



A dendroclimatological assessment of shelterbelt trees in a moisture limited environment



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ABSTRACT

The goal of this paper is to apply dendroclimatological methods to the analysis of two commonly planted shelterbelt tree species, *Fraxinus pennsylvanica* (green ash), and *Picea glauca* (white spruce), to assess their current relationship with climate and determine how their growth may be affected by climate change in the moisture limited region of southeastern Saskatchewan. Spring precipitation and more importantly spring drought, as represented by the standardized precipitation evapotranspiration index (SPEI), were found to be the most important factors controlling the growth of green ash and white spruce in southeastern Saskatchewan. Furthermore, a breakdown in the radial growth–climate relationship was observed in individuals planted far from their typical native ranges, a potential indication of climate induced stress. Considering these findings, and projections of future climate, it is suggested that conditions beyond the northern limit of the artificial green ash range, and into the boreal forest, may become more suitable for green ash growth, while the southern limit of the artificial white spruce range is expected to recede northward. This information can help guide the management of shelterbelt systems in the Canadian Prairies to ensure they provide maximum practical and ecological benefits for now and into the future.

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1. Introduction

Agroforestry has been gaining mainstream popularity, yet it has been common practice in the Canadian Prairies since 1901, when the Prairie Farm Rehabilitation Administration (PFRA) began providing free seedlings to landowners in the Prairie Provinces (Agriculture and Agri-Food Canada, 2008). This initiative has been an indispensable resource for landowners who wish to install shelterbelts to help cope with the harsh environment of the open prairie. Since the shelterbelt program began, over 600 million trees have been delivered, providing benefits such as protection from high wind, erosion, and snow retention, all of which have been associated with an increase in crop yields (Kort, 1988; Agriculture and Agri-Food Canada, 2008).

Although the numerous practical benefits of shelterbelts have long been understood, there remains an increasing need to recognize their associated ecological benefits. In their latest assessment report, the Intergovernmental Panel on Climate Change discussed the advantages of agroforestry as a tool to mitigate further climate

change (IPCC, 2014). In over 100 years of service, an estimated 218 megatons of carbon dioxide have been removed from the atmosphere and stored in plant biomass thanks to the Canadian Shelterbelt Program (Agriculture and Agri-Food Canada, 2008). Prairie shelterbelts also represent an efficient and crucial form of adaptation needed to help bolster food security (Verchot et al., 2007; IPCC, 2014), and protect biodiversity (Guo, 2000), during climatically turbulent times. While this type of agroforestry can be considered as a serious option for future GHG mitigation and climate change adaptation (IPCC, 2014), shelterbelts are also vulnerable to the same changes they mitigate against. It is therefore important to gauge the internal resilience of shelterbelt systems to climatic change, to ensure that shelterbelts planted today will continue to offer their numerous associated benefits. As a first step, it is important to understand how tree growth is currently being affected by climate and how this is expected to change.

The effects of climate change are becoming increasingly widespread and are now of global concern (IPCC, 2013). Stress is placed on entire populations requiring them to adjust to the changes, with ecological communities being forced to either move to an area with more favorable conditions, or to rapidly evolve as a form of adaptation (Hoffmann and Sgrò, 2011). Trees on the other hand cannot simply move if they encounter some form of environmental limitation. Native range boundaries must therefore

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shrink or shift, and by doing so, currently established individuals will perish if they cannot adapt to a rapid shift in climate (McKenney et al., 2007; Woodall et al., 2009; Thomas, 2010). The province of Saskatchewan, and its legacy of shelterbelt trees, provides a unique platform where the spatial reach of certain tree species extends far past their typical native ranges, both northward and southward.

Dendroclimatology is a tool used to study past and present climates by statistically matching annually dated tree-ring chronologies with instrumental climate data (Kaennel and Schweingruber, 1995). This technique provides insight into how climate has impacted radial growth over a tree's lifetime. By utilizing a form of correlation function analysis, it is possible to determine the main climatic factors that are driving radial tree growth, such as temperature, and precipitation, with approximately monthly resolution (Biondi and Waikul, 2004). Tree growth is commonly driven by one (or a small subset) of these two factors, depending on whether the species in question is more sensitive to precipitation or temperature.

Much of southern Saskatchewan lies within the Palliser's Triangle, a region known for its aridity. Mean annual precipitation in Saskatchewan is 395 mm with values increasing in a southwesterly (~325 mm) to northeasterly (~475 mm) direction across the region. Of this annual total, approximately 70–80% falls as rain with June and July being the wettest months (20–35% of the annual total) (McGinn, 2010). In this area, it is common to have levels of evaporation that exceed the total annual amount of precipitation, leading to an overall moisture deficit (Lemmen and Dale-Burnett, 1999). Considered as the driest part of the Canadian Prairies, the triangle delineates a mixed grassland ecoregion that has long been plagued by the common occurrence of droughts. Palliser's Triangle has been host to several large-scale drought events throughout the 20th century, the most severe of which occurred in the 20's, 30's, and 1980's (Lemmen and Dale-Burnett, 1999). In such an arid environment, it is likely that drought will be a limiting factor for many trees in the region.

The goal of this project is to apply dendroclimatological methods in the assessment of two commonly planted shelterbelt tree species, one coniferous, *Picea glauca* (white spruce), and one deciduous, *Fraxinus pennsylvanica* (green ash), to determine how their growth is being affected by climate in the moisture limited region of southeastern Saskatchewan. Due to the spatial extent of these planted shelterbelt trees that extend far past their typical native ranges (white spruce southward of its native range, and green ash northward of its native range), it is hypothesized that there exists a spatial boundary where the growth of these species becomes overly taxed due to being exposed to less than optimal growing conditions outside of their historical ranges.

2. Study sites

Two commonly planted shelterbelt species were chosen for this analysis based on the findings from Davis et al. (2013), who assessed the dendrochronological potential of nine commonly planted shelterbelt species based on their capacity to express a common growth signal, their sensitivity to climate, and their commonality. Green ash was ranked fifth in terms of its suitability for dendrochronological analysis but was chosen nonetheless due to its high inter-series correlation and environmental sensitivity, two characteristics that speak to its potential for climate analysis (Davis et al., 2013). Another desirable quality of green ash is its commonality, which is important when undertaking a study that is geographically widespread. Green ash is native to most of southern Canada east of Alberta, and extends northward towards the center of Saskatchewan. It is a fast growing, small to medium-sized tree that is relatively long lived, upwards of a hundred years (Hosie,

1969; Farrar 1995). Often used as third row in farmyard shelterbelts, and as a single row in field-shelterbelts, it is occasionally mixed with shrub species to provide increased height to rows of trees (Agriculture and Agri-Food Canada, 2007). Green ash is known to have a moderately high drought tolerance while it is less tolerant to flooding or excessive moisture (Herman et al., 1996).

White spruce was also chosen since it was ranked most useful for dendrochronological study among the nine shelterbelt species considered by Davis et al. (2013). This is due to its strong inter-series correlation and its high sensitivity to climate. White spruce is native to much of the forested regions in Canada and is found in every Canadian province. In Saskatchewan the white spruce range descends from the northern boreal forest and covers the upper two thirds of the province, leaving the remaining southern portion unrepresented. It is a slow growing medium sized tree that is long-lived, often up to two hundred years (Hosie, 1969; Farrar 1995). White spruce is commonly used as one of the inside two rows of a farmstead windbreak, and is rarely used in a field shelterbelt (Agriculture and Agri-Food Canada, 2007). Drought conditions impact the normal physiological functioning of white spruce, if severe enough, damage can occur at a cellular level and radial growth can be reduced. (Zwiazek, 1991; Barber et al., 2000).

A theoretical latitudinal transect was drawn east of Regina, SK, Canada, at about 103.5°W, with sites located at intervals of 0.5° latitude starting at the 49th parallel. Sampling occurred if the trees were a minimum of 50-years old and thus, potential sites were identified by selectively searching the PFRA's database for trees delivered pre-1960 to farms within the boundaries of the transect. Seven sets of 40 green ash samples and eight sets of 40 white spruce samples were drawn from shelterbelt systems along this transect, two samples from each tree, for a total of 600 cores (Fig. 1). The set interval of 0.5° and minimum age of 50-years was respected as much as possible with some minor deviations when sample sites could not be located at a given latitude, or when trees of an appropriate age could not be identified.

3. Methods

A 5.1 mm increment corer was used to extract sample cores from 13 distinct sample sites, seven of which contained living green ash trees (G1-G7), and eight, living white spruce trees (W1-W8). All sites, with the exception of one (Site G1), were sampled during the spring and summer of 2012. Site G1 was sampled the year prior, in the fall of 2011. Extracted samples were later glued to slotted mounting boards and sanded with progressively finer sandpaper: 80, 120, 220, 320, and 400 grit. The polished nature of these sanded samples made it possible to clearly view cell structure at a cellular level. Radial growth was measured using a Velmex stage system under a 63X Nikon stereomicroscope, with a precision of 0.001 mm.

The program COFECHA (Holmes, 1983; Grissino-Mayer, 2001) was subsequently incorporated to statistically cross-date the samples and fix an overall annual-growth pattern for trees within each site. By comparing each core to a site-specific master chronology, the program outputs a mean series inter-correlation (MSI) value, based on 30-year overlapping segments. COFECHA also flags individual chronologies that likely contain errors such as missed or false rings. The measurements are then checked until there are no remaining flags or until the MSI value is well above 0.4226, the minimum value for significance at the 99% confidence level (Grissino-Mayer, 2001). COFECHA also provides values for average mean sensitivity and autocorrelation. Average mean sensitivity is a measure of how responsive the tree is to its surrounding environment, while an autocorrelation value provides a measure of the degree to which previous year's conditions affect growth during the current growing season (Grissino-Mayer, 2001).

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