Using GIS to Determine the Effects of Slope and Aspect on Tree Growth Rates
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Introduction

It is widely accepted that slope and aspect are two of the most important variables controlling the rate of tree growth. Slopes of 25º are most productive because they are very well drained and, when facing south, allow for more direct adsorption of solar radiation. The objective of this study was to test this theory on Blue Spruce (Picea pungens). If this is true, trees growing on steeper south facing slopes should grow at faster rates than any other trees. The Blue Spruce is a coniferous tree native to the northwest United States but is also common in the Central Interior of British Columbia.

Site Description

The study area is a Christmas tree farm located in the interior of British Columbia (Fig. 1). The area is 9.4 ha (93626 m2) and bounded by the following UTM coordinates: (5974581, 523117 and 5974237, 523401). The climate is characterized by a mean annual precipitation of 650 mm and a mean annual air temperature of 3.7ºC. The naturally occurring vegetation consists mainly of lodgepole pine (Pinus contortas), paper birch (Betula papyrifera), poplar (Populus tremuloides), white spruce (Picea glauca), a number of willows (salix sp.), various grasses and an assortment of undergrowth species. Also present were several species of lichen and fungi. Soils are generally thick and of the sandy clay loam variety.

The study area was divided into three sites. Site one is located in the southwest corner of the study area and has negligible slope and aspect. Site two is located towards the center of the study area. This site is situated upon an east facing slope of approximately 30º. Site three is located in the central northeastern portion of the study area and has a south facing slope of approximately 25º. Each of the sites was, at least partially, planted with Blue Spruce. Each site was planted in 2m x 2m grid fashion to ensure a combination of optimal tree growth and maximized efficiency of land use.

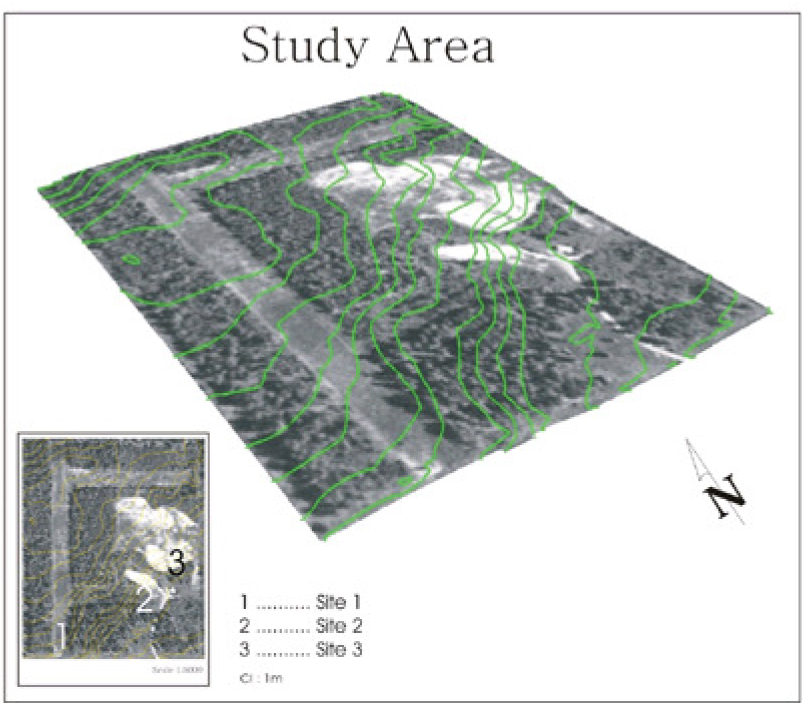

Fig. 1. Map of study area (Produced with Arcplot and Corel Draw)

Materials and Methods

GPS coordinates were collected for two opposite corners or each grid of trees where the term grid, in this case, refers to the pattern in which the trees were planted. An empty 2m x 2m grid was created using CIMPRO in PCI Works with these GPS coordinates.Thus, each grid squarerepresented a tree and was automatically georeferenced in relation to the GPS coordinates from which the grid was created. The ARC/INFO command, gridpoint, was used to transform this grid into a point coverage. Data pertaining to slope and aspect was also obtained using ARC/INFO. The command, SAI, produced an SAI grid (fig. 4) in which each pixel was assigned a value from the slope and aspect index. The SAI index contains values ranging from 0 to 60 with 0 being the poorest site for tree growth in terms of slope and aspect. This SAI grid was produced from a lattice (that had elevation attributes associated with it) that was made from the contour coverage. The commands arctin and tinlattice were used to transform the contour coverage into a tin then to a lattice. Another ARC/INFO command, latticespot, was used to transfer those values to the overlying point features. (For a complete list of ARC/INFO commands required to accomplish this project, see appendix)

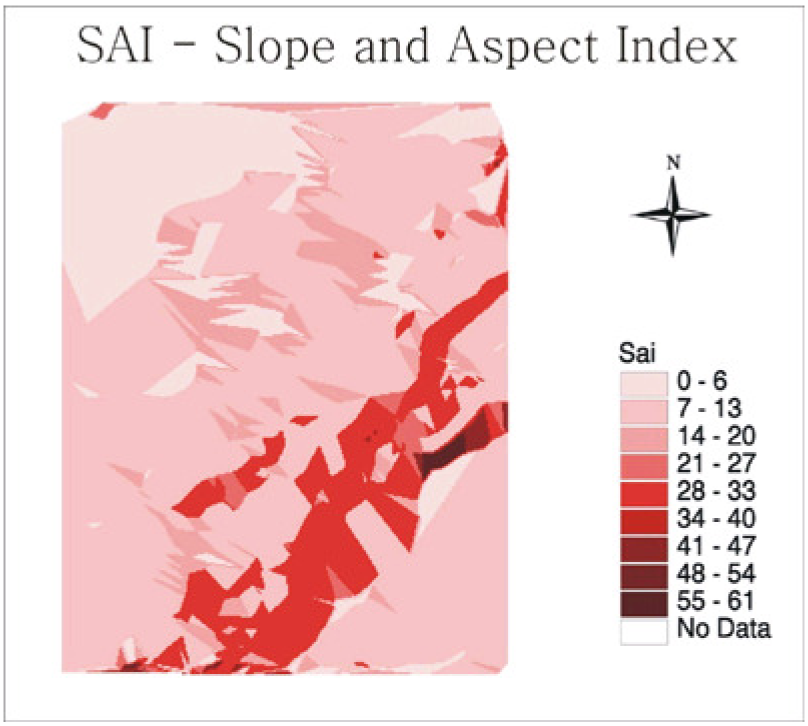

Fig. 4. SAI distribution of study area (Produced in Arcview)

Elevation data was obtained from the city of Prince George and was imported to ARC/INFO from the AutoCAD drawing exchange format (.dxf) using the command, dxfarc. The orthophoto used was obtained from TRIM II data. The resolution of such orthocphotos is 1 m. Growth rates (cm/year) were determined using measured tree heights and known ages. All graphs were produced by exporting the attribute table of the point coverage to Microsoft Excel (command: infodbase).

Results

Graphing the growth rates of each tree versus its respective SAI value yielded an R2 correlation of less than 0.1 with a regular best fit line. However, an R2 value of 0.78 was obtained from a 4th degree polynomial trendline (fig. 2).

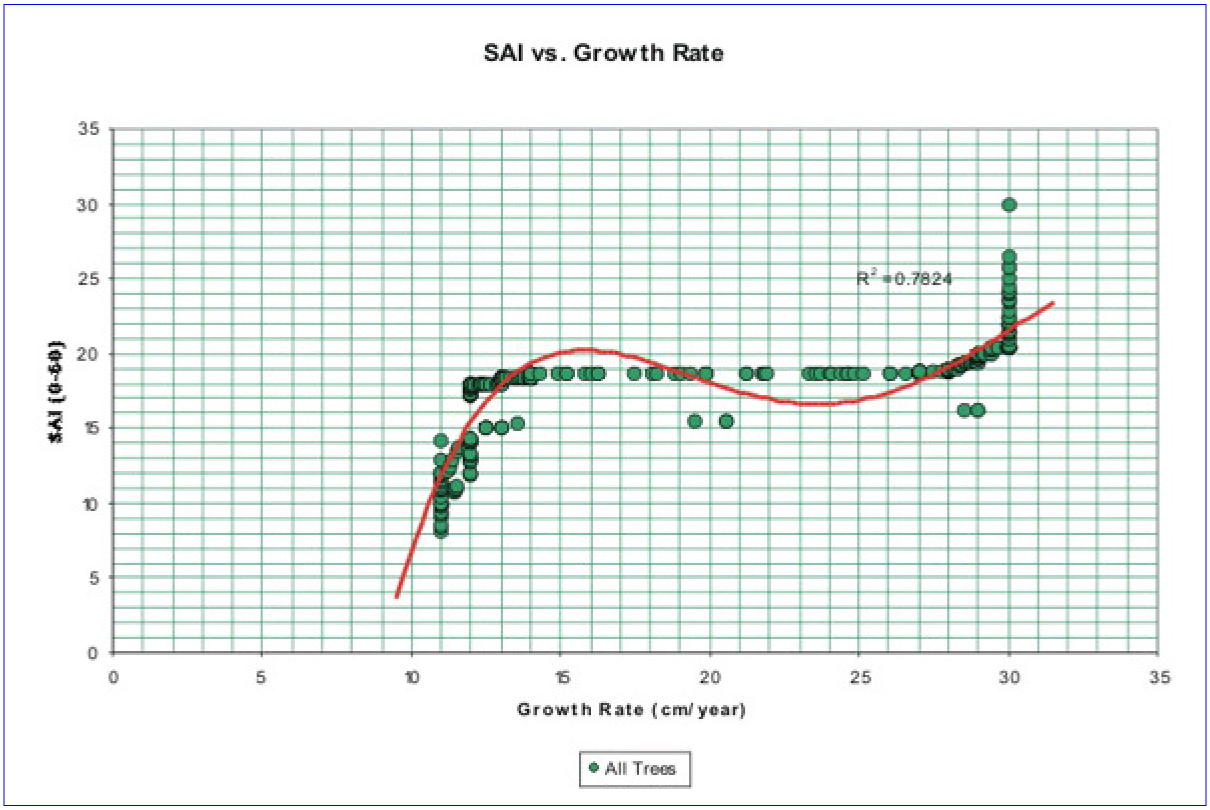

Fig. 2. Growth rates of all Blue Spruce trees studied

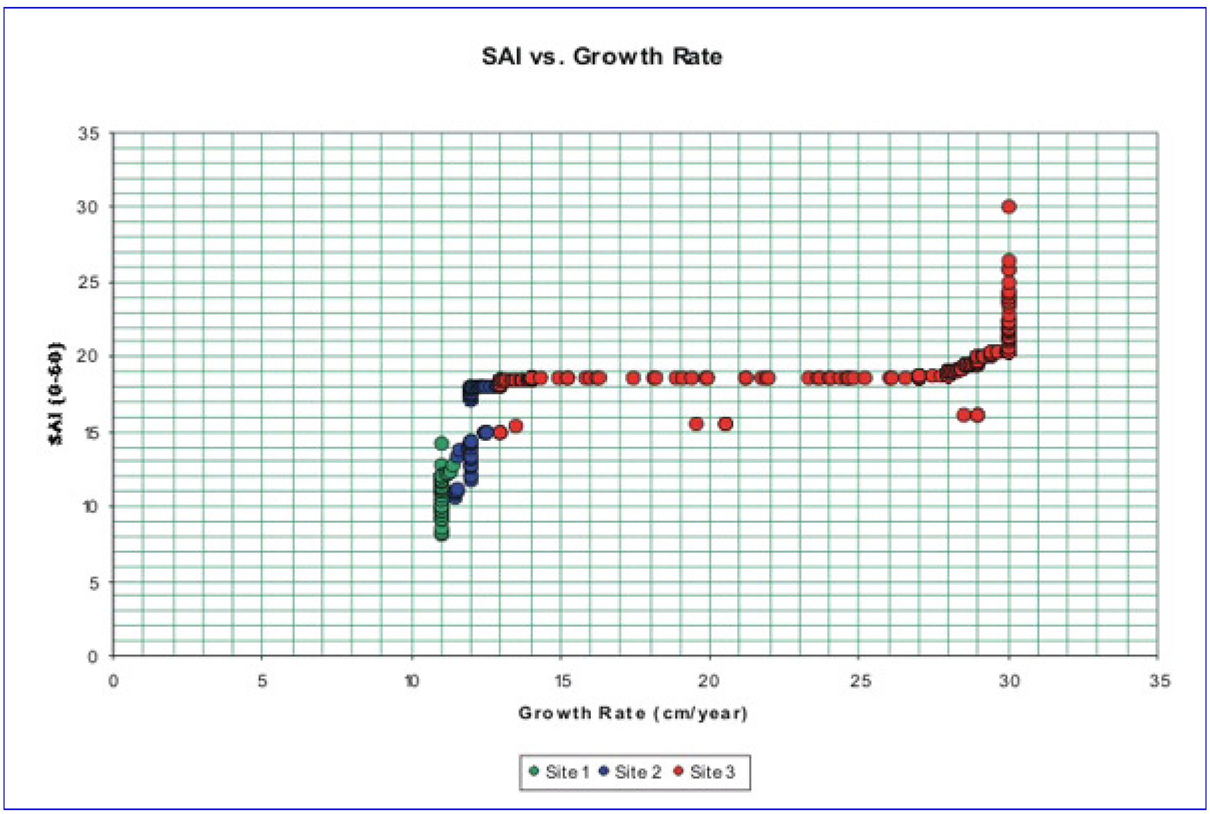

Fig. 3. Growth rates separated by site

Sites one and two showed much more uniformity in growth rates than did site three (fig. 3). Growth rates were site specific for sites one and two but not for three. SAI values ranged from 11 to 30 for the three sites with their averages shown in table 1.

Site	Height (cm)	Age (years)	Growth Rate (cm/year)	SAI (0 – 60)
1	59	6	9.81	13.2
2	98	5	19.6	25.6
3	90	5	17.9	18.0

Table 1. Average values for each site

Discussion

The R2 value from the trendline shows that SAI and growth rate are related to some degree but there are instances where SAI increases with no change in growth rate and where SAI remains constant and growth rates vary. The average values (table 1) seem to show a good relationship but, after looking at the graph, it becomes apparent that this is not the case. This suggests that, despite the significant R2 value, SAI and growth rates are not interdependent and that there may be sources of error or other controlling factors that were not taken into account that had an affect on the data.

It seemed reasonable to assume that each tree received the same amount and distribution of precipitation as well as annual hours of sunlight because the study area is relatively small. For this same reason, the soil was considered to act as a constant. Therefore, in theory, slope and aspect should have been the only variables. In retrospect, however, it was not practical to assume that each of the trees employed in the study were subject to identical growing conditions and, realistically, these conditions most likely displayed a significant degree of variance. The problem lying therein is that accurately quantifying many of these variables is near impossible. No fertilizers were used but it is entirely possible that nutrient supply was not constant. Also, biogenic influences (ie. moose selectively feeding on tree buds and various animals burrowing within the root masses) were not accounted for. These factors may have inhibited tree growth. Also neglected were possible enhancements of growth rates due to symbiotic effects of micorhizae.

The contour data had a number of abnormalities. Certain contours stopped abruptly and some contours were missing all together. This raises questions pertaining to the accuracy and reliability of this data. Considering the quality of elevation data used, values for the slope and aspect index were, in actuality, too precise. A wide range of SAI values was given for slopes that were observed to be relatively uniform. For such a small study area, a smaller number of SAI categories may have been more useful. Relative SAI values from each site matched up with observations but absolute values did not. This was likely due to inherent limitations of the contour data. However, this should not have had much of an impact on the results. The distribution of sample points may have also skewed the results. There were much more sample points from site three than from sites one and two. The total number of sample points was also relatively small. 537 trees may not provide an all inclusive description of the relationship between SAI and growth rates. The diversity of SAI values was also limited. There were three main SAI values, basically one for each site. Intermediate SAI values would have also provided a better characterization of the SAI-growth rate relationship.

Conclusion

The findings of this study show some evidence supporting the theory that slope and aspect are controlling variables of the growth rate of Blue Spruce. However, there is also evidence to disprove this theory. Overall, the findings are inconclusive. Growth rates can be site specific but are controlled by factors other than slope and aspect. A more extensive study is required for further understanding of the theory.
Appendix

Important ARC/INFO commands used in the duration of this project:

Arc:
- dxfarc (to import .dxf contours to ARC/INFO coverage)
- arctin (to create a tin from the contour coverage)

- tinlattice (to create a lattice from the tin; for purpose of latticespot)
- clip (used to clip the contour coverage)
- gridclip (used to clip the orthophoto to match the contour coverage)
- SAI (used to assign slope and aspect index values to the study area)
- Latticespot (used to assign SAI values to tree attributes)