2	821	96	42	27
86	10.4	0.25	3.95	24.8	-16.2	41	6.8	-8.6	17.3	-9.7	884	100	50	20
87	12.4	0.25	4.73	23.4	-25.3	48.7	14	-8.7	15.2	-16.7	836	98	42	26

Prov	Climate Variables													
	diurnran	isotherm	tempseas	maxtempwp	mintempcp	tempanran	mtempwetq	mtempdryq	mtempwarmq	mtempcoldq	annprecip	precipwp	precipdp	precipseas
88	9.8	0.25	3.75	24.6	-14.5	39.1	13.2	-2.9	17.3	-8.1	812	92	42	20
89	10.3	0.26	3.8	25.3	-14.8	40.1	13.2	-7.5	17.6	-8.3	816	93	42	20
90	13	0.27	4.76	23.1	-25.8	48.9	13.6	-9	14.7	-17.2	722	82	35	26
91	11.3	0.27	3.98	21.7	-20.7	42.4	4.7	-5.5	14.4	-12.4	1020	110	60	21
92	13	0.27	4.56	22.7	-25.7	48.4	13	-8.8	14.3	-16.4	826	95	43	26
93	13.2	0.28	4.5	23.4	-24.7	48	13.8	-7.9	15	-15.4	789	92	42	27
94	12.9	0.26	4.8	23.6	-25.7	49.3	13.9	-8.8	15.2	-17.1	721	85	36	28
95	12.5	0.27	4.47	23.7	-22.9	46.6	14.3	-7.2	15.5	-14.7	812	93	45	24
96	11.6	0.26	4.4	23.8	-21.2	44.9	14.8	-6.4	15.8	-13.9	847	94	48	22
97	12	0.26	4.52	22.7	-23.5	46.2	13.8	-7.7	14.9	-15.6	810	93	44	25
98	12.3	0.26	4.65	22.7	-24.8	47.6	13.7	-8.5	14.8	-16.5	770	90	38	29
99	10.6	0.26	3.98	20.6	-19.8	40.4	10.3	-5.7	14.1	-12.6	854	91	49	21
100	12.7	0.26	4.85	23.3	-26.3	49.6	13.7	-15.8	15	-17.6	734	89	32	35
101	13.1	0.25	5.04	23.9	-27.7	51.6	13.7	-16.8	15.2	-18.7	716	92	28	41
102	12.5	0.25	4.81	22.9	-26.6	49.5	13.4	-15.9	14.7	-17.7	745	90	30	38
103	13	0.25	5.09	23.8	-28.3	52	13.6	-17.3	15.1	-19.2	697	99	25	46
104	11.1	0.25	4.27	20.6	-23.3	43.9	13	-7.7	13.6	-15	810	94	37	30
105	13	0.25	5.03	23.8	-28	51.8	13.7	-16.8	15.1	-18.7	709	96	26	43
106	8.7	0.25	3.39	23.4	-11.4	34.8	-2.5	-1.7	17.2	-5.9	920	103	58	21
107	10.1	0.25	3.92	19.7	-20.4	40.1	10.3	-6.1	13.6	-12.7	823	95	40	26
108	11.9	0.25	4.56	21.8	-25.5	47.3	13	-8.8	14	-16.7	787	93	33	34
109	12.5	0.25	4.7	22.8	-26.5	49.3	13.3	-15.4	14.5	-17.1	771	93	31	36
110	12	0.25	4.57	22	-26	48	12.9	-8.8	13.9	-16.8	815	96	34	33
111	13.1	0.25	4.89	23.9	-27.7	51.6	13.7	-16.1	15	-18	738	93	28	40
112	11.1	0.25	4.22	22.2	-22.1	44.3	10.5	-6.4	14.8	-13.7	808	93	36	28
113	13.3	0.25	4.94	23.9	-28.2	52.1	13.5	-16.5	14.9	-18.4	739	96	28	41
114	12.8	0.25	4.71	23.6	-26.9	50.6	13.6	-8.6	14.8	-17	796	93	32	34
115	11.6	0.25	4.37	22.9	-23.4	46.3	10.2	-6.9	15	-14.6	813	93	35	30
116	12	0.25	4.48	23.5	-24.1	47.6	14.3	-7.1	15.2	-15.1	806	92	33	32
117	11.9	0.25	4.41	23.5	-23.3	46.8	14.4	-6.8	15.3	-14.6	798	91	33	31
118	12.7	0.26	4.53	24.2	-24.4	48.6	14.5	-13.3	15.6	-15.2	741	88	30	34
119	13.7	0.26	4.92	24.2	-28	52.1	14.9	-16.2	14.9	-18.3	718	97	29	40
120	12.7	0.27	4.44	23.8	-23.9	47.7	13.9	-7	15.1	-15.1	782	93	33	34
121	12.4	0.27	4.15	24.6	-20.6	45.3	14.9	-4.9	15.9	-12.5	797	97	32	32
122	13.1	0.26	4.79	24.3	-26.8	51.1	15.6	-16.8	15.6	-16.8	738	98	32	38
123	13.6	0.28	4.52	24.5	-24.6	49	14	-6.9	15.3	-15.4	790	99	34	35
124	13.2	0.27	4.53	24.2	-24.5	48.7	14	-13.3	15.3	-15.4	796	100	33	38
125	12.8	0.26	4.74	23.7	-26.1	49.8	15.3	-14.6	15.3	-16.8	775	102	31	43
126	12	0.26	4.43	25.2	-21.5	46.6	17.1	-13.2	17.1	-13.2	724	101	20	50
130	10	0.26	3.67	26.5	-11.9	38.3	18.1	-5.5	18.9	-6.4	800	89	46	18

Prov	Climate Variables													
	precipwettq	precipdryq	precipwarmq	precipcoldq	daystart	dayend	daygrow	tprecipp1	tprecipp2	tprecipp3	tprecipp4	ggdp3	annmtemp	annmintemp
1	278	182	267	206	106	317	212	187.8	102.5	586.7	484.2	1885	6.04	1.01
2	288	200	288	223	111	308	198	200.7	111.4	585.4	474	1635	4.69	-0.8
3	287	198	287	221	111	307	197	199.4	112.1	581.5	469.4	1625	4.6	-0.96
4	309	193	309	211	117	299	183	193.2	125.3	579.2	453.9	1420	3.37	-2.64
5	274	194	274	217	110	311	202	195.7	109.5	574.9	465.4	1727	5	-0.48
6	259	188	259	210	108	314	207	189.1	106.9	564.6	457.7	1807	5.39	-0.13
7	286	197	286	217	114	302	189	198.9	117.6	561.4	443.8	1543	3.91	-1.89
8	301	198	301	217	117	298	182	201.5	123.4	567.2	443.8	1408	3.19	-2.73
9	275	200	275	222	112	305	194	201.4	114.9	559.8	444.9	1618	4.42	-1.22
10	256	177	245	197	106	318	213	180.5	101.4	557.9	456.5	1895	6.24	1.07
11	248	176	242	194	107	317	211	179.9	99.8	537.7	437.9	1864	5.89	0.68
12	249	183	248	201	109	313	205	186.3	103	532.2	429.1	1781	5.3	-0.1
13	265	199	265	219	112	305	194	201.4	111	539.4	428.4	1611	4.41	-1.04
14	276	181	276	197	114	302	189	184.9	109.7	533.6	423.9	1555	3.93	-1.92
15	265	187	265	206	112	304	193	189.4	107.6	527.6	420	1627	4.41	-1.31
16	294	178	294	198	118	300	183	180.9	111.1	542.4	431.3	1414	3.1	-2.83
17	238	176	234	193	108	313	206	179.4	100.3	514.2	413.9	1788	5.45	0.05
18	236	176	235	194	108	312	205	178.7	99.9	510.5	410.5	1787	5.35	-0.22
19	277	189	277	208	115	302	188	191.1	109.8	530.8	420.9	1505	3.67	-2.05
20	305	176	303	203	121	300	180	177.8	109.7	541.7	432	1338	2.58	-3.22
21	254	193	254	213	112	305	194	193.9	105.9	513.8	407.8	1628	4.49	-1.13
22	276	179	276	200	115	302	188	182.1	108.4	530	421.6	1489	3.6	-2.12
23	229	163	228	183	108	310	203	168	98	493.4	395.4	1760	5.22	-0.46
24	237	174	209	193	107	315	209	178.5	100.3	498.6	398.4	1779	5.68	0.34
25	239	159	239	180	109	307	199	164.1	100	500	400	1724	4.94	-0.85
26	266	197	266	216	113	303	191	197.5	108.7	524.2	415.5	1577	4.13	-1.52
27	277	172	277	192	116	302	187	176.5	108.4	528.5	420.1	1473	3.5	-2.22
28	245	152	245	173	110	306	197	158.2	102.2	507	404.7	1709	4.82	-1.02
29	260	201	201	229	105	321	217	203.6	105.5	524	418.4	1893	6.69	1.69
30	252	199	219	222	110	308	199	201.3	105	490.7	385.7	1670	5.01	-0.58
31	248	154	248	170	111	305	195	161.6	103	505.3	402.4	1631	4.5	-1.29
32	226	162	226	181	112	302	191	170.8	97.4	459.6	362.2	1580	4.46	-1.44
33	239	147	239	163	111	304	194	155.5	99.4	484.6	385.2	1627	4.54	-1.47
34	247	157	247	169	112	305	194	165.2	104	501.4	397.4	1626	4.49	-1.24
35	256	156	256	171	114	303	190	162.7	103	502.1	399.1	1570	4.1	-1.81
36	239	155	239	169	116	299	184	166.1	103.6	467.1	363.5	1482	4.04	-2.09
37	236	187	213	201	109	316	208	189	101.1	496.5	395.4	1742	5.77	0.37
38	250	174	243	187	116	300	185	179	107	483.9	376.8	1503	4.28	-1.72
39	232	182	218	196	108	317	210	184.4	99.3	501.8	402.5	1764	5.93	0.59
40	247	183	239	196	113	303	191	184.1	105.6	491.8	386.2	1576	4.69	-1.16
41	235	182	223	196	108	319	212	186.4	100.6	515.7	415.1	1752	6.16	1.24
42	271	179	267	198	118	299	182	180	110.1	512.2	402.2	1421	3.67	-2.41

Prov	Climate Variables													
	precipwettq	precipdryq	precipwarmq	precipcoldq	daystart	dayend	daygrow	tprecipp1	tprecipp2	tprecipp3	tprecipp4	ggdp3	annmtemp	annmintemp
43	242	186	235	204	110	314	205	186.3	103.3	516.9	413.6	1722	5.52	0.02
44	311	170	304	181	126	298	173	174.6	118.4	544.7	426.4	1258	1.86	-4.18
45	292	186	284	206	121	298	178	188	115.2	532.2	417	1338	3.12	-2.89
46	280	166	273	183	117	304	188	168.9	103.9	528.7	424.8	1534	4.01	-2.13
47	303	196	290	220	119	299	181	198.3	116.5	559	442.6	1337	3.17	-2.74
48	322	129	307	139	131	292	162	139.7	125.8	529.9	404.1	1031	-0.12	-6.21
49	308	180	299	191	121	301	181	184.6	110.8	553.4	442.6	1368	2.87	-2.97
50	296	173	284	187	116	304	189	175.9	105.9	556.9	451	1500	3.88	-2.06
51	306	181	299	192	123	300	178	185.8	113.4	546.3	432.9	1326	2.46	-3.4
52	305	177	293	189	118	303	186	180.9	108.9	563.2	454.2	1433	3.45	-2.38
53	251	186	244	210	109	317	209	187.2	105.2	548.9	443.7	1725	5.75	0.5
54	304	209	260	264	113	308	196	214.9	115.3	568.7	453.4	1539	4.62	-1.07
55	298	172	293	182	123	300	178	178	113.2	536.5	423.4	1321	2.25	-3.62
56	307	178	296	188	118	303	186	182.2	107	561.4	454.4	1418	3.22	-2.48
57	297	175	291	185	123	300	178	180.7	112.4	533.1	420.7	1335	2.39	-3.46
58	328	223	278	277	115	302	188	227.6	117.8	582.5	464.7	1427	3.91	-1.9
59	303	180	293	189	119	302	184	183.8	106.8	549.2	442.4	1398	2.98	-2.71
60	302	172	287	184	115	305	191	176.1	107.3	574.1	466.9	1525	3.97	-1.68
61	245	168	243	181	108	319	212	170.9	100.9	536.6	435.6	1774	6.21	1.26
62	306	173	288	187	115	305	191	177.9	110	584.7	474.7	1510	3.96	-1.58
63	307	140	292	152	127	295	169	145.6	120.3	527.4	407.2	1204	1.17	-4.98
64	318	213	283	262	116	301	186	216.6	117	582.1	465.1	1391	3.58	-2.14
65	320	217	272	282	115	302	188	222.5	115.3	573.8	458.6	1450	4.05	-1.83
66	295	150	287	164	126	296	171	154.5	117.1	513.8	396.7	1220	1.28	-4.76
67	266	150	266	156	121	302	182	155.5	104.4	494.3	389.9	1404	2.5	-3.26
68	267	154	265	161	120	303	184	162.1	103.9	499.7	395.9	1420	2.79	-2.83
69	318	217	283	257	118	299	182	219.9	119.9	564.3	444.4	1351	3.45	-2.42
70	275	167	267	174	120	302	183	174.2	106	507.6	401.5	1405	2.8	-2.7
71	335	211	253	303	114	311	198	220.4	109.6	581.8	472.2	1524	4.48	-1.04
72	263	154	260	164	122	298	177	155.7	103.7	472.9	369.2	1353	2.01	-4.03
73	289	197	252	254	114	310	197	202	107	561.2	454.1	1548	4.34	-1.12
74	259	180	255	190	110	317	208	186.2	102.2	548.8	446.6	1650	5.65	0.61
75	288	201	262	251	113	315	203	206.6	102.3	577.1	474.8	1559	5.18	0.61
76	274	154	269	172	125	297	173	156.5	110	480.8	370.8	1279	1.57	-4.47
77	286	140	279	165	127	296	170	143.3	112	487.7	375.7	1214	1.11	-5.05
78	309	212	256	288	108	323	216	229	101.2	608	506.8	1723	6.32	1.61
79	286	140	279	158	130	295	166	145.5	112.1	477.4	365.2	1151	0.58	-5.7
80	241	121	235	133	132	293	162	125.7	97.3	401.5	304.3	1105	0.08	-6.36
81	277	141	272	157	129	296	168	145.7	109.6	469.9	360.4	1205	0.88	-5.43
82	276	150	276	166	128	296	169	154.6	114.7	477.8	363.1	1211	1.07	-5.26
83	263	173	214	233	116	325	210	177.4	89.2	524.5	435.3	1492	5.62	1.47
84	272	170	220	185	115	301	187	169.9	98.2	482.2	384	1482	3.94	-2.08
85	272	142	269	152	129	296	168	147.3	111.2	467.6	356.4	1205	0.88	-5.42
86	278	171	219	191	113	310	198	172.2	100	515.2	415.3	1547	4.48	-0.73
87	275	145	272	154	131	294	164	151.7	113	465.3	352.3	1127	0.3	-5.88

Prov	Climate Variables													
	precipwettq	precipdryq	precipwarmq	precipcoldq	daystart	dayend	daygrow	tprecipp1	tprecipp2	tprecipp3	tprecipp4	ggdp3	annmtemp	annmintemp
88	248	158	204	179	113	318	206	157.8	91.1	490.2	399.2	1574	5.15	0.25
89	251	153	216	170	112	315	204	154.7	94.6	500.2	405.6	1606	5.19	0.03
90	236	127	232	136	135	292	158	133.2	99.1	387	287.9	1049	-0.2	-6.7
91	309	185	272	242	125	298	174	187.2	110.2	533.8	423.6	1112	2.04	-3.6
92	271	140	261	158	131	293	163	146.5	111.2	454.8	343.6	1005	0.04	-6.45
93	262	132	250	151	129	296	168	136.7	106.5	448.3	341.8	1114	0.91	-5.7
94	242	121	236	133	132	293	162	125.3	97.4	402	304.6	1121	0.13	-6.29
95	262	139	251	164	126	295	170	141.4	103.8	455.4	351.6	1197	1.34	-4.91
96	264	149	255	178	122	295	174	150.5	100.9	472.7	371.8	1252	1.78	-4.01
97	259	138	251	164	128	295	168	140.2	103.3	450.1	346.8	1093	0.71	-5.3
98	257	126	252	141	130	294	165	130.2	104.8	439.3	334.5	1065	0.22	-5.91
99	262	155	251	184	123	299	177	156.7	99.2	476.3	377.1	1063	1.81	-3.49
100	259	111	256	117	132	293	162	119.6	107.7	434.2	326.5	1080	-0.19	-6.52
101	266	96	262	102	134	292	159	113.5	110	434.5	324.5	1081	-0.64	-7.17
102	267	106	266	112	133	293	161	120.4	115	447.8	332.8	1028	-0.41	-6.68
103	273	83	265	90	135	291	157	106.6	107.8	432.9	325.2	1053	-0.97	-7.44
104	266	127	263	148	129	296	168	133	115.3	474	358.7	952	0.46	-5.07
105	271	88	265	95	134	292	159	109.6	109.3	438.6	329.3	1064	-0.73	-7.23
106	283	179	219	255	112	325	214	187.7	86.9	537.9	451	1593	6.01	1.68
107	267	133	248	169	127	301	175	137.1	111.3	480.8	369.6	991	1.59	-3.45
108	272	118	271	128	132	293	162	128	119	464.1	345.1	961	-0.22	-6.18
109	272	111	270	120	132	292	161	122.6	116.2	458	341.8	1010	-0.23	-6.46
110	279	122	277	137	132	291	160	131.7	120.4	470.3	349.8	946	-0.35	-6.37
111	272	98	268	107	132	291	160	114.5	110.2	446.8	336.6	1065	-0.36	-6.91
112	263	124	254	157	126	299	174	128	107.7	475.3	367.6	1128	1.64	-3.93
113	276	97	272	105	133	290	158	116	110.4	445.7	335.3	1037	-0.65	-7.28
114	275	117	273	131	131	290	160	125.3	115.1	460.2	345.1	1053	-0.02	-6.44
115	266	122	262	150	128	297	170	126.7	110.6	474.5	363.9	1128	1.24	-4.58
116	267	118	265	144	129	296	168	123.8	110.8	470.2	359.4	1145	1.15	-4.85
117	265	121	263	142	128	296	169	126.4	109.4	467	357.6	1155	1.36	-4.58
118	257	115	257	117	129	294	166	124.1	108.1	443.3	335.2	1176	1.21	-5.12
119	270	103	270	103	133	290	158	121.4	109	432.4	323.3	1048	-0.52	-7.37
120	275	125	272	127	130	292	163	134.4	115.7	462.9	347.1	1104	0.92	-5.44
121	276	128	270	135	125	296	172	131.9	110.9	482.8	371.9	1270	2.54	-3.66
122	269	109	269	109	129	292	164	124.3	112	453.2	341.2	1157	0.39	-6.14
123	282	123	279	128	131	291	161	132.2	118.7	468.9	350.2	1137	0.97	-5.83
124	290	120	289	120	130	292	163	129.8	121.3	487.3	365.9	1149	0.98	-5.65
125	295	104	295	107	130	294	165	120.2	125.1	500.3	375.2	1143	0.47	-5.94
126	292	77	292	77	119	299	181	103	110	516.9	406.9	1464	2.95	-3.05
130	239	155	237	166	107	321	215	157.6	92.4	516	423.7	1842	6.65	1.63

Prov	Climate Variables													
	annmaxtemp	mtempp3	tempranp3	janmintemp	febmintemp	marmintemp	aprmintemp	maymintemp	junmintemp	julmintemp	augmintemp	sepmintemp	octmintemp	novmintemp
1	11.08	14.25	28.08	-14.76	-13.74	-7.1	0.78	6.96	11.92	14.84	13.68	9.21	3.45	-2.09
2	10.18	13.74	27.2	-17.47	-16.29	-9.03	-1.04	5.35	10.41	13.24	12.16	7.59	2.01	-3.48
3	10.17	13.73	27.21	-17.74	-16.56	-9.23	-1.18	5.21	10.27	13.1	12.04	7.46	1.9	-3.57
4	9.38	13.22	26.42	-19.82	-18.81	-11.17	-2.78	3.55	8.78	11.53	10.49	6.03	0.66	-4.95
5	10.47	13.92	27.62	-17.25	-16.05	-8.74	-0.72	5.74	10.79	13.61	12.53	7.93	2.32	-3.12
6	10.9	14.15	28.26	-17.05	-15.81	-8.37	-0.34	6.13	11.26	14.04	12.94	8.31	2.66	-2.75
7	9.71	13.56	26.91	-19.1	-17.95	-10.41	-2.03	4.42	9.53	12.33	11.32	6.75	1.23	-4.32
8	9.11	13.18	26.11	-20.06	-19	-11.41	-2.85	3.59	8.79	11.56	10.56	6.02	0.59	-5.06
9	10.05	13.81	27.27	-18.26	-17.08	-9.64	-1.43	5.08	10.15	12.95	11.9	7.32	1.76	-3.76
10	11.41	14.25	28.22	-14.53	-13.76	-6.91	0.62	6.89	11.86	14.8	13.67	9.13	3.44	-1.83
11	11.1	14.19	28.31	-15.34	-14.47	-7.4	0.31	6.71	11.76	14.6	13.43	8.88	3.2	-2.19
12	10.7	14.08	27.97	-16.69	-15.65	-8.34	-0.38	6.12	11.2	13.98	12.83	8.28	2.63	-2.88
13	9.87	13.76	27.01	-17.78	-16.73	-9.45	-1.32	5.25	10.31	13.06	11.94	7.42	1.86	-3.76
14	9.78	13.66	26.95	-19.34	-18.17	-10.6	-2.04	4.39	9.61	12.41	11.4	6.86	1.36	-4.37
15	10.14	13.92	27.3	-18.53	-17.34	-9.85	-1.47	5	10.13	12.94	11.88	7.35	1.78	-3.89
16	9.04	13.2	26.16	-20.54	-19.51	-11.97	-3.02	3.41	8.94	11.7	10.69	6.21	0.99	-5.11
17	10.86	14.08	27.99	-16.27	-15.39	-8.15	-0.24	6.18	11.14	14	12.86	8.38	2.7	-2.77
18	10.91	14.12	28.17	-16.88	-15.85	-8.48	-0.42	5.99	10.96	13.82	12.7	8.24	2.54	-3
19	9.39	13.43	26.67	-19.39	-18.21	-10.84	-2.27	4.26	9.43	12.24	11.18	6.74	1.3	-4.65
20	8.39	12.86	25.54	-21.05	-20.06	-12.75	-3.58	2.9	8.67	11.42	10.37	6	1.01	-5.5
21	10.12	13.87	27.37	-18.09	-16.96	-9.6	-1.33	5.17	10.14	12.98	11.86	7.44	1.84	-3.9
22	9.32	13.39	26.62	-19.54	-18.28	-11.02	-2.36	4.16	9.36	12.2	11.13	6.75	1.36	-4.74
23	10.91	14.08	28.14	-17.06	-16.1	-8.7	-0.62	5.75	10.62	13.5	12.35	8	2.31	-3.23
24	11.02	13.89	28.04	-14.95	-14.71	-7.73	-0.04	6.19	10.98	13.92	12.83	8.56	2.82	-2.46
25	10.73	14.07	27.97	-17.81	-16.63	-9.19	-0.99	5.41	10.28	13.17	12.03	7.72	2.06	-3.62
26	9.77	13.69	26.95	-18.62	-17.48	-10.1	-1.73	4.8	9.86	12.67	11.58	7.12	1.58	-4.21
27	9.22	13.35	26.57	-19.67	-18.37	-11.22	-2.5	4.02	9.25	12.12	11.07	6.73	1.38	-4.82
28	10.67	14.08	27.9	-18.15	-16.84	-9.43	-1.15	5.22	10.14	13.06	11.92	7.63	2.02	-3.72
29	11.69	14.09	28	-12.54	-12.58	-6.14	0.91	6.87	11.72	14.82	13.9	9.82	3.93	-1.1
30	10.6	13.81	27.85	-15.63	-15.78	-8.69	-0.79	5.53	10.24	12.96	11.79	7.63	1.85	-3.38
31	10.3	13.85	27.65	-18.39	-16.96	-9.82	-1.48	4.89	9.86	12.8	11.7	7.41	1.88	-3.92
32	10.37	13.74	27.58	-17.25	-16.93	-9.5	-1.62	4.71	9.51	12.24	10.98	6.84	1.2	-4.02
33	10.55	13.88	27.84	-18.5	-17.22	-9.78	-1.56	4.67	9.61	12.5	11.31	7.13	1.67	-3.9
34	10.23	13.85	27.56	-18.22	-16.72	-9.77	-1.5	4.89	9.85	12.82	11.77	7.46	1.9	-3.88
35	10.01	13.69	27.35	-18.96	-17.5	-10.54	-2.18	4.21	9.29	12.29	11.36	7.09	1.59	-4.29
36	10.18	13.56	27.03	-18.32	-17.5	-10.03	-2.51	3.86	8.81	11.62	10.37	6.27	0.67	-4.46
37	11.18	13.73	27.66	-14.39	-14.11	-7.41	-0.34	5.9	10.73	13.64	12.52	8.42	2.55	-2.31
38	10.29	13.61	26.83	-17.6	-16.82	-9.62	-2.39	4.08	9.04	11.87	10.68	6.57	0.83	-4.19
39	11.28	13.78	27.65	-14.11	-13.71	-7.23	-0.19	6.12	10.92	13.81	12.63	8.57	2.74	-2.08
40	10.54	13.69	26.96	-16.72	-16.07	-9.1	-1.86	4.61	9.53	12.33	11.15	7.07	1.31	-3.65
41	11.08	13.61	26.93	-12.68	-12.3	-6.47	0.32	6.43	11.11	14.09	13.07	9	3.19	-1.53
42	9.75	13.26	26.58	-18.65	-17.71	-10.84	-2.95	3.43	8.34	11.14	10.21	6.18	0.65	-4.74

Prov	Climate Variables													
	annmaxtemp	mtempp3	tempranp3	janmintemp	febmintemp	marmintemp	aprmintemp	maymintemp	junmintemp	julmintemp	augmintemp	sepmintemp	octmintemp	novmintemp
43	11.02	13.77	27.63	-15.06	-14.47	-8.14	-0.7	5.75	10.55	13.32	12.13	8.11	2.38	-2.57
44	7.91	12.75	25.72	-22.54	-21.29	-14.23	-4.54	2.3	7.61	10.76	9.76	5.61	0.55	-6.5
45	9.13	12.98	26.12	-19.23	-18.4	-11.72	-3.42	2.91	7.84	10.72	9.92	5.93	0.53	-5.16
46	10.16	13.58	27.47	-18.71	-18.16	-11.28	-2.72	3.3	8.49	11.61	11.02	7.07	1.71	-4.12
47	9.08	12.86	26.04	-18.87	-18.2	-11.68	-3.23	3.03	7.89	10.76	9.99	6.07	0.71	-5.01
48	5.97	11.77	24.65	-25.45	-24.08	-17.12	-6.58	0.94	6.04	9.31	8.2	4.25	-0.78	-8.42
49	8.7	12.97	26.13	-20.03	-19.41	-12.6	-3.55	2.84	8.03	11.22	10.45	6.51	1.3	-5.1
50	9.82	13.4	27	-18.47	-18.12	-11.39	-2.65	3.36	8.52	11.67	11.03	7.18	1.87	-4.05
51	8.32	12.86	25.92	-21	-20.08	-13.16	-3.95	2.7	7.9	11.11	10.27	6.22	1.06	-5.61
52	9.27	13.15	26.59	-18.92	-18.5	-11.81	-2.95	3.2	8.34	11.5	10.78	6.91	1.62	-4.44
53	11.01	13.6	27.52	-14.17	-13.48	-7.71	-0.39	5.82	10.56	13.44	12.5	8.55	2.87	-2.04
54	10.31	13.28	26.57	-16.46	-15.84	-9.7	-1.82	4.49	9.28	12.01	11.25	7.38	1.86	-3.32
55	8.13	12.83	25.92	-21.79	-20.59	-13.54	-4.16	2.74	8.01	11.25	10.28	6.06	1.02	-5.86
56	8.93	13.06	26.43	-19.48	-18.78	-12.03	-3.04	3.36	8.5	11.71	10.87	6.92	1.64	-4.68
57	8.24	12.9	25.9	-21.44	-20.32	-13.31	-4.02	2.82	8.04	11.29	10.37	6.21	1.1	-5.7
58	9.71	13.02	26.32	-17.53	-16.76	-10.57	-2.35	3.85	8.47	11.25	10.5	6.6	1.17	-4.24
59	8.66	13.01	26.19	-20.08	-19.16	-12.33	-3.27	3.34	8.46	11.71	10.82	6.8	1.53	-4.98
60	9.62	13.39	26.76	-18.3	-17.48	-10.89	-2.17	4.1	9.12	12.26	11.39	7.43	2.01	-3.92
61	11.16	13.69	27.49	-12.68	-12.04	-6.56	0.17	6.21	11.01	13.89	12.97	9.02	3.33	-1.47
62	9.51	13.32	26.61	-18.18	-17.15	-10.66	-2.03	4.33	9.25	12.35	11.4	7.38	1.93	-3.92
63	7.32	12.57	25.7	-24.23	-22.64	-15.15	-4.89	2.07	7.12	10.37	9.23	5.08	0.02	-7.39
64	9.31	12.91	26.18	-18.19	-17.09	-10.8	-2.55	3.74	8.37	11.26	10.46	6.39	0.99	-4.38
65	9.92	13.17	26.54	-17.68	-16.57	-10.3	-2.27	3.9	8.49	11.38	10.69	6.61	1.18	-3.96
66	7.33	12.6	25.5	-23.99	-22.54	-15.09	-4.79	2.28	7.49	10.72	9.52	5.23	0.25	-7.16
67	8.26	13.16	26.3	-22.32	-20.66	-13.42	-3.89	3.44	8.99	12.26	10.95	6.27	1.55	-5.44
68	8.42	13.19	26.28	-21.47	-19.89	-12.82	-3.6	3.67	9.14	12.44	11.21	6.64	1.79	-5.02
69	9.31	12.9	25.92	-18.12	-17.46	-11.13	-2.87	3.43	8.12	10.82	9.99	6.13	0.71	-4.84
70	8.3	13.13	25.93	-20.98	-19.49	-12.53	-3.35	3.83	9.13	12.39	11.15	6.68	1.68	-5.04
71	10	13.05	26.61	-16.79	-15.79	-9.64	-1.74	4.41	9.15	12.27	11.58	7.47	2.08	-3.14
72	8.06	13.08	26.13	-23.23	-21.83	-14.31	-4.01	3.07	8.35	11.55	10.27	5.77	0.79	-6.5
73	9.8	13.22	26.69	-17.56	-16.39	-9.95	-1.72	4.62	9.49	12.65	11.79	7.6	2.23	-3.33
74	10.69	13.3	26.87	-12.94	-12.44	-7.3	-0.44	5.53	10.26	12.78	11.84	8.19	2.73	-1.9
75	9.74	13.01	25.77	-12.3	-12.79	-7.94	-0.63	5.26	10.1	12.97	12.27	8.67	3.14	-2.17
76	7.62	12.86	25.79	-23.72	-22.42	-14.97	-4.55	2.71	7.91	11.19	9.9	5.52	0.52	-6.93
77	7.27	12.61	25.62	-24.39	-23.17	-15.7	-5.17	2.15	7.27	10.63	9.41	5.18	0.26	-7.42
78	11.02	13.32	26.74	-10.89	-11.33	-6.65	0.22	5.54	10.4	13.47	12.96	9.52	4.18	-0.62
79	6.86	12.34	25.49	-24.89	-23.81	-16.49	-6.19	1.44	6.47	10	8.79	4.63	-0.04	-7.96
80	6.51	12.27	25.24	-25.75	-24.8	-17.68	-6.44	0.81	6.62	9.8	8.32	4.02	-0.62	-9.75
81	7.19	12.62	25.86	-24.85	-23.71	-16.36	-5.96	1.71	6.94	10.42	9.18	5.02	0.19	-7.7
82	7.4	12.61	25.75	-24.57	-23.34	-16.02	-5.66	1.9	7.04	10.4	9.05	4.93	0.14	-7.5
83	9.76	12.43	24.31	-10.91	-11.57	-6.87	-0.73	3.99	8.86	13.28	13.55	10.02	5.05	-0.14
84	9.95	13.36	27.62	-18.26	-17.12	-10.44	-2.39	3.8	8	11.64	10.69	6.37	1.14	-4.68
85	7.18	12.62	25.75	-24.96	-23.82	-16.52	-5.92	1.65	7.11	10.46	9.2	5.13	0.13	-7.81
86	9.69	13.19	26.54	-16.21	-16.2	-9.97	-1.4	4.69	9.44	12.94	12.05	8.16	2.82	-3.31
87	6.49	12.25	25.08	-25.31	-24.21	-17.02	-6.4	1.16	6.74	10.04	8.82	4.72	-0.33	-8.53

Prov	Climate Variables												
	annmaxtemp	mtempp3	tempranp3	janmintemp	febmintemp	marmintemp	aprmintemp	maymintemp	junmintemp	julmintemp	augmintemp	sepmintemp	octmintemp	novmintemp
88	10.04	13	26.45	-14.49	-14.51	-8.87	-0.95	4.71	9.47	13.26	12.76	9.14	3.76	-1.78
89	10.35	13.27	27.1	-14.73	-14.81	-9.03	-0.89	4.79	9.46	13.26	12.58	8.85	3.28	-2.32
90	6.3	12.06	24.74	-25.77	-24.81	-17.83	-6.71	0.09	5.99	8.94	7.84	3.75	-0.97	-10.18
91	7.68	11.8	23.45	-20.7	-18.26	-12.35	-4.17	2.3	5.77	9.41	10.02	6.07	0.58	-5.79
92	6.52	11.56	24.41	-25.73	-24.45	-17.28	-6.79	0.92	5.91	8.81	7.42	3.11	-0.78	-8.57
93	7.53	12.13	25.11	-24.69	-24	-16.54	-6.03	1.59	6.64	9.46	8.26	4.04	-0.03	-7.95
94	6.56	12.33	25.24	-25.68	-24.74	-17.61	-6.38	0.88	6.68	9.88	8.39	4.09	-0.57	-9.7
95	7.59	12.47	25.34	-22.92	-22.72	-15.29	-5.11	2.29	7.26	10.37	9.2	4.92	0.02	-8.01
96	7.56	12.64	25.7	-20.79	-21.16	-13.81	-4.1	3.05	7.85	11.28	10.23	5.92	0.03	-8.05
97	6.72	11.98	24.57	-23.53	-22.89	-15.86	-5.34	1.68	6.76	10.06	9.01	4.81	-0.17	-8.7
98	6.34	11.92	24.44	-24.81	-23.9	-16.98	-6	1.14	6.55	9.91	8.66	4.43	-0.35	-9.31
99	7.12	11.44	22.26	-19.82	-19.05	-12.66	-3.48	2.43	6.37	9.72	10.07	6.27	1.02	-6.49
100	6.13	12.11	24.96	-26.28	-25.13	-18.29	-6.72	0.73	6.59	10.1	8.42	4.07	-0.57	-10.03
101	5.89	12.26	25.66	-27.68	-26.34	-19.54	-7.5	0.36	6.63	10.28	8.15	3.62	-0.92	-10.81
102	5.86	11.81	24.78	-26.55	-25.08	-18.31	-6.98	0.61	6.27	9.82	8.23	3.84	-0.76	-10.02
103	5.51	12.15	25.5	-28.28	-26.7	-19.9	-7.97	0.18	6.5	10.2	8.16	3.47	-1.17	-11.08
104	6	11.06	22.23	-23.32	-21.8	-15.06	-5.41	1.35	5.86	9.18	8.93	4.99	0.24	-7.72
105	5.77	12.13	25.72	-27.95	-26.26	-19.45	-7.69	0.36	6.48	10.16	8.2	3.55	-1.07	-10.77
106	10.33	12.78	25.04	-10.82	-11.4	-6.72	-0.24	4.65	9.54	13.57	13.6	10.09	4.96	-0.11
107	6.63	11.08	21.37	-20.41	-19.21	-12.44	-3.82	2.2	6.18	9.38	9.97	6.4	1.52	-5.73
108	5.74	11.33	23.54	-25.52	-23.69	-16.96	-6.59	0.82	5.83	9.3	8.33	4.05	-0.62	-9.11
109	6	11.69	24.58	-26.5	-24.22	-17.43	-6.94	0.84	5.98	9.56	8.33	3.83	-0.88	-9.42
110	5.67	11.3	23.74	-25.98	-23.62	-16.9	-6.94	0.75	5.61	9.14	8.14	3.7	-1	-9.14
111	6.19	12.09	25.72	-27.71	-25.22	-18.3	-7.44	0.73	6.18	9.87	8.29	3.56	-1.16	-10.07
112	7.21	11.89	23.95	-22.08	-20.06	-13.22	-4.52	2.11	6.68	10.16	9.93	5.82	0.91	-6.37
113	5.98	12	25.83	-28.21	-25.73	-18.74	-7.85	0.47	5.96	9.67	8.02	3.2	-1.48	-10.5
114	6.4	11.99	25.45	-26.94	-23.81	-16.93	-7.08	1.01	5.92	9.62	8.35	3.59	-1.2	-9.22
115	7.05	12.02	24.74	-23.42	-21.03	-14.07	-5.23	1.73	6.56	10.13	9.54	5.2	0.33	-7.09
116	7.15	12.26	25.32	-24.14	-21.56	-14.44	-5.5	1.58	6.61	10.24	9.46	4.99	0.12	-7.42
117	7.29	12.29	25.22	-23.3	-20.97	-13.84	-5.17	1.61	6.69	10.32	9.49	5.01	0.2	-7.34
118	7.54	12.59	25.97	-24.4	-21.82	-14.5	-5.41	1.55	6.68	10.38	9.12	4.42	-0.29	-8.47
119	6.33	12.1	26.09	-27.98	-25.97	-18.27	-7.66	0.45	5.79	9.58	7.81	2.96	-1.56	-11.21
120	7.28	12.21	25.68	-23.89	-21.49	-14.51	-5.59	1.01	6.15	9.61	8.3	3.64	-0.95	-8.8
121	8.75	12.8	26.51	-20.62	-18.2	-11.8	-3.99	2.14	6.84	10.62	9.49	4.81	0.11	-6.93
122	6.92	12.49	26.2	-26.83	-23.63	-16.09	-6.22	1.6	6.79	10.74	8.71	3.63	-1	-10.62
123	7.76	12.51	26.32	-24.57	-21.77	-15.04	-5.75	0.92	5.97	9.2	7.95	3.33	-1.2	-9.18
124	7.6	12.47	26.11	-24.45	-21.73	-14.92	-5.67	1.12	6.24	9.58	8.25	3.7	-0.97	-9.15
125	6.88	12.36	25.48	-26.06	-23.65	-15.9	-5.97	1.25	6.94	10.31	8.44	3.97	-0.43	-9.57
126	8.95	13.52	27.01	-21.45	-19.04	-11.7	-3.23	3.36	8.65	12.16	11.06	6.43	1.08	-7.03
130	11.67	13.98	28.08	-11.88	-11.55	-6.09	0.41	6.28	11.22	14.06	13.16	9.35	3.69	-1.02

Prov	Climate Variables													
	decmintemp	janmaxtemp	febmaxtemp	marmaxtemp	aprmaxtemp	maymaxtemp	junmaxtemp	julmaxtemp	augmaxtemp	sepmaxtemp	octmaxtemp	novmaxtemp	decmaxtemp	janprecip
1	-11.08	-5.28	-4	2.17	11.06	18.57	23.31	26.37	24.86	19.94	13.16	5.45	-2.65	60.7
2	-12.99	-6.67	-4.64	1.7	10.23	18.16	22.86	25.6	23.93	18.78	11.93	4.13	-3.86	70.92
3	-13.18	-6.75	-4.65	1.72	10.23	18.2	22.9	25.61	23.92	18.76	11.9	4.07	-3.92	70.7
4	-15.23	-7.45	-5.21	1.42	9.44	17.63	22.24	24.72	22.88	17.73	10.94	3.09	-4.85	68.4
5	-12.76	-6.59	-4.52	1.83	10.55	18.51	23.3	26.05	24.36	19.21	12.33	4.39	-3.75	68.72
6	-12.56	-6.42	-4.28	2.17	11.03	19.02	23.91	26.64	24.97	19.77	12.85	4.76	-3.63	66.78
7	-14.43	-7.34	-5.1	1.43	9.8	17.94	22.62	25.22	23.45	18.26	11.44	3.41	-4.6	69.08
8	-15.49	-7.81	-5.59	1.04	9.16	17.4	22.02	24.52	22.71	17.52	10.77	2.78	-5.2	68.33
9	-13.62	-7.06	-4.88	1.56	10.13	18.2	22.97	25.64	23.91	18.72	11.87	3.81	-4.26	71.47
10	-10.5	-4.75	-3.46	2.84	11.3	18.66	23.4	26.53	25	20.09	13.36	5.87	-1.96	59.67
11	-11.27	-5.51	-3.98	2.39	11.1	18.68	23.52	26.53	24.99	19.91	13.1	5.28	-2.81	57.95
12	-12.32	-6.29	-4.42	2	10.78	18.6	23.49	26.32	24.74	19.55	12.69	4.57	-3.59	61.49
13	-13.3	-7.05	-5.1	1.27	9.89	17.84	22.69	25.42	23.76	18.59	11.78	3.64	-4.33	68.6
14	-14.54	-7.41	-5.13	1.54	9.9	17.98	22.82	25.34	23.59	18.42	11.63	3.39	-4.69	61.55
15	-13.71	-7.05	-4.85	1.72	10.27	18.25	23.12	25.74	24.06	18.88	12.04	3.75	-4.28	64.73
16	-15.73	-8.18	-5.88	1.05	9.07	17.17	22.27	24.53	22.65	17.6	10.97	2.68	-5.5	61.78
17	-11.9	-5.88	-4.16	2.2	10.93	18.57	23.41	26.38	24.82	19.66	12.8	4.75	-3.17	57.88
18	-12.2	-6.07	-4.14	2.27	11.05	18.76	23.64	26.52	24.96	19.77	12.87	4.61	-3.3	59.08
19	-14.41	-7.74	-5.5	1.08	9.46	17.46	22.44	24.93	23.18	18.06	11.31	2.91	-4.94	65.58
20	-16.12	-8.87	-6.57	0.46	8.31	16.32	21.8	23.87	21.88	16.99	10.5	2.08	-6.07	64.84
21	-13.16	-6.9	-4.82	1.57	10.23	18.08	22.98	25.7	24.09	18.91	12.06	3.65	-4.1	66.64
22	-14.43	-7.9	-5.56	1.06	9.39	17.38	22.45	24.89	23.09	18.02	11.29	2.8	-5.03	62.45
23	-12.31	-6.01	-4.06	2.29	11.06	18.74	23.58	26.51	24.94	19.74	12.84	4.5	-3.25	53.78
24	-11.3	-4.91	-3.7	2.44	10.96	18.27	23	26.3	24.75	19.63	12.82	5.14	-2.47	55.72
25	-12.66	-6.38	-4.2	2.17	10.91	18.68	23.56	26.35	24.77	19.59	12.69	4.15	-3.52	53.47
26	-13.72	-7.29	-5.15	1.32	9.86	17.8	22.71	25.33	23.67	18.51	11.69	3.33	-4.5	68.33
27	-14.6	-8.08	-5.65	1.02	9.29	17.31	22.4	24.82	22.92	17.88	11.2	2.7	-5.19	59.6
28	-12.94	-6.59	-4.23	2.22	10.87	18.72	23.59	26.31	24.63	19.49	12.61	4.08	-3.68	51.81
29	-9.33	-2.96	-2.52	3.24	11.29	18.03	23	26.33	24.99	20.13	13.33	6.3	-0.91	70.28
30	-12.64	-5.47	-4.19	1.94	10.64	18.18	22.84	26.17	24.47	19.16	12.36	4.41	-3.36	65.16
31	-13.5	-7.08	-4.48	2.08	10.49	18.54	23.29	25.96	24.01	18.94	12.15	3.82	-4.16	49.73
32	-13.49	-6.09	-4.35	1.91	10.41	18.27	22.81	25.89	24.08	18.95	12.16	4.1	-3.7	50.19
33	-13.6	-6.7	-4.19	2.3	10.74	18.74	23.42	26.18	24.28	19.2	12.39	4.1	-3.82	46.58
34	-13.54	-7.19	-4.46	2.13	10.42	18.55	23.2	25.89	23.82	18.77	12.01	3.81	-4.24	49.07
35	-14.11	-7.4	-4.62	1.93	10.15	18.22	23.03	25.67	23.64	18.58	11.85	3.52	-4.42	51.46
36	-13.85	-6.35	-4.21	2.12	10.06	18.21	22.57	25.35	23.39	18.65	11.95	4.03	-3.65	49.21
37	-10.81	-4.17	-3.05	2.87	10.83	18.22	22.9	25.9	24.34	19.62	12.97	5.58	-1.82	60.69
38	-13.15	-5.93	-3.97	2.3	10.04	18.2	22.5	25.18	23.26	18.73	12.1	4.3	-3.23	57.79
39	-10.43	-4.15	-2.96	2.9	10.87	18.32	23.03	25.93	24.4	19.74	13.17	5.73	-1.64	59.13
40	-12.46	-5.49	-3.75	2.4	10.26	18.27	22.67	25.38	23.56	19.01	12.4	4.61	-2.85	61.01
41	-9.31	-3.67	-2.73	2.8	10.49	17.55	22.31	25.3	23.96	19.36	12.89	5.88	-1.13	58.01
42	-14.03	-6.76	-4.45	1.77	9.73	17.75	22.19	24.86	22.91	18.14	11.49	3.4	-3.98	64.75

Prov	Climate Variables													
	decmintemp	janmaxtemp	febmaxtemp	marmaxtemp	aprmaxtemp	maymaxtemp	junmaxtemp	julmaxtemp	augmaxtemp	sepmaxtemp	octmaxtemp	novmaxtemp	decmaxtemp	janprecip
43	-11.09	-4.83	-3.45	2.46	10.72	18.44	23.13	25.96	24.32	19.58	12.96	5.16	-2.22	63.67
44	-17.7	-9.3	-7.5	-0.61	7.74	16.1	21.48	23.92	21.91	16.76	10.02	1.23	-6.89	59.83
45	-14.63	-7.43	-5.15	1.06	9.12	17.12	21.75	24.42	22.4	17.48	10.92	2.67	-4.75	67.24
46	-13.82	-6.73	-4.54	1.83	10.11	18.02	23.07	25.73	23.77	18.76	12.32	3.7	-4.17	59.73
47	-14.39	-7.28	-5.23	0.96	9.07	17.01	21.63	24.32	22.27	17.39	10.9	2.69	-4.72	73.21
48	-20.85	-12.41	-9.68	-2.89	5.95	14.68	19.91	22.9	20.86	14.77	7.86	-0.71	-9.62	49.92
49	-15.3	-8.22	-6.24	0.28	8.52	16.74	21.76	24.43	22.38	17.29	10.79	2.3	-5.58	63.8
50	-13.71	-6.84	-4.97	1.38	9.71	17.61	22.68	25.37	23.38	18.4	12.06	3.5	-4.41	62.05
51	-16.22	-8.82	-6.73	-0.1	8.11	16.51	21.49	24.15	22.12	16.92	10.31	1.85	-6.01	63.52
52	-14.23	-7.41	-5.56	0.83	9.12	17.12	22.16	24.86	22.82	17.83	11.44	2.96	-4.93	62.66
53	-9.97	-4.44	-3.23	2.43	10.62	18.03	22.8	25.76	24.26	19.47	12.78	5.28	-1.67	68.63
54	-11.94	-5.42	-3.79	2.07	10.18	17.83	22.28	24.97	23.34	18.67	12.11	4.18	-2.69	91.52
55	-16.85	-9.26	-7.08	-0.37	7.87	16.4	21.46	24.09	22.12	16.81	10.14	1.64	-6.28	60.43
56	-14.78	-7.97	-6.01	0.5	8.77	16.89	21.87	24.61	22.57	17.52	11	2.64	-5.27	63.33
57	-16.57	-9.11	-6.89	-0.21	8	16.52	21.47	24.15	22.17	16.87	10.2	1.78	-6.09	60.97
58	-13.21	-6.19	-4.34	1.67	9.75	17.46	21.8	24.58	22.67	17.84	11.38	3.52	-3.56	97.44
59	-15.35	-8.43	-6.31	0.26	8.49	16.77	21.64	24.42	22.39	17.25	10.62	2.36	-5.51	63.49
60	-13.66	-7.05	-5.15	1.26	9.55	17.38	22.32	25.11	23.12	18.18	11.67	3.48	-4.39	60.55
61	-8.67	-3.92	-3.04	2.55	10.55	17.82	22.81	25.82	24.36	19.57	12.78	5.69	-1.1	57.07
62	-13.63	-7.07	-5.17	1.18	9.45	17.23	22.08	24.92	22.93	17.99	11.44	3.44	-4.33	60.81
63	-19.39	-10.99	-8.11	-1.21	7.44	16.09	20.92	24	21.97	16.08	9.16	0.51	-8.06	52.43
64	-13.94	-6.74	-4.93	1.08	9.24	17.02	21.58	24.44	22.52	17.39	11.01	3.23	-4.07	90.51
65	-13.39	-6.03	-4.21	1.71	9.85	17.54	22.05	24.91	23.1	17.93	11.6	3.87	-3.32	99.61
66	-19.07	-10.74	-8.16	-1.22	7.23	15.86	21.01	23.83	21.8	16.14	9.37	0.63	-7.83	56.34
67	-16.84	-9.74	-7.25	-0.51	7.83	16.46	21.93	24.48	22.66	17.11	10.54	1.94	-6.3	52.87
68	-16.06	-9.36	-6.9	-0.26	8.01	16.57	21.82	24.46	22.63	17.14	10.55	2.19	-5.83	53.71
69	-13.8	-6.71	-4.77	1.34	9.37	17.24	21.53	24.23	22.23	17.51	10.97	2.97	-4.15	88.3
70	-15.84	-9.22	-6.9	-0.31	7.96	16.41	21.52	24.27	22.35	16.96	10.34	2.1	-5.86	57.18
71	-12.33	-5.7	-4.13	1.6	9.72	17.21	21.87	24.89	23.25	18.13	11.8	4.25	-2.9	113.27
72	-18.34	-10.07	-7.57	-0.53	7.82	16.46	21.84	24.51	22.47	17.01	10.36	1.5	-7.1	56.5
73	-12.9	-6.34	-4.64	1.35	9.59	17.2	21.98	25	23.26	18.13	11.66	3.96	-3.5	90.7
74	-8.94	-4.59	-3.56	1.74	10.1	17.51	22.44	25.19	23.91	19.44	12.74	5.15	-1.78	58.86
75	-9.23	-4.62	-4.33	0.9	8.88	16.26	21.16	24.1	22.72	18.33	11.68	4.29	-2.46	84.46
76	-18.82	-10.5	-7.97	-0.85	7.47	16.05	21.43	24.13	22.01	16.45	9.89	0.98	-7.66	59.66
77	-19.61	-11.05	-8.36	-1.17	7.25	15.81	21.17	23.95	21.82	16.1	9.51	0.56	-8.3	57.9
78	-7.43	-3.39	-2.85	2.28	10.18	17.27	22.22	25.11	23.86	19.6	12.96	5.87	-0.9	102.81
79	-20.37	-11.78	-8.93	-1.65	6.92	15.54	21.03	23.82	21.7	15.68	9.07	0.07	-9.16	55.05
80	-20.82	-12.73	-9.37	-1.85	6.92	15.09	20.98	23.6	21.69	15.9	8.48	-1.07	-9.55	46.71
81	-19.99	-11.57	-8.61	-1.3	7.21	15.77	21.42	24.14	22.12	16.13	9.4	0.38	-8.76	54.26
82	-19.44	-11.14	-8.24	-0.95	7.3	15.91	21.49	24.03	21.99	16.23	9.74	0.64	-8.19	55.95
83	-6.85	-3.28	-3.15	1.49	8.22	14.51	19.3	22.62	21.86	17.9	12.17	5.84	-0.32	82.99
84	-13.75	-6.15	-4.62	1.2	9.69	17.49	22.29	25.81	23.78	18.41	11.61	3.69	-3.75	61.91
85	-19.71	-11.55	-8.52	-1.24	7.11	15.56	21.37	23.97	22.09	16.23	9.39	0.29	-8.49	52.72
86	-11.8	-5.91	-4.73	1.17	9.43	16.93	21.51	24.78	22.92	18.01	11.47	3.74	-3.08	61.21
87	-20.21	-12.24	-9.18	-1.95	6.42	14.87	20.66	23.36	21.51	15.58	8.55	-0.56	-9.18	54.29

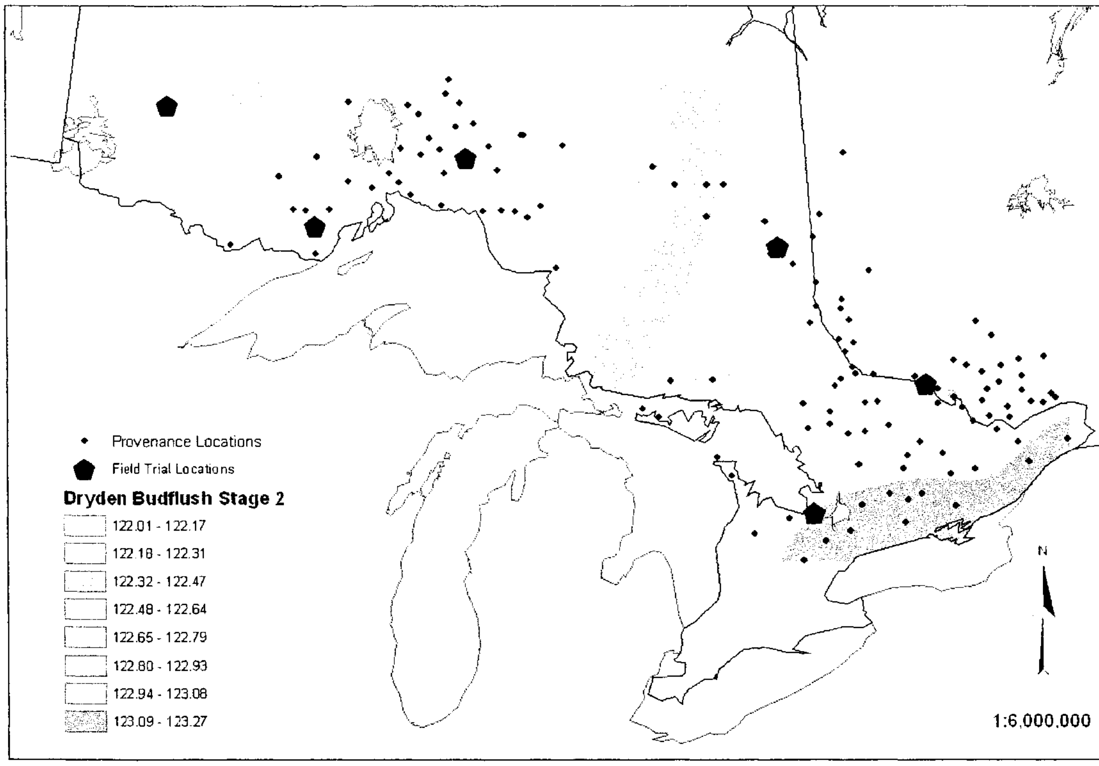
Prov	Climate Variables													
	decmintemp	janmaxtemp	febmaxtemp	marmaxtemp	aprmaxtemp	maymaxtemp	junmaxtemp	julmaxtemp	augmaxtemp	sepmaxtemp	octmaxtemp	novmaxtemp	decmaxtemp	janprecip
88	-9.49	-4.77	-3.85	1.42	9.24	16.14	20.97	24.57	23.03	18.41	12.06	4.95	-1.65	60.27
89	-10.09	-4.65	-3.65	1.75	9.7	16.82	21.64	25.25	23.46	18.74	12.14	4.83	-1.81	55.74
90	-20.69	-13.03	-9.47	-2.04	6.69	14.73	20.81	23.11	21.68	16.1	8.09	-1.49	-9.6	47.3
91	-16.03	-8.1	-5.83	-0.25	7.58	15.33	18.61	21.73	21.01	15.98	9.51	2.02	-5.46	78.57
92	-19.98	-11.39	-8.67	-1.9	6.42	14.92	20.12	22.71	20.97	14.96	8.53	-0.23	-8.16	55.99
93	-19.18	-9.85	-7.48	-0.75	7.44	15.66	20.79	23.36	21.76	15.97	9.58	0.75	-6.93	54.44
94	-20.77	-12.65	-9.3	-1.78	6.98	15.13	21	23.64	21.72	15.94	8.55	-1	-9.5	46.71
95	-18.92	-9.31	-7.3	-0.65	7.79	16.07	20.68	23.68	21.77	15.95	9.14	0.41	-7.17	59.5
96	-18.55	-8.57	-7.07	-0.61	8.06	16.38	20.3	23.78	21.58	15.76	8.53	-0.01	-7.39	65.27
97	-19.46	-10.79	-8.28	-1.35	7.23	15.09	19.84	22.72	20.98	15.42	8.51	-0.41	-8.37	59.16
98	-20.21	-11.97	-9	-1.75	6.84	14.69	19.99	22.74	20.88	15.33	8.4	-0.86	-9.16	50.08
99	-16.27	-8.16	-6.41	-0.38	7.71	14.45	17.76	20.62	20.14	15.41	9.13	1.2	-6.04	68.99
100	-21.18	-13.19	-9.71	-2.06	6.59	14.62	20.6	23.32	21.04	15.39	8.41	-1.32	-10.08	40.22
101	-22.24	-14.33	-10.42	-2.46	6.31	14.64	21.15	23.94	21.2	15.3	8.24	-1.89	-11.04	33.88
102	-21.19	-13.29	-9.79	-2.3	6.3	14.36	20.01	22.93	20.68	14.88	8.09	-1.4	-10.13	37.65
103	-22.74	-14.92	-10.85	-2.9	5.95	14.4	20.73	23.77	21.08	14.89	7.77	-2.22	-11.55	29
104	-18.13	-10.81	-8.28	-1.69	6.31	13.46	17.62	20.62	19.63	14.42	8.32	0.08	-7.73	53.38
105	-22.34	-14.42	-10.42	-2.58	6.24	14.64	20.73	23.8	21.18	15.01	7.98	-1.86	-11.08	31.07
106	-6.94	-2.95	-2.78	1.97	9	15.37	20.25	23.42	22.6	18.61	12.65	6.08	-0.24	91.47
107	-15.42	-8.8	-6.91	-0.72	6.75	13.12	16.81	19.66	19.49	14.94	9.3	1.62	-5.65	63.78
108	-20.03	-12.32	-9.21	-2.27	6.12	13.95	18.61	21.81	20.11	14.29	7.84	-0.89	-9.2	44.16
109	-20.66	-12.75	-9.22	-2.16	6.46	14.64	19.3	22.78	20.81	14.55	7.94	-0.87	-9.51	40.81
110	-20.16	-12.46	-9.19	-2.46	6.02	14.17	18.42	22.03	20.25	13.97	7.51	-0.94	-9.28	47.15
111	-21.69	-13.5	-9.48	-2.11	6.77	15.28	20.2	23.85	21.53	14.91	8.05	-1.05	-10.13	35.09
112	-16.52	-9.9	-7.08	-0.64	7.34	14.66	18.77	22.17	21.17	15.64	9.49	1.37	-6.52	55.87
113	-22.21	-13.92	-9.77	-2.36	6.57	15.2	20.14	23.88	21.46	14.7	7.77	-1.36	-10.49	34.23
114	-20.62	-12.58	-8.72	-1.93	6.9	15.52	19.54	23.64	21.59	14.66	7.96	-0.5	-9.23	44.1
115	-17.6	-10.83	-7.56	-0.97	7.24	14.99	19.25	22.85	21.5	15.54	9.14	0.84	-7.34	51.97
116	-18.17	-11.34	-7.72	-0.96	7.37	15.32	19.77	23.45	21.92	15.75	9.18	0.7	-7.68	48.47
117	-17.61	-10.99	-7.47	-0.82	7.41	15.24	19.88	23.46	21.95	15.94	9.4	0.74	-7.31	48.87
118	-18.67	-11.31	-7.38	-0.59	7.87	15.87	20.58	24.22	22.49	16.24	9.55	0.45	-7.47	41.63
119	-22.4	-13.86	-9.44	-1.77	6.98	15.39	20.48	24.16	21.75	15.24	8.24	-1.27	-9.91	34.98
120	-18.8	-11.07	-7.35	-0.93	7.58	15.65	20.38	23.81	22.06	15.84	9.2	-0.02	-7.74	45.39
121	-16.37	-8.37	-5.24	0.68	9.12	16.85	20.77	24.64	22.87	16.96	10.63	2	-5.95	49.48
122	-20.78	-12.78	-8.23	-1.15	7.56	16	20.59	24.31	22.19	15.48	8.71	-1.05	-8.62	39.19
123	-19.76	-11.18	-6.86	-0.35	8.43	16.82	21.27	24.48	22.74	16.34	9.52	-0.01	-8.06	46.42
124	-19.76	-11.22	-6.99	-0.38	8.3	16.74	21.07	24.25	22.4	16.1	9.38	-0.17	-8.3	43.36
125	-20.66	-12.75	-8.25	-0.99	7.38	15.93	20.98	23.74	21.62	15.54	9.31	-0.79	-9.22	36.11
126	-16.91	-9.38	-5.57	1.3	9.7	17.57	22.08	25.18	23.55	17.55	10.87	1.22	-6.67	28.44
130	-8.03	-3.52	-2.77	2.83	10.97	18.32	23.48	26.46	24.99	20.32	13.49	6.19	-0.76	52.34

Prov	Climate Variables										
	febprecip	marprecip	aprprecip	mayprecip	junprecip	julprecip	augprecip	sepprecip	octprecip	novprecip	decprecip
1	59.41	61.87	74.18	72.29	83.09	86.18	98.09	93.72	78.26	87.57	85.87
2	60.96	67.69	72.91	80.52	96.06	91.93	100.37	93.35	86.19	93.56	91.11
3	60.35	67.43	72.48	81.28	96.39	91.54	99.36	92.67	86.48	92.81	90.4
4	57.52	66.62	68.48	87.99	107.18	99.52	102.59	95.96	90.46	87.62	84.75
5	59.25	65.93	72.34	79.45	91.07	87.71	94.97	89.87	83.96	91.02	88.87
6	57.1	63.97	70.62	78.17	86.68	83.4	89.35	85.48	81.28	87.92	86.16
7	60.04	67.43	71.86	84.58	97.19	91.35	97.34	91.19	88.03	90.52	87.65
8	61.47	67.87	71.58	87.15	101.42	97.78	101.81	95.83	90.55	90.82	87.15
9	60.47	68.19	73.56	83.23	93.21	87.17	94.41	89.07	86.97	92.65	90.42
10	56.19	60.94	69.17	73.44	77.11	80.06	88.15	87.98	76.2	85.7	81.61
11	56.59	61.53	66.38	73.05	76.57	82.1	82.86	83.3	73.33	81.49	79.4
12	58.05	63.68	67.11	75.51	80.77	83.82	83.29	81.58	75.5	82.47	81.58
13	62.16	68.3	71.64	80.43	88.21	87.03	90.19	86.26	82.32	89.67	88.3
14	56.48	62.97	66.19	78.77	93.41	88.26	94.74	86.42	81.06	82.01	79.22
15	58.27	64.31	67.59	78.15	89.38	85.05	90.3	83.53	80.12	83.78	82.51
16	56.49	60.18	63.17	77.03	96.05	97.05	101.25	94.54	80.18	82.79	79.36
17	56.52	61.28	65.39	73.67	76.87	78.08	79.28	80.62	73.16	80.04	78.98
18	56.26	60.66	64.86	73.57	78.65	77.43	79.39	78.69	73.35	78.84	79.03
19	59.23	64.34	67.13	78.14	93.27	88.85	94.42	86.57	80.87	84.11	83.34
20	56.18	58.66	60.87	72.83	97.02	101.31	104.82	99.02	77.01	84.8	82
21	61.26	64.86	67.82	76.81	85.85	82.3	85.91	81.12	78.15	83.93	84.88
22	55.65	60.98	65.54	77.05	93.46	88.97	93.82	88.12	80.1	81.3	81.42
23	53.26	56.45	63.08	72.21	78.26	73.53	76.67	78.42	71.43	74.56	75.5
24	56.95	61.36	65.59	73.69	71.17	65.27	72.74	82.81	72.39	81.59	80.43
25	51	54.56	63.35	73.63	83.22	75.97	79.76	79.76	74.04	72.92	75.11
26	61.91	66.45	68.73	78.39	89.6	85.71	90.33	83.49	80.46	85.95	85.93
27	53.16	59.24	64.2	76.39	93.82	89.27	93.74	89.78	79.34	79.51	79.32
28	47.39	52.82	63.29	75.15	85.92	77.23	81.4	81.54	76.5	71.08	73.87
29	66.1	67.61	71.29	76.72	70.89	58.13	72.09	80.94	75.5	91.76	93.06
30	64.75	69.48	67.98	76.99	78.81	64.15	76.13	82.98	75.54	84.51	91.9
31	48.38	55.84	62.18	75.66	88.04	77.25	82.45	82.9	74.79	72.05	71.56
32	56.24	56.02	61.46	70.57	81.17	67.78	77.39	80.78	67.27	72.78	74.61
33	47.88	52.14	60.58	72.77	85.61	74.18	79.47	80.32	70.97	69.1	68.43
34	49.34	58.2	61.72	76.17	88.05	76.31	82.19	83.06	73.69	72.89	70.46
35	49.12	55.17	60.39	74.18	88.05	82.03	86.26	85.83	73.16	72.01	70.4
36	51.93	53.9	61.4	73.88	82.69	74.08	82.27	83.08	71.89	74.8	68.3
37	58.44	67.68	64.58	74.75	72.53	62.57	78.03	79.21	70.9	82.42	82.18
38	54.34	61.96	62.76	76.96	82.45	73.88	87.15	86.9	75.48	82.09	75.02
39	57.12	66	63.42	73.66	72.79	66.4	79.22	76.43	70.62	81.53	79.76
40	56.02	65.63	62.75	77.48	80.26	71.98	86.36	85.77	74.93	84.12	78.97
41	58.09	65.44	66.93	73.52	73.92	68.52	80.48	75.88	72.53	83.49	79.42
42	55.45	58.72	64.65	77.11	89.58	83.21	94.03	93.51	81.36	87.06	77.77

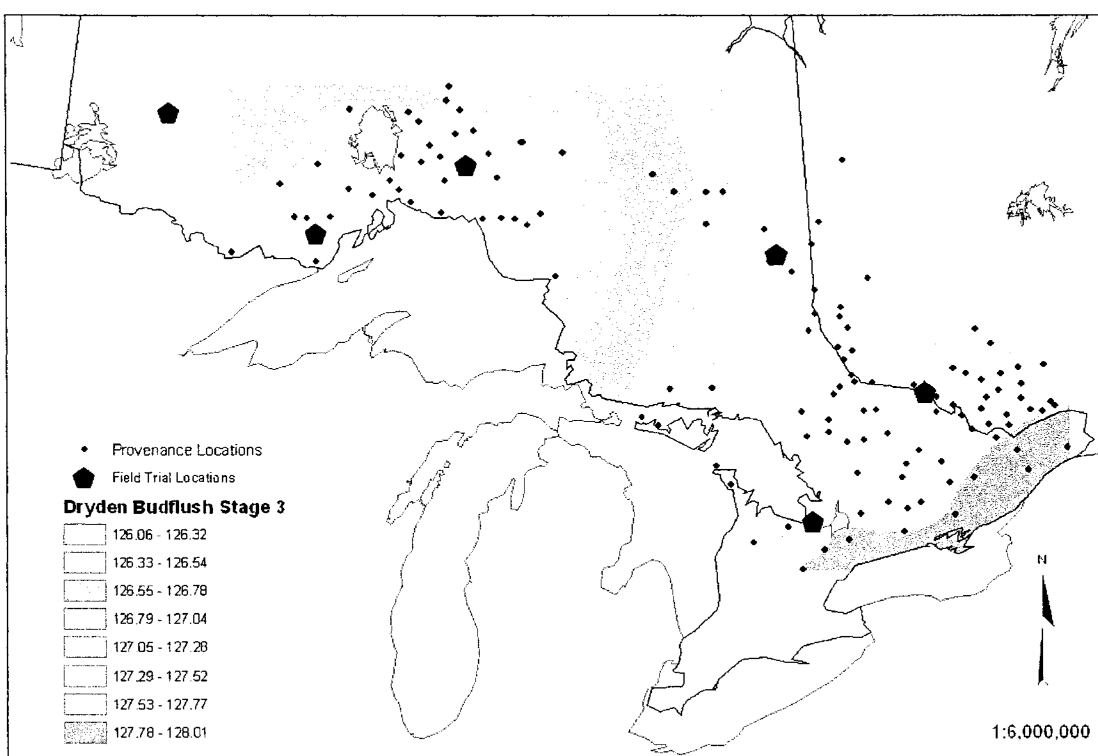
Prov	Climate Variables										
	febprecip	marprecip	aprprecip	mayprecip	junprecip	julprecip	augprecip	sepprecip	octprecip	novprecip	decprecip
43	57.75	66.14	62.21	77.09	77.67	73.09	83.96	80.06	73.43	86.36	82.13
44	49.62	60.61	60.44	76.22	96.61	102.27	105.03	104.01	88.09	77.74	71.48
45	57.38	61.3	67.17	78.93	93.16	91.51	99.54	100.54	85.18	89.78	80.95
46	50.29	56.02	62.12	72.93	88.07	90.65	94.07	95.54	78.7	78.54	72.79
47	60.09	66.16	70.23	81.09	94.32	93.16	102.84	106.55	91.22	97.82	86.29
48	32.56	47.86	48.46	76.58	98.17	106.55	102.74	112.99	84.79	65.7	56.27
49	53.24	63.24	66.12	74.69	94.66	102.24	102.51	103.11	84.29	83.57	74.12
50	51.03	59.92	64.84	74.7	90.65	95.14	98.5	102.39	84.25	84.24	73.99
51	53.61	63.8	65.76	75.08	95.41	101.19	102.83	102.46	84.74	82.55	74.41
52	52.12	61.87	66.1	75.64	93.01	98.93	101.26	104.56	85.66	85.51	74.32
53	57.56	64.61	63.9	78.67	79.66	76.28	87.64	84.08	77.75	89.66	83.86
54	68.36	71.98	68.88	84.64	87.17	79.52	93.35	100.16	91.22	107.37	104.62
55	50.68	60.97	63.66	74.61	95.36	96.85	100.92	100.17	83.62	77.63	71.09
56	52.22	62.86	66.12	73.94	93.1	101.61	101.35	103.73	83.54	83.36	72.86
57	51.72	61.96	64.43	74.19	94.57	96.78	100.1	100.31	82.05	79.26	71.92
58	71.53	75.42	75.68	84.58	90.42	85.42	102.19	111.05	100.31	116.19	108.12
59	52.83	63.58	66	73.13	92.68	100.67	100.08	102.43	80.99	82.15	72.54
60	50.19	60.9	65.67	76.38	91.09	95.62	99.89	106.89	87.65	86.4	73.68
61	50.59	60.29	63.68	74.94	76.88	77.08	89.21	78.23	71.53	80.56	72.85
62	50.5	61.69	66.63	78.63	91.74	94.86	100.93	110.38	91.15	89.11	75.42
63	38.02	51.18	50.65	76.68	95.68	96.75	99.86	109.93	83.66	65.41	61.76
64	67.48	71.07	74.6	83.65	90.21	89.95	102.65	112.91	99.87	105.49	103.91
65	70.77	71.54	74.79	82.8	87.22	85.23	99.77	110.34	99.82	108.21	111.64
66	43.52	54.81	52.08	74.76	94.94	93.66	97.97	103.05	79.03	67.4	63.93
67	43.3	53.59	56.98	69.49	90.33	85.07	90.46	90.47	72.99	64.98	59.53
68	45.18	54.99	60.74	70.01	90.01	84.97	90.46	91.85	72.57	67.64	62.09
69	68.69	73.97	74.29	84.77	93.07	87.13	102.8	108.55	96.76	112.53	99.82
70	50.02	59.75	63.06	72.73	87.9	87.53	91.65	96.06	74.23	72.59	66.67
71	73.63	66.5	70.45	79.11	82.84	77.45	92.75	110.64	98.3	105.42	116.44
72	46.6	56.3	50.88	69.07	87.07	84.22	88.36	90.08	69.01	65.94	60.94
73	64.98	63.42	68.28	77.39	80.44	80.1	91.37	106.94	90.35	92.03	98.66
74	54.32	66.77	68.61	74.12	80.15	78.82	96.06	84.42	74.38	82.03	76.38
75	67.38	67.84	66.09	73.67	83.88	78.66	99.02	98.4	89.95	98.71	99.02
76	47.96	57.4	48.58	70.84	89.92	87.29	91.61	94.92	69.32	68.32	64.66
77	43.84	53.43	42.85	69.68	91.32	92.55	94.86	98.18	69.7	66.98	63.01
78	76.46	70.18	66.85	74.5	81.49	76.1	98.79	98.52	89.03	96.98	109.19
79	40.66	54.54	44.75	68.74	88.77	98.9	91.71	95.14	71.92	71.76	62.46
80	35.6	43.1	42.42	55.2	78.65	81.8	74.99	84.48	66.54	60.59	50.85
81	40.87	53.73	45.93	68.92	86.42	96.87	88.48	91.84	71	70.73	61.59
82	44.97	56.55	48.62	72.4	91.04	94.82	90.1	90.78	70.94	70.22	64.89
83	55.47	57.8	59.84	63.81	66.35	63.4	84.29	95.61	81.65	85.63	94.71
84	47.04	60.91	61.84	71.46	68.54	65.74	86.13	97.03	88.75	80.65	76.08
85	41.98	52.15	47.48	71.65	85.68	95.64	87.77	89.06	72.21	67.79	57.33
86	49.98	60.1	62.71	73.15	69.92	65.47	83.13	100.49	87.76	90.22	79.56
87	41.94	52.97	49.85	70.99	86.98	97.51	87.17	90.74	76.41	69.64	57.98

Prov	Climate Variables										
	febprecip	marprecip	aprprecip	mayprecip	junprecip	julprecip	augprecip	sepprecip	octprecip	novprecip	decprecip
88	42.18	56.26	59.79	66.06	64.38	58.77	80.5	92.21	75.1	79.2	76.86
89	41.61	55.44	59.55	69.22	68.88	63.73	82.95	93.24	75.09	77.94	72.2
90	35.23	46.11	45.91	54.08	78.09	81.26	72.86	81.54	66.05	60.57	53.37
91	60.79	64.34	60.3	72.1	89.67	91.73	90.9	110.43	107.53	91.53	102.3
92	43.17	48.14	48.94	70.42	84.53	89.47	86.71	95.02	74.59	69.52	59.23
93	41.73	43.76	46.17	69.39	80.48	84.67	85.16	92.01	69.87	66.63	55.19
94	35.64	42.91	42.17	55.34	78.68	81.76	75.1	84.64	66.69	60.59	50.78
95	44.95	47.54	46.24	67.75	81.89	83.95	84.8	92.84	74.46	68.9	59.24
96	48.57	52.36	47.73	67.23	84.66	84.12	85.85	94.28	80.95	71.85	63.72
97	44.61	49.49	43.6	63.49	84.01	84.12	82.54	92.55	77.44	68.24	60.29
98	38.41	44.81	42.53	62	84.73	84.9	82.14	90.2	73.75	63.8	52.98
99	49.92	55.62	49.4	64.13	85.51	81.11	84.56	91.49	86.39	71.97	65.04
100	31.96	38.87	41.1	61.6	85.94	87.34	82.83	89.11	70.03	59.55	45.14
101	28.01	34.05	40.75	60.99	86.64	92.44	83.17	90.51	67.97	57.41	40.11
102	30.26	38.32	41.29	65.69	89.94	89.04	87.43	90.47	71.36	59.48	43.76
103	24.94	28.89	40.8	58.28	85.1	98.92	81.11	92.68	65.75	55.3	35.73
104	36.86	45.46	44.66	70.56	90.85	82.28	89.46	94.21	82.02	62.44	57.47
105	26.09	31.29	40.92	60.45	86.53	95.88	83.09	91.88	67.48	56.41	38.07
106	60.58	58.18	59.86	62.3	67.68	65.66	85.21	95.82	81.78	89.09	102.72
107	39.86	47.39	46.01	70.94	86.89	75.38	86.06	95.05	85.76	60.57	65.46
108	32.95	42.04	43.26	69.71	92.64	87.29	91.09	93.27	77.62	62.22	50.67
109	30.82	39.25	42.72	67.37	91.4	89.13	89.92	92.78	76.01	61.71	48.83
110	34.03	43.26	44.9	70.33	94.12	89.43	93.2	95.97	81.58	65.85	55.59
111	27.78	34.95	42.08	62.95	88.27	93.04	87.1	91.47	71.9	59.03	43.88
112	36.14	44.52	43.83	67.61	87.93	78.26	87.8	93.08	82.34	66.35	64.6
113	27.6	34.93	42.95	62.18	88.03	96.12	87.81	91.63	71.61	58.7	43.3
114	32	41.16	43.84	66.98	91.92	89.71	91.84	93.18	80	66.69	54.88
115	34.62	43.61	43.55	66.78	90.19	81.89	90.34	93.33	82.72	70.11	63.77
116	32.95	42.2	42.83	65.29	90.63	83.58	91.07	92.27	82.26	71.95	62.28
117	33.27	44.25	43.42	67.19	88.22	84.12	90.5	90.3	79.37	68.98	59.9
118	30.21	43.52	42.45	69.99	82.02	87.91	86.84	82.74	71.15	57.08	45.54
119	28.91	38.71	42.54	64.95	84.44	97.14	88.13	81.43	67.15	50.59	39.15
120	32.81	47.57	44.9	73.37	88.27	93.29	90.87	91.27	69.46	56.69	48.31
121	32.08	46.74	49.05	70.97	91.38	86.94	91.65	97	69.42	59.33	52.96
122	32.06	42.98	40.79	74.15	83.4	97.89	87.89	81.95	69.24	50.39	37.59
123	34.35	46.48	42.33	72.21	92.18	98.66	88.54	95.01	69.51	57	47.06
124	32.87	43.85	44.27	73.3	96.2	100.39	92.61	96.6	72.23	55.83	44
125	31.34	36.69	42.03	77.07	97.08	101.8	95.87	94.44	74.61	48.6	39.27
126	19.81	35.3	49.36	74.06	101.16	92.72	98.01	88.42	67.66	39.81	28.97
130	46.2	55.96	59.7	68.35	71.91	75.84	89.2	74.17	66.79	72.52	67.35

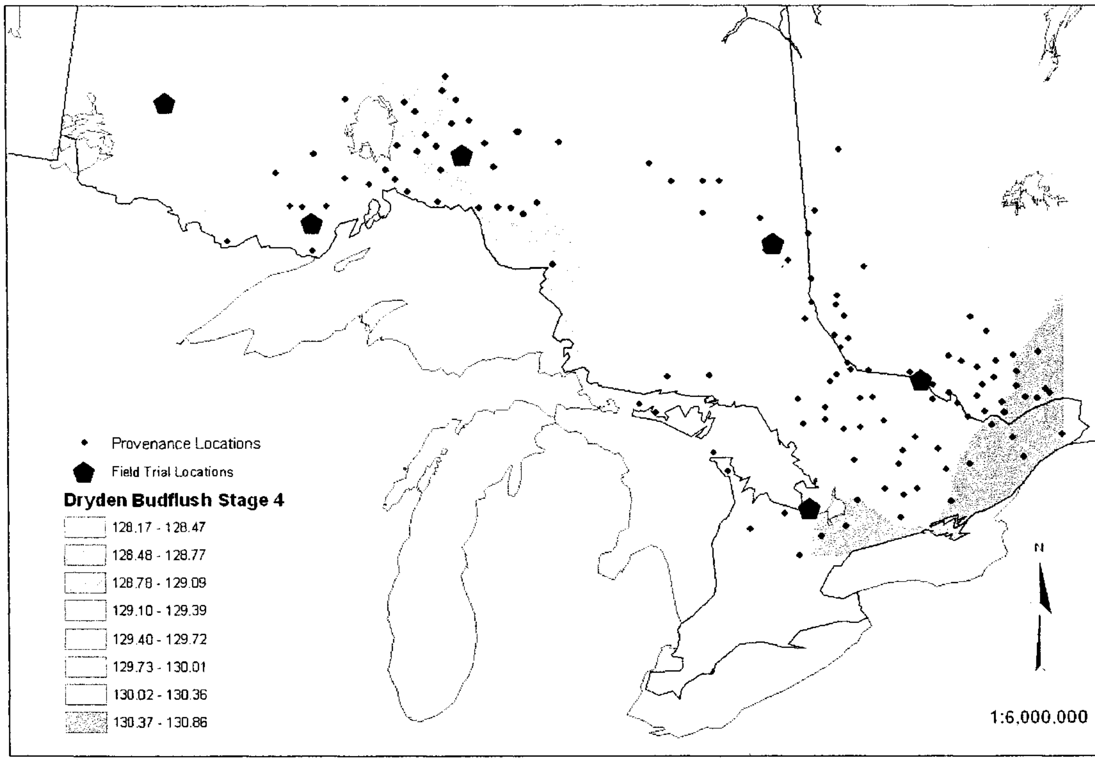
APPENDIX IV
INTERPOLATED CONTOUR MAPS OF MEASURED VARIABLES



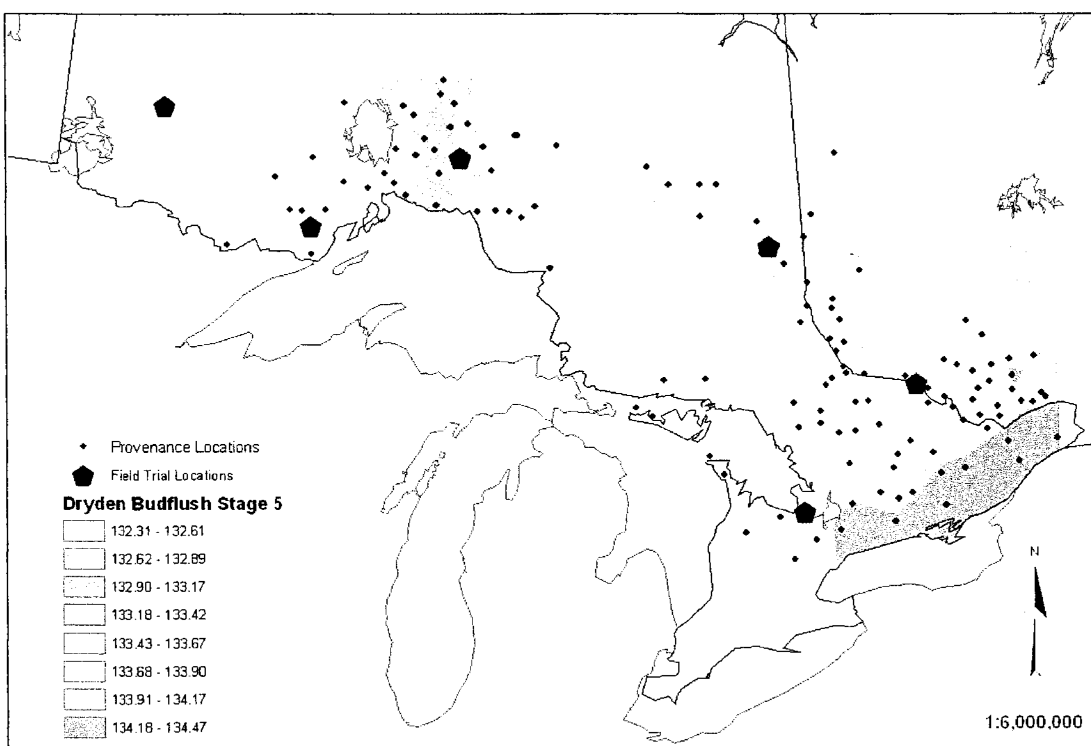
Contour map of mean number of days from Jan. 1 to reach budflush stage 2 at the Dryden field trial



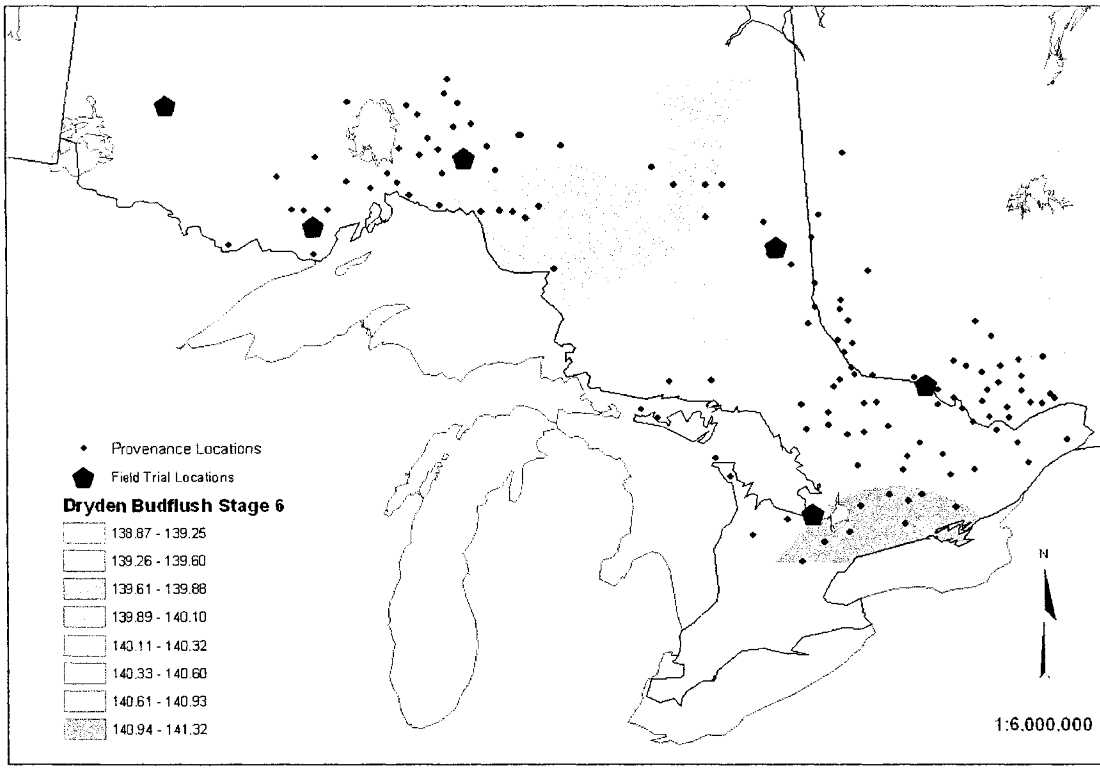
Contour map of mean number of days from Jan. 1 to reach budflush stage 3 at the Dryden field trial



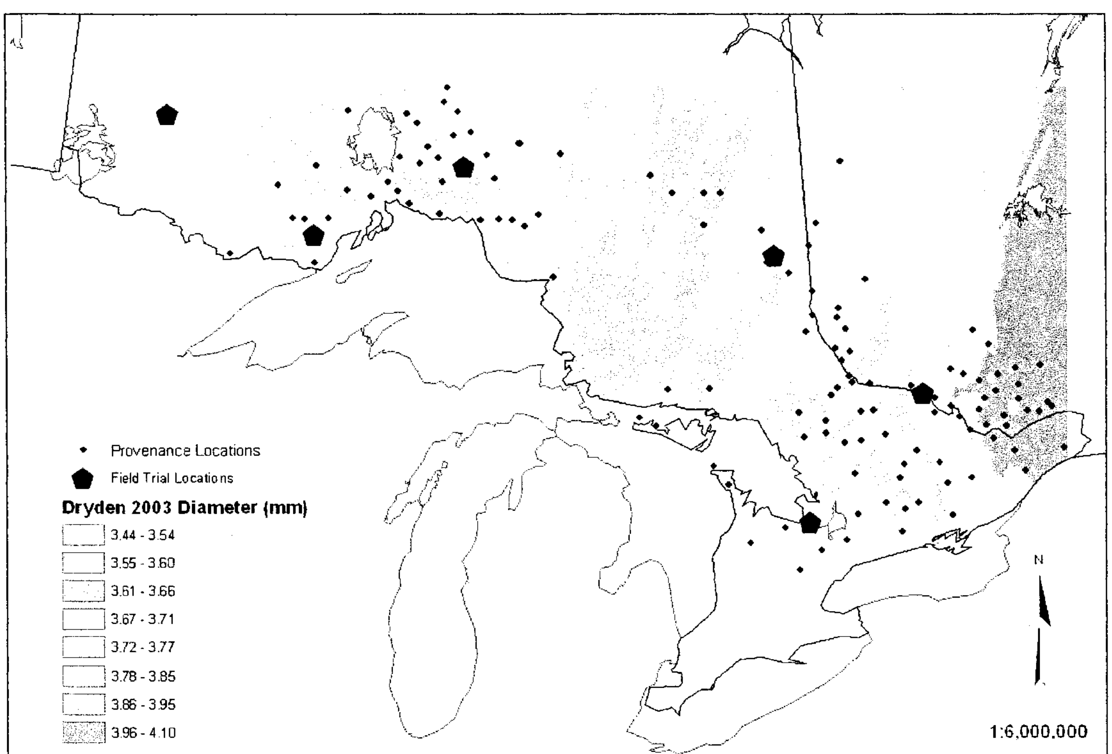
Contour map of mean number of days from Jan. 1 to reach budflush stage 4 at the Dryden field trial



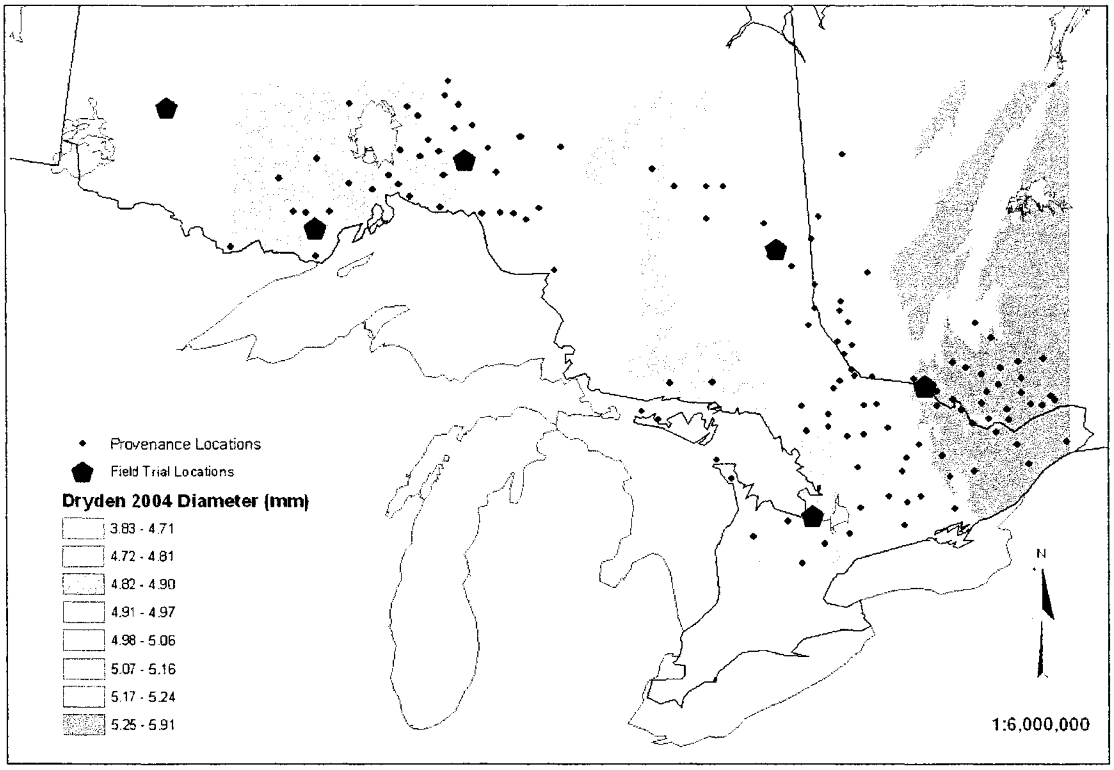
Contour map of mean number of days from Jan. 1 to reach budflush stage 5 at the Dryden field trial



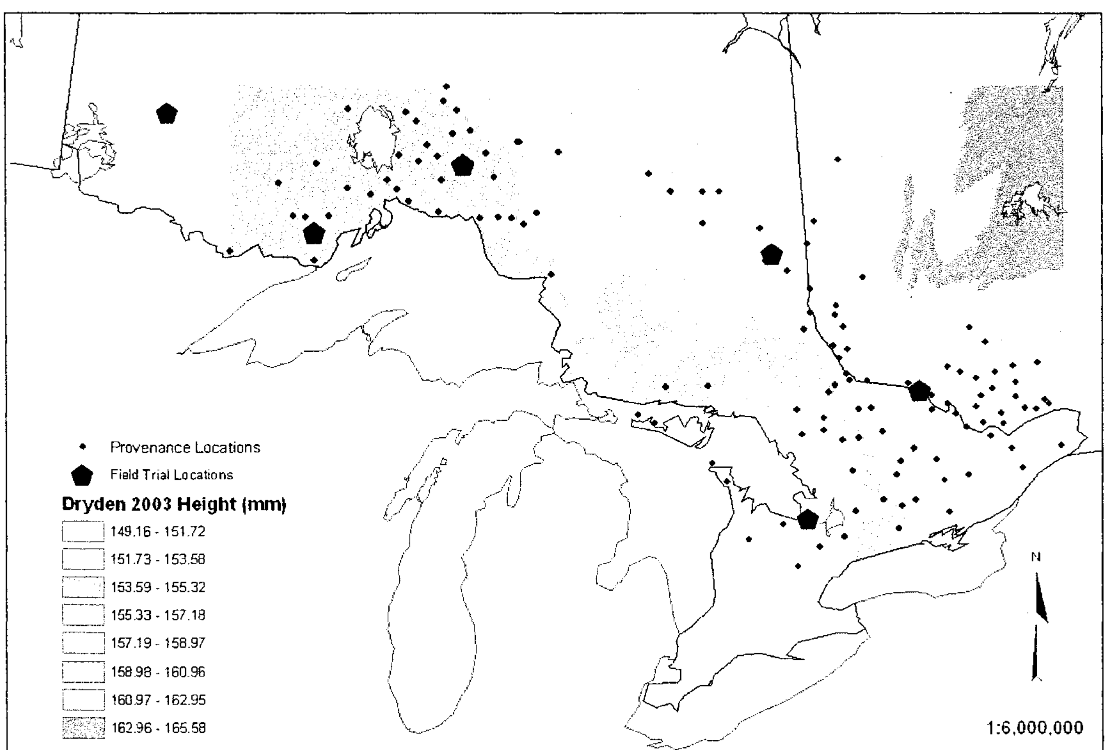
Contour map of mean number of days from Jan. 1 to reach budflush stage 6 at the Dryden field trial



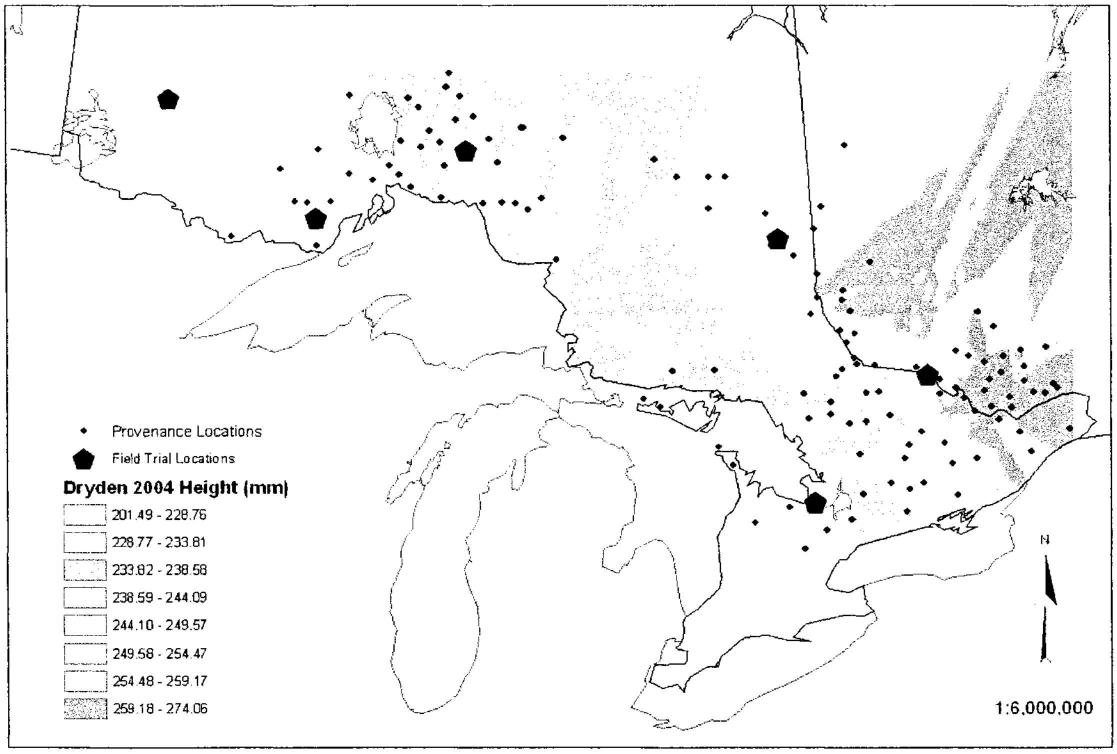
Contour map of mean root collar diameter in 2003 at the Dryden field trial



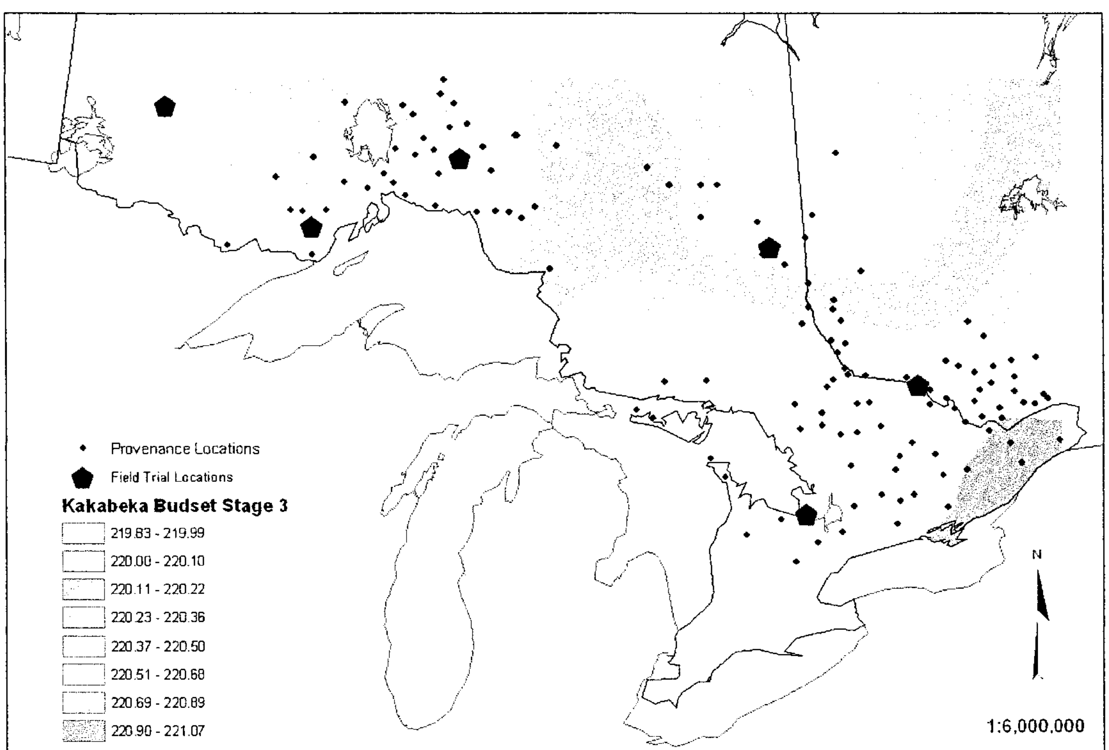
Contour map of mean root collar diameter in 2004 at the Dryden field trial



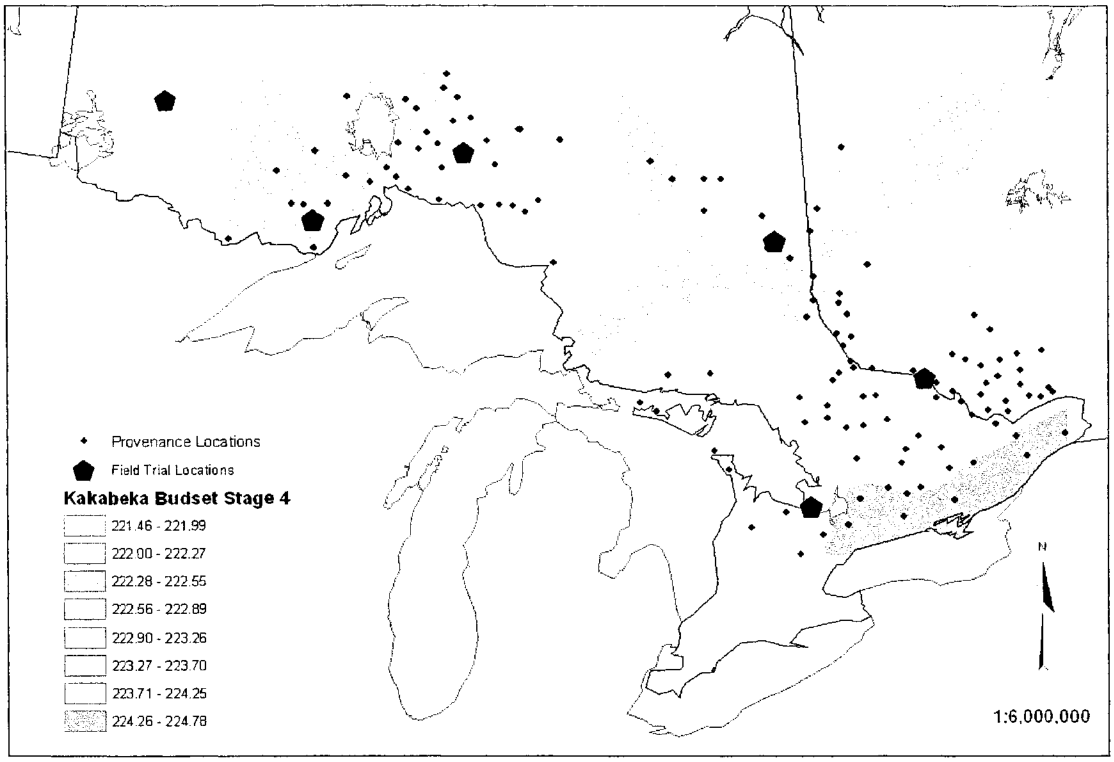
Contour map of mean height in 2003 at the Dryden field trial



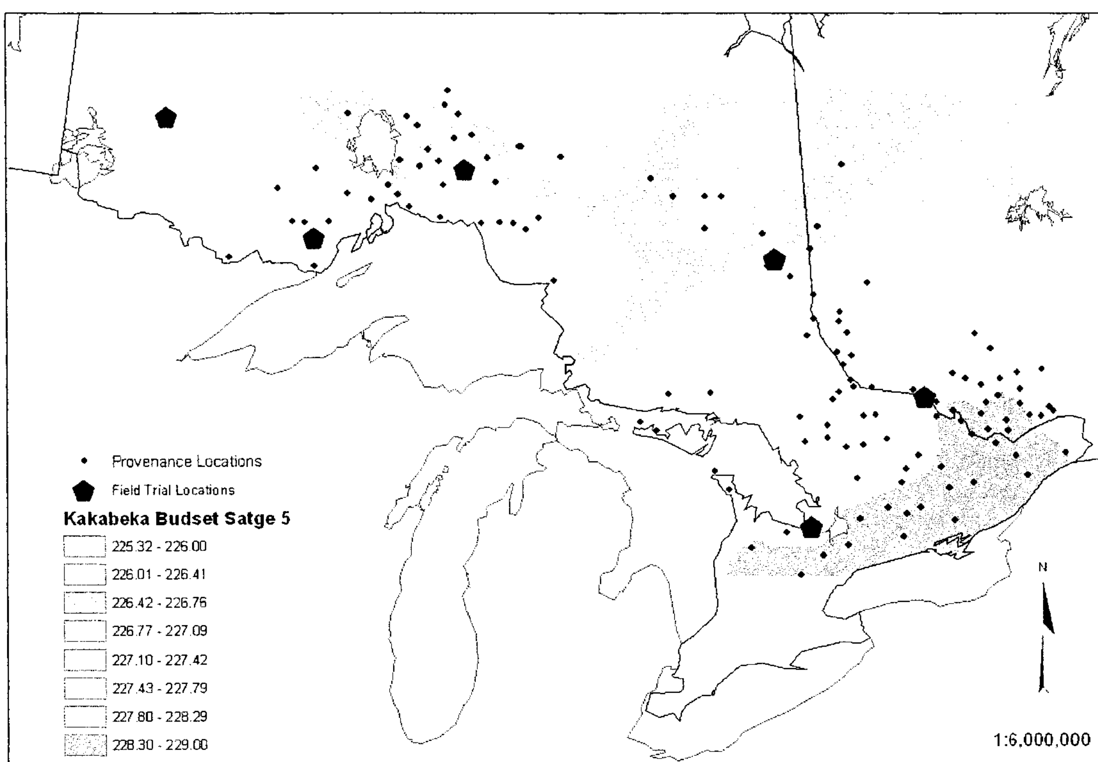
Contour map of mean height in 2004 at the Dryden field trial



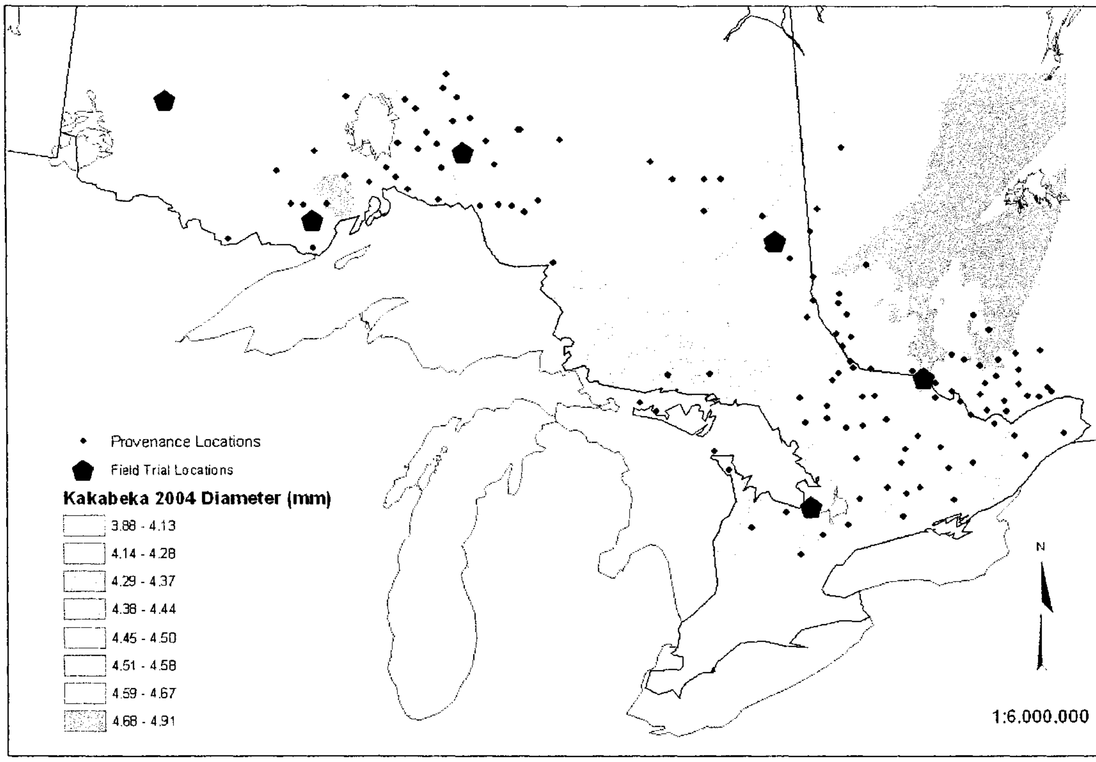
Contour map of mean number of days from Jan. 1 to reach budset stage 3 at the Kakabeka field trial



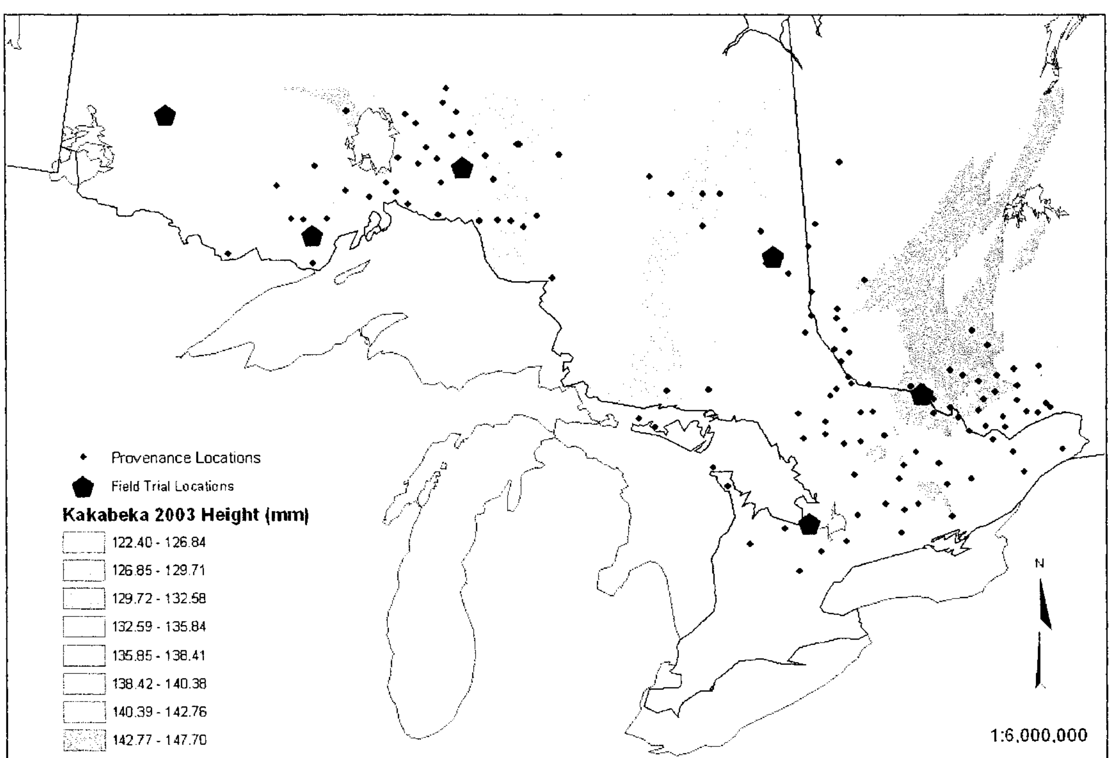
Contour map of mean number of days from Jan. 1 to reach budset stage 4 at the Kakabeka field trial



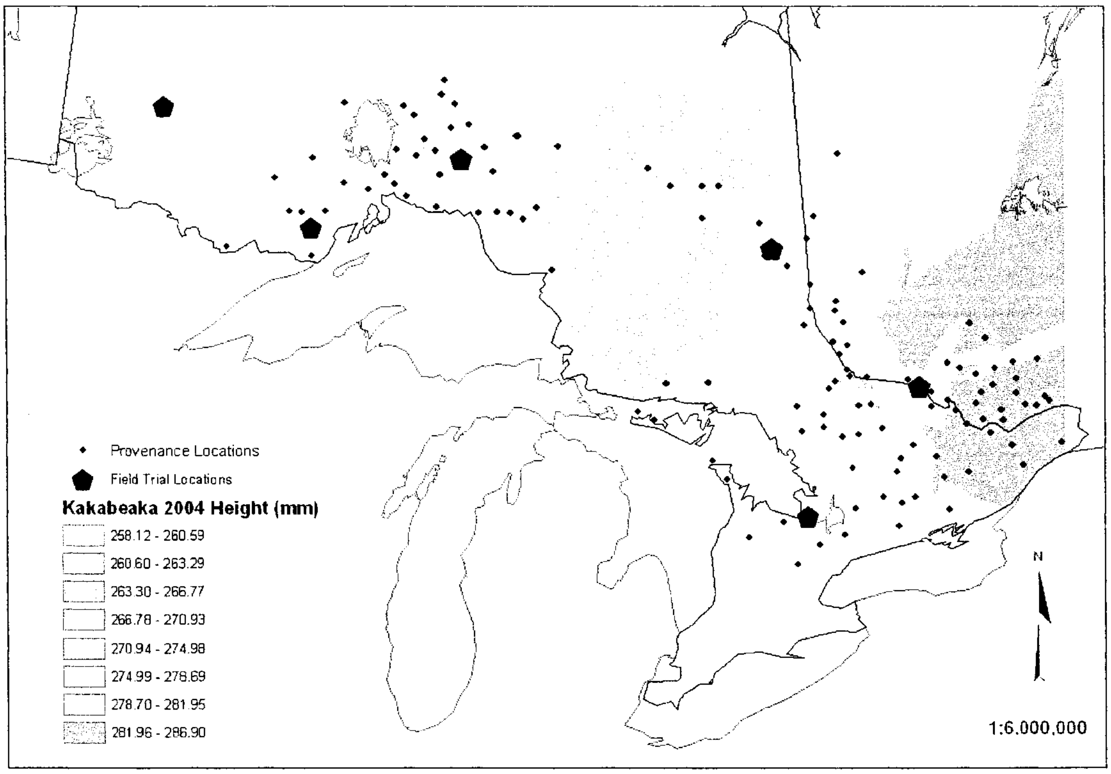
Contour map of mean number of days from Jan. 1 to reach budset stage 5 at the Kakabeka field trial



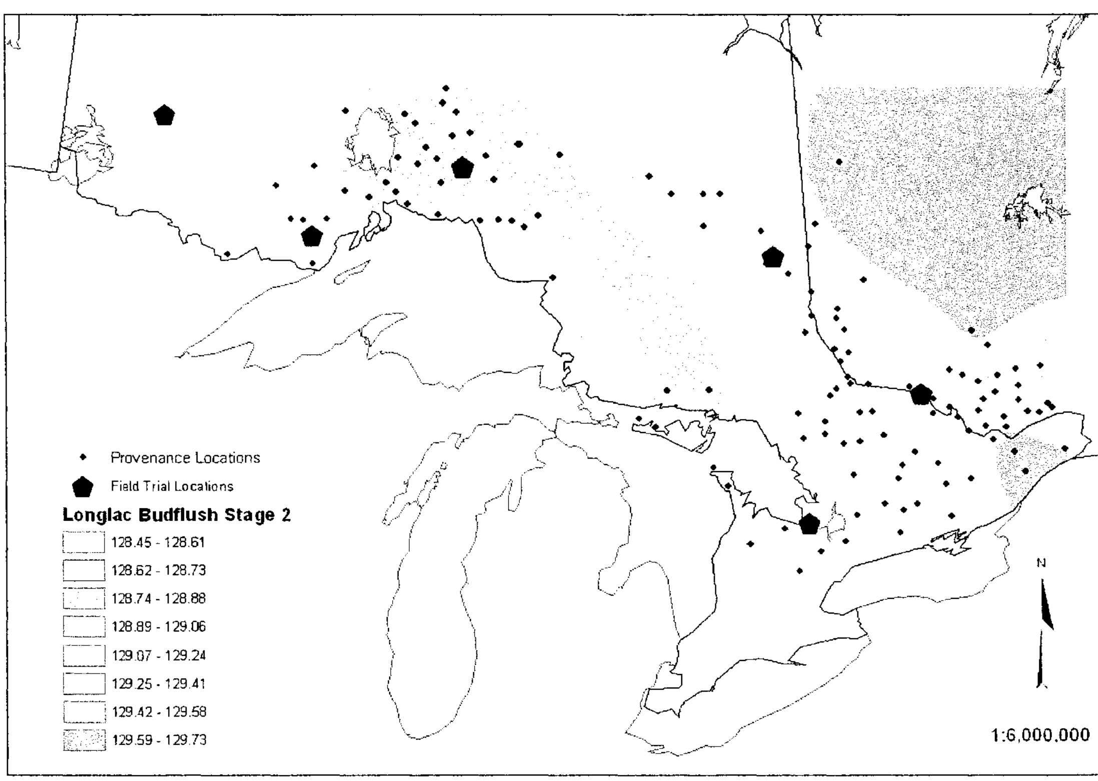
Contour map of mean root collar diameter in 2004 at the Kakabeka field trial



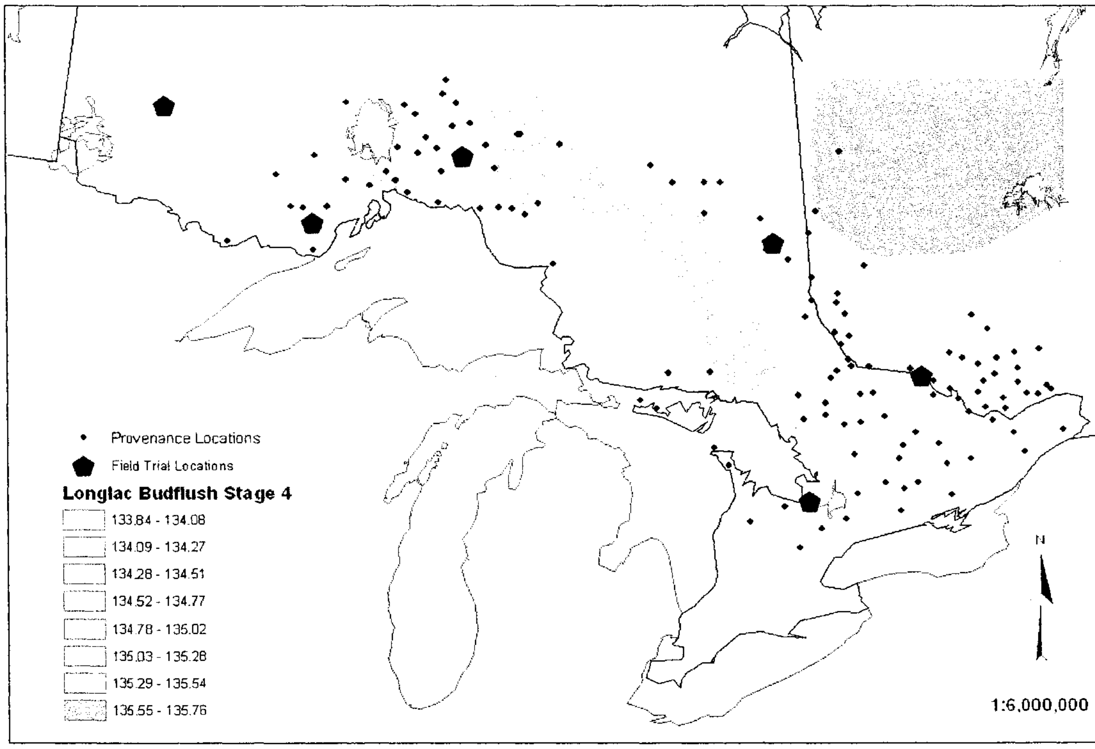
Contour map of mean height in 2003 at the Kakabeka field trial



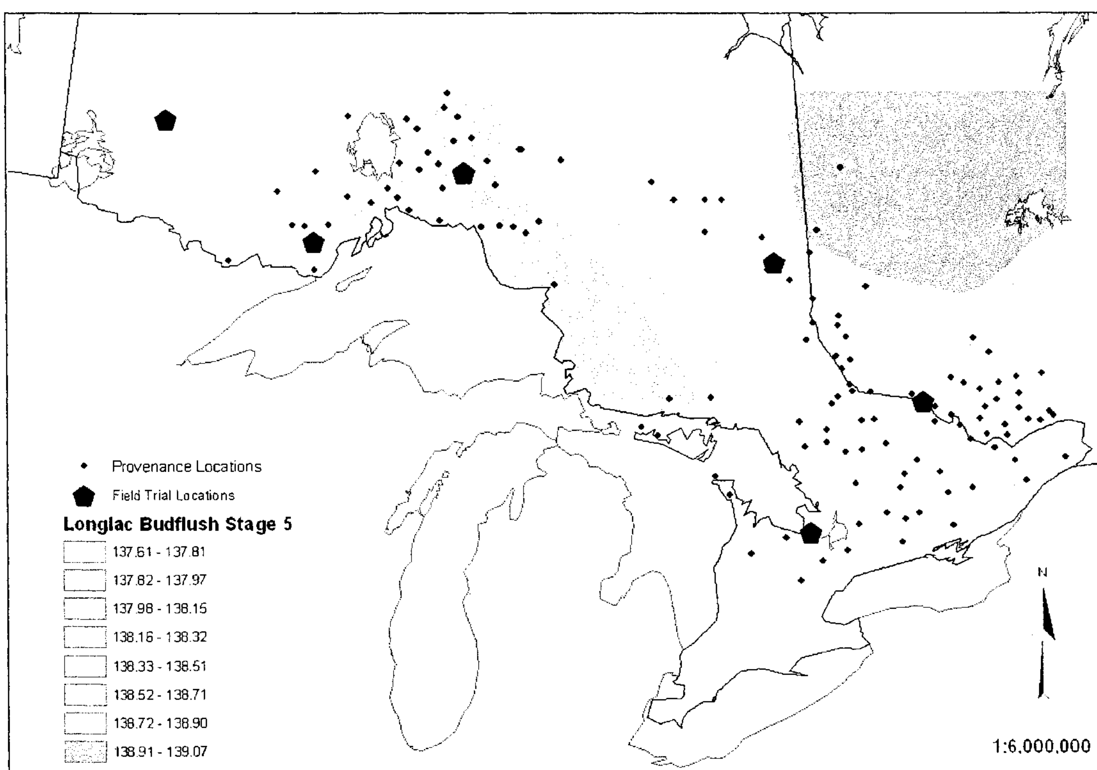
Contour map of mean height in 2004 at the Kakabeka field trial



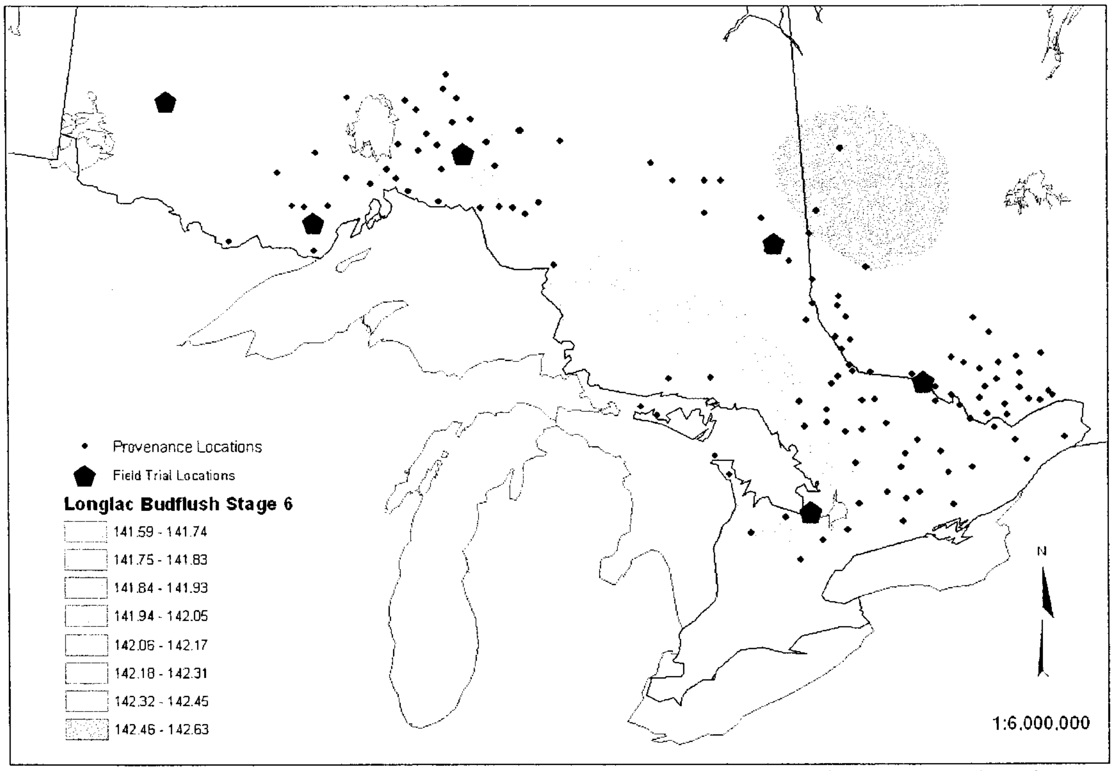
Contour map of mean number of days from Jan. 1 to reach budflush stage 2 at the Longlac field trial



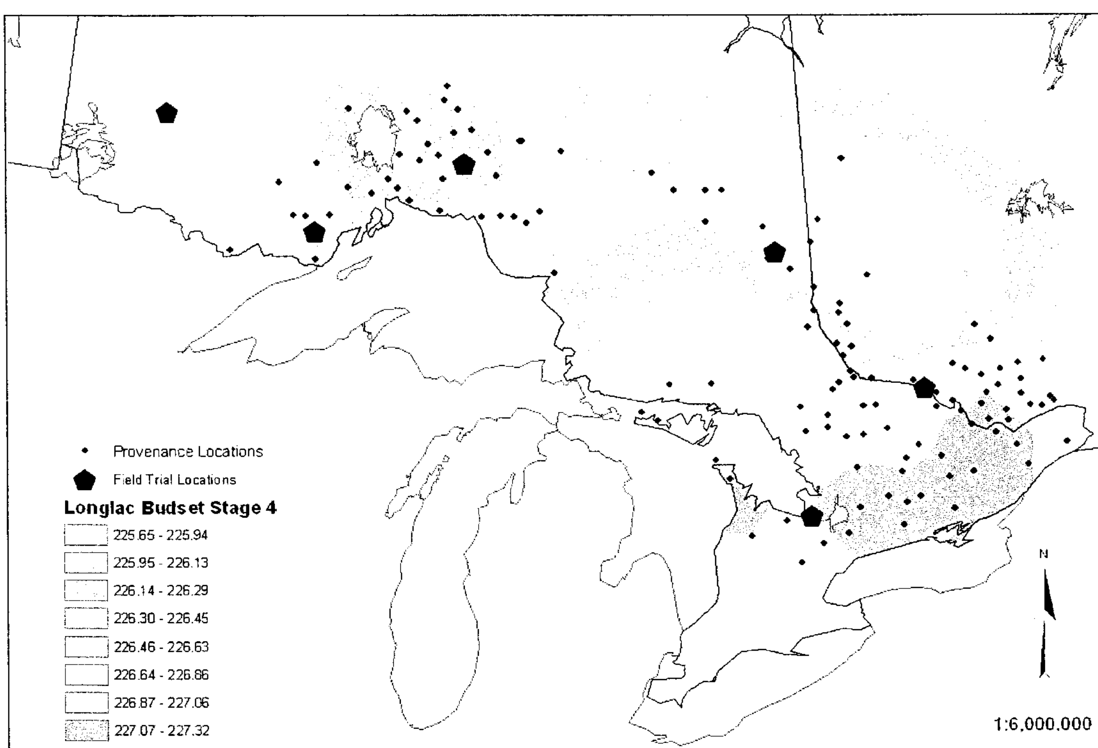
Contour map of mean number of days from Jan. 1 to reach budflush stage 4 at the Longlac field trial



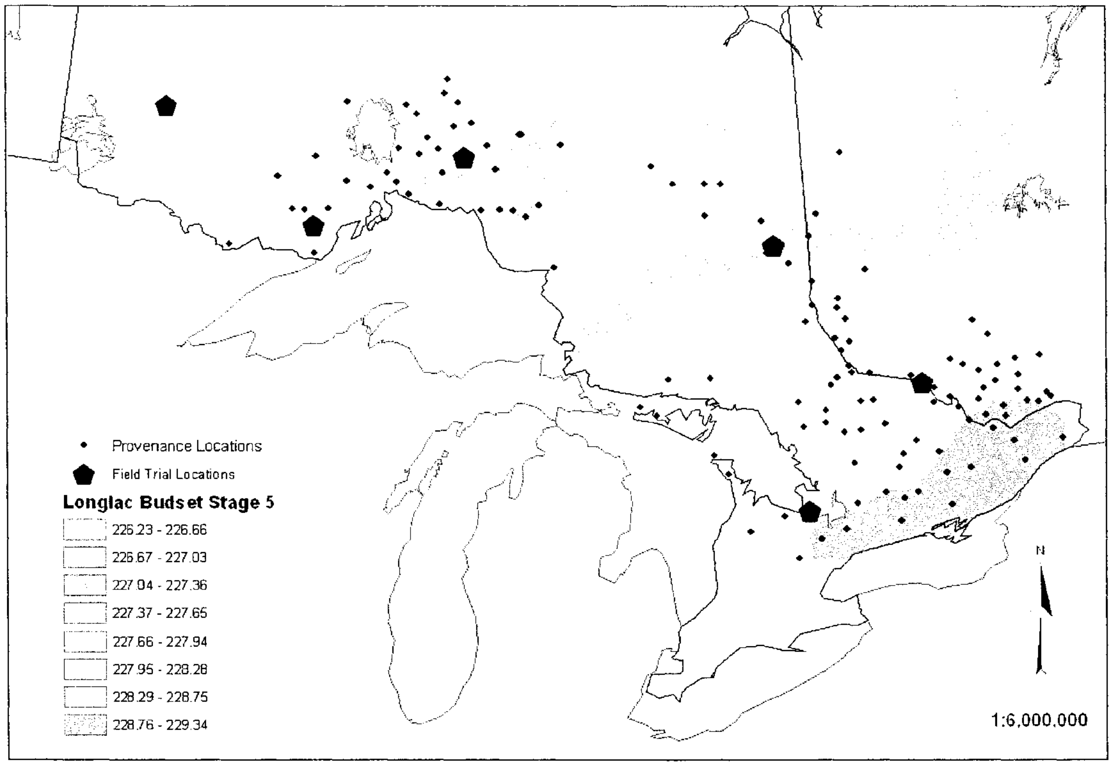
Contour map of mean number of days from Jan. 1 to reach budflush stage 5 at the Longlac field trial



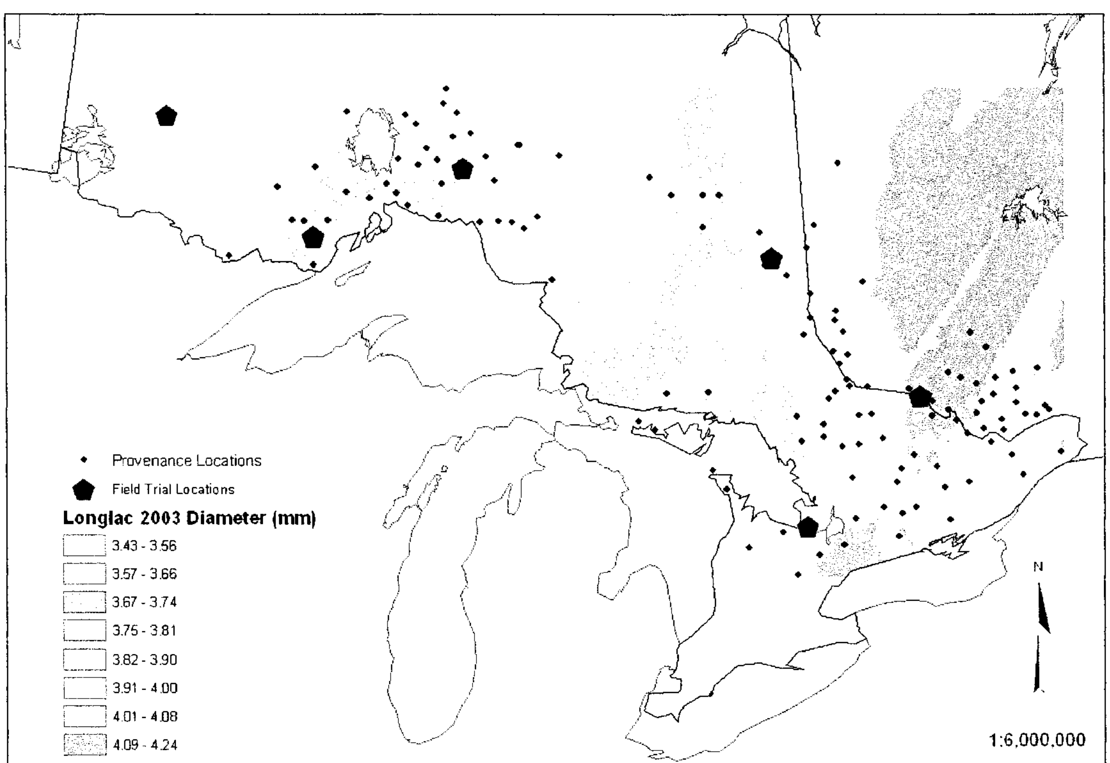
Contour map of mean number of days from Jan. 1 to reach budflush stage 6 at the Longlac field trial



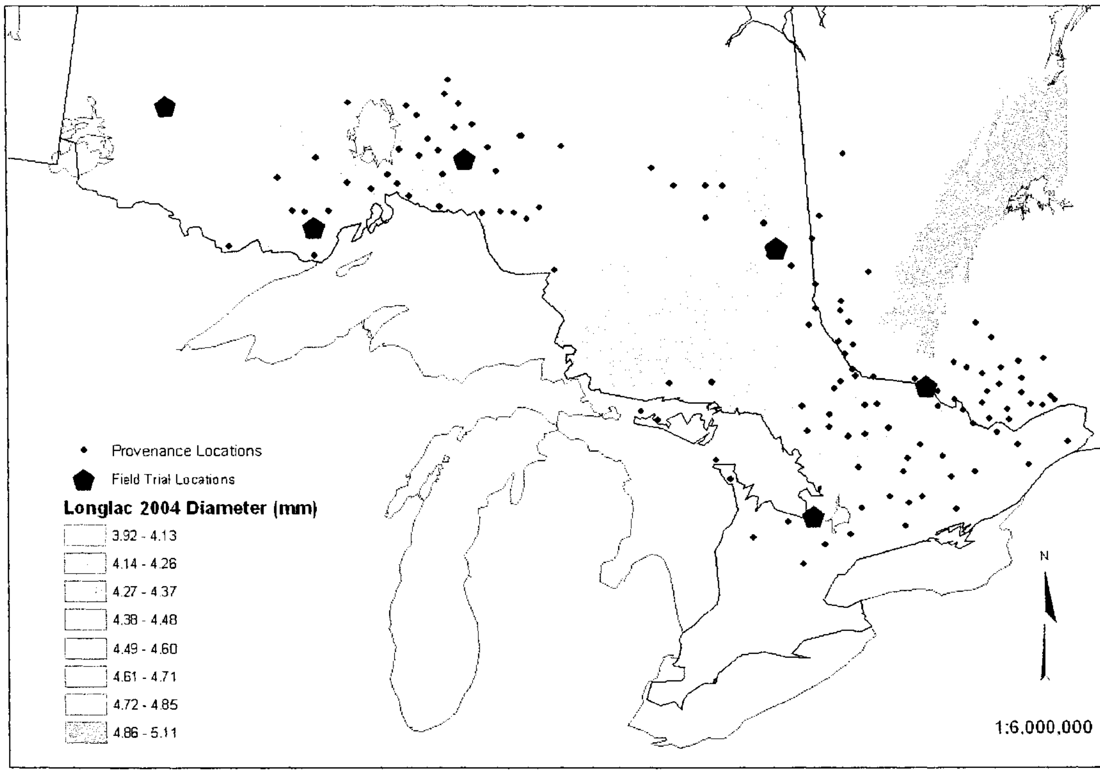
Contour map of mean number of days from Jan. 1 to reach budset stage 4 at the Longlac field trial



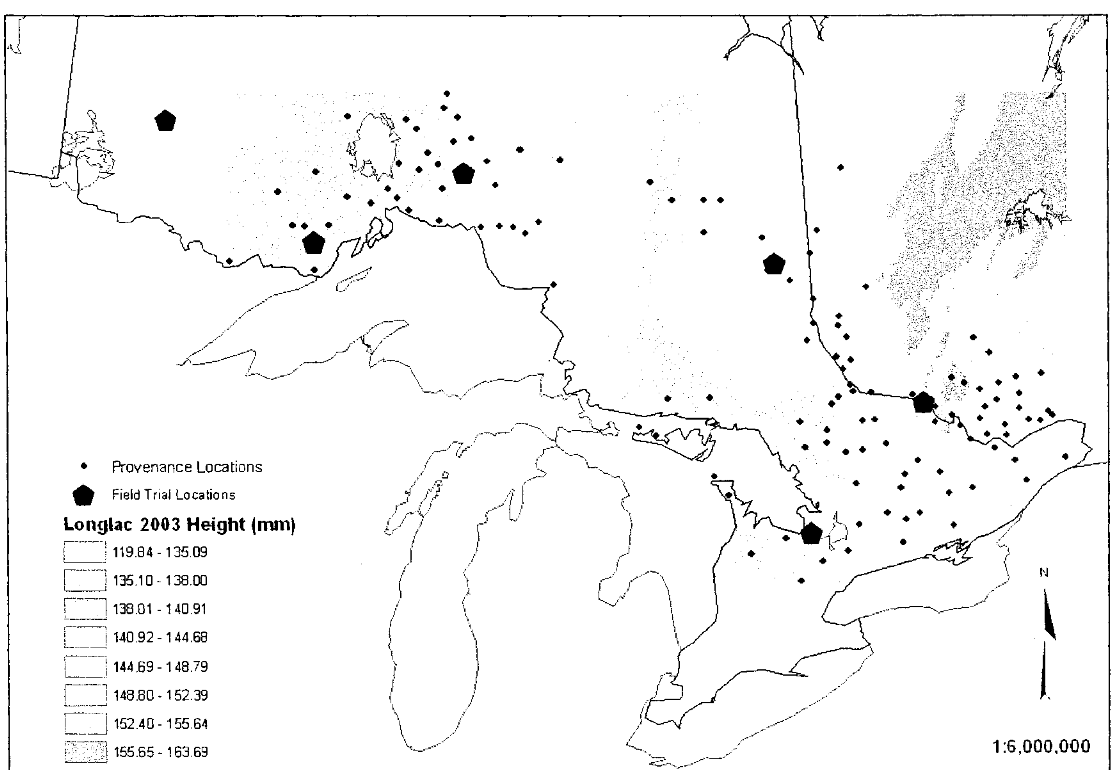
Contour map of mean number of days from Jan. 1 to reach budset stage 5 at the Longlac field trial



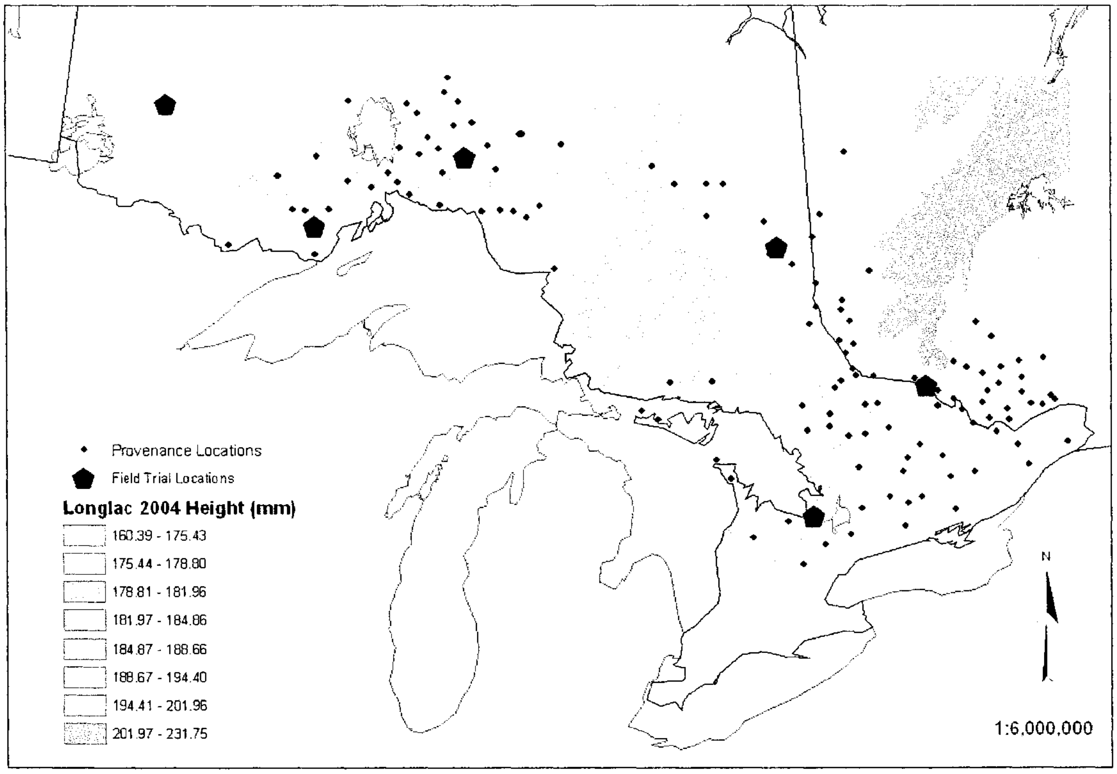
Contour map of mean root collar diameter in 2003 at the Longlac field trial



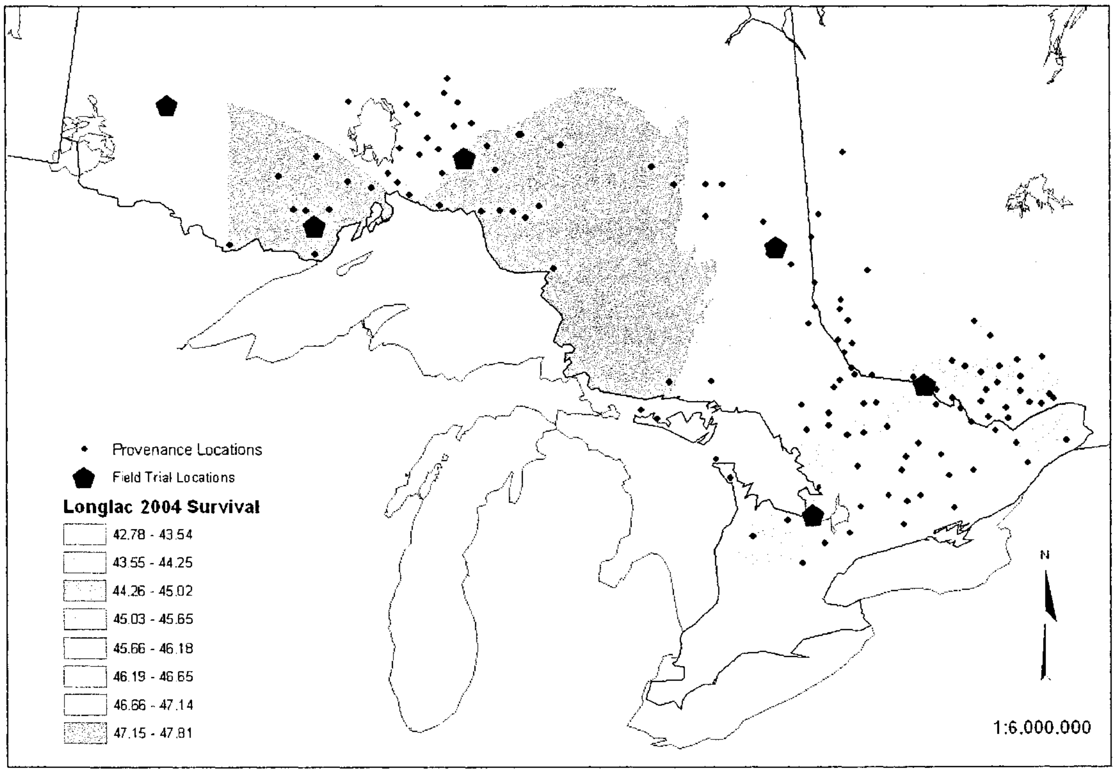
Contour map of mean root collar diameter in 2004 at the Longlac field trial



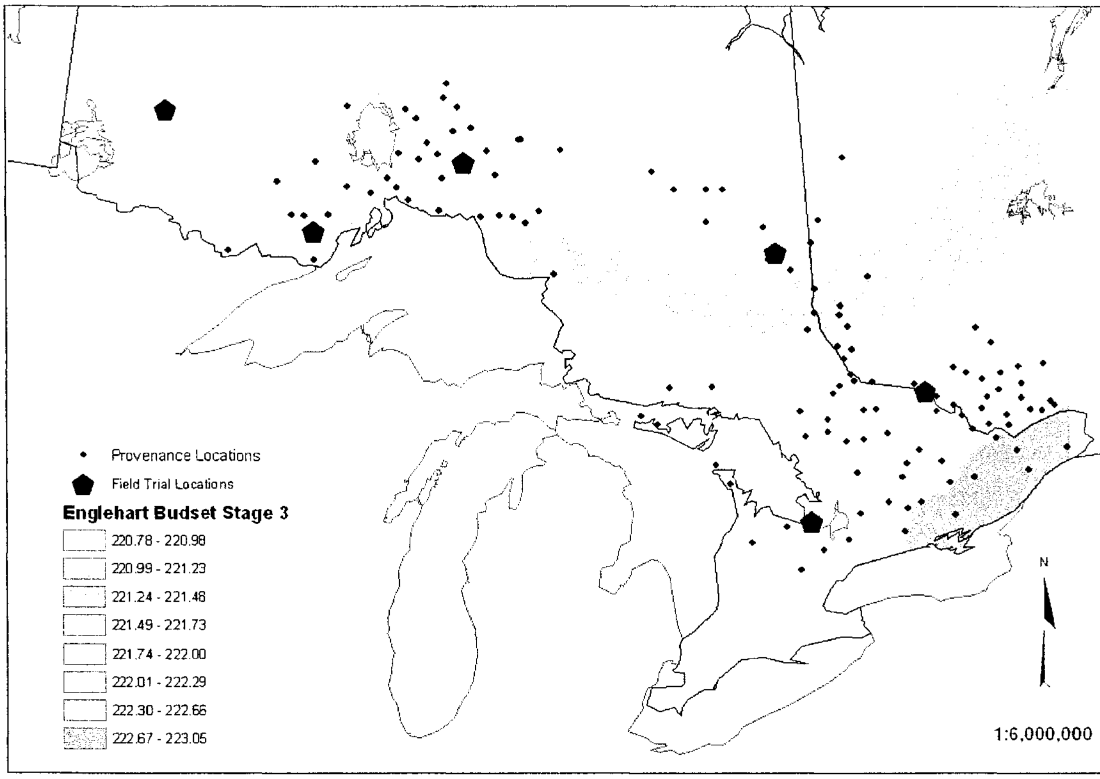
Contour map of mean height in 2003 at the Longlac field trial



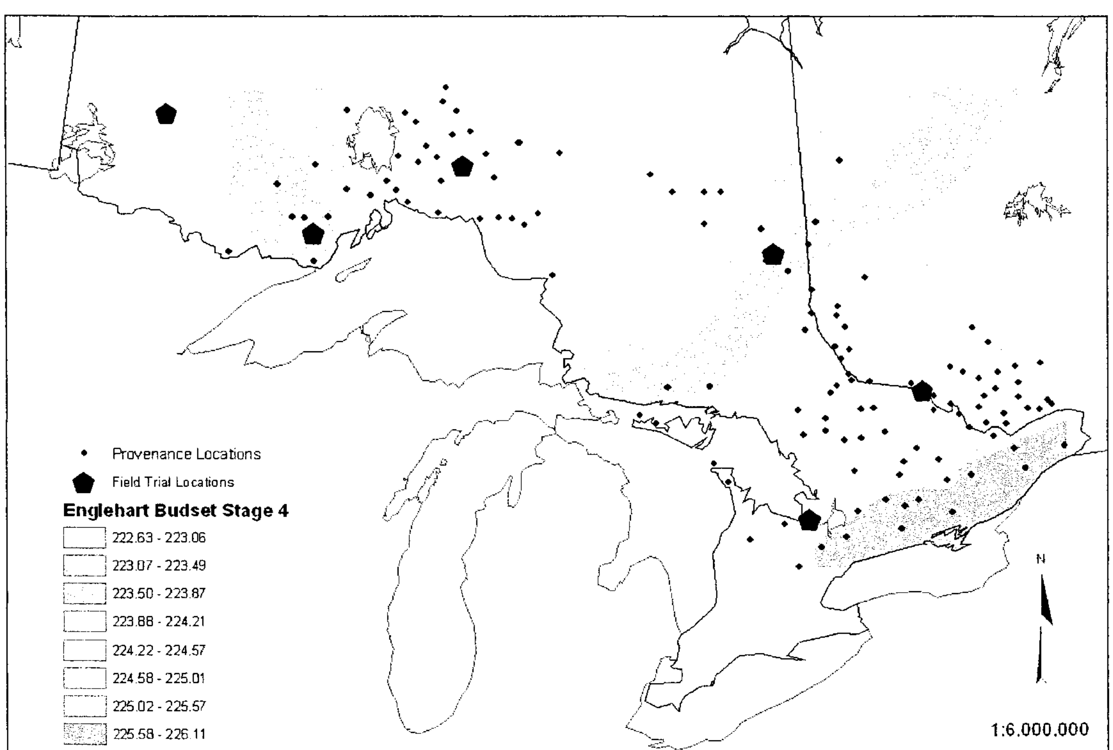
Contour map of mean height in 2004 at the Longlac field trial



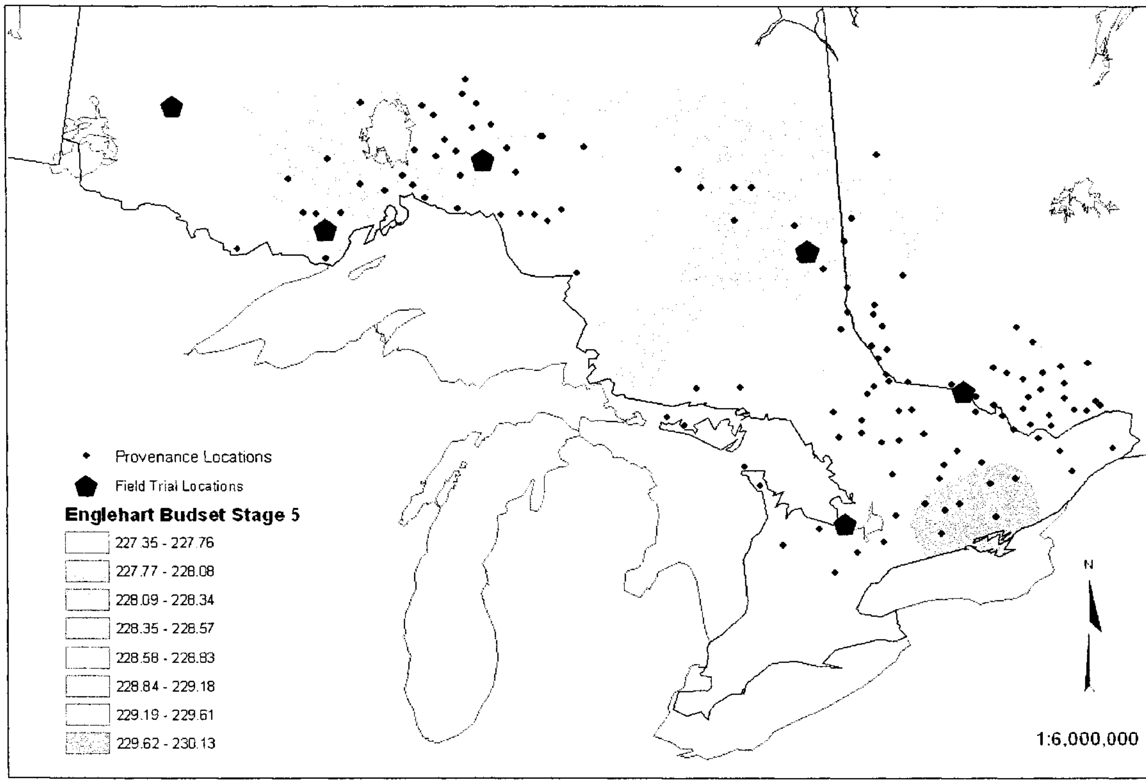
Contour map of mean survival in 2004 at the Longlac field trial



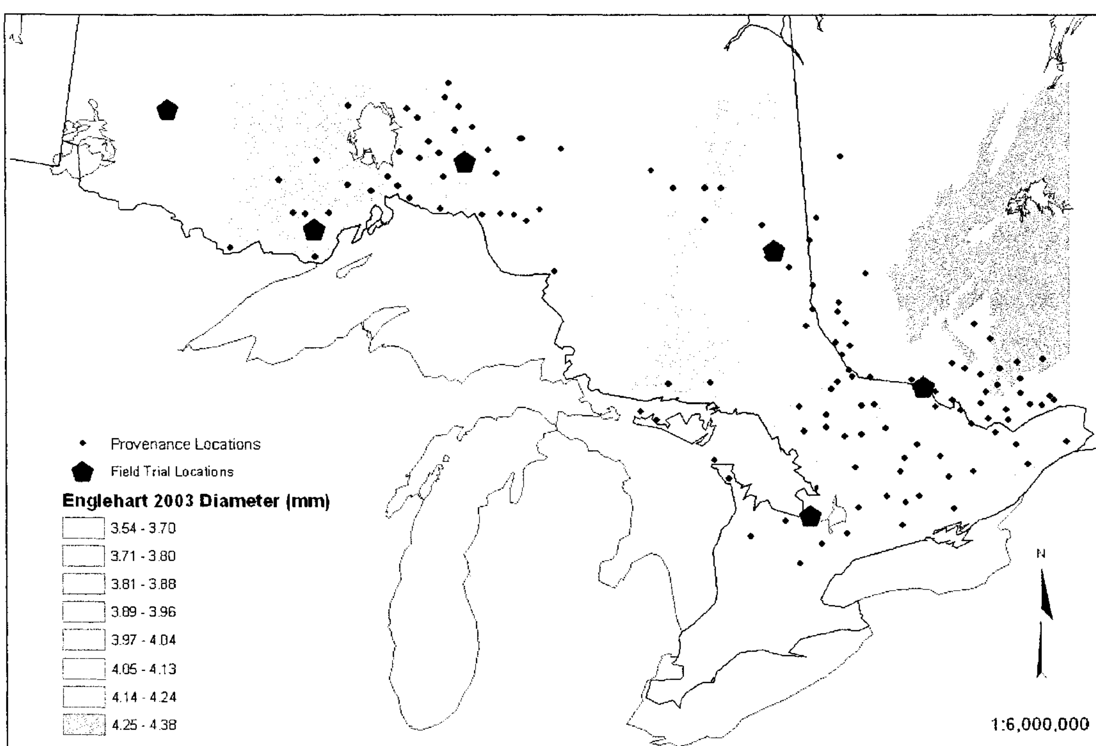
Contour map of mean number of days from Jan. 1 to reach budset stage 3 at the Englehart field trial



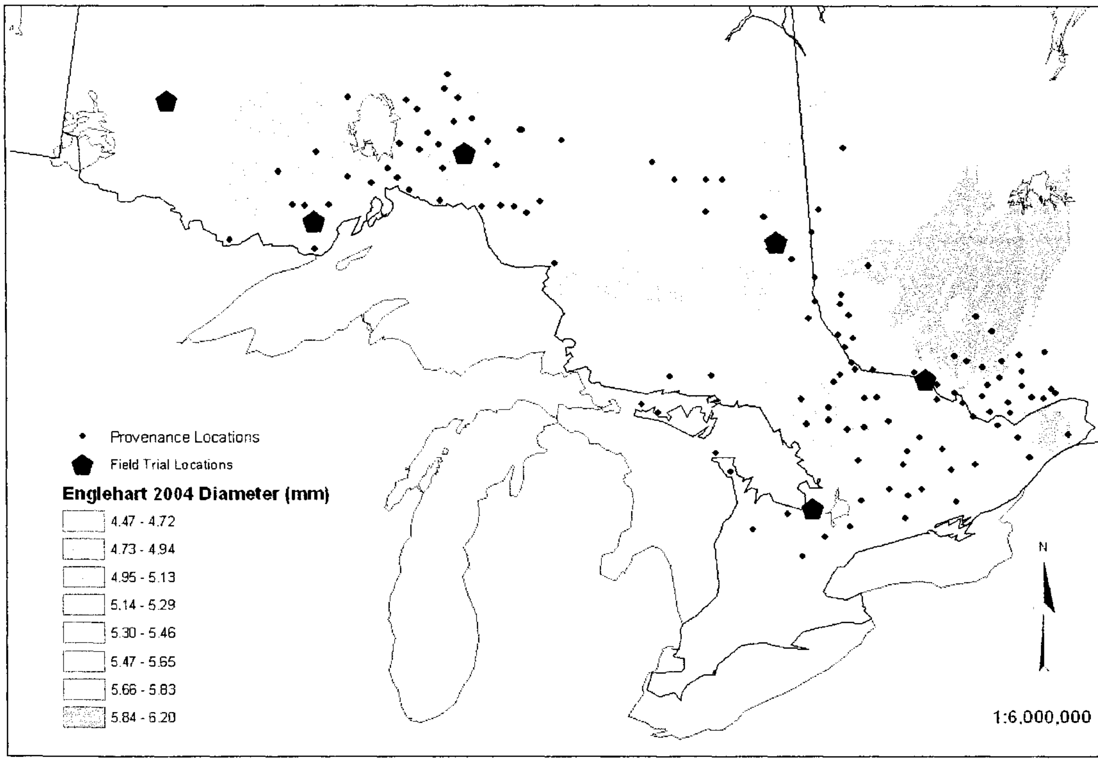
Contour map of mean number of days from Jan. 1 to reach budset stage 4 at the Englehart field trial



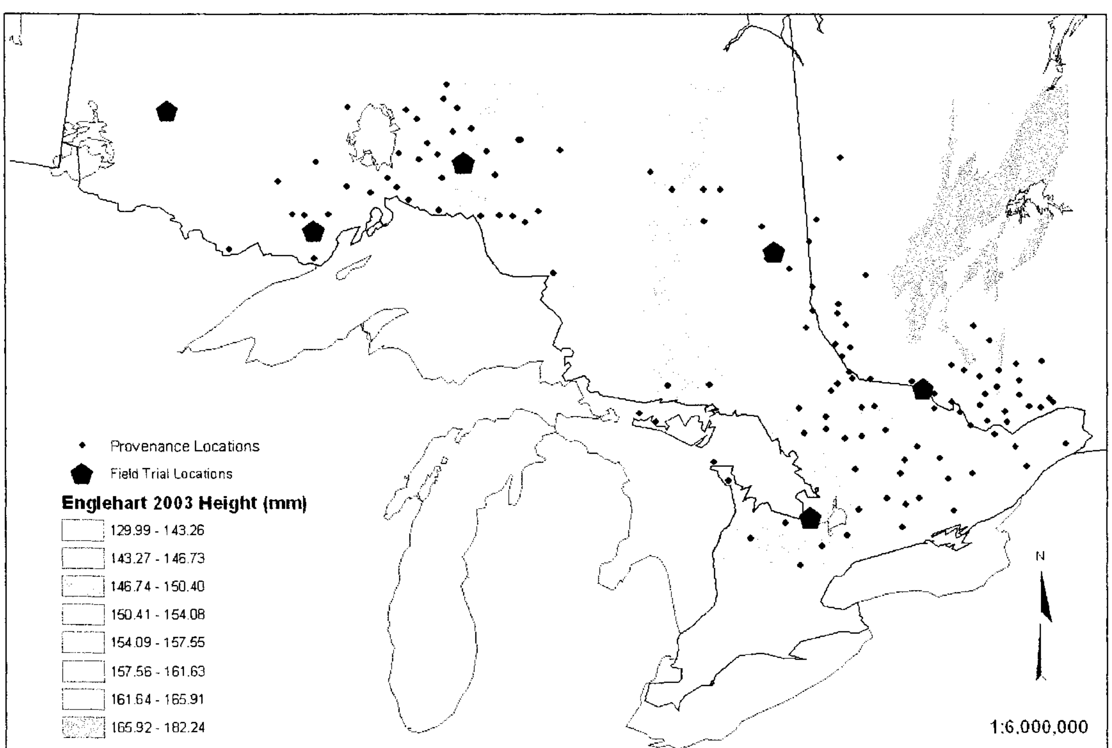
Contour map of mean number of days from Jan. 1 to reach budset stage 5 at the Englehart field trial



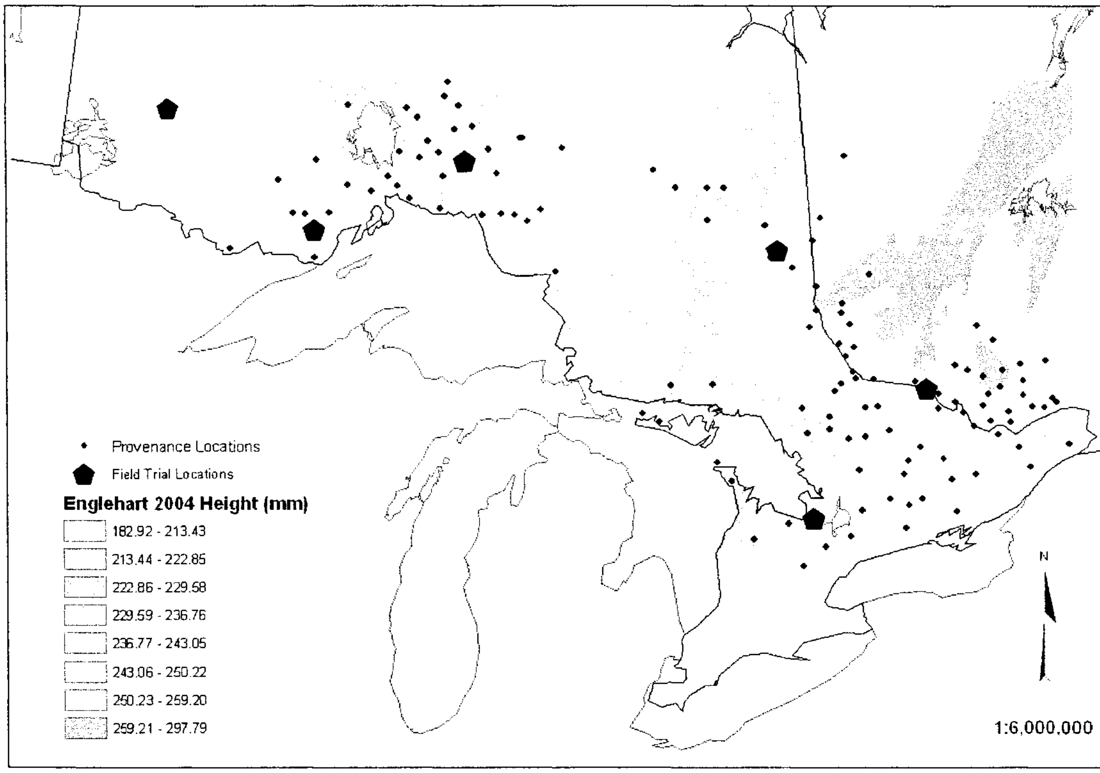
Contour map of mean root collar diameter in 2003 at the Englehart field trial



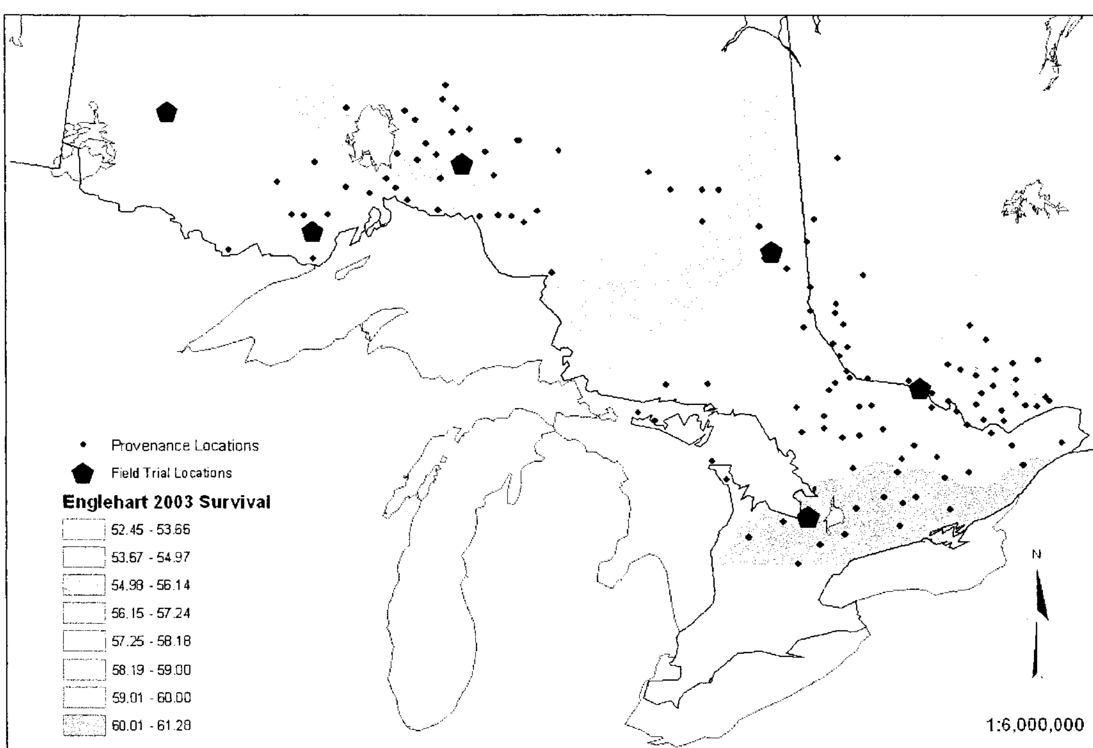
Contour map of mean root collar diameter in 2004 at the Englehart field trial



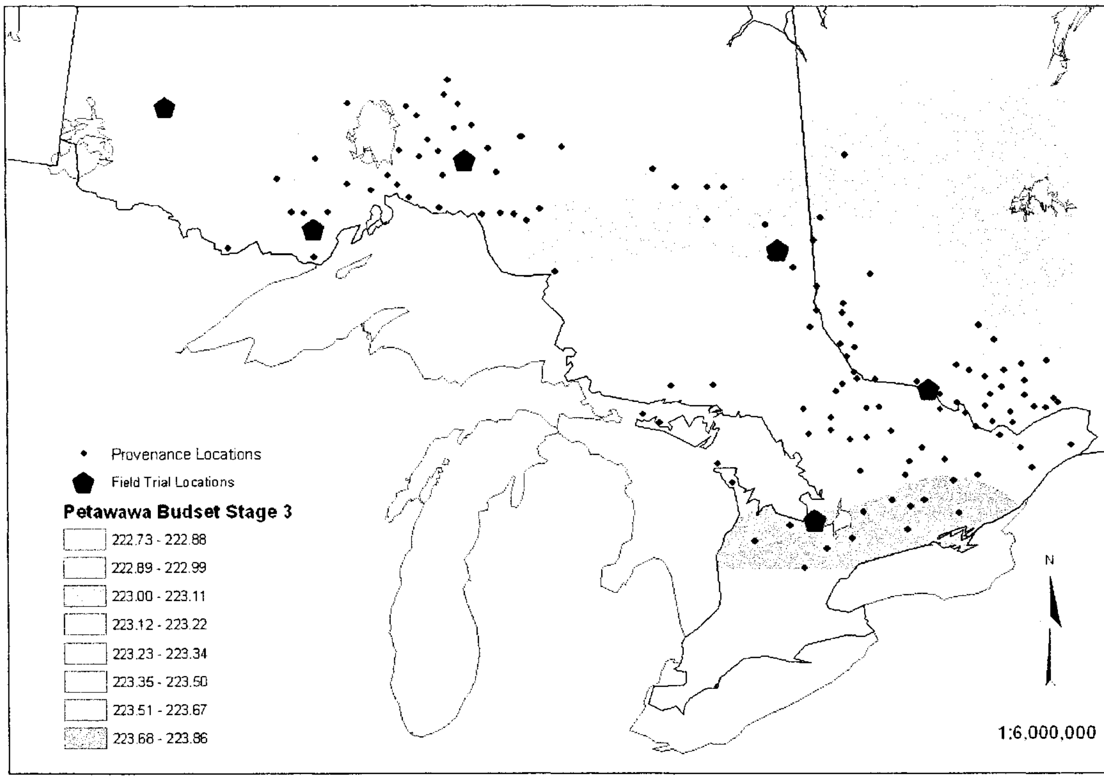
Contour map of mean height in 2003 at the Englehart field trial



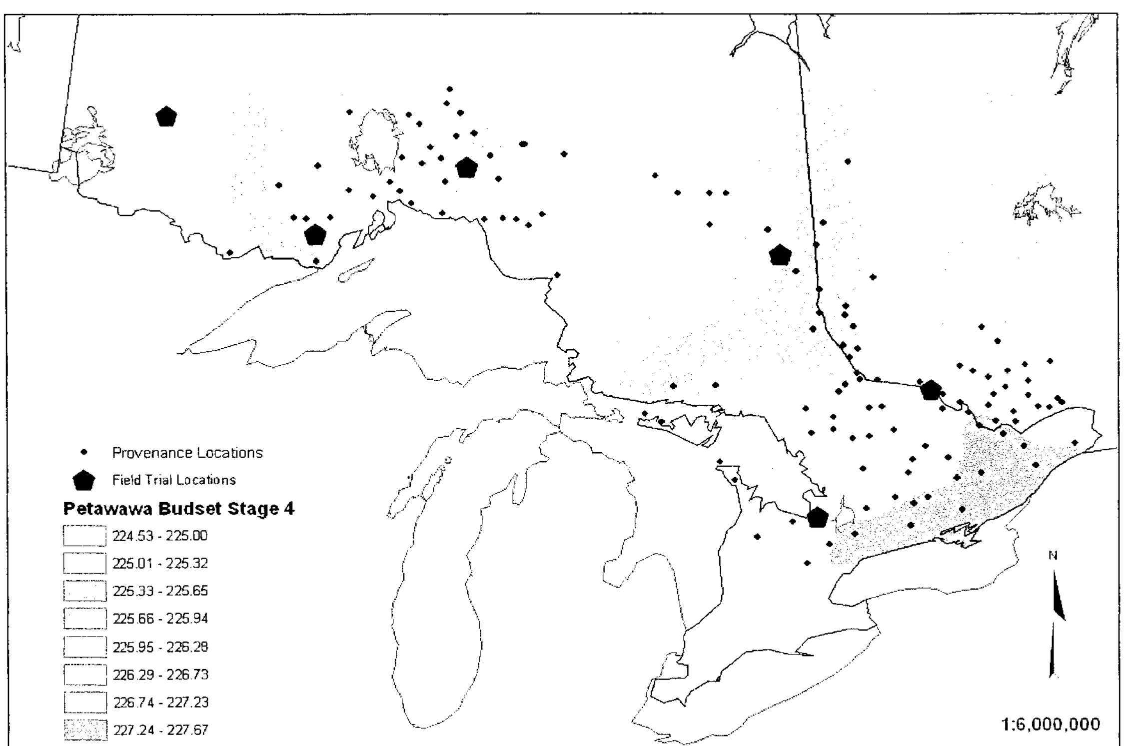
Contour map of mean height in 2004 at the Englehart field trial



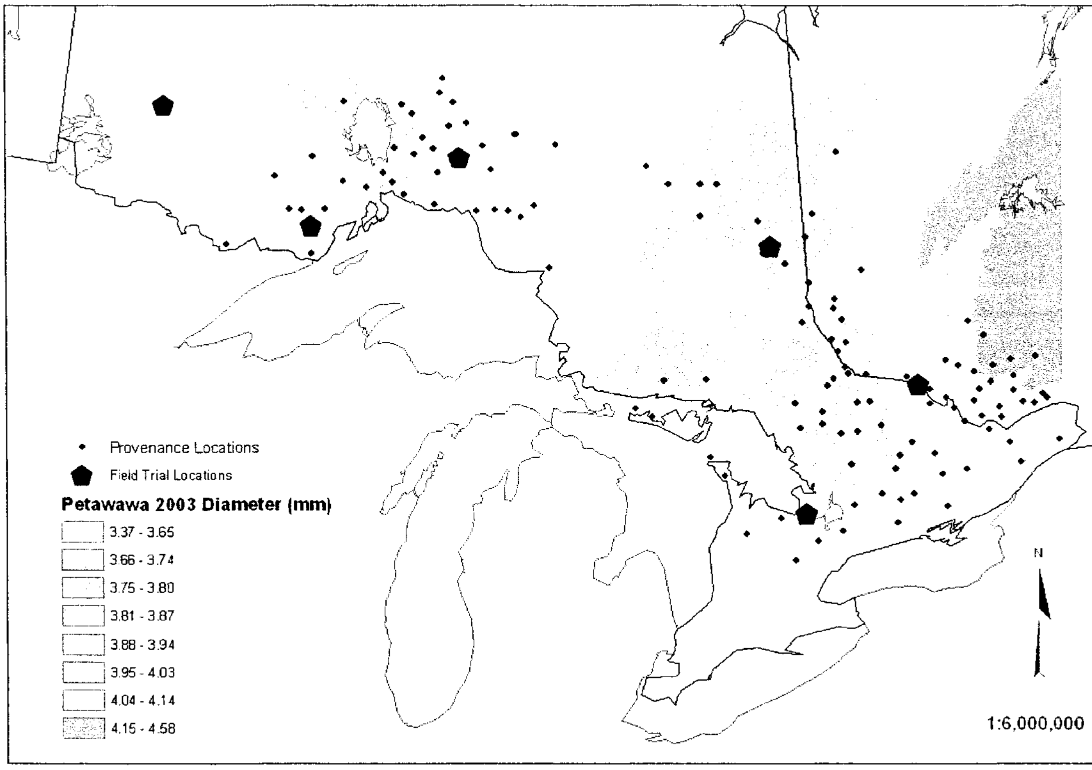
Contour map of mean survival in 2003 at the Englehart field trial



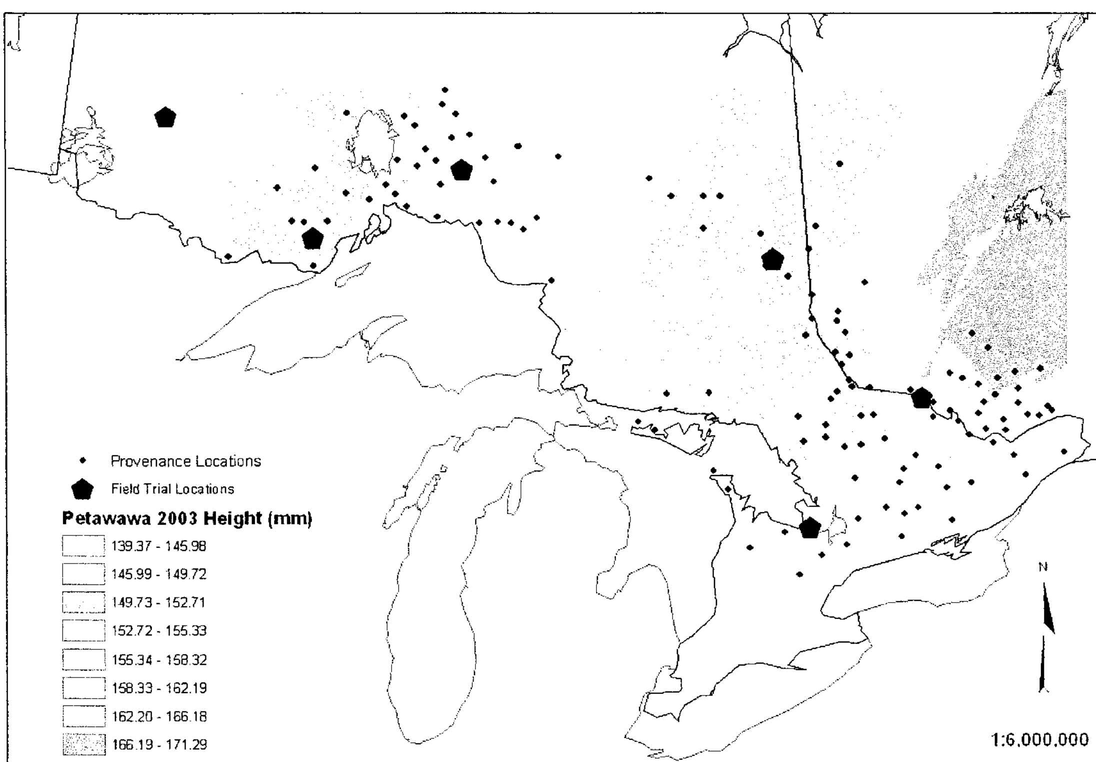
Contour map of mean number of days from Jan. 1 to reach budset stage 3 at the Petawawa field trial



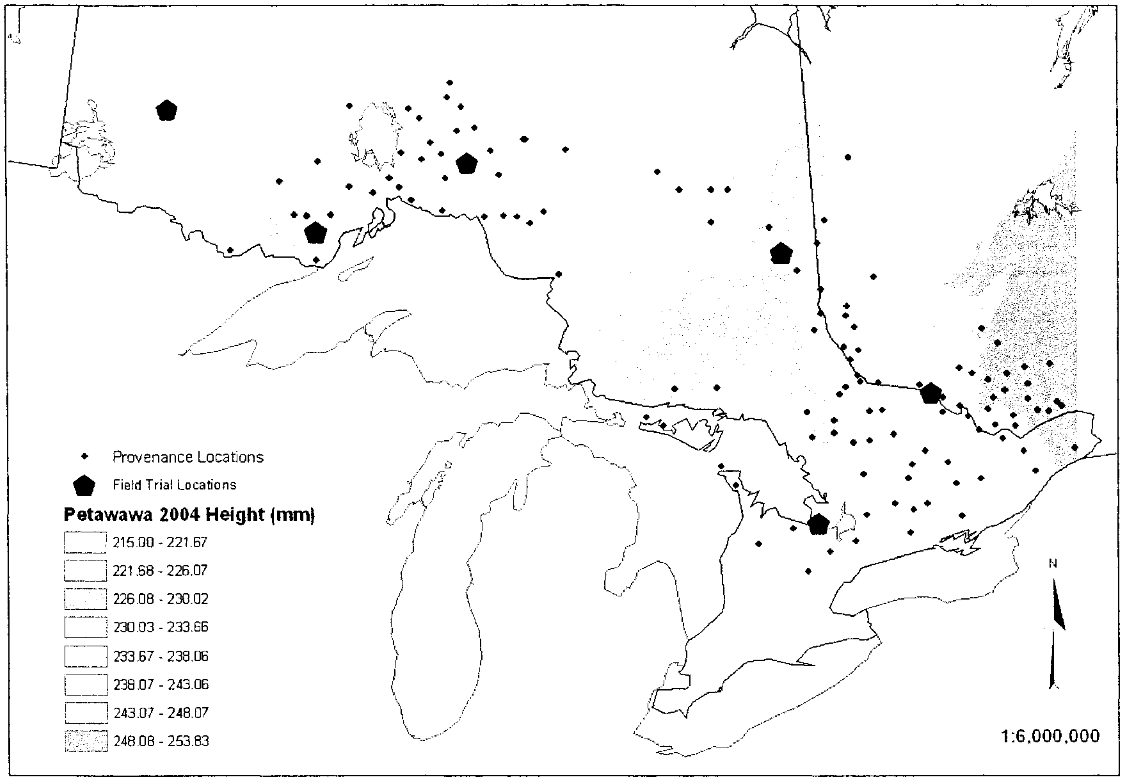
Contour map of mean number of days from Jan. 1 to reach budset stage 4 at the Petawawa field trial



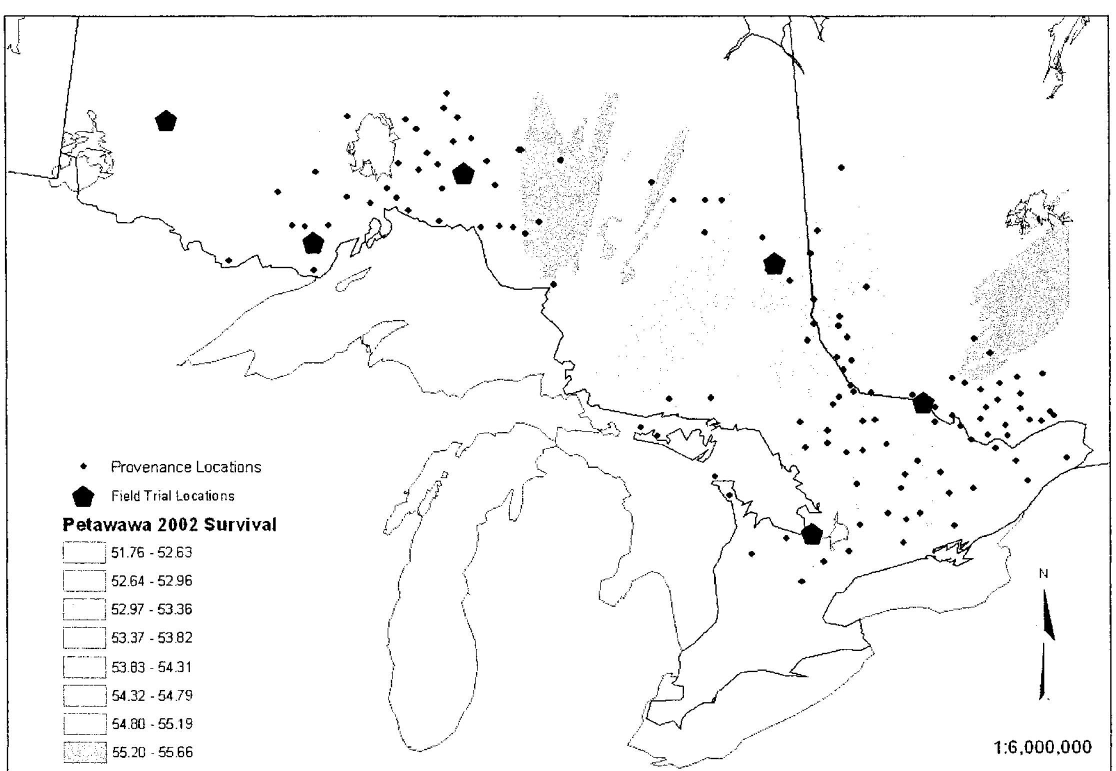
Contour map of mean root collar diameter in 2003 at the Petawawa field trial



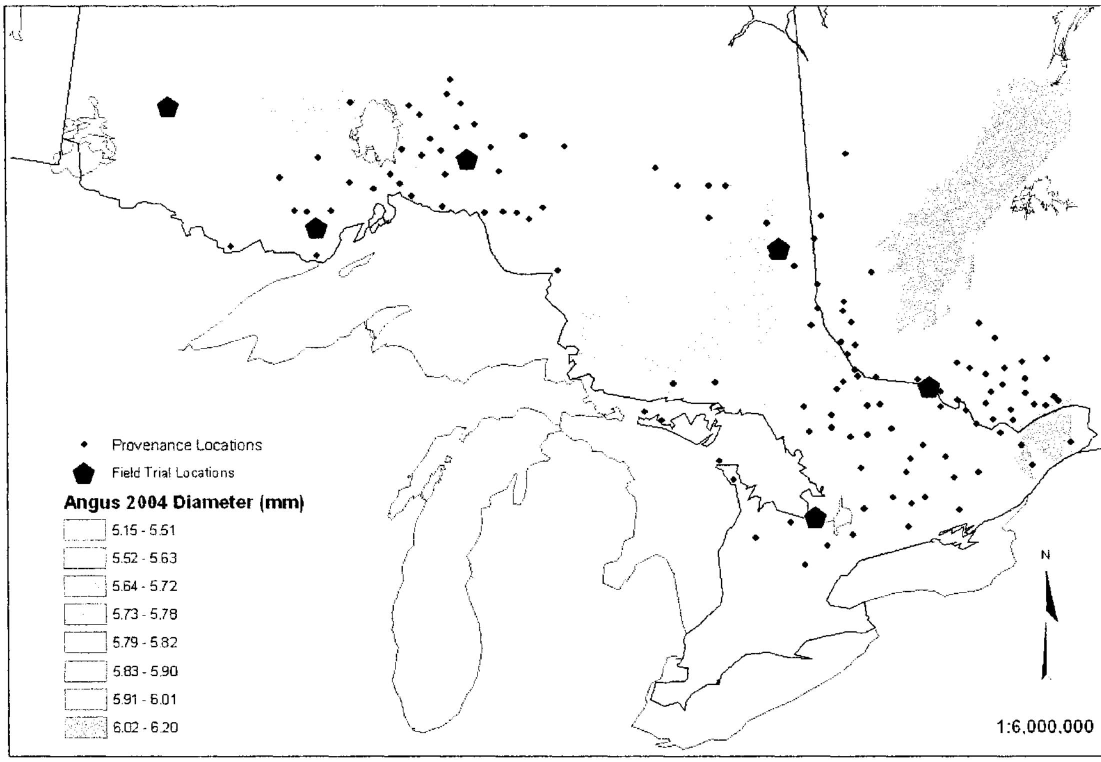
Contour map of mean height in 2003 at the Petawawa field trial



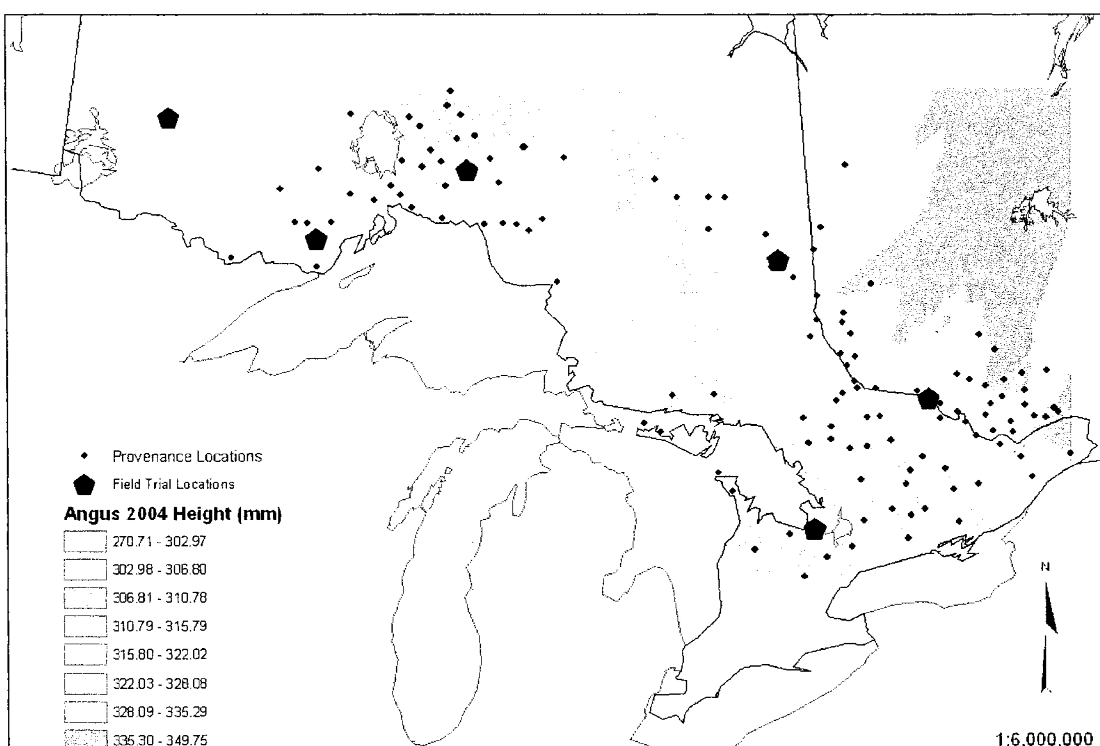
Contour map of mean height in 2004 at the Petawawa field trial



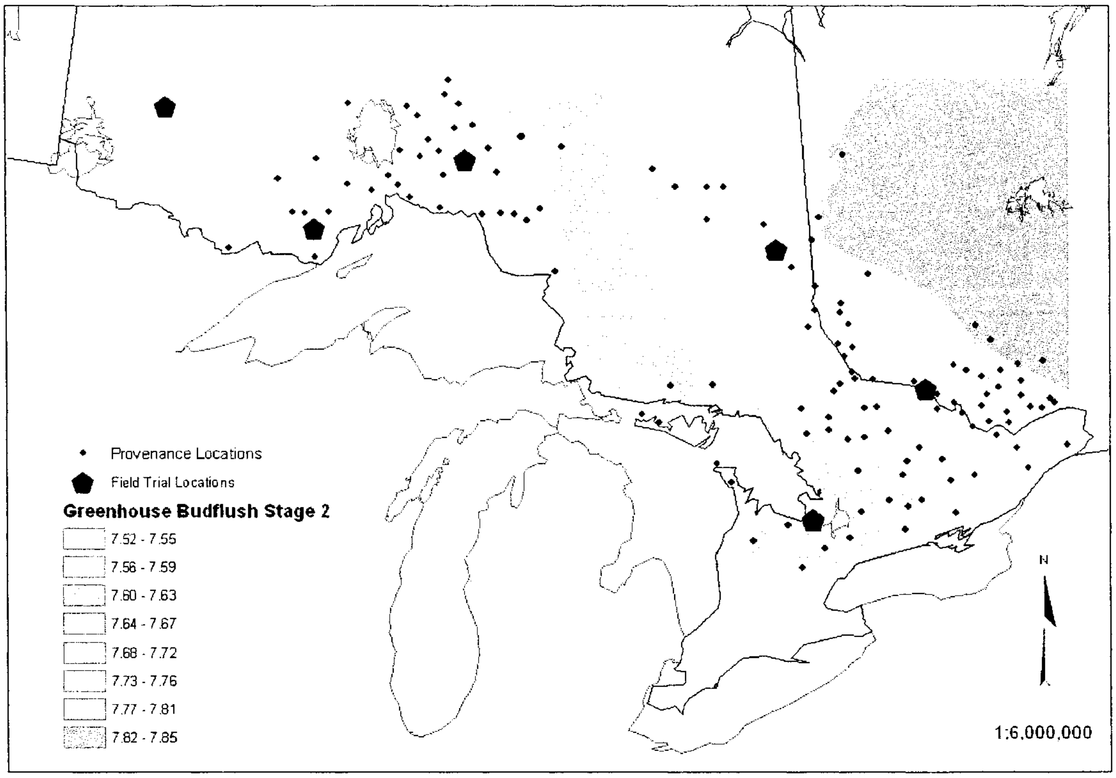
Contour map of mean survival in 2002 at the Petawawa field trial



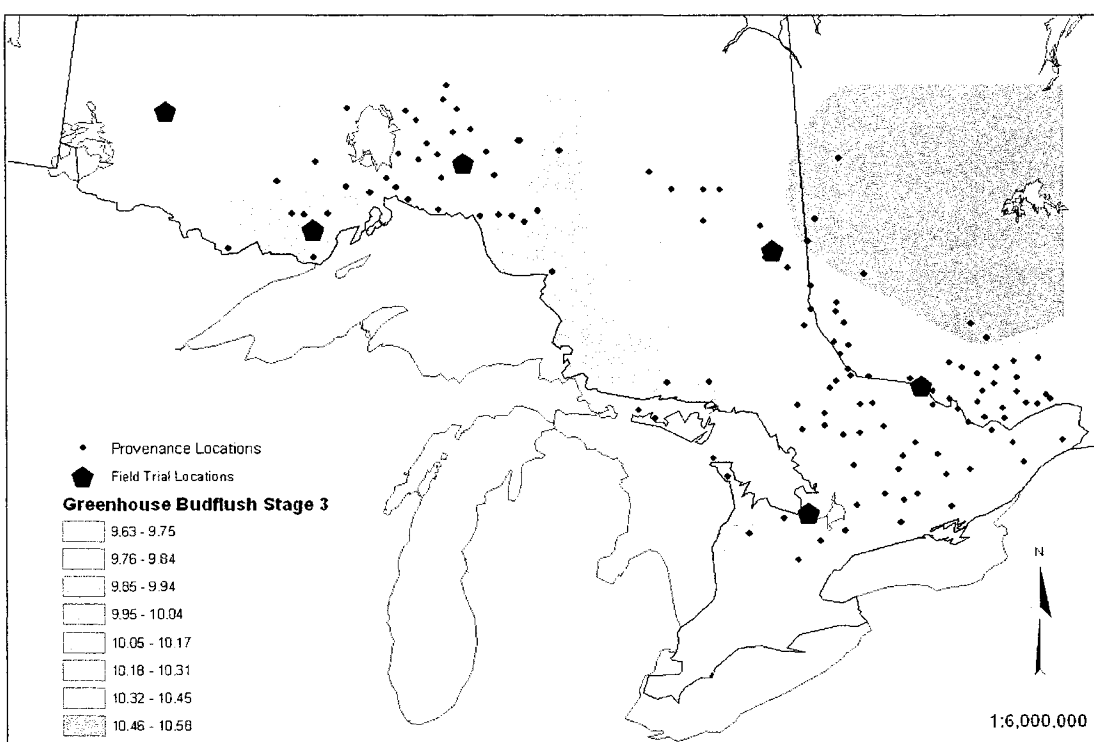
Contour map of mean root collar diameter in 2004 at the Angus field trial



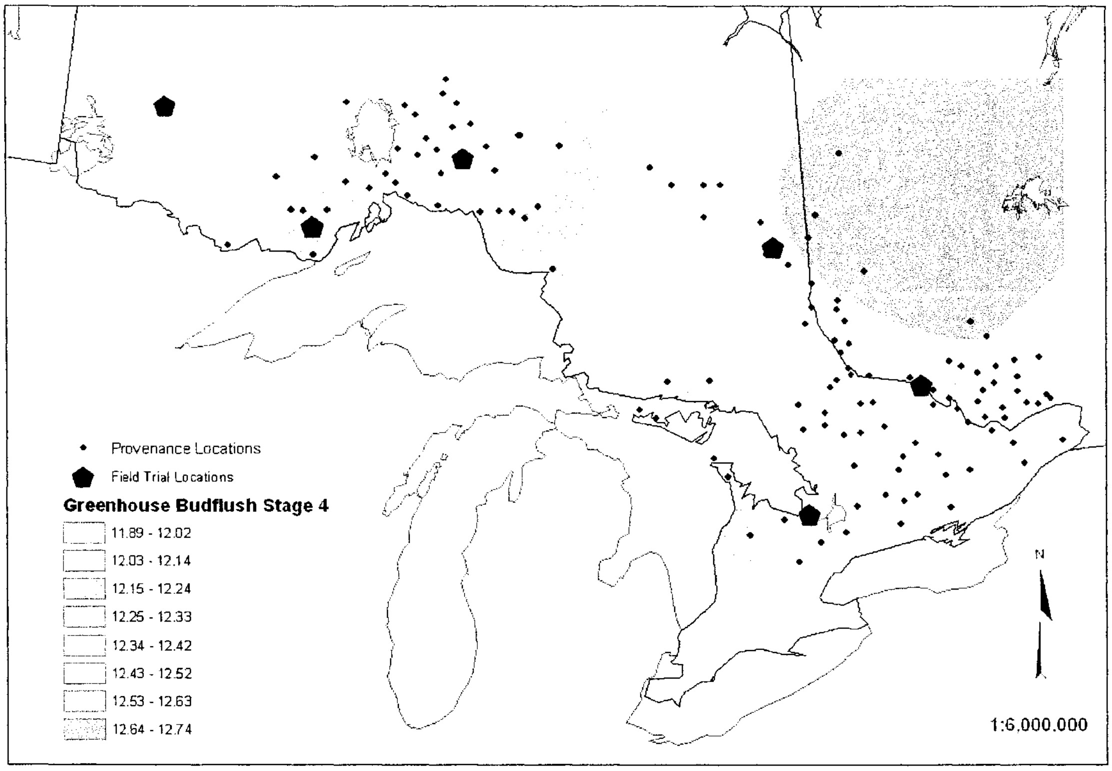
Contour map of mean height in 2004 at the Angus field trial



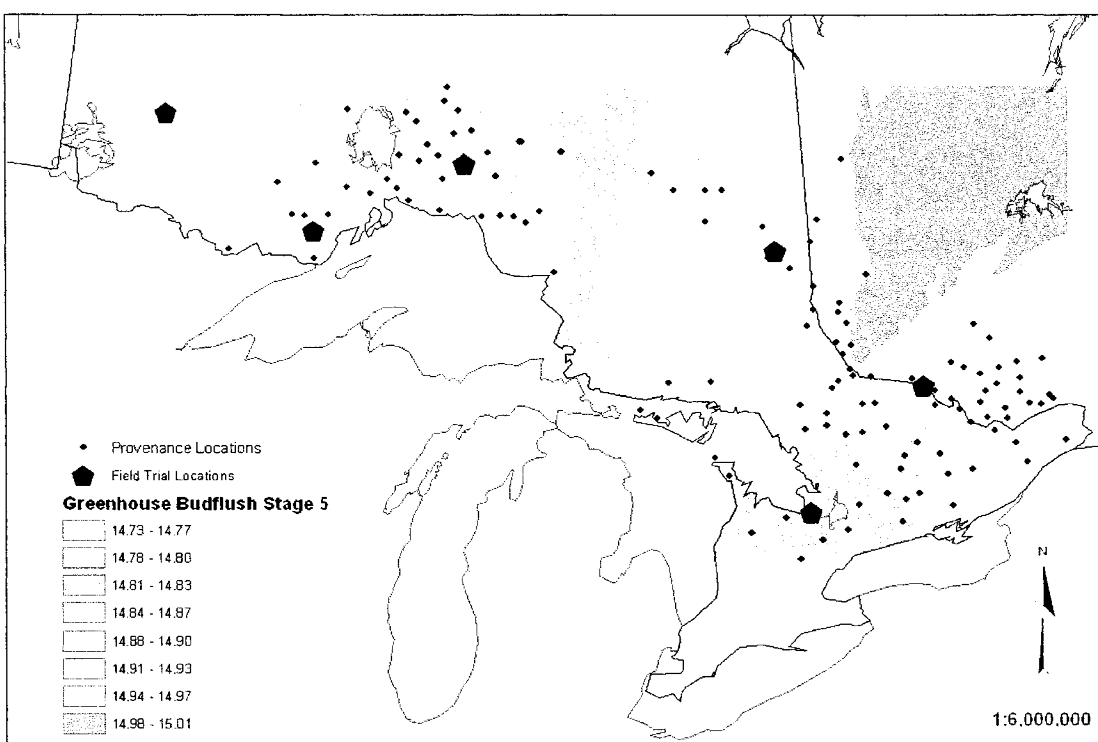
Contour map of mean number of days from removal from cold storage to reach budflush stage 2 at the Lakehead greenhouse trial



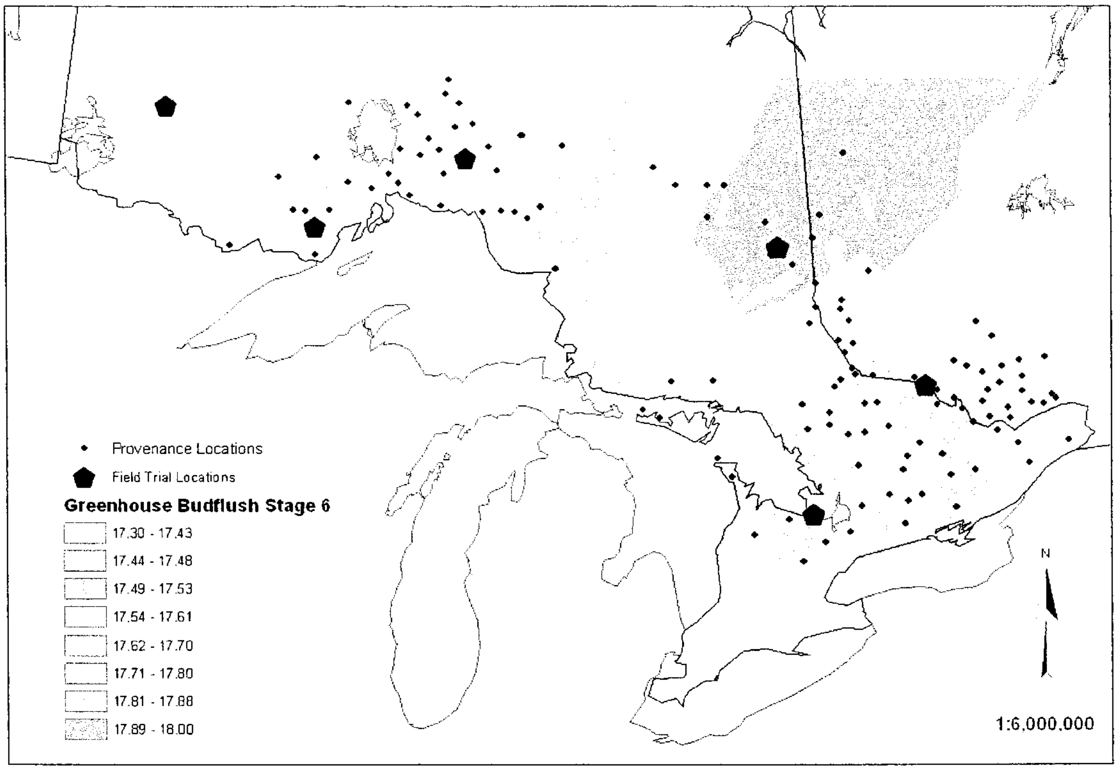
Contour map of mean number of days from removal from cold storage to reach budflush stage 3 at the Lakehead greenhouse trial



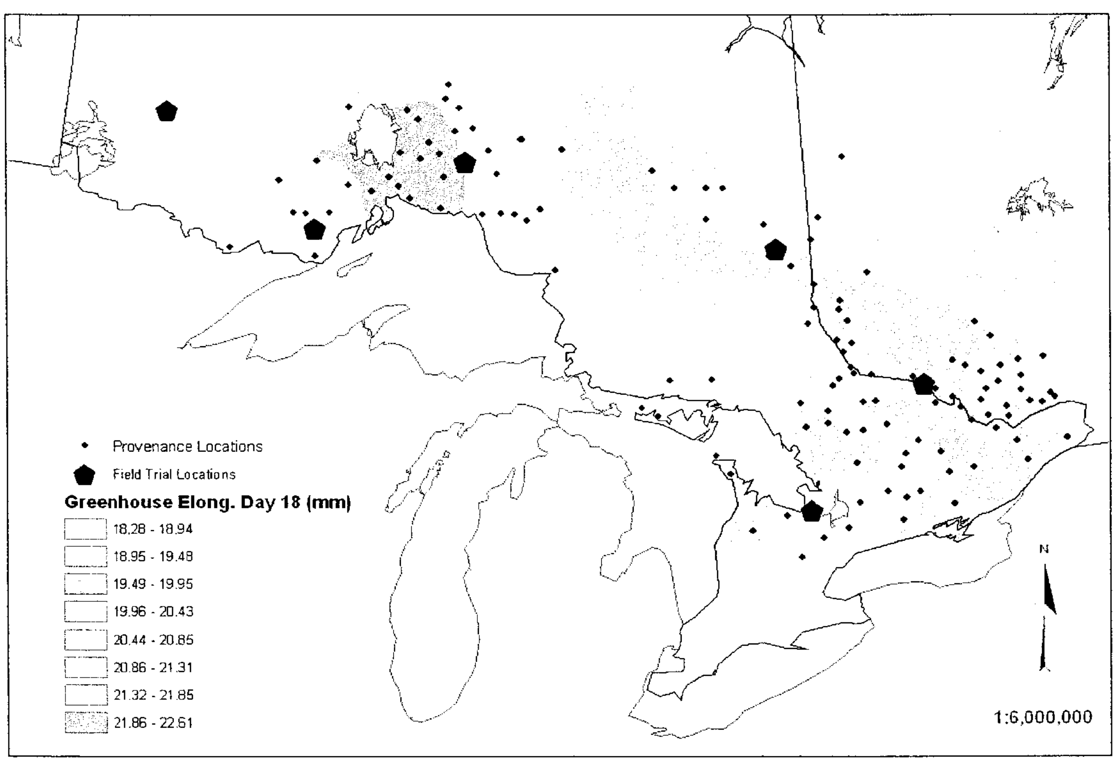
Contour map of mean number of days from removal from cold storage to reach budflush stage 4 at the Lakehead greenhouse trial



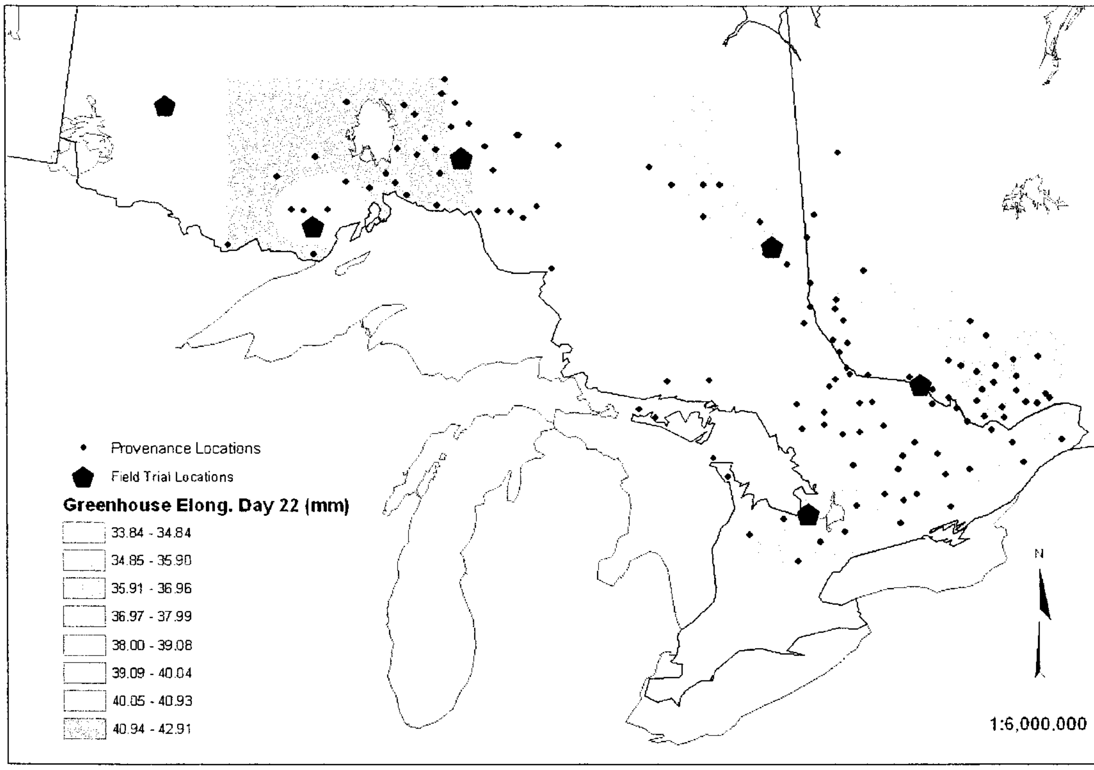
Contour map of mean number of days from removal from cold storage to reach budflush stage 5 at the Lakehead greenhouse trial



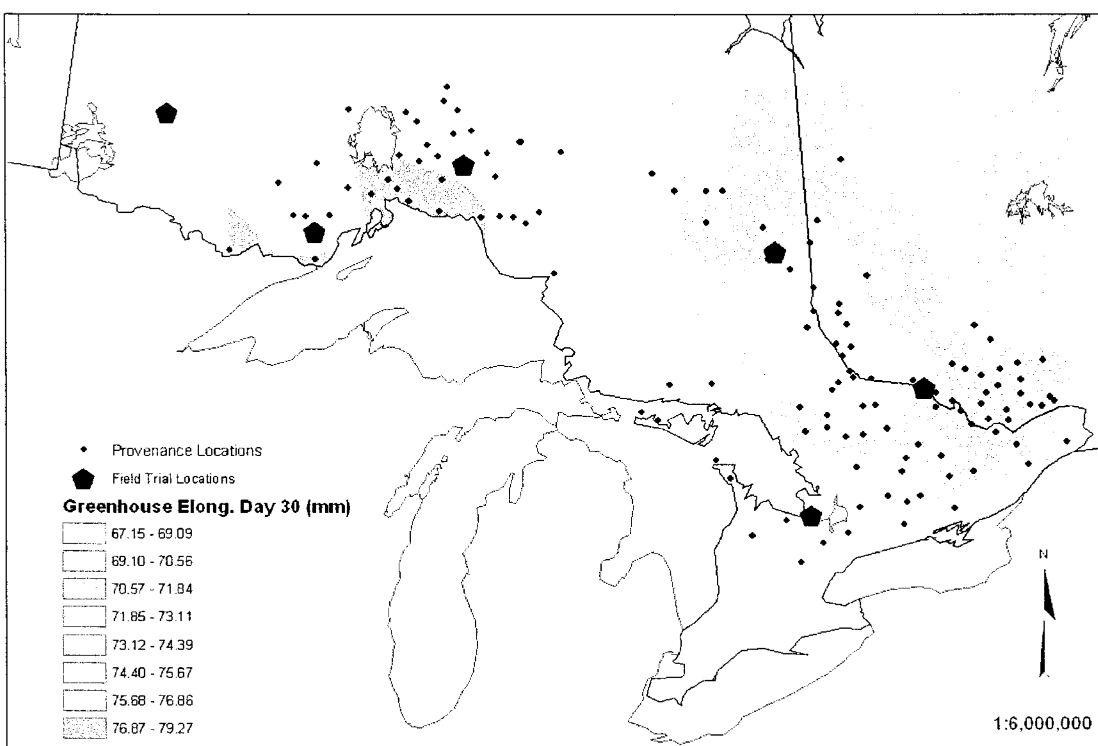
Contour map of mean number of days from removal from cold storage to reach budflush stage 6 at the Lakehead greenhouse trial



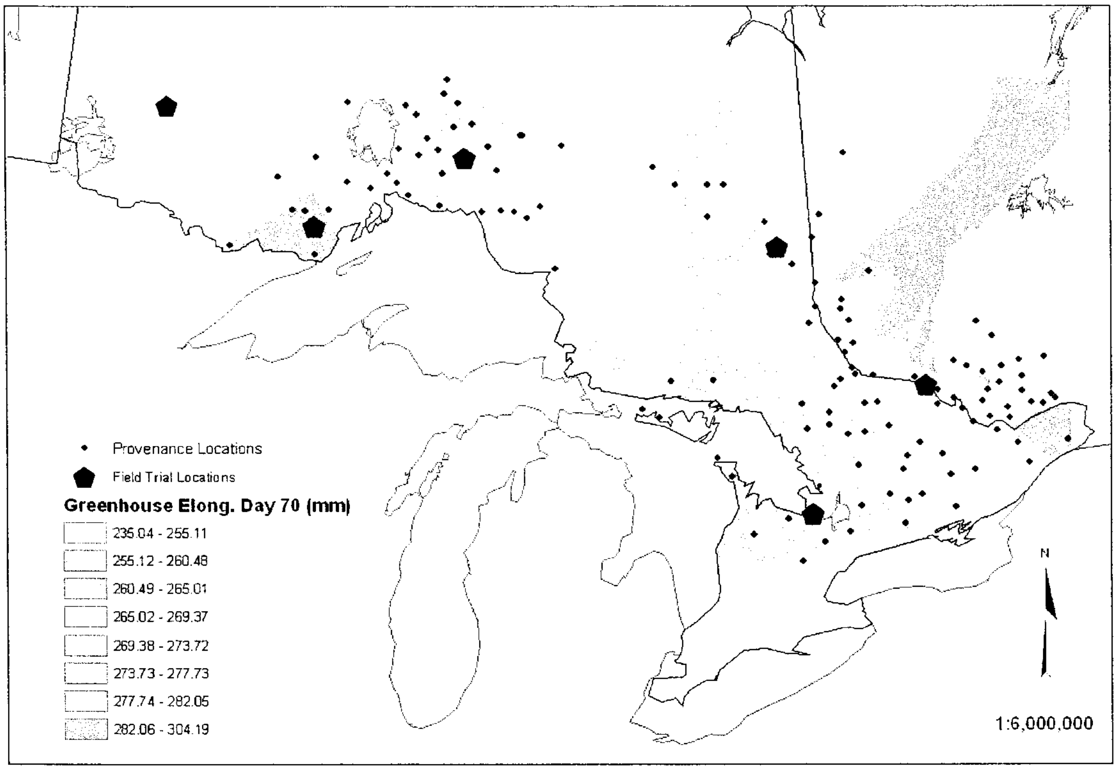
Contour map of shoot elongation at the Lakehead greenhouse trial 18 days after removal from cold storage



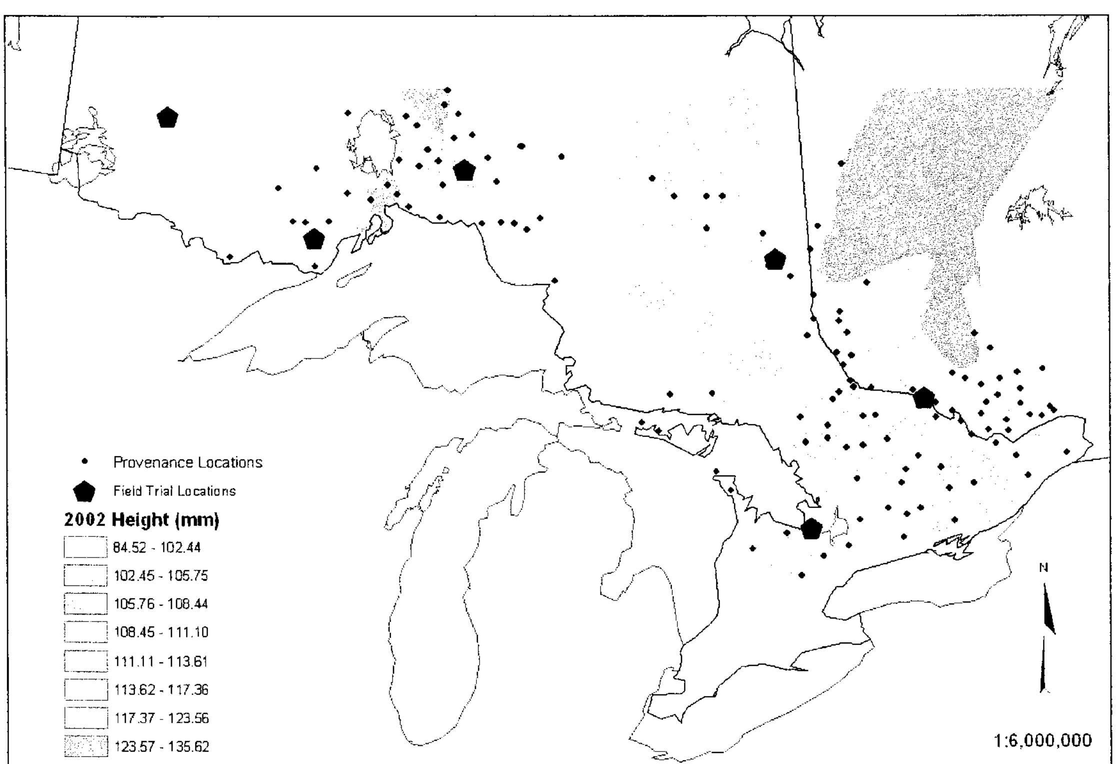
Contour map of shoot elongation at the Lakehead greenhouse trial 22 days after removal from cold storage



Contour map of shoot elongation at the Lakehead greenhouse trial 30 days after removal from cold storage

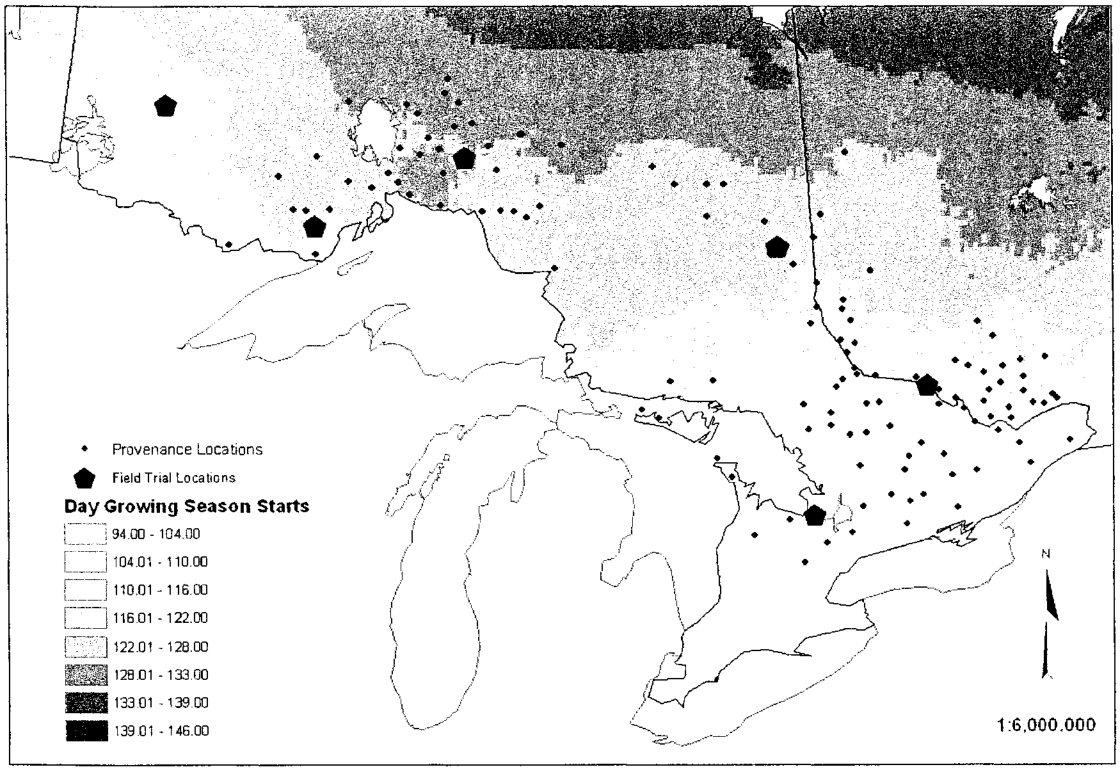


Contour map of shoot elongation at the Lakehead greenhouse trial 70 days after removal from cold storage

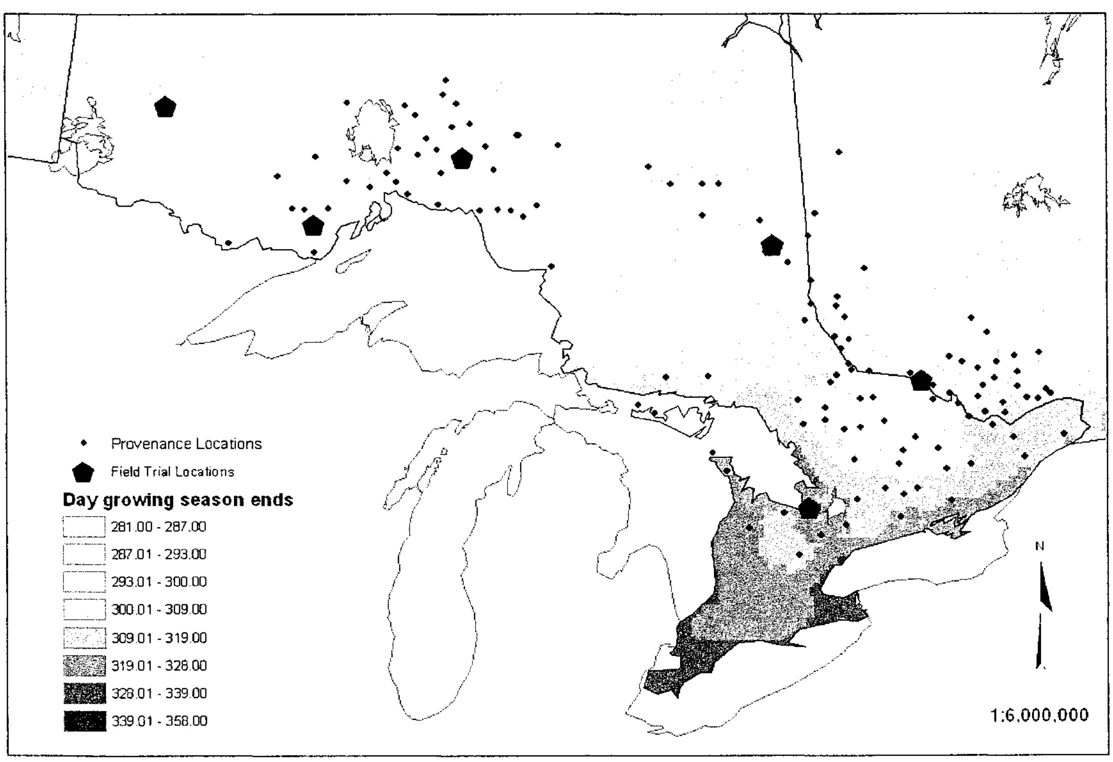


Contour map of mean height in 2002 over all tests

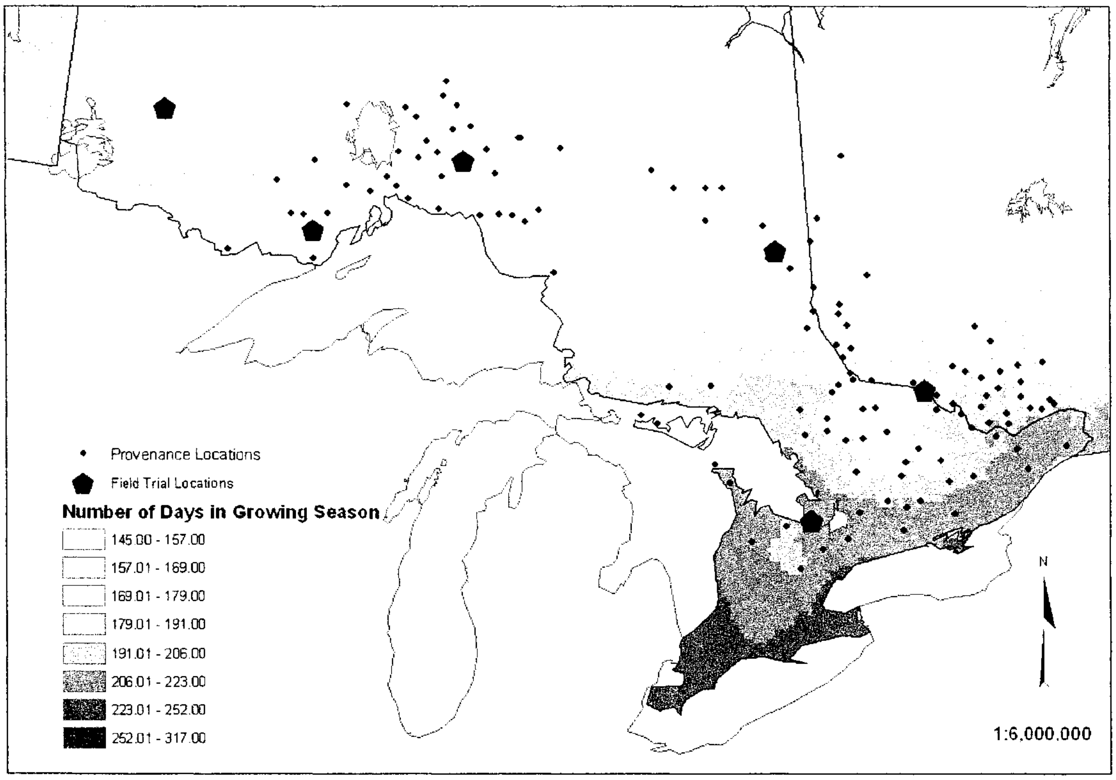
APPENDIX V
CONTOUR MAPS OF SELECTED CLIMATE GRIDS



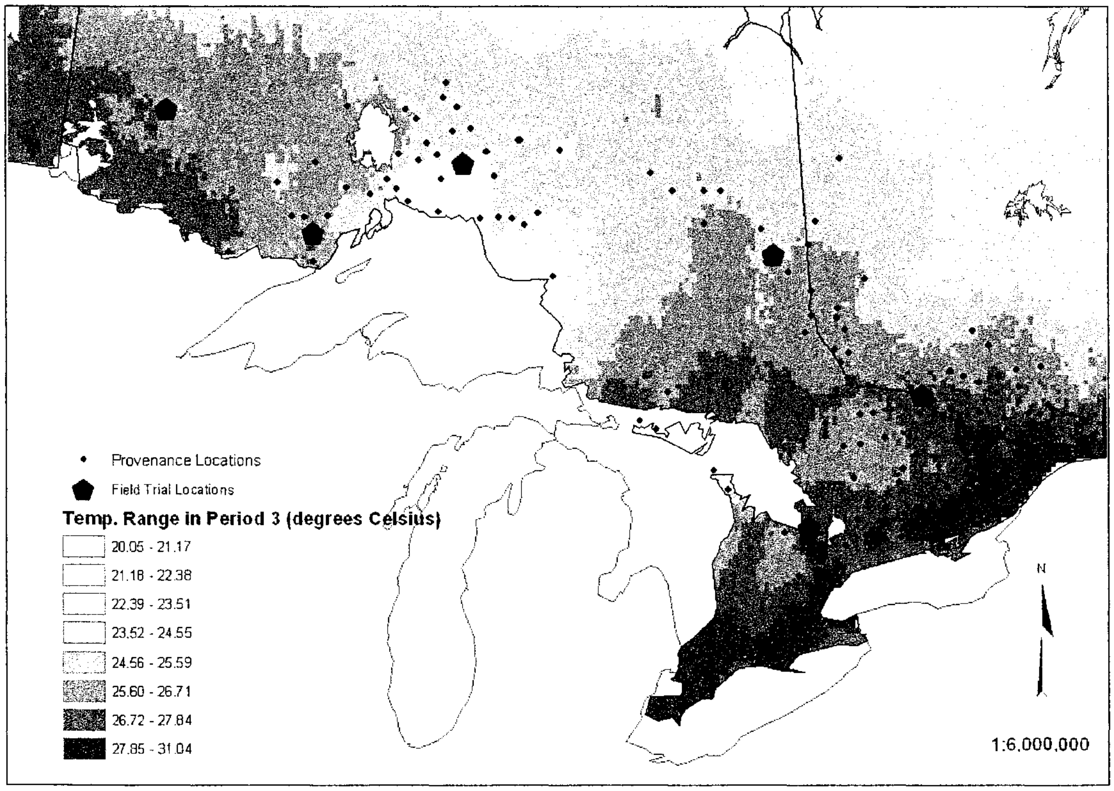
Contour map of number of Julian days until start of growing season, which begins following March 1st after there are 5 consecutive days greater than or equal to 5°C



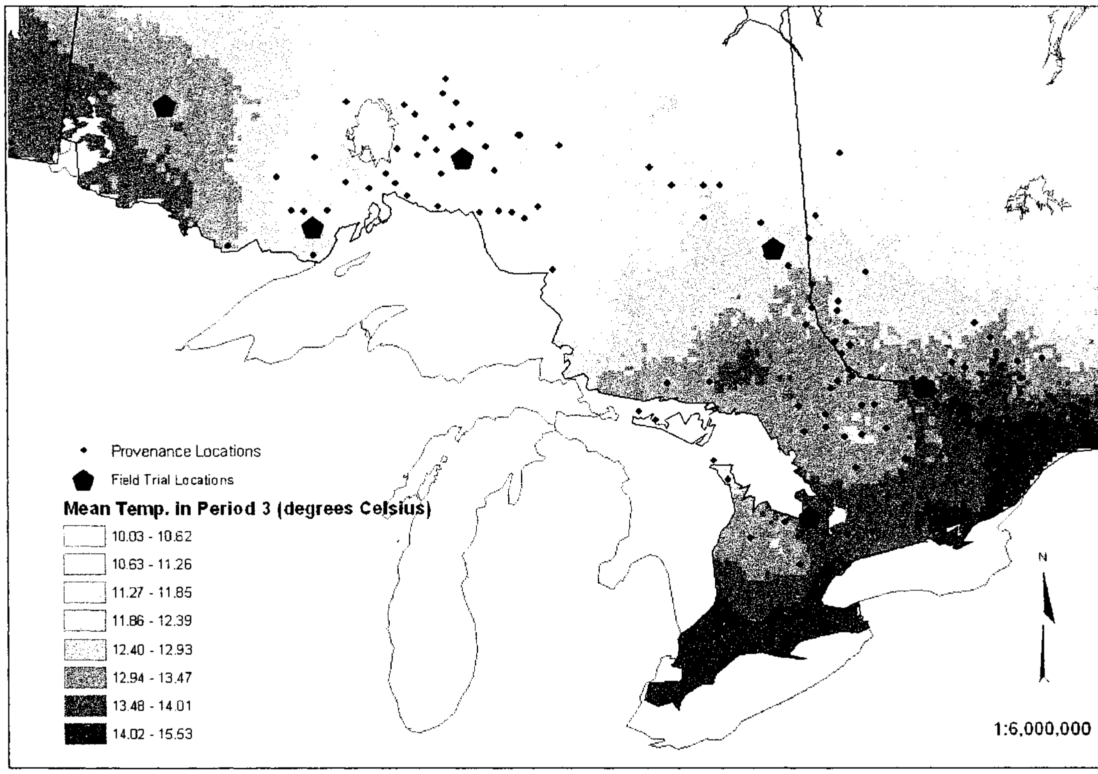
Contour map of number of Julian days until end of growing season, which occurs when min. temp falls below -2°C following August 1st



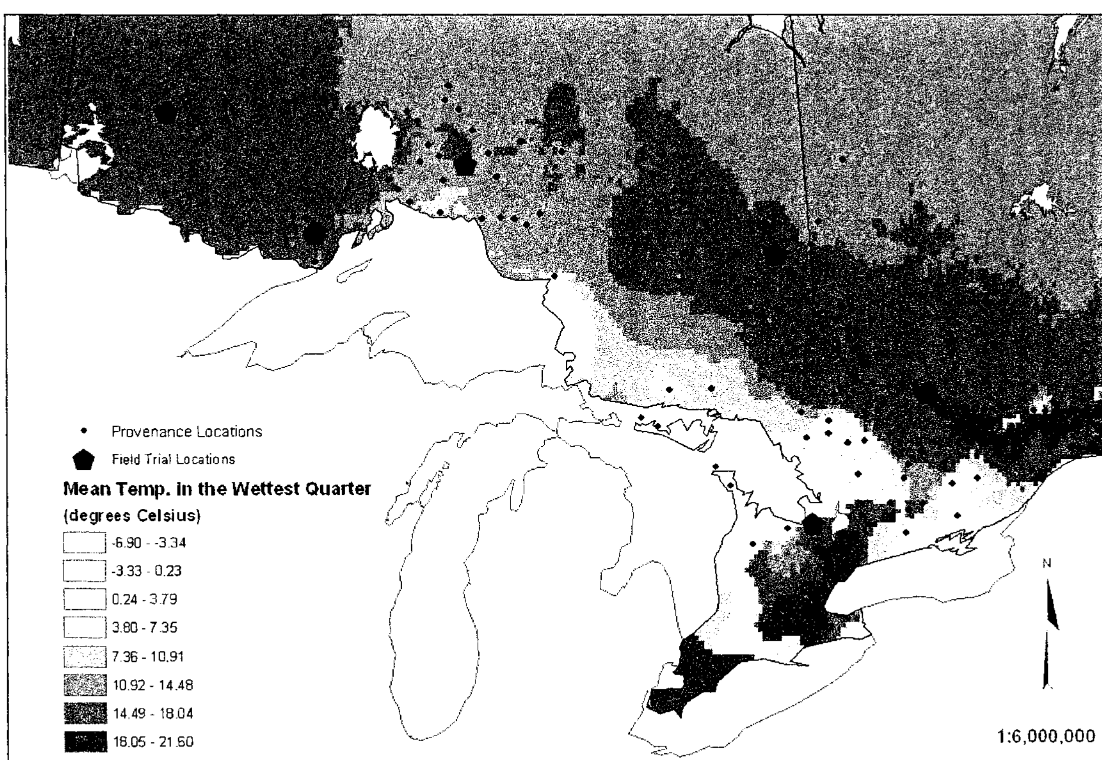
Contour map of number of Julian days in the growing season



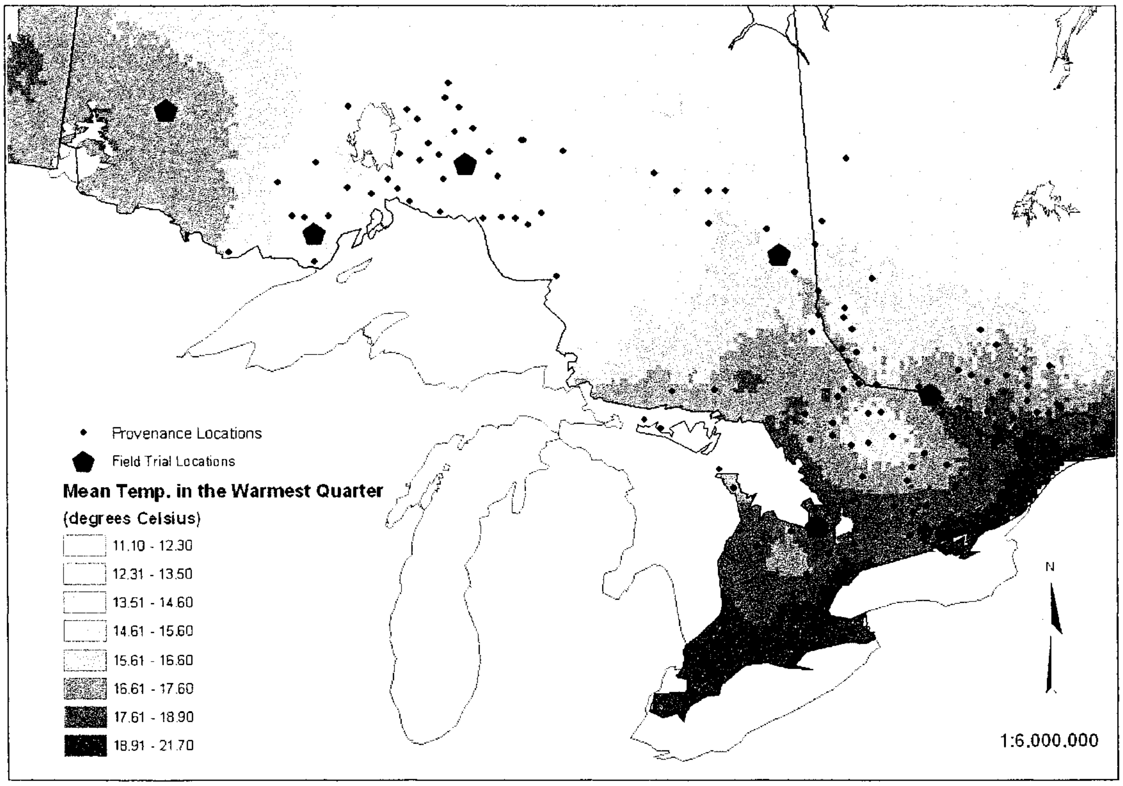
Contour map of temperature range in period three, the entire growing season



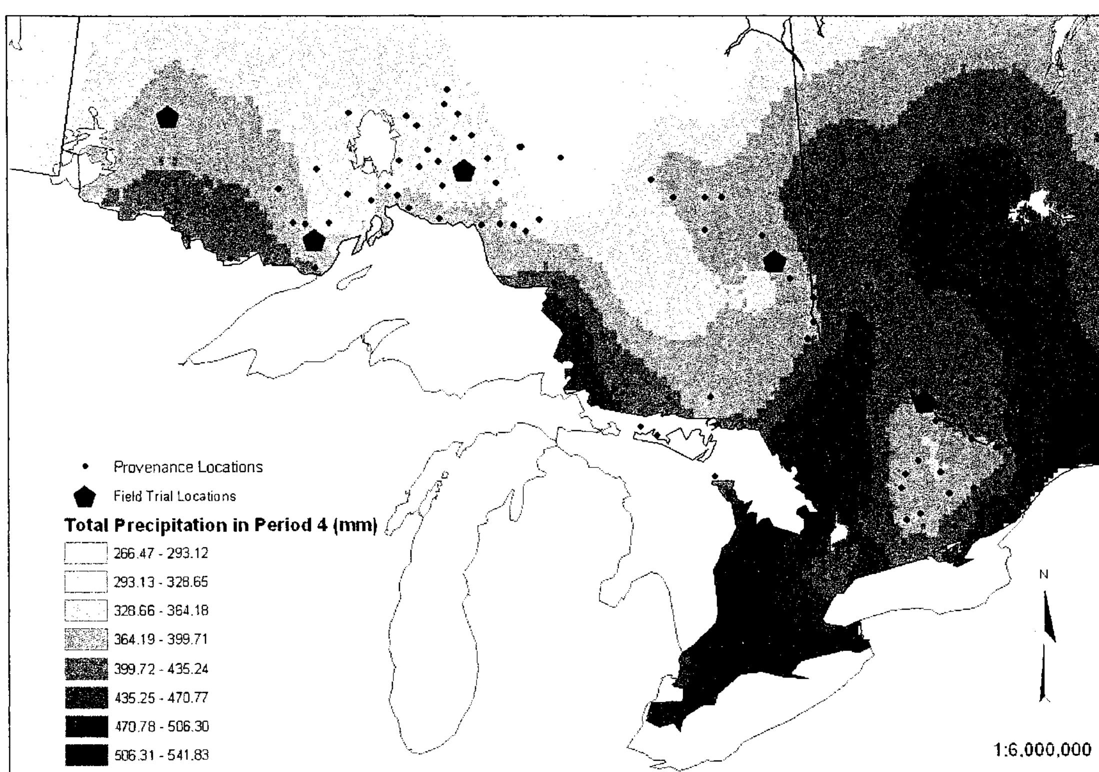
Contour map of mean temperature in period three, the entire growing season



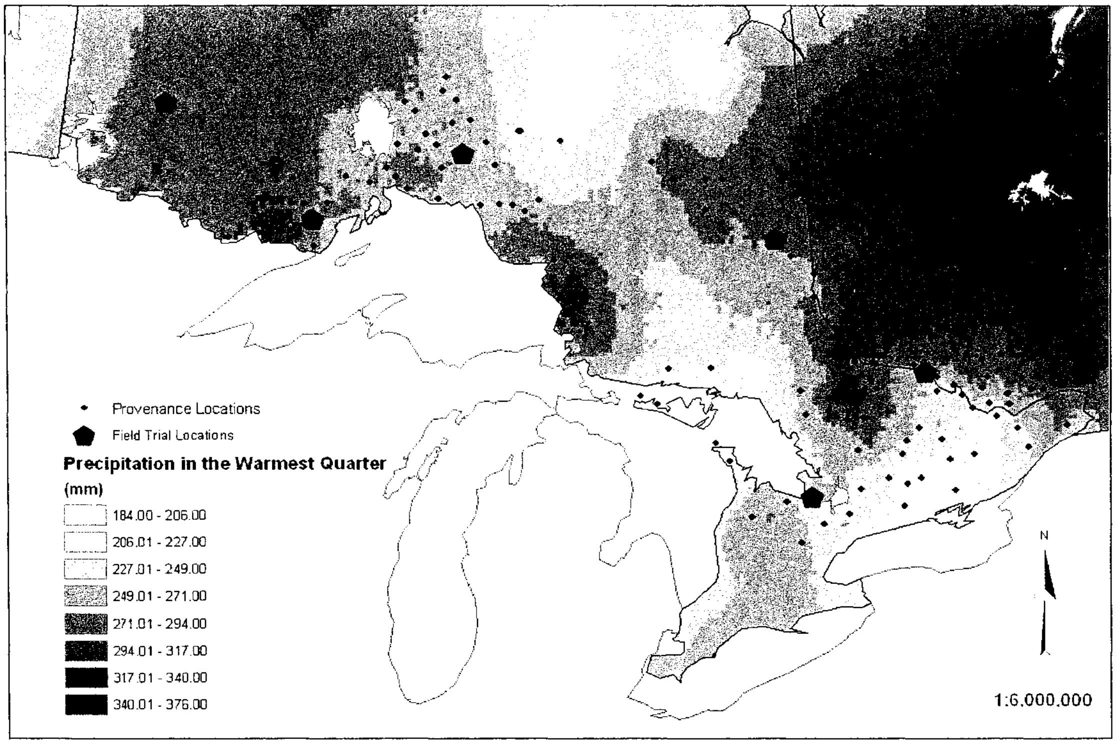
Contour map of mean temperature in the wettest quarter of the year



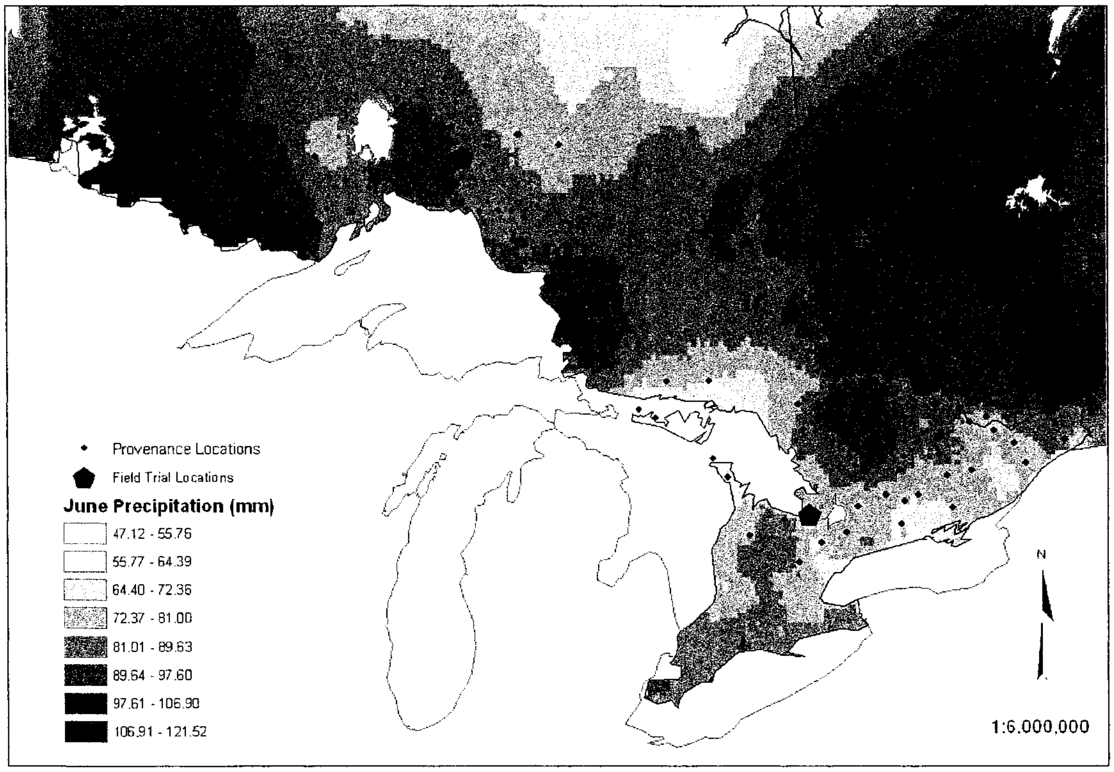
Contour map of mean temperature in the warmest quarter of the year



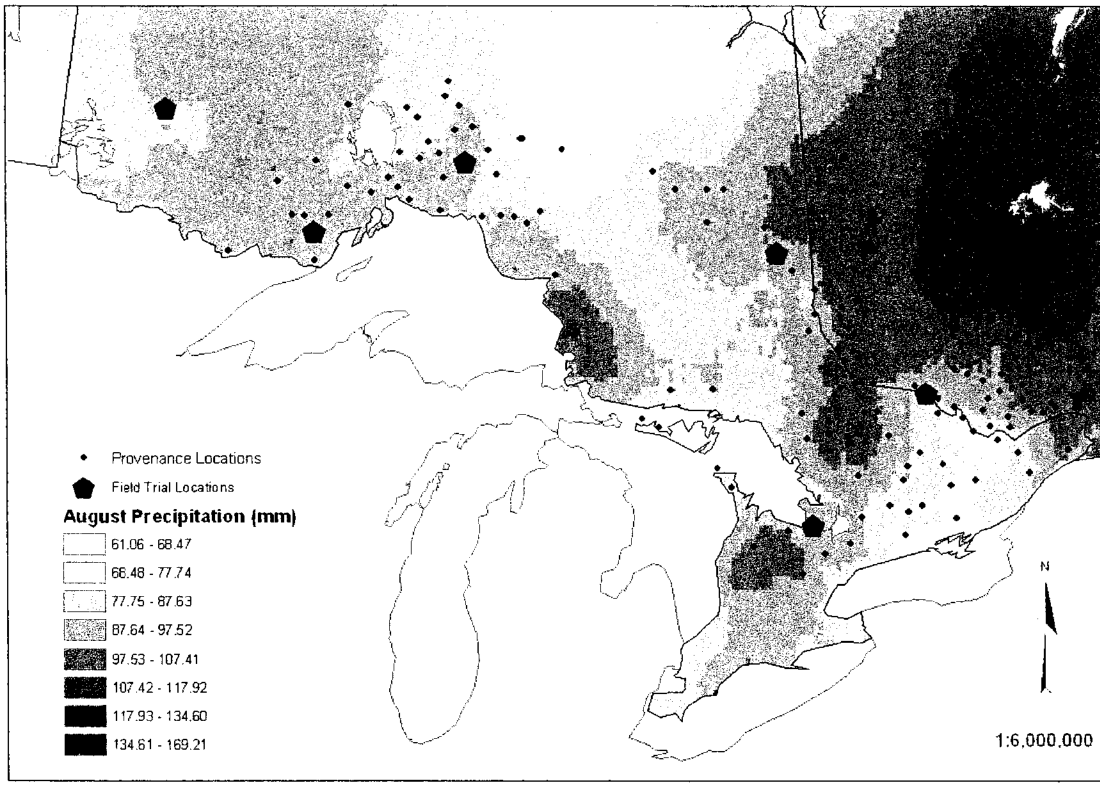
Contour map of total precipitation in period four, the difference between period three and period two



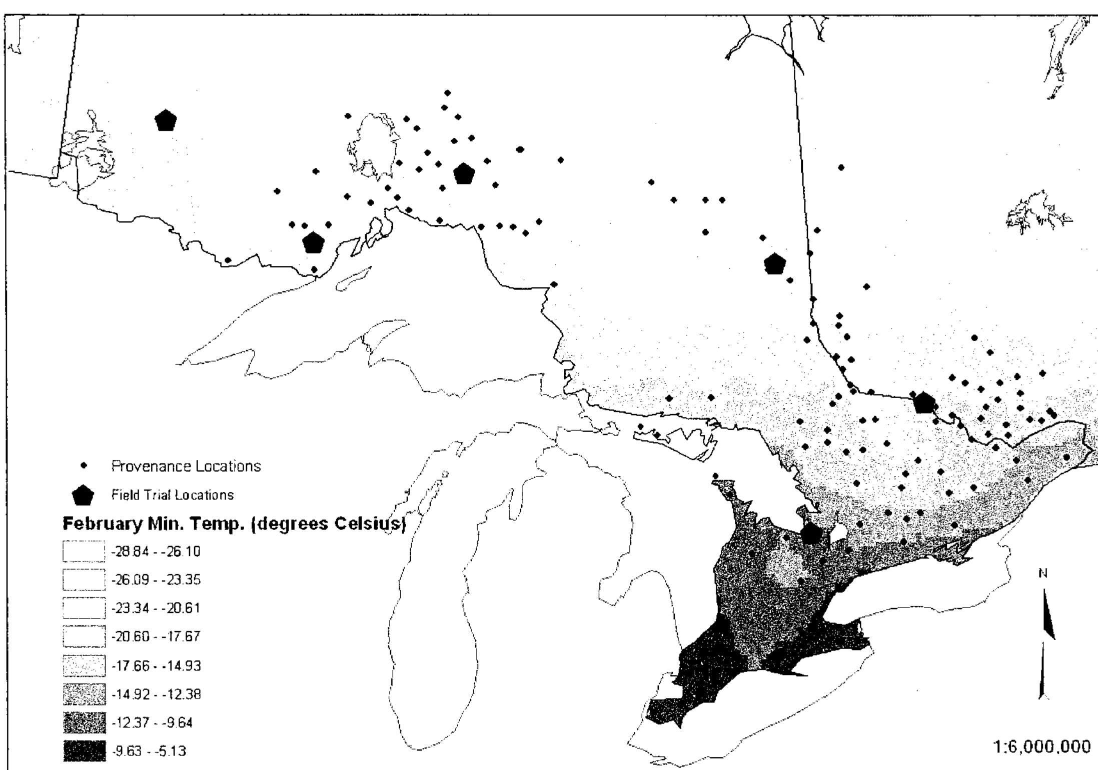
Contour map of precipitation in the warmest quarter of the year



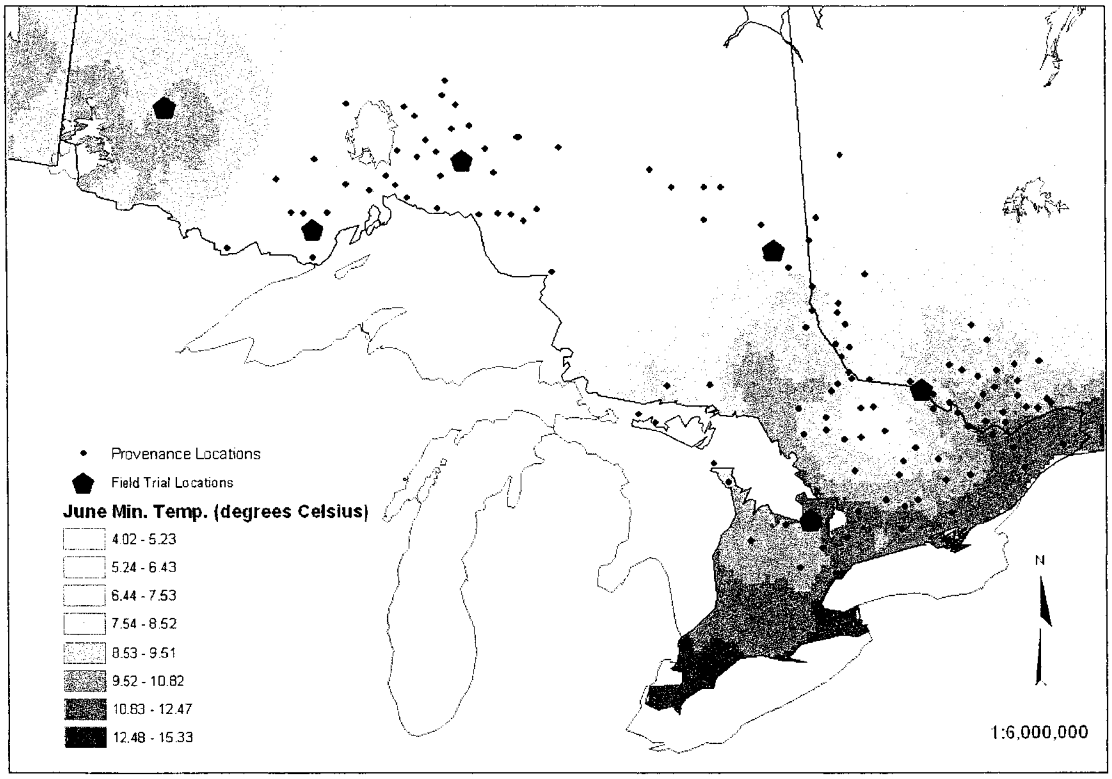
Contour map of mean June precipitation



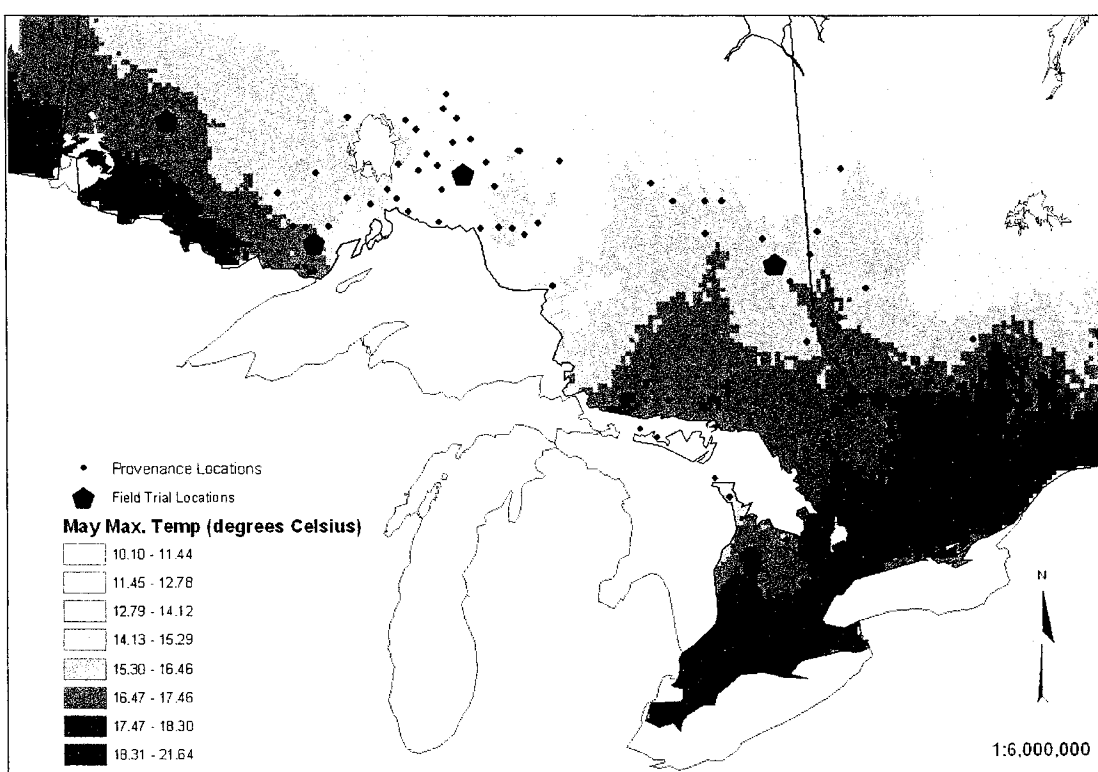
Contour map of mean August precipitation



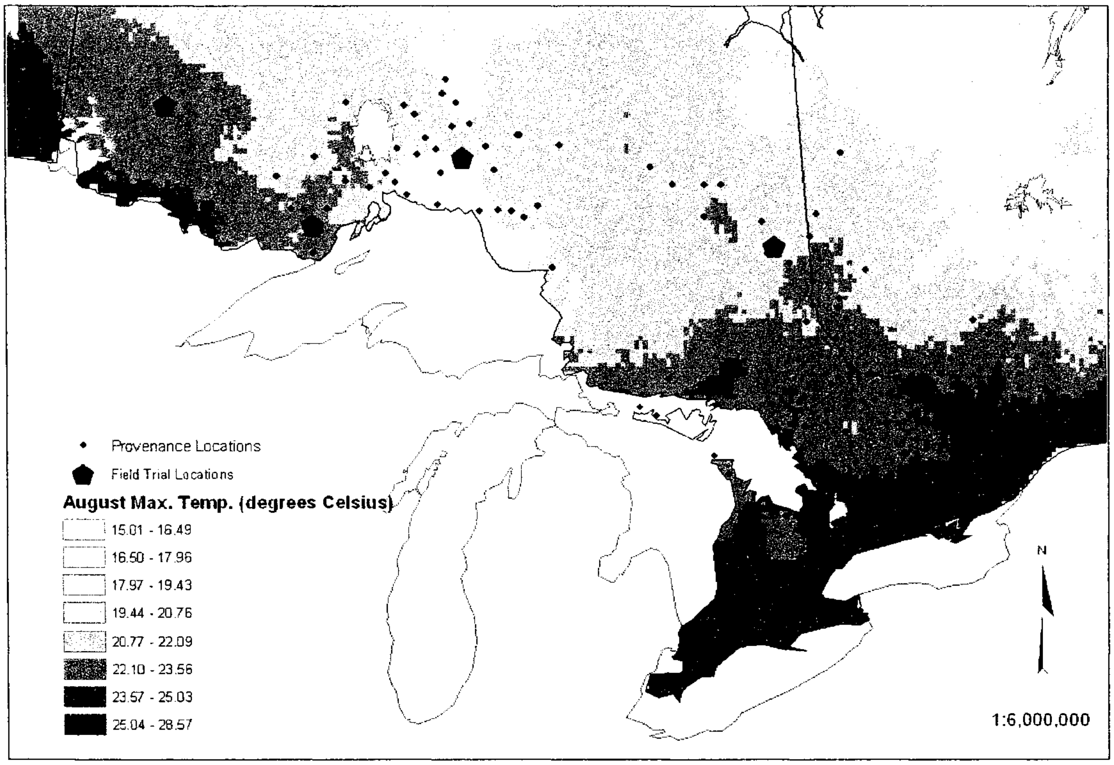
Contour map of mean February minimum temperature



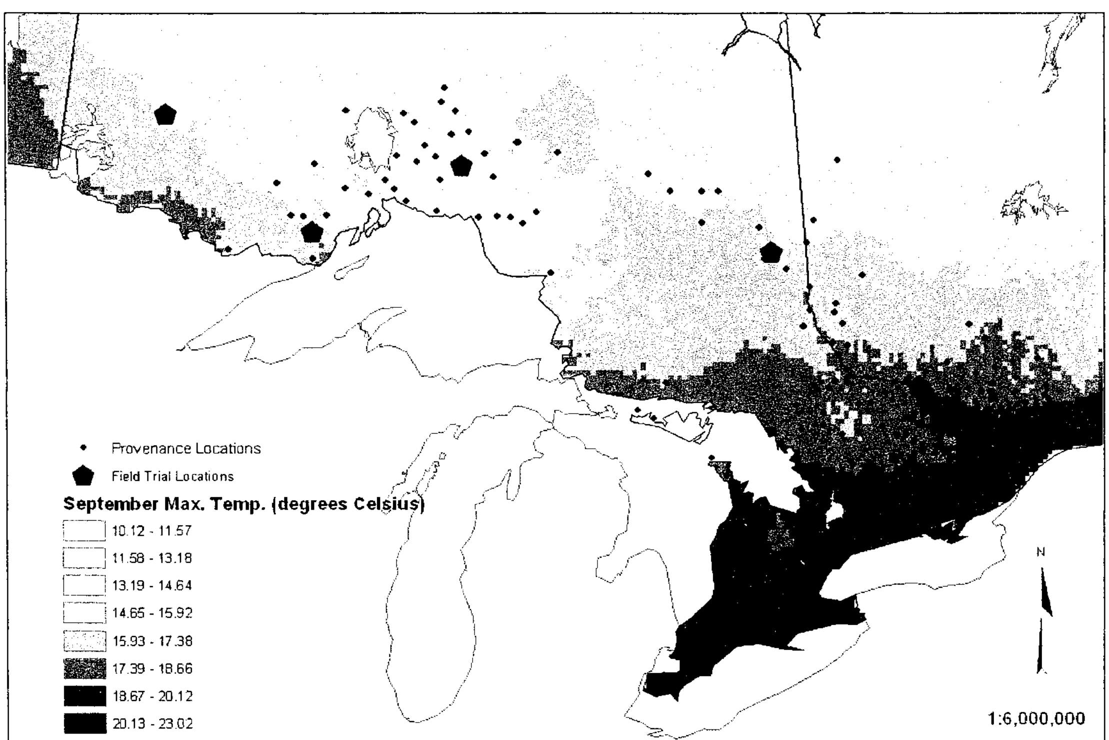
Contour map of mean June minimum temperature



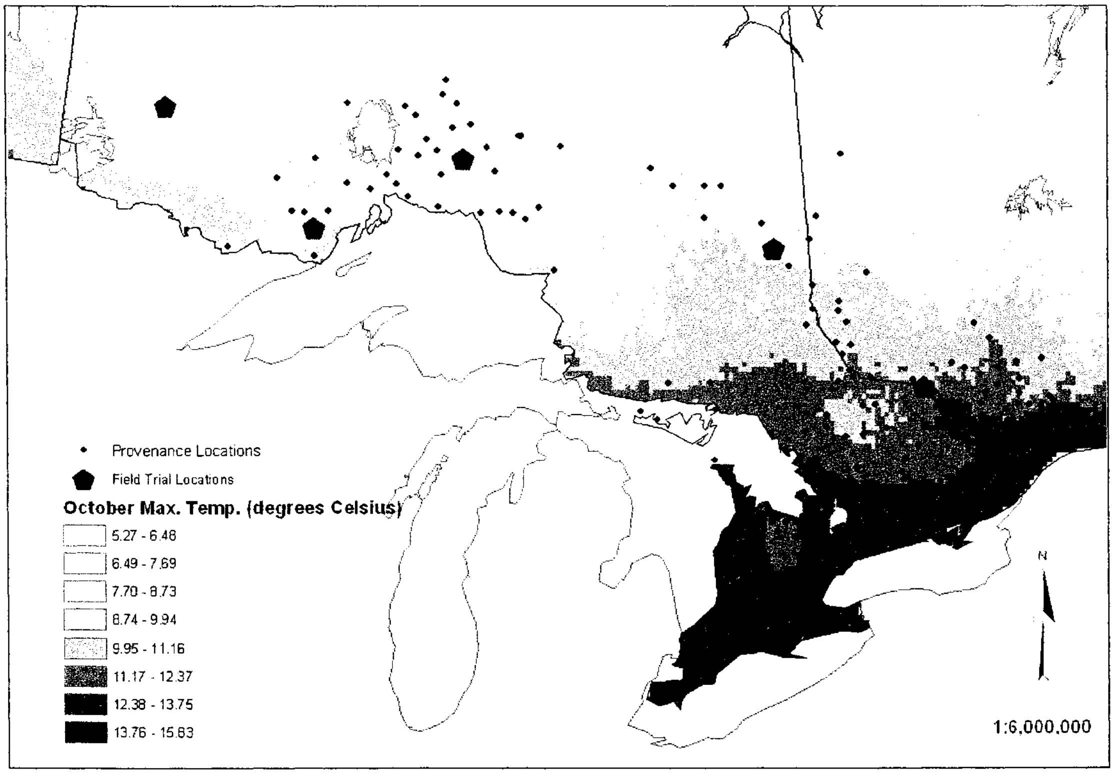
Contour map of mean May maximum temperature



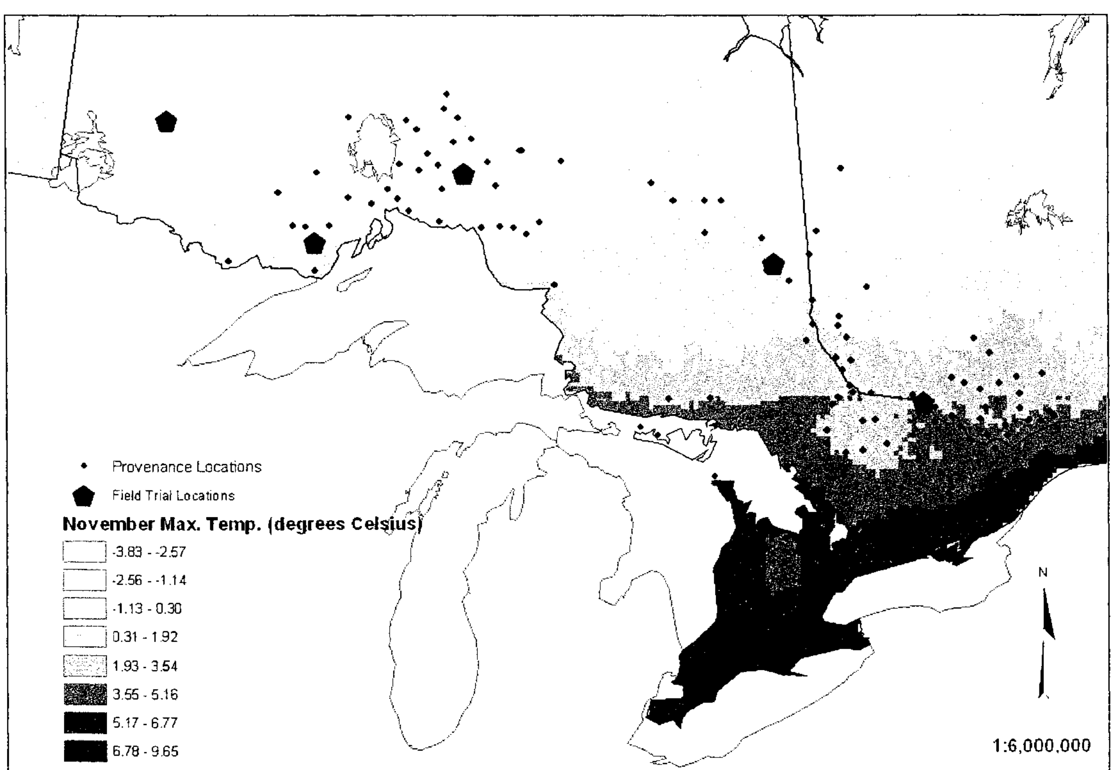
Contour map of mean August maximum temperature



Contour map of mean September maximum temperature



Contour map of mean October maximum temperature



Contour map of mean November maximum temperature

APPENDIX VI
FOCAL POINT SEED ZONE AML

```
/* ****************************************************************
/* c:\final_fpszsw\focalpsw.aml    November 31, 2004
/*
/* M.R. Lesser October 2004
/* adapted from
/*        W.H. Parker, Faculty of Forestry, Lakehead University
/*      Thunder Bay, Ontario
/*      February, 2004
/*
/* aml routine to run a focal point seed zone based on grid arithmetic.
/*    based on stored geographic coordinates (decimal degree)
/*    in an ASCII file for white spruce in  Ontario
/*
/*   Three regression grids are intersected in this version.
/*      rpc1grd  rpc2grd  rpc3grd
/*   Geo coordinates are stored in sitegeo.txt.
/*  5 grids are produced from this version; these are grd4, which shows the final seed
zones for the /*  given point, grd's 5,6,and 7 show the respective predicted PCA grids
standardized to the given /*  point, and grd 8 shows the standardized PC1 grd intersected
with the PC2 grd.
/*   Other files needed in working directory: fpshades3.shd geotolam.txt
/*   Coverages required in working directory: swprovs (mpextpts) provslam
/*                                         lakeslam
/*
/* ****************************************************************
&type Running fpszsw
 &messages &off
/* &messages &on
/* Define the file name and open file
&setvar fil = sitegeo.txt
&setvar filunit = [open %fil% openstatus -read]
/*
/* Check for error in opening file
&if %openstatus% <> 0 &then
  &return &warning Error opening file.
/*
/* Read from file
/*
   &setvar .rec = [read %filunit% readstatus]
```

```
/*
/* Close the file
&if [close %filunit%] <> 0 &then
   &return &warning Unable to close %fil%
    &type focal point location =  %.rec%
/*
/* The first step generates lambert coords from inputed geo coordinates.
/*
&severity &error &ignore
/*
/* Delete temporary files and grids from last run
/*
del sitegeo
del sitelam
del sitelam.prj
kill grd1
kill grd2
kill grd3
kill grd4
kill grd5
kill grd6
kill grd7
kill grd8
kill site
/*
/* create lat and long file
/*
&setvar file = sitegeo
&setvar fileunit = [open %file% ostat -write]
/*     &type %fileunit%
&if %ostat% ne 0 &then &return Unable to open file.
/*
&setvar cover = %.rec%
&if [write %fileunit%  %.rec%] ne 0 &then
             &return FATAL ERROR. Cannot write record.
/* &type %file% written successfully
/* &if [close %fileunit%] = 0 &then &type %file% closed successfully
/*
/* project file
/*
project file sitegeo sitelam geotolam.txt
/*
&s ostat [close -all]
/*
/* open and read lambert coordinates
/*
&setvar file = sitelam
```

```
&setvar funit = [open %file% ostat -READ]
&if %ostat% ne 0 &then &return Error %ostat% Unable to open file %file%.
&s rec = [read %funit% ostat]
&if %ostat% ne 0 &then &return FATAL ERROR. Cannot read record.
/*
/* parse x lambert coordinate
/*
&s blank [search %rec% ' ']
&do &until %blank% ne 1
 &s rec [after %rec% ' ']
 &s blank [search %rec% ' ']
&end
&s .xlam [before %rec% ' ']
&s rec [after %rec% ' ']
/*
/* parse y lambert coordinate
/*
&s blank [search %rec% ' ']
&do &until %blank% ne 1
 &s rec [after %rec% ' ']
 &s blank [search %rec% ' ']
&end
&s .ylam [before %rec% ' ']
/*
/* close file
/*
&if [close %funit%] ne 0 &then &return Cannot close file %file%
/*
/* create generate file
/*
&setvar file = sitelam.gen
&setvar funit = [open %file% ostat -write]
&if %ostat% ne 0 &then &return Error %ostat% Unable to open file %file%.
&s rec '1,'%.xlam%','%.ylam%
/*     &type %rec%
&if [write %funit% %rec%] ne 0 &then &return Error wrting file %file%.
&s rec 'end'
/* &type %rec%
&if [write %funit% %rec%] ne 0 &then &return Error wrting file %file%.
&if [close %funit%] ne 0 &then &return Cannot close file %file%
generate site
input sitelam.gen
points
q
/*
/* Run grid and calculate focal point seed zone
/*
```

```
grid
display 9999
mapextent swprovs
&setvar filgrd1 = rpc1grd
&setvar filgrd2 = rpc2grd
&setvar filgrd3 = rpc3grd
&setvar wchfile = tempwch
&watch %wchfile%
ap cellvalue %filgrd1% %.xlam% %.ylam% none
ap cellvalue %filgrd2% %.xlam% %.ylam% none
ap cellvalue %filgrd3% %.xlam% %.ylam% none
&watch &off
&setvar funit = [open %wchfile% openstatus -read]
    &setvar rec1 = [read %funit% readstatus]
    &s rec1 [after %rec1% 'value ']
    &setvar rec2 = [read %funit% readstatus]
    &s rec2 [after %rec2% 'value ']
    &setvar rec3 = [read %funit% readstatus]
    &s rec3 [after %rec3% 'value ']
&if [close %funit%] ne 0 &then
   &return &warning Unable to close %wchfile%
&messages &on
&type Calculating adjusted rpca1 grid
grd1 = %filgrd1% - %rec1%
&type Calculating adjusted rpca2 grid
grd2 = %filgrd2% - %rec2%
&type Calculating adjusted rpca3 grid
grd3 = %filgrd3% - %rec3%
&type Calculating intersected rpca1, rpca2 and rpca3 grids
grd4 = con(grd1 ge -1.5 & grd1 le 1.5 & grd2 ge -1.5 & grd2 le 1.5 ~
        & grd3 ge -1.5 & grd3 le 1.5, ~
   con(grd1 ge -1.0 & grd1 le 1.0 & grd2 ge -1.0 & grd2 le 1.0 ~
        & grd3 ge -1.0 & grd3 le 1.0, ~
   con(grd1 ge -.5 & grd1 le .5 & grd2 ge -.5 & grd2 le .5 ~
        & grd3 ge -.5 & grd3 le .5,1,2),3),0)
grd5 = con(grd1 ge -1.5 & grd1 le 1.5, ~
      con(grd1 ge -1.0 & grd1 le 1.0, ~
      con(grd1 ge -.5 & grd1 le .5 ~
         ,1,2),3),0)
grd6 = con(grd2 ge -1.5 & grd2 le 1.5, ~
      con(grd2 ge -1.0 & grd2 le 1.0, ~
      con(grd2 ge -.5 & grd2 le .5 ~
         ,1,2),3),0)
grd7 = con(grd3 ge -1.5 & grd3 le 1.5, ~
      con(grd3 ge -1.0 & grd3 le 1.0, ~
      con(grd3 ge -.5 & grd3 le .5 ~
         ,1,2),3),0)
```

```
grd8 = con(grd1 ge -1.5 & grd1 le 1.5 & grd2 ge -1.5 & grd2 le 1.5,~
        con(grd1 ge -1.0 & grd1 le 1.0 & grd2 ge -1.0 & grd2 le 1.0,~
        con(grd1 ge -.5 & grd1 le .5 & grd2 ge -.5 & grd2 le .5,1,2),3),0)
q
&messages &off
&type RegPCA1 value =  %rec1%
&type RegPCA2 value =  %rec2%
&type RegPCA3 value =  %rec3%
/*
/* Enter Arcplot and plot the focal point seed zone
/*
arcplot
display size 975 800
display position 10 10
mapext swprovs
mappos cen cen
shadeset fpshades3.shd
gridnodatasymbol white
gridshades grd4 value identity nowrap
linecolor black
arcs ontmap
linecolor blue
arcs lakeslam
markersymbol 70
markercolor RGB 0 0 125
markersize .45
points site
markerset mineral.mrk
markersymbol 102
markersize .1
markercolor black
points swprovs
&messages &on
/* q
&return end of job
```

APPENDIX VII
NORMALIZED PROVENANCE FACTOR SCORES FOR PRINCIPAL COMPONENTS 1, 2 AND 3

Provenance	PC Axis 1	PC Axis 2	PC Axis 3	Provenance	PC Axis 1	PC Axis 2	PC Axis 3
1	2.254	1.466	0.132	65	-0.077	0.491	-0.711
2	0.155	-0.107	-0.074	66	1.608	-1.417	-2.032
3	0.710	-0.096	-0.079	67	1.118	0.368	-0.300
4	0.251	0.694	-0.064	68	0.097	0.025	-0.664
5	0.449	0.185	0.742	69	-0.453	-1.015	0.102
6	0.899	0.839	-0.193	70	-1.404	-0.119	0.196
7	1.563	0.545	1.558	71	-0.458	0.389	-0.671
8	0.086	-0.471	-0.233	72	-0.432	-0.151	-0.122
9	0.703	-0.325	-0.133	73	0.614	0.638	0.364
10	1.296	0.987	0.787	74	1.356	0.649	-0.058
11	-0.168	2.291	0.320	75	-0.234	1.228	-2.122
12	-0.293	1.023	0.759	76	-1.261	0.511	-1.666
13	1.400	1.357	0.436	77	-0.719	0.523	-2.301
14	-0.182	1.475	-0.015	78	-0.099	0.823	1.958
15	-0.650	0.591	-0.032	79	-0.284	-0.476	-2.209
16	1.629	-0.922	-0.781	80	-2.061	-0.089	-0.309
17	0.299	0.016	1.157	81	-0.169	-1.605	-1.180
18	0.482	-0.446	0.508	82	-0.983	0.209	-0.925
19	1.345	-0.019	0.592	83	-0.797	1.099	-0.020
20	1.484	0.188	-2.559	84	-0.737	-0.011	0.756
21	1.091	0.176	-0.806	85	-0.708	-0.387	-1.587
22	1.430	-0.461	0.391	86	1.110	-0.830	1.877
23	0.492	1.708	-0.053	87	-1.174	-0.008	-1.124
24	-1.203	2.835	1.108	88	-0.210	-0.633	0.573
25	0.525	0.552	-0.155	89	-0.315	0.212	1.212
26	-0.077	1.222	-0.714	90	-0.771	-0.313	-1.755
27	0.778	-0.882	1.721	91	-1.145	-1.024	-0.864
28	1.866	1.032	0.358	92	-0.852	-1.012	0.479
29	-0.382	1.812	0.250	93	-0.284	-0.328	-1.018
30	0.530	0.746	0.598	94	0.498	-1.161	-0.188
31	-0.387	1.220	-0.152	95	-0.175	-0.963	-1.452
32	1.224	0.537	-0.134	96	-1.587	-0.107	-1.180
33	0.008	1.158	1.641	97	-1.368	0.192	-0.366
34	-0.475	0.299	0.324	98	-1.236	-0.991	-0.120
35	0.774	-0.095	0.479	99	-0.324	-1.151	-0.686
36	0.556	-0.663	-0.482	100	-2.244	1.057	-0.759
37	0.096	1.373	0.689	101	1.166	-1.283	0.091
38	-0.068	1.166	-1.174	102	-0.438	-0.380	-0.697
39	0.802	0.325	1.324	103	-0.997	-1.228	0.668
40	-0.307	0.289	0.258	104	-0.579	-1.316	0.786
41	-0.149	1.474	1.161	105	-0.194	-1.855	1.343
42	1.153	-0.118	-1.002	106	-0.880	1.072	0.804
43	0.951	1.012	1.865	107	-1.959	-1.766	2.018
44	1.477	-0.779	-0.627	108	-0.522	-0.459	-0.184
45	-0.644	1.077	0.912	109	-1.163	-0.880	1.727
46	0.621	-1.036	0.833	110	-1.696	-0.012	-0.741
47	-0.649	0.904	0.148	111	-0.682	-0.688	0.135
48	0.303	0.171	-2.913	112	0.695	-2.247	-0.140
49	1.510	-0.993	0.823	113	-0.627	-0.332	1.106
50	1.276	-0.727	0.238	114	-0.839	-1.167	0.078
51	-1.804	0.521	-1.538	115	1.013	-1.789	0.252
52	-0.833	0.538	-0.183	116	-1.434	-1.600	2.228
53	1.632	1.727	-0.400	117	1.505	-1.938	0.122
54	-1.596	0.680	0.071	118	-0.329	-0.956	-0.612
55	1.928	-0.873	-0.535	119	-1.740	-0.579	-0.664
56	-0.001	0.294	-0.845	120	0.648	-0.491	-0.266
57	0.329	-0.075	0.423	121	-0.739	-1.443	1.260
58	0.100	-0.074	0.161	122	-0.794	-0.874	1.736
59	1.470	-0.947	-0.488	123	0.251	-0.611	-0.475
60	-0.945	0.818	0.571	124	-0.654	-0.943	0.607
61	1.035	2.971	-0.073	125	-0.634	-0.480	1.294
62	-0.876	0.439	-0.351	126	-0.751	-0.794	0.475
63	1.947	-0.998	-1.076	130	-0.586	1.142	1.127
64	-0.104	-0.351	-0.686				

APPENDIX VIII
SAMPLE CANCORR PROCEDURE IN SAS

```
libname canon 'C:\Documents and Settings\Administrator\My Documents\masters thesis
2004\canonical';
run;
data canon;
infile 'C:\Documents and Settings\Administrator\My Documents\masters thesis
2004\canonical\final_cancorr\allvariablemeanswithclimate.csv'
dlm=',' linesize=3000;
input prov drht04 kbht04 lcht04 enht04 pwht04 anht04 drdia04 kbdia04
lcdia04 endia04 pwdia04 andia04 drsurv04 kbsurv04 lcsurv04 ensurv04
pwsurv04 ansurv04 ghelong1 ghelong2 ghelong3 ghelong4 ghelong5
drht03  kbht03 lcht03  enht03 pwht03 drdia03 kbdia03 lcdia03 endia03 pwdia03
ht02 drsurv02  ensurv02 kbsurv02 lcsurv02 pwsurv02 drsurv03
ensurv03 kbsurv03 lcsurv03 pwsurv03 drbs2drbs3 drbs4 drbs5
kbbs2  kbbs3  kbbs4  kbbs5  lcbs2   lcbs3   lcbs4   lcbs5   enbs2  enbs3
enbs4  enbs5  pwbs2 pwbs3  pwbs4  pwbs5  drbf2   drbf3   drbf4   drbf5
drbf6  kbbf2  kbbf3  kbbf4  kbbf5  kbbf6  lcbf2   lcbf3   lcbf4   lcbf5
lcbf6   enbf2   enbf3   enbf4   enbf5   enbf6   pwbf2  pwbf3  pwbf4  pwbf5
pwbf6  ghbf2  ghbf3  ghbf4  ghbf5  ghbf6  long lat elev diurnran
isotherm tempseas maxtempwp mintempcp   tempanran mtempwetq mtempdryq
mtempwarmq  mtempcoldq annprecip precipwp precipdp precipseas precipwettq
precipdryq      precipwarmq  precipcoldq    daystart dayend daygrow tprecipp1
tprecipp2       tprecipp3       tprecipp4       ggdp3  annmtemp       annmintemp
annmaxtemp mtempp3 tempranp3    janmintemp     febmintemp      marmintemp
aprmintemp     maymintemp junmintemp      julmintemp       augmintemp     sepmintemp
octmintemp     novmintemp     decmintemp janmaxtemp       febmaxtemp    marmaxtemp
aprmaxtemp    maymaxtemp  junmaxtemp    julmaxtemp augmaxtemp       sepmaxtemp
octmaxtemp    novmaxtemp    decmaxtemp   janprecip        febprecip marprecip
aprprecip        mayprecip       junprecip         julprecip          augprecip        sepprecip
octprecip        novprecip        decprecip;
title 'Canonical Correlation Analysis of Sw biological and climate data' ;
proc cancorr data=canon out= canon.cancorr redundancy
vprefix=bio vname='Biological Variables'
wprefix=clim wname='Climate Variables';
option pagesize=100 linesize=80;
var drbf2 drbf3 drbf4 drbf5 drbf6 ghbf2 ghbf3 ghbf4 ghbf5 ghbf6 lcbf2 lcbf3 lcbf4
lcbf5 lcbf6 drbs5  enbs3 enbs4 enbs5 kbbs3 kbbs4 kbbs5  lcbs4 lcbs5 pwbs3 pwbs4
anht04 drht03 drht04  enht03 enht04 ht02 kbht03 kbht04 lcht03 lcht04 pwht03 pwht04
```

```
andia04 drdia03 drdia04 endia03 endia04 kbdia04 lcdia03 lcdia04 pwdia03 pwdia04
ensurv03 ensurv04 lcsurv04 pwsurv02 ghelong1 ghelong2 ghelong3 ghelong4 ghelong5;
with diurnran  isotherm tempseas maxtempwp mintempcp  tempanran mtempwetq
mtempdryq mtempwarmq mtempcoldq annprecip precipwp precipdp precipseas
precipwettq precipdryq precipwarmq precipcoldq daystart dayend  daygrow tprecipp1
tprecipp2      tprecipp3      tprecipp4      ggdp3  annmtemp      annmintemp
annmaxtemp mtempp3 tempranp3 janmintemp febmintemp marmintemp
aprmintemp   maymintemp  junmintemp   julmintemp   augmintemp   sepmintemp
octmintemp novmintemp    decmintemp   janmaxtemp   febmaxtemp   marmaxtemp
aprmaxtemp   maymaxtemp junmaxtemp    julmaxtemp   augmaxtemp   sepmaxtemp
octmaxtemp   novmaxtemp  decmaxtemp janprecip      febprecip    marprecip
aprprecip    mayprecip   junprecip    julprecip augprecip   sepprecip octprecip
novprecip    decprecip;
run;
proc print;
option pagesize=80;
var bio1 bio2 bio3 clim1 clim2 clim3;
run;
```

APPENDIX IX
CANCORR GRID STANDARDIZATION AML

```
/* swgridpoint.aml   January, 1996  Revised for nov 2004 swpoints
/* revised november 2004 for sw provenance points
/* aml routine to capture point data from 3 grid coverages
/*    and write the point data to 3 output files.
/*
&type Running gridpoint
 &messages &off
 &setvar maxn2 4
 &setvar cnt2 = 0
 &setvar n = 1
 &setvar filvar = c:/final_cancorrfpsz/var      /*file containing 3 grid prefixes
 &label restrt
 &setvar varfil = [open %filvar% openstatus -read]
   &if %openstatus% <> 0 &then
     &return &warning Error opening variable file.
 &do &until %cnt2% = %n%
   &setvar cnt2 = %cnt2% + 1
   &setvar rec = [read %varfil% readstatus]
 &end
 &if [close %varfil%] <> 0 &then
    &return &warning Unable to close %filvar%.
   &type %n%
   &type %rec%
   &call grpt
   &setvar n = %n% + 1
   &setvar cnt2 = 0
 &if %n% lt %maxn2% &then &goto restrt
   &else
     &message &on
     &return End of job
&routine grpt
 &setvar str = %rec%
/* Define the file name and open file
/* Set the number of points -- maxn
&setvar maxn 127
&setvar cnt = 0
&setvar filin = c:/final_cancorrfpsz/lampoints.txt
display 9999
mapextent c:/final_cancorrfpsz/ontmap
```

```
&setvar filgrd = c:/final_cancorrfpsz/%str%grd
&setvar filout = c:/final_cancorrfpsz/std%str%
&type Outfile is %filout%
/*
&setvar wchfile = temp.wch
&watch %wchfile%
&setvar filunit = [open %filin% openstatus -read]
/*
/* Check for error in opening file
 &if %openstatus% <> 0 &then
   &return &warning Error opening file.
&setvar outfile = [open %filout% openstatus -write]
/*
/* Start the loop
  &do &until %cnt% = %maxn%
      &setvar cnt = %cnt% + 1
/*       &type %cnt%
/*   Read next line
      &setvar rec = [read %filunit% readstatus]
/*
/*   parse x lambert coordinate
/*
    &s blank [search %rec% ' ']
      &do &until %blank% ne 1
        &s rec [after %rec% ' ']
        &s blank [search %rec% ' ']
      &end
    &s .xlam [before %rec% ' ']
    &s rec [after %rec% ' ']
/*
/*   parse y lambert coordinate
/*
    &s blank [search %rec% ' ']
      &do &until %blank% ne 1
        &s rec [after %rec% ' ']
        &s blank [search %rec% ' ']
      &end
    &s .ylam [before %rec% ' ']
/*
/*  get point value from grid
/*
    ap cellvalue %filgrd% %.xlam%  %.ylam%
  &end
 &watch &off
 &setvar funit = [open %wchfile% openstatus -read]
 &setvar cnt = 0
  &do &until %cnt% = %maxn%
```

```
    &setvar cnt = %cnt% + 1
   /* Read next line
    &setvar rec = [read %funit% readstatus]
    &s rec [after %rec% 'value ']
    &if [write %outfile% %rec%] ne 0 &then
      &return Unable to write to %filout%
  &end
/* Close the files
&if [close %funit%] ne 0 &then
    &return &warning Unable to close %wchfile%
&if [close %outfile%] ne 0 &then
    &return &warning Unable to close %filout%
&if [close %filunit%] <> 0 &then
   &return &warning Unable to close %filin%
&return
```