Climate Change Program   Quicknote 1 (revised)

January 2004   By: Travis Logan & David Price

Investigating Effects of Climate on Site Index of Lodgepole Pine in Western Alberta

The purpose of this study is to examine the effects of historical temperature and precipitation patterns on lodgepole pine (Pl) growth within Western Alberta. We anticipate the results of this research can be used in validation of a process–based growth and yield model (StandLEAP), which in turn can be used to modify traditional growth and yield models to take account of possible changes in future climate. See the climate change program web page for more background information (http://www.fmf.ab.ca/pa_ClimateChange.html)

Analysis of Lodgepole Pine Growth during the 20th Century

Stand level observations at permanent sample plots (PSP) indicate that site index (at 50 years, SI_{50}) of Pl has increased for both fire origin and post-harvest stands, when recently established stands are compared to older stands growing on similar neighbouring sites or when new stands are established on old PSP locations. To confirm this, we examined stem analysis data collected by Alberta Sustainable Resource Development (ASRD) from 165 pine-dominated PSPs (i.e., where Pl contributed more than 75% of total plot basal area), distributed across the natural range of Pl in Alberta. In total, measurement data for over 800 trees were used: each tree was cut into sections at heights of 30cm and 130cm, and at every additional 250cm up the tree and rings counted at each height interval. Analyses were stratified into three different regions, consisting of southern, central and northern plots to allow for differences in climate due to elevation and latitude and possible genetic differences among Pl populations. We assumed that stands of harvest and natural (fire) origin were equally represented. Preliminary results suggest that, on average, trees from stands established more recently show significantly faster mean height increment than older trees measured in the same region. Furthermore, this increase followed a gradual but consistent trend throughout the 20th Century (Figure 1).

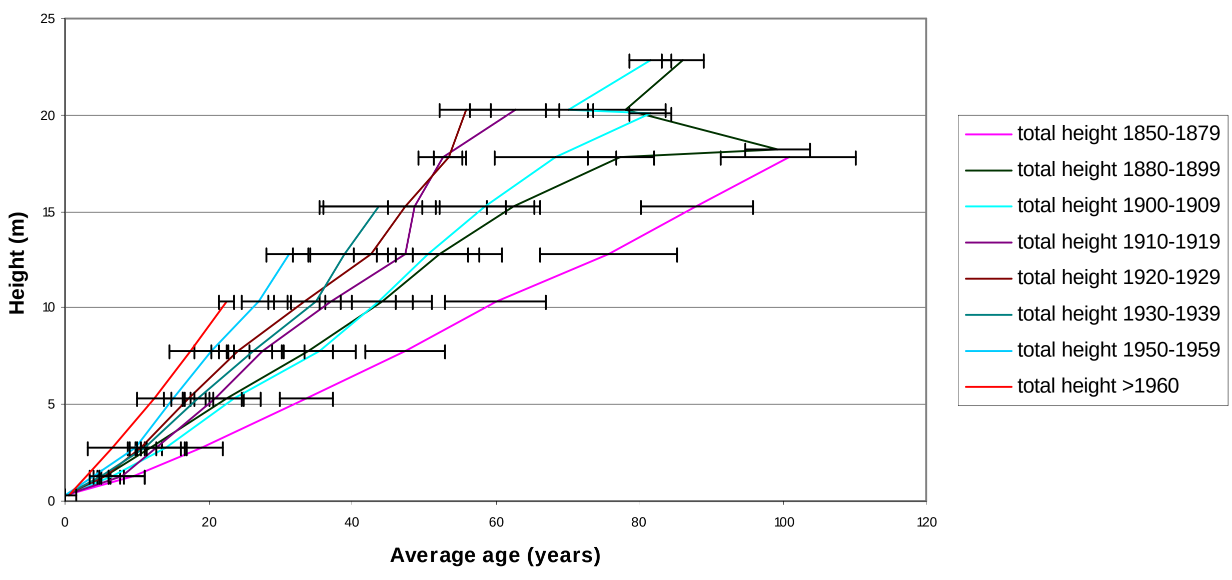

Figure 1. Lodgepole pine height growth trajectories in central region of Alberta, for trees with different establishment periods. (Stem analysis data are from trees sectioned at regular height increments; error bars are 95% confidence intervals indicating variability in age at a given height). There is a gradual but consistent increase in the slope of the growth curves over the period of observation, including most of the 20th Century.

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Several possible causes of bias in the data must be examined. Ted Hogg (CFS, Edmonton) asked whether the trend of increasing growth rate in younger stands might be due simply to differences in elevation between young and old sites. I.e., low-elevation sites of higher productivity might be more likely to have been burned or harvested more recently than stands at high elevation. If so, then the data set may be biased towards more productive sites in the younger age classes—which could explain much of the observed "increase" in productivity over time. To investigate this, we determined the correlations between stand age and elevation for the sample plots. Results indicate there is some bias in the plots for southern Alberta, but this does not appear to be the case in the central region (Figure 2), where there is a larger number of stem analysis plots. Another possible cause of bias in the data could be that trees used for stem analysis were selected on the basis of superior growth. If this was the case and such trees grew more poorly with increasing age, the SI of older stands would be systematically lower than SI of young stands on the same site.

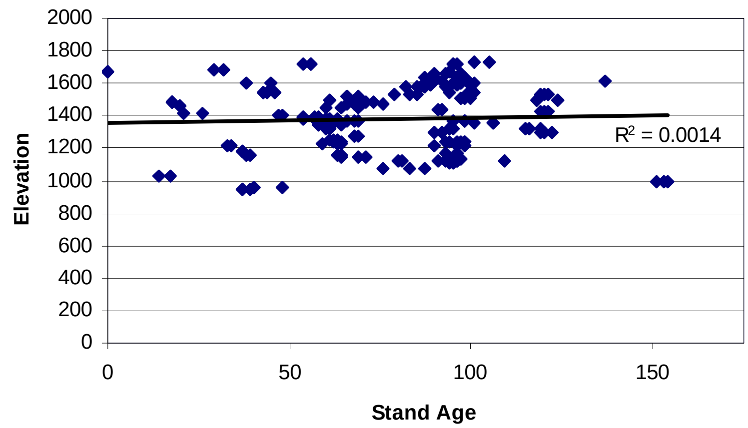

Figure 2. Scatterplot of stand age with elevation for Permanent Sample Plots in central Alberta. There is evidently no strong bias in toward older stands growing at higher elevations among these plots.

These preliminary results raise a number of questions. If the causes of bias can be quantified, possible explanations for height growth increasing with time include: gradual improvements in forest management practices, increased nitrogen deposition, and, possibly, increased atmospheric carbon dioxide concentrations. Another possible factor is that regional climate warming in the past century has gradually improved growing conditions and/or lengthened growing seasons. To address this last possibility, time-series of historical monthly climate data were interpolated (10 km resolution) to estimate changes in temperature at PSP locations during the period 1901-2000. We examined the relationship between the mean annual height increment for each tree section and the average local temperature during the period of growth of that individual section (Figure 2). Temperature variables examined included mean annual maximum and minimum, and the averages for spring (May-June) and the entire growing season (May-August). Graphs were plotted to compare tree sections of similar ages (5-year intervals) to reduce the influence of differences in tree age on annual growth increment.

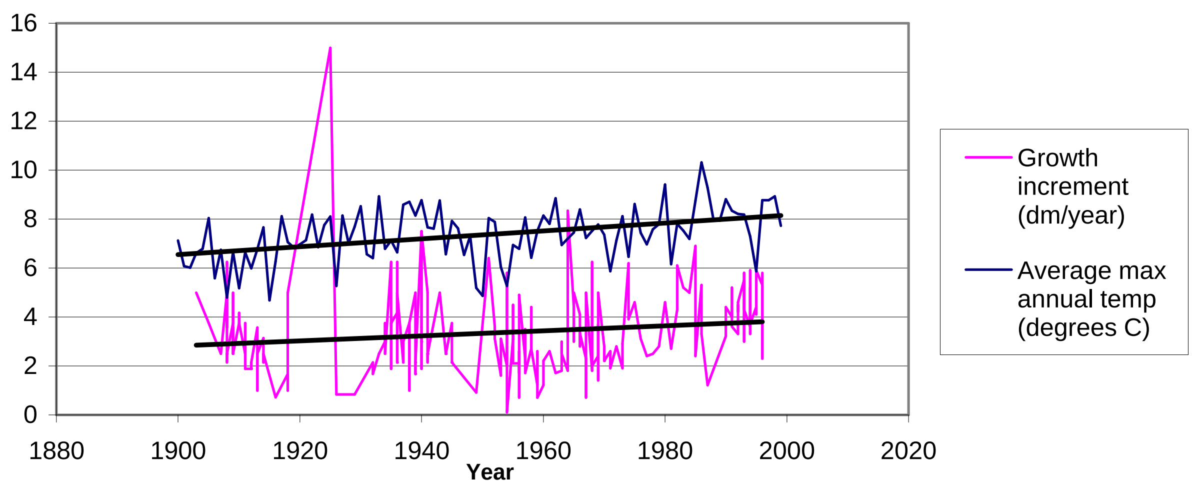

Figure 3. An example plot of average yearly tree growth increment (dm yr-1) and corresponding local mean annual maximum temperature values (°C), for trees of the same age (10-15 years) at different times in the last century (Central region of the study area). The obvious outlier (reported increment of 1.5 m yr^{-1} in a single tree) is presumably spurious, but had only a minor effect on the calculated correlation coefficient. [Note: 1 dm = 0.1 m].

Thus, the graph represents the growth of different individual tree sections of the same age, but growing at different periods during the 20th Century.

Figure 3 confirms that there was a significant warming in Alberta during the 20th Century. (We show mean annual maxima, but similar trends can be seen in other seasonal measures of temperature). Further, Figure 3 also shows that warmer periods are generally correlated with faster annual tree growth. Correlation coefficients (R) were mostly in the range 0.25–0.5 depending on the age class and temperature variable examined. Part of the explanation for these relatively low R values could be the obvious contradictions where extreme high mean temperatures appear to be causing lower than normal growth. Such events could be indicators of periods of drought stress, suggesting that it is necessary to investigate historical precipitation records. To date, the interpolation of past precipitation has been problematic: station data for the period prior to 1950 are incomplete with poor coverage in remote and high elevation regions. We are currently trying to improve the maps of past precipitation by using more stations, particularly in the USA just south of the Alberta border. Another contributing factor could be the relatively poor resolution of elevation effects on temperature and precipitation. In the near future we will have local climate histories interpolated to the exact coordinates (latitude, longitude and elevation) of individual PSPs.

Results to date suggest a significant correlation between local climate and tree growth. Future work will concentrate on performing multivariate analysis (growth as a function of precipitation as well as temperature) as well as developing a method to maintain adequate sample size to examine these relationships at a finer spatial resolution, while accounting for possible sources of bias in the stem analysis measurements.

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