Forest Cover Type Analyses in the 100 Mile House and Kamloops Timber Supply Areas

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Abstract

The debate surrounding the accuracy of the forest inventory in British Columbia has increasingly gained media attention in recent years. It is widely recognised by professionals within the forestry community that limitations exist with the current timber inventory. An analysis of selected forest cover types was conducted from operational cruise plots in the 100 Mile House and Kamloops Timber Supply Areas (TSAs) to examine possible differences in stand attributes from each data source. Forest cover types were stratified based on the spatial location within three biogeoclimatic subzones. Age and site index information were pooled from all available data sources due to limitations on available age data. The study determined that stand attributes in the IDFdk3 were overestimated and were undervalued in the MSxk2 and SBPSmk by the Vegetation Resource Inventory (VRI). Cruise information indicated that stand volumes were slightly higher relative to age in comparison to the VRI. This corresponded with a slight undervaluation by the VRI of site index. The study provides further confirmation that the VRI is not an accurate base for forecasting timber inventory for short term harvest planning horizons.

Acknowledgements

I would like to acknowledge that this report would not be possible without the aid of the staff at West Fraser Mills 100 Mile Lumber division. I appreciate Mark Runge's assistance in developing the study topic for this analysis. I would like to thank Dave Cromarty for his help in compiling the spatial and VRI data. I also acknowledge Jason Armeneau's instruction on the cruise compilation software. Finally, I would like to thank my mother for supporting me throughout my education.

1.0 Introduction

Short term harvest planning horizons rely on forest cover polygon attributes for strategic and efficient land use planning on the forest estate. The precision and accuracy of Vegetation Resource Inventory (VRI) forest cover polygons for harvest planning purposes remains a main source of concern for forest managers in British Columbia (Moss, 2006).

Cruise plot data is required to estimate timber volumes, species distribution, and other information by forest licensees for the purposes of appraising timber values for stumpage calculations prior to harvesting. This standardised obligation can be used in a cost effective manner to validate the accuracy of the VRI from plots that are located in known forest cover types (Thrower, 2003). Since some aspects of the data are not collected in a pre-defined sampling frame, the results are not statistically valid. However a sufficient amount of cruise plots located in mature forest cover types can provide some insight for the accuracy of the VRI forest cover attributes (Thrower, 2003).

The purpose of this essay is to determine the accuracy of the forest cover polygons in the 100 Mile House and Kamloops TSA with respect to the information obtained from cruise plot data. This essay initially examines past and current forest inventory standards and then proceeds with an analysis of VRI forest cover types with spatially referenced cruise plot data. This is followed with a discussion and conclusion that provides explanations for the variation between the two data sets.

1.1 History of the Vegetation Resource Inventory

Thrower et al. (1992) provided the history that is summarised in this subsection.

The first attempt at establishing a standing timber inventory was prior to 1910. It consisted of compilations of existing ground samples and speculative estimates for large areas of the province.

Subsequent compilations from 1911 to 1950 utilised ground surveys from limited regions in the province to better quantify the available standing timber inventory. These surveys became quickly outdated as technological improvements and new markets allowed improved utilisation of the forest resource.

The development of aerial photography after World War II allowed for the first comprehensive inventory of the province. Between 1951 and 1960, aerial surveys in conjunction with ground surveys were carried out but budgetary and logistical constraints restricted the development of a stratified random sampling design. This resulted in no determination of the number of samples required for each type. Ground sampling was particularly limited to older and mature forest cover types in accessible locations and was conducted in stands representative of forest cover types stratified from the aerial photography.

The creation of Public Sustained Yield Units (PSYU) resulted in a re-inventory of the Province's available timber supply from 1961 to 1977. Enhanced aerial photography technology allowed for higher resolution photos at larger scales and ground surveys were improved to reflect more refined forest cover type stratification by sampling age, height, stocking, and site variables. As with the first complete inventory, logistical and financial constraints limited the ability to introduce stratified random sampling. Sampling bias was thus introduced by representative sampling the largest, mature and economically accessible strata.

Subsequently after the second complete inventory there was a desire to create a stand level inventory for short-term operational harvest planning horizons. Prior forest inventories provided estimates of forest cover attributes of similar timber types for the entire PSYU. An attempt was made to introduce more detailed estimates for stands from with low level, high resolution aerial photography with the intention to define relationships between photographs and ground sampling.

A lack of funding and technical training resulted in the failure to implement this new sampling method.

During the 1980's the inventory was updated to reflect natural disturbances and harvesting activities. A re-inventory program was initiated in 1988 and forest cover data was converted to digital format. Aerial photo reclassification was conducted to assign standing timber volumes to Variable Density Yield Prediction (VDYP) equations from sample plots collected from 1961 to 1977.

In 1991, the Forest Resources Commission recommended a review of the provincial forest resource inventory. The desire for more information on forest attributes for forest estate planning resulted in the creation of the VRI in 1995 (Sandvoss, 2005). In addition to this growth and yield modelling was developed and an inventory of second growth stands was implemented to increase the accuracy of the VRI.

The current forest inventory strategy is to update the VRI forest cover data every two years to account for harvest activity, natural disturbance, and to add additional forest resource attributes to reflect changing demands from the forest estate.

1.2 Current VRI

The following information regarding current VRI data collection procedures has been summarised from that provided by Sandvoss el al. (1992).

The main intended purpose of the VRI, like that of the old forest cover data, is to provide forest cover attributes for forest estate level planning in timber supply areas. It is currently viewed as effective in achieving this objective. Like all aerial photography, its effectiveness relies on the premise that only what can be seen from the photographs is included in the interpretation.

The VRI spatial data is divided into map sheets, each encompassing approximately 15,440 hectares (NPC, 2009). Polygon delineation is conducted on medium level photography at 1:15,000 to 1:50,000 scales. Polygons are delineated by either hard or soft lines. Hard lines are easily distinguished bioterrain boundaries that are precisely delineated by features such as lakes, rivers, and swamps. Soft lines are features that are gradual or non-specific bioterrain boundaries found between differences in species, age, and height and other attributes. Each polygon within a map sheet is assigned a unique polygon ID to reflect its distinctive attributes relative to adjacent polygons. The individuality of each polygon is attributed to species, age, height, crown closure, density and basal area.

The interpretation of species composition is determined by basal area species distribution information derived from nearby field calibrated stands. Tone, colour, texture, shape size, location, and tree crown shape are also used to interpret species makeup. Age attributes are dependent on field calibration data and past disturbance history information. This can be verified to some degree from species, crown closure, crown size and vertical complexity stand characteristics.

Height interpretation is mainly calculated using scanned aerial photographs that can be stereoscopically viewed on computer monitors. Height measuring applications from computer software allow for accurate automatic interpretation from high resolution photographs. Crown closure calculation is similarly limited to photo resolution and relies on calibration data that is mainly developed from aerial sampling.

Ground calibration data is critical to determine basal area and stand density. Basal area estimates can also be derived from height and crown closure relationships developed from ground sampling in local areas. Accurate stand density estimates also rely on a sufficient amount of ground calibration samples from localised areas.

2.0 Methods

2.1 Description of Study Area

The study area included West Fraser Mills (referred to as the "licensee" hereafter) operating areas in the 100 Mile House and Kamloops TSAs. Data in the 100 Mile House TSA were derived from cutting permits under forest licenses A20001 and A20002. Kamloops TSA data comprised of cutting permits from forest licenses A18690 and A18694. The majority of cruise plots in this analysis were located within the 100 Mile House TSA. Figure 1 depicts the spatial location of cutting permits used in this study.

The 100 Mile House TSA encompasses 1.23 million hectares of which 896,000 hectares is classified as productive forest. The Timber Harvesting Land Base (THLB) is 638,787 hectares of the productive forest. Nearly 42% of the THLB is comprised of trees greater than 100 years of age. Tree species by volume in the THLB are comprised of Lodgepole pine (57%), Douglas fir (29%) Spruce (8%) deciduous species (4%) and other species (2%) (MOFR, 2006). The majority of the forest inventory data in the TSA originates from 1972 to 1976 with subsequent updates to account for changes in growth and disturbances (MFLNRO, 2012).

The TSA is approximately 2.77 million hectares of which 45% is considered available for harvest (KFFS, 2009). Mature stands available for harvest are 66% of the THLB. Proportional species distributions on the THLB are comprised of Douglas fir (33%), Lodgepole pine (30%), Spruce (18%), Sub-alpine fir (9%) and other species (10%) (KFFS, 2009). The VRI in the TSA is derived from forest inventory data collected between 1967 and 1976. Annual updates have subsequently been conducted to account for changes in growth and disturbances (MFLNRO, 2012).

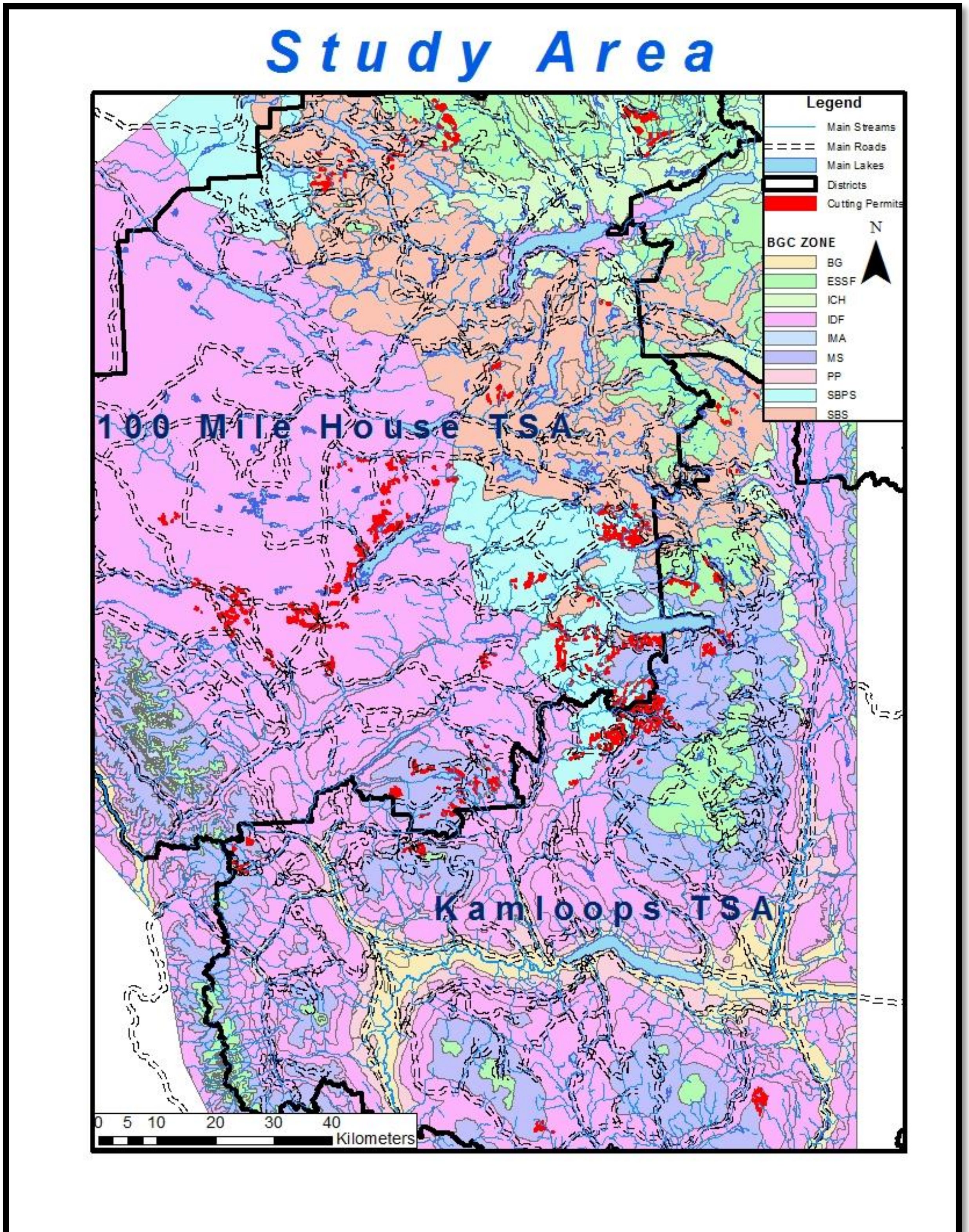


Figure 1 – Map of study area

The majority of forest cover types in the study were conducted biogeoclimatic subzones characterised by frequent stand replacing disturbances. The derived data are weighted towards Lodgepole pine dominated types reflecting early seral characteristics typical of reoccurring stand replacing events in these subzones. The exceptions to this were stands located in the ESSFdc3, ESSFwk1 and ESSFwc3 subzones which were mixed species stands classified as Natural Disturbance Type 2.

Cruise plot samples were obtained from cutting permits within the licensee's operating area in the Kamloops and 100 Mile House TSAs. A total of 2073 plots from 167 forest cover types were derived from all cutting permits cruised from 2007. The number of plots per forest cover type are depicted in Tables 1 to 11 in Appendix A. For the purposes of further analysis, forest cover polygons were stratified into 11 strata according to their biogeoclimatic subzone.

2.2 Sampling

Ground sampling procedures for the cruise plots are described in *Ministry of Forests, Lands, and Natural Resource Operations Cruising Manual* (MFLNRO, 2006). Due to the licensee's operational requirements, only mature forest types consisting of mainly mountain pine beetle salvage cutting permits were used for this analysis. Forest Cover polygons were selected from cutting permit appraisal maps on the basis of having a minimum of 5 plots per polygon. Plots located near the boundary of the polygon were removed from the study to eliminate edge effect. The vast majority of plots consisted of full measure plots. Plot location varied within polygons in accordance with block location, cutting permit and timber type size reflecting the requirements of the interior appraisal manual for stumpage calculations.

Cruise plots were compiled using CruiseComp® compilation software provided by the licensee. All plots were compiled with a minimum diameter at breast height 12.5 cm for Lodgepole pine and 17.5 cm for all other species. A 30 cm stump height was used for all species. Forest cover polygons were assigned a unique ID for each type for the purposes of assorting and managing data. Cruise compilation reports were then produced for each subzone.

Forest Cover polygons were queried from their mapsheet and polygon ID number from the 2011 VRI layer from the Ministry of Forests, Lands, and Natural Resources operations using ArcMap® software. Some forest cover polygons were updated to their recent harvest status resulting in a change in their forest cover attributes to reflect their standing volume removal. These types were then rejected from this study to due to their incompatibility to their associated pre-harvest cruise data.

Plots located in different forest cover polygons with the same forest cover label had their VRI data calculated with a weighted average for the simplicity in comparing their attributes to the associated cruise compilation data. In most cases, multiple forest cover types had identical attributes reducing irregularities between polygons.

2.3 Statistical Analysis

The volume statistical summary from the cruise compilation reports provided the net merchantable volume coefficient of variation for each forest cover type. Forest cover types with coefficient of variations less than 50% were selected from the 167 types to increase the accuracy of the samples and decrease the time to compare polygons to the VRI forest cover data. After rejecting samples that did not meet the statistical test, 73 types were available to compare with the VRI data.

VRI volume attribute data is only currently available as net merchantable volume per hectare. This is defined as volume net of the utilisation levels. Gross merchantable volume statistical summaries are not available with the cruise compilation software, but due to the significant variation in volume reductions for debris, waste and breakage, it is assumed that the gross merchantable volumes have significantly less variation compared to the net merchantable volumes.

VRI age and height attributes are derived from the leading and secondary species for the dominant, co-dominant, and high intermediate tree layer (MFLNO, 2011). Basal area and stand density are calculated from all visible trees within the dominant, co-dominant, and high intermediate trees (MFLNO, 2011). High intermediate trees are assumed to correlate with the minimum utilisation levels used in the cruise compilation for the purposes of this study.

Currently, it is not mandatory to sample trees for age in mountain pine beetle cutting permits. This substantially reduced the forest cover samples available for VRI age comparison. The available age information was calculated manually from the cruise plots. Ages were compiled with a weighted average from the leading and secondary species within the forest cover types. The corresponding height data was derived from the extended type summary in the cruise reports. It was calculated using a weighted average of the biological volume of all tree species at the minimum DBH utilisation level (MFLNO, 2011).Basal area and stand density information were developed from the cruise compilation report extended type summaries and type basal area tables.

Primarily tree species and in mixed stands, secondary tree species, from the dominate tree layer were compiled from cruise plot data to determine site index. Each dominate tree had an individual site index calculated using Site Tools Software®. An average site index was then determined from the sample trees. Mixed species stands had a weighted average applied to adjust for productivity differences among species.

An R-equivalency test was conducted for volume, height, basal area, and total stems in forest cover types located in the IDFdk3, MSxk2 and SBPSmk subzones using software developed by Robinson et al. (2005). In addition, age and site index were also tested. The null hypothesis for R-equivalency test is contrary to other statistical hypothesis tests in that the null hypothesis (Ho) assumes that no relationship exists between the cruise compilation data and the VRI data (Robinson, 2005).

The mean attribute value, average difference, and confidence interval were calculated from the VRI forest cover type and the corresponding cruise data. The average difference was computed as the cruise plot data minus the VRI forest cover attribute (Thrower, 2003). The 95% confidence interval was calculated from the standard deviation from forest cover types within the subzone. The confidence interval was then compared to the average forest cover difference, which was defined as the mean forest cover difference of the cruise plot data within the VRI forest cover type minus the VRI estimated attribute (Thrower, 2003).

3.0 Results

A lack of sufficient forest cover types from all subzones sampled resulted in limiting statistical comparison of forest cover attributes to three subzones: Interior Douglas Fir dry kool variant 3 (IDFdk3) Montane Spruce very dry kool variant 2 (MSxk2), and Sub-Boreal Pine Spruce moist kool (SBPSmk). These three subzones had samples containing sufficient variation in VRI age, height, crown closure and site index attributes to allow for a more accurate representation of mature forest cover types within each subzone for statistical analysis (Figure 2). Summary tables are available detailing the percent differences in Appendix A.

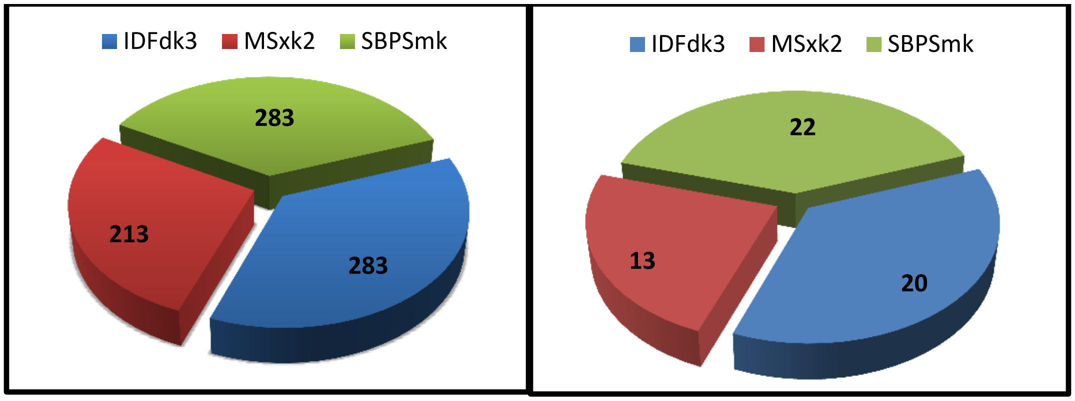


Figure 2: Distribution of plots (left) and forest cover types (right) by subzone

The 95% confidence interval cannot be computed because plots within the sampling frame were not predefined. The cruise plot data confidence interval is a measure of the variation within forest cover types. The term confidence interval is used rather than 95% confidence interval to emphasis the method's deficient statistical validity (Thrower, 2003).

Appendix C illustrates the equivalency results computed in this analysis for forest cover attributes. An interpretation of the results is available in Robinson et al. (2005).

3.1 IDFdk3

Figure 16 in Appendix B contains a graph depicting forest cover type VRI and cruise compilation percent differences for volume/ha, height, basal area/ha, and total stems/ha. The equivalency test results for each forest cover attribute are illustrated in Figure 22, Appendix C. The test confirmed that the cruise and VRI are not related.

Mean volume for all forest cover types sampled in the IDFdk3 strata was 163.93 m^3/ha. This was 12.7% less than the estimated average VRI gross merchantable volume/ha. Approximately 45% of the forest cover types were within the confidence interval. One forest polygon sampled was 236.41% higher than the VRI estimate in average gross merchantable volume/ha. The VRI estimated volume for this forest cover type is assumed to be an error in the photo interpretation.

The irregularity in volume difference for this type increases the mean volume for all cruised sampled types. Analysing the average gross merchantable volume/ha for all forest cover types with the removal of the irregular forest cover type resulted in 36.2% less average gross merchantable volume/ha for all cruised forest cover types compared to the VRI. About 42% of forest cover types were within the confidence interval.

Mean height for all forest cover types sampled in the IDFdk3 strata was 19.1 meters. This was 13.3% lower than the estimated average VRI height. Over 10% of the forest cover types were within the confidence interval. Average basal area/ha for all forest cover types sampled in the IDFdk3 strata was 22.3 m^2/ha. This was 20.3% less than the estimated average VRI basal area/ha. Approximately 40% of the forest cover types were within the confidence interval.

Mean total stems/ha for all forest cover types sampled in the IDFdk3 strata was 606.1. This was 31.8% below the estimated average VRI total stems/ha. Nearly 20% of the forest cover types were within the confidence interval. Figures 3 – 6 illustrate the VRI and cruise compilation results.

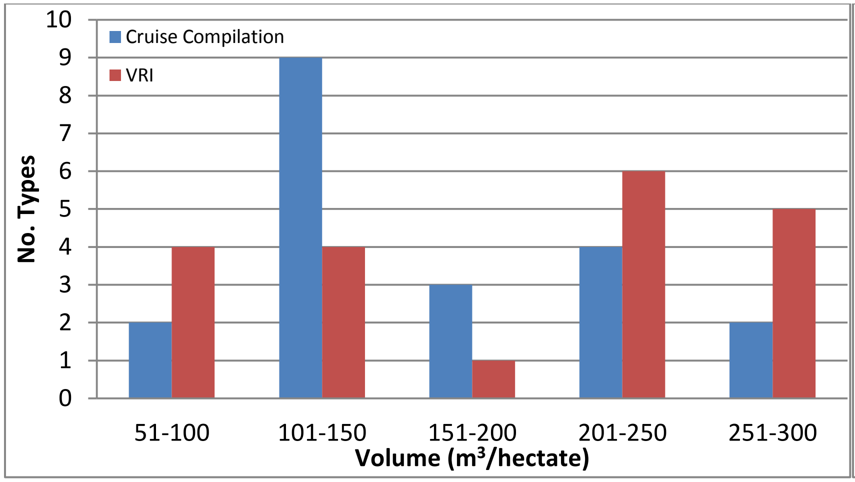


Figure 3 – IDFdk3 cruise and VRI volume

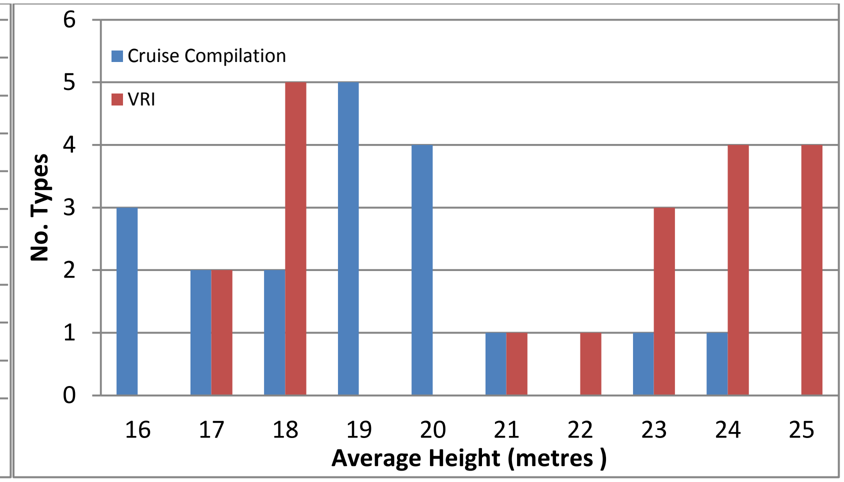


Figure 4 – IDFdk3 cruise and VRI height

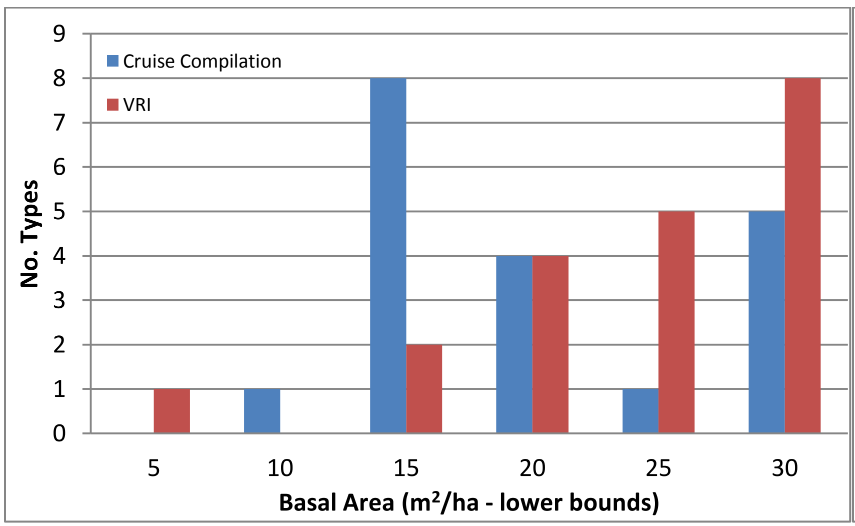


Figure 5 – IDFdk3 cruise and VRI basal area

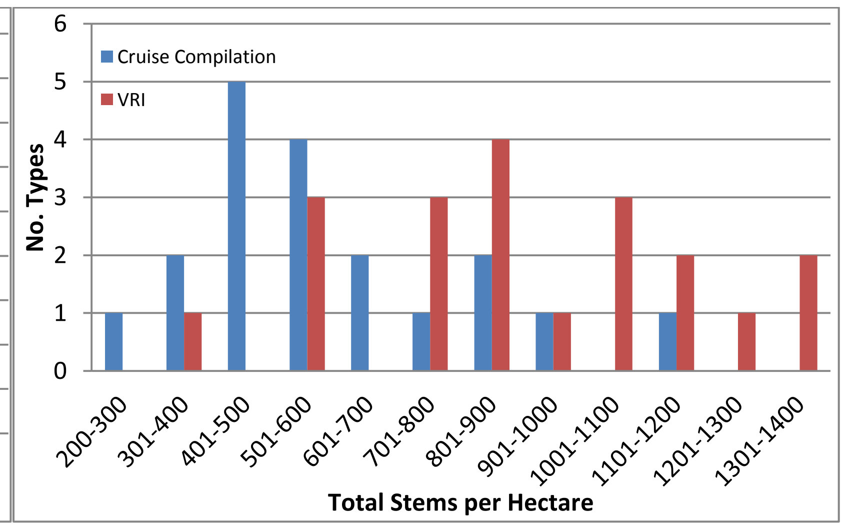


Figure 6 – IDFdk3 cruise and VRI total stems

3.2 MSxk2

Figure 17 in Appendix B contains a graph depicting forest cover type VRI and cruise compilation percent differences for volume/ha, height, basal area/ha, and total stems/ha. The equivalency test results for each forest cover attribute are illustrated in Figure 23, Appendix C. The test confirmed that the cruise and VRI data were not similar.

Mean volume for all forest cover types sampled in the MSxk2 strata was 298.4 m^3/ha. This was 18.5% higher than the estimated average VRI volume/ha. Approximately 58.4% of the forest cover types were within the confidence interval. Average height for all forest cover types sampled in the MSxk2 strata was 21.2 meters. This was 5.2% less than the estimated average VRI height. No forest cover types were within the confidence interval.

Mean basal area/ha for all forest cover types sampled in the MSxk2 strata was 35.8 m^2/ha. This was 5.3% higher than the estimated average VRI basal area/ha. Approximately 46.2% of the forest cover types were within the confidence interval. Average total stems/ha for all forest cover types sampled in the MSxk2 strata was 606.1. This was 14.6% lower than the estimated average VRI total stems/ha. About 46.2% of the forest cover types were within the confidence interval. Figures 7 – 10 depict the VRI and cruise compilation results.

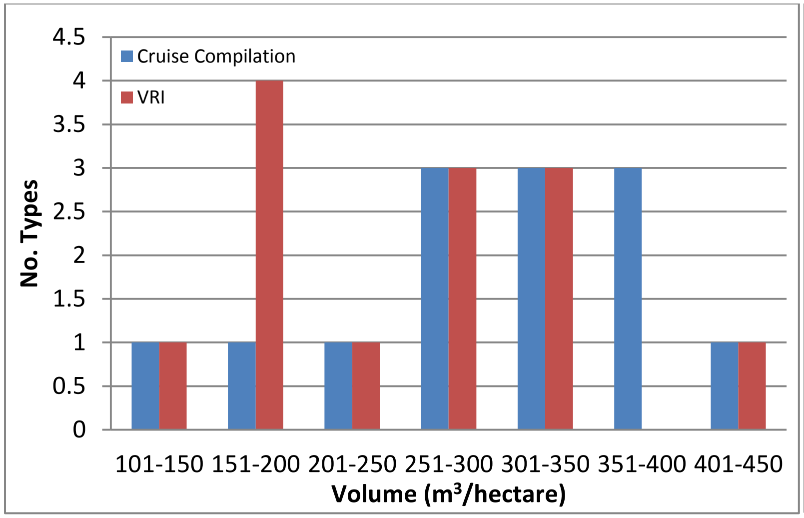


Figure 7 – MSxk2 cruise and VRI volume

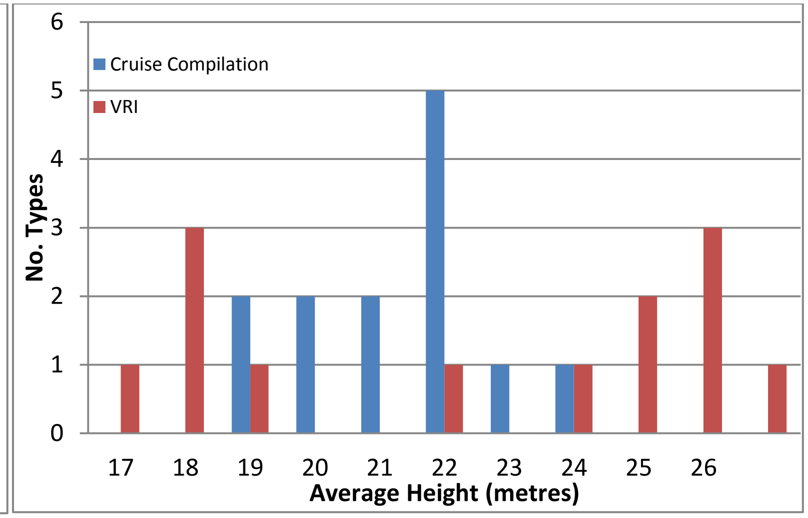


Figure 8 – MSxk2 cruise and VRI height

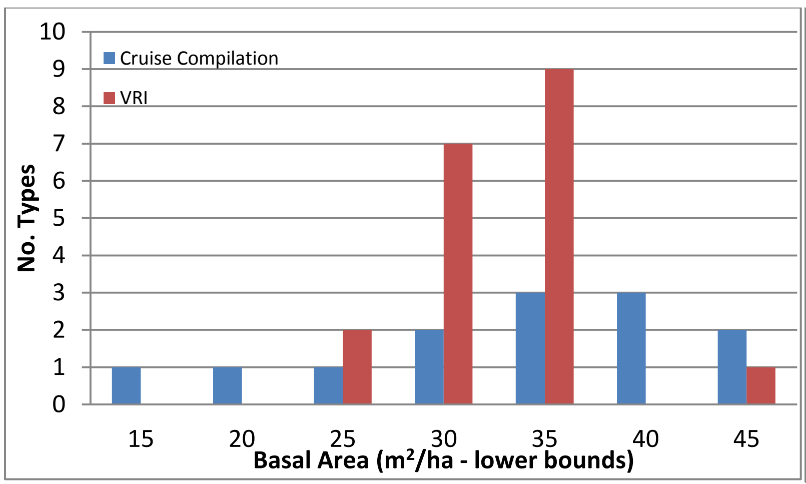


Figure 9 – MSxk2 cruise and VRI basal area

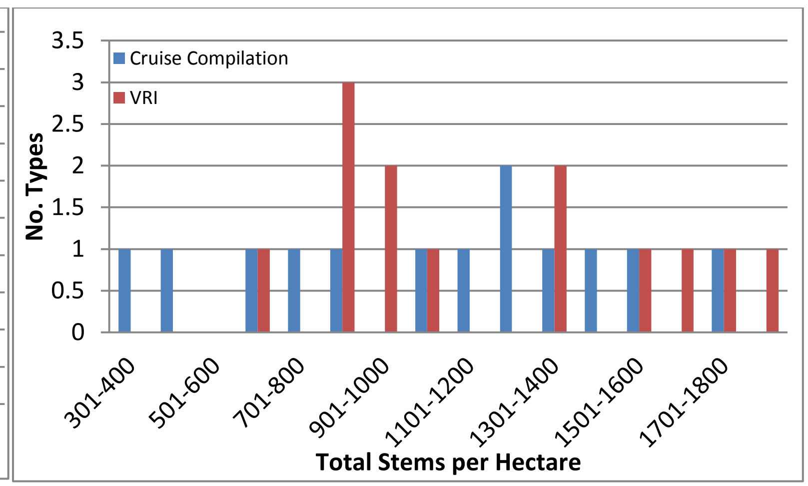


Figure 10 – MSxk2 cruise and VRI total stems

3.3 SBPSmk

Figure 18 in Appendix B depicts a graph of the forest cover type VRI and cruise compilation percent differences for volume/ha, height, basal area/ha, and total stems/ha. The equivalency test results for each forest cover attribute are illustrated in Figure 24, Appendix C. The test confirmed that the cruise and VRI were not related.

Mean gross merchantable volume/ha for all forest cover types sampled in the SBPSmk strata was 271.0 m^3/ha. This was 20% greater than the estimated average VRI gross merchantable volume/ha. Approximately 4.6% of the forest cover types were within the confidence interval.

Mean height for all forest cover types sampled in the SBPSmk strata was 21.6 meters. This was 1.5% above the estimated average VRI height. Approximately 18.2% of the forest cover types were within the confidence interval. Average basal area/ha for all forest cover types sampled in the SBPSmk strata was 32.5 m^2/ha. This was 2.3% higher than the estimated average VRI basal area/ha. Approximately 27.3% of the forest cover types were within the confidence interval.

Mean total stems/ha for all forest cover types sampled in the SBPSmk strata was 984.6 stems/ha. This was 10.6% less than the estimated average VRI total stems/ha. Approximately 33.3% of the forest cover types were within the confidence interval. Figures 11 – 14 illustrate the VRI and cruise compilation results.

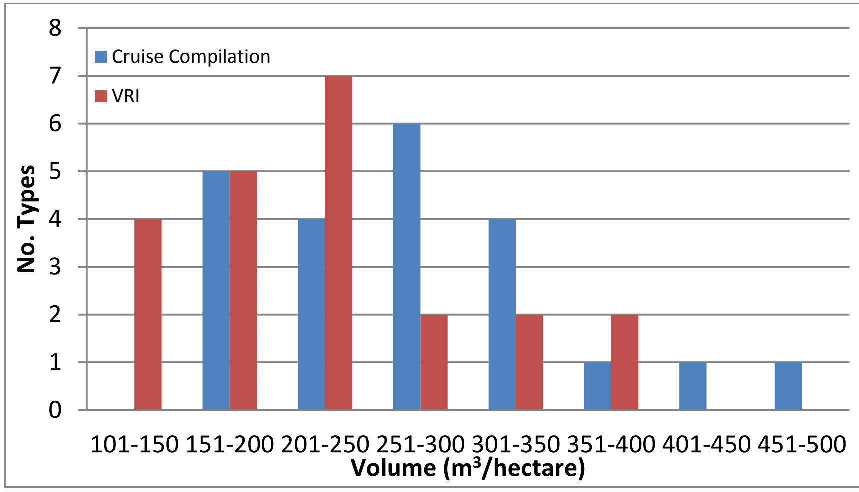


Figure 11 – SBPSmk cruise and VRI volume

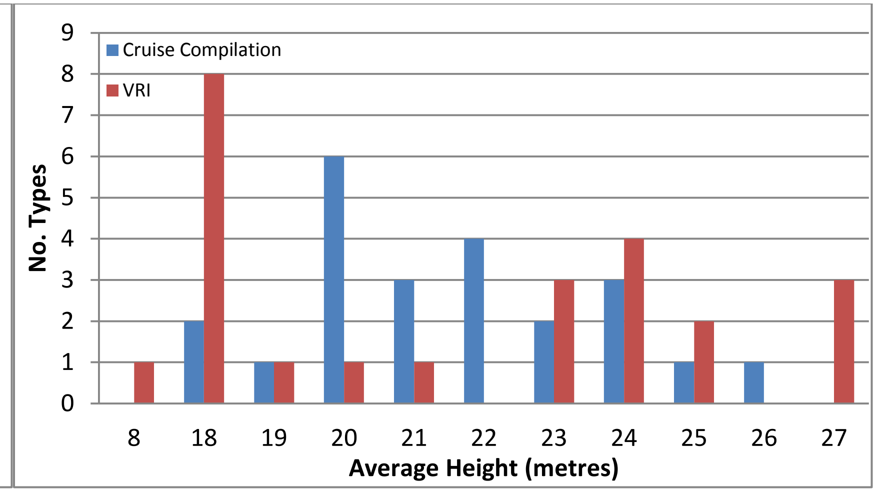


Figure 12 – SBPSmk cruise and VRI height

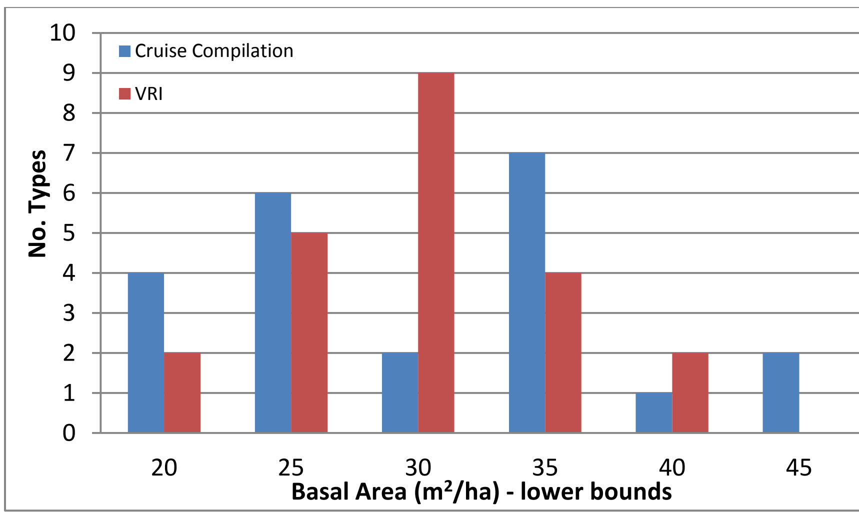


Figure 13 – SBPSmk cruise and VRI basal area

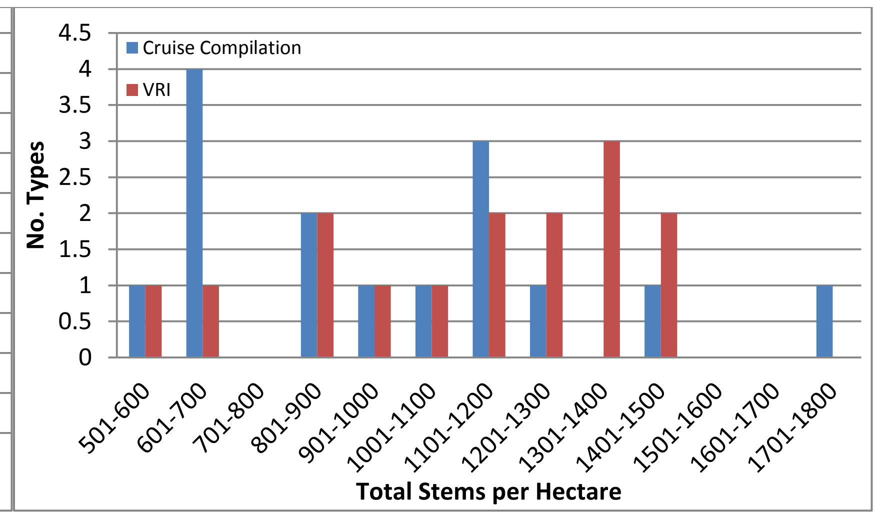
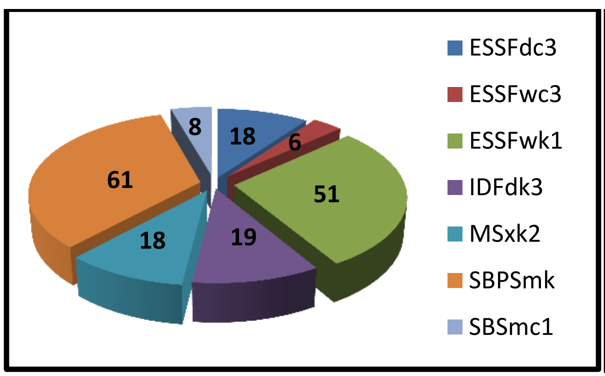


Figure 14 – SBPSmk cruise and VRI total stems

3.4 Average Age and Site Index

Age and site index was compiled from sampled tree ages in the cruise plot data. This information was limited compared to other forest cover attributes. The mean, average difference and confidence interval for all forest cover types were calculated using the same method for the other forest cover attributes (Appendix A Table 12). Figure 15 depicts cruise plot location and forest cover types within the subzones where age information was available for the calculations. Appendix B provides an analysis of cruise site index and volume difference relative to age (Figure 20) and VRI and cruise volumes relative to age (Figure 21). Figure 25 in Appendix C illustrates the equivalency test results. The test determined no relationship existed between the cruise data and VRI data.



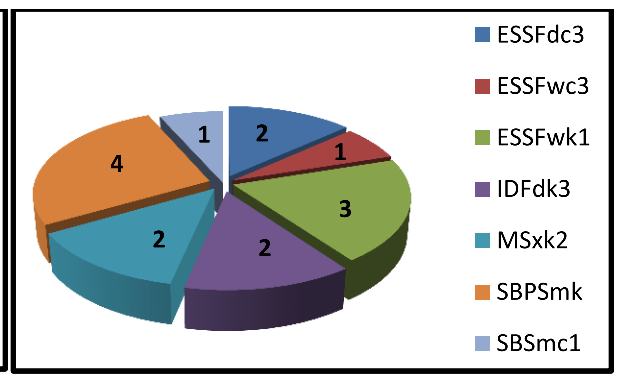


Figure 15: Distribution of plots (left) and forest cover types (right) by subzone for age and site index

Mean age for all forest cover types sampled was 116.35 years. This was 10.5% lower than the estimated average VRI mean age. Approximately 26.6% of the forest cover types were within the confidence interval. Average site index for all forest cover types sampled was 16.64. This was 8.5% above the estimated average VRI mean site index. About 33.3% of the forest cover types were within the confidence interval.

4.0 Discussion

The VRI was designed to provide a strategic level vegetation inventory for land cover reporting at the TSA level. It was never developed with the intention of providing reliable data for short term harvest forecasting. This study was also not intended to provide a statistically defensible analysis of the VRI but rather to provide some insight as to the accuracy of the VRI forest cover types.

Total stems/ha in all subzones were generally over estimated in the VRI. An analysis of basal area for cruised forest cover types determined that basal area/ha was generally underestimated for most VRI forest cover types. This could be due to utilisation limits in the cruise compilation software not capturing all the high intermediate trees within the stand. It is also plausible that high intermediate trees are not always easily photo interpreted resulting in the average height being weighted towards dominate and co-dominant tree layers in some stands. The exact definition of a high intermediate tree is not available and so it is difficult to conclude the exact cause for the overestimation. Trees close to utilisation limits are assumed to meet the definition of high intermediate trees for this study. Further studies should examine high intermediate tree attributes to better clarify their definition and correspondingly allow for changes in cruise plot data utilisation in the compilation to allow for a more accurate comparison of cruise plot to the VRI forest cover attributes.

Mean DBH was not analysed in this study but further examination might conclude that DBH is in fact under undervalued in the VRI. A study of cruise plots and their corresponding forest cover polygons in the Morice TSA found that DBH was on average 4% higher in cruise plot samples (Thrower, 2003). This difference could be attributed to an error in the VRI calculations province wide. In the future, DBH information should be collected and included in future studies to confirm this.

Average height was also found to be less in cruise plot samples than the VRI. An analysis of the extended type stand and stock tables determined that the VRI average height was typically interpreted from the dominate trees rather than co-dominate and high intermediate trees. This difference could be attributed to higher emphasis on dominant trees in weighting the average basal area for tree heights in forest cover types. A study of cruise plots and their corresponding forest cover polygons in the Morice TSA found that average height was on average 5% lower in cruise plot samples (Thrower, 2003). As with DBH, this difference could be attributed to a standardised error in calculating VRI height throughout the entire province and/or errors in interpreting high-intermediate trees in aerial photos.

Variations in the average difference in volume/ha of cruise plot and VRI data were observed between subzones. The IDFdk3 subzone, with the exclusion of one forest over type, had significantly less volume/ha than the VRI. Basal area/ha, average height, and total stems/ha were all lower on average for cruise plots than the VRI. IDFdk3 stands are characterised as having poor productivity and vulnerable to frequent low intensity stand disturbances. It is not known what factor could attribute to lower average volume/ha due to the low amount of age samples available in this study.

Cruise plots in the MSxk2 and SBPSmk were determined to have higher volume/ha on average than the VRI. The majority of forest cover types sampled contained basal area/ha measurements significantly higher than the VRI. However, total stems/ha had no significant difference. These subzones are located in higher productivity areas characterised by stand replacing disturbances. The higher productivity and longer intervals between disturbances allow for self-thinning and subsequent diameter growth. Insufficient age information prevented an analyses of the correlation between average age and site index to determine cause for higher volume/ha from the cruise plot data.

Age and site index data for this study were limited due to the cruising standards for mountain pine beetle stands. Age information collected from pine leading stands to calculate site index does not reflect the additional age accumulated since mortality. This results in a slight over estimation of site index. In addition, the licensee in the 100 Mile TSA has been granted an exemption to derive average age from ground samples where it is deemed necessary for mountain pine beetle stands. This is for the purposes of calculating loss factors (DWB) in the cruise compilation software for stumpage appraisal. At the discretion of the timber cruiser, stands bordering between age groups old immature (60 – 121 years) and mature (>121 years) or stands assumed to have the incorrect age group had tree ages sampled. This consequently introduced non-random sampling bias into the derived age data.

Limitations in the cruise compilation software prevented an analysis of individual forest cover type standard deviation and coefficient of variation for gross merchantable volume/ha, height, basal area/ha, and total stems/ha. This limited an examination of data variability within each forest cover type. Future studies should attempt to find alternate software programs or methods to analyse the statistical variability for individual forest cover types.

Statistical assumptions were not established prior to equivalency tests. Due to the high variability in the results it was intended that assumptions would be tested if the null hypothesis was rejected to investigate the possible correlation between cruise compilation and VRI data. This was considered the most efficient method to test the statistical variability given time restraints.

In many cases, block boundaries did not encompass entire forest cover polygons. This restricted cruise plot locations to areas within cutting permits. It is plausible that cruise plots were positioned in areas within the polygon that had a higher than average volume per hectare than the overall forest cover type. This possibly skews the derived cruise data to over value forest cover stand attributes.

A further analysis should incorporate more age information from cruise plot data. The current cruising standards for mountain pine beetle stands limit the extent at which age and site index can be examined. If another study is conducted, age information should be collected from all cruise plots to provide a more complete representation of forest cover types for their comparison to the VRI.

Efficiencies in compiling cruise plot data from the corresponding spatial location within forest cover types can be realised by creating a point feature in Arc Catalogue® that incorporates all cruise plots from past and present cutting permits. This feature would have the forest cover polygon, license, cutting permit, and biogeoclimatic subzone available in the attribute table. This would allow for querying forest cover types from the cruise plot point feature.

VRI and cruise plot species composition data was not explored in this study. The variation between the two data sets would be a useful addition to further studies. This would allow for the opportunity examine possible patterns between differences in stand attributes and species distribution in forest cover types.

Spruce bark beetle salvage harvest is currently in progress in the 100 Mile House TSA. Cruise plot data from cutting permits for this forest cover type could provide an interesting analysis for non-pine species. Spruce is a critical component to the midterm timber supply in the 100 Mile House TSA and cruise data derived from spruce leading stands for a comparative analysis to the VRI would be interesting to examine in further studies.

Currently, the 100 Mile House TSA is undergoing a VRI phase 1 re-inventory which is projected to be completed in December 2013. A further forest cover type analysis using cruise plot data should attempt to incorporate the new inventory once it is completed.

5.0 Conclusion

The VRI data is not an accurate tool for forecasting short term harvest planning horizons. This determination is the result of a limited analysis from operational cruise plots located in their corresponding VRI forest cover types.

As mentioned previously, the VRI was not designed to be a stand level inventory. It was created with the intention of incorporating aerial photography and limited ground sampling to provide an estimation of timber supply for TSAs. At this time, ground sampling and/or timber reconnaissance is still required to plan future forest development. This in itself can be time consuming and expensive, especially in developing total chance plans. Introducing a stand level inventory for the province could greatly increase the efficiencies and accuracy in forecasting timber development for forest planners (Moss, 2006).

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Appendix A – List of Tables

The forest cover type percent attribute difference is calculated as the cruised attribute subtracted by the VRI attribute. The difference is then divided by the cruised attribute. Note that a negative age value is interpreted as the cruised age being less than the VRI.

Table 1 – ESSFdc3 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
1	ESSFdc3	PlSe(Bl) 736-0/14	6	58.55%	15.14%	4.09%	-23.49%		
2	ESSFdc3	Pl(SeBl) 736-0/17	7	-3.32%	-9.74%	-15.00%	-21.35%		
3	ESSFdc3	PlSe 635-0/18	13	-27.40%	-25.96%	-11.15%	-66.23%	-1.96%	-6.22%
5	ESSFdc3	Se(Bl) 744-0/16	5	-15.95%	-15.13%	-22.07%	-28.54%	-23.66%	-1.34%
			Average	**2.97%**	**-8.92%**	**-11.03%**	**-34.91%**		
			Median	**-9.63%**	**-12.43%**	**-13.08%**	**-26.02%**	**-12.81%**	**-3.78%**
			Standard Deviation	**38.34%**	**17.40%**	**11.05%**	**21.10%**	**15.34%**	**3.45%**
			Coefficient of Variation	**1290.64%**	**-195.00%**	**-100.15%**	**-60.46%**		

Table 2 – ESSFwk1 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
1	ESSFwk1	Pl 744-21/20	5	-12.47%	-11.05%	-12.07%	-1.60%		
2	ESSFwk1	PlS 635-19/18	8	55.84%	42.82%	-5.20%	-3.89%		
3	ESSFwk1	PlS 645-23/22	20	0.87%	15.01%	-17.00%	-16.33%	3.20%	-19.83%
4	ESSFwk1	PlS 744-21/20	20	-2.48%	-3.04%	-13.45%	-14.78%	-16.92%	-1.93%
5	ESSFwk1	PlS(B) 635-16/16	38	55.78%	20.74%	1.74%	-38.09%		
8	ESSFwk1	SPl 844-15/14	11	-0.60%	3.06%	-17.93%	-37.23%	-19.26%	17.87%
			Average	**16.16%**	**11.26%**	**-10.65%**	**-18.65%**	**-10.99%**	**-1.30%**
			Median	**0.13%**	**9.04%**	**-12.76%**	**-15.56%**	**-16.92%**	**-1.93%**
			Standard Deviation	**31.07%**	**19.34%**	**7.57%**	**15.82%**	**12.35%**	**18.86%**

Table 3 – ESSFwc3 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
1	ESSFwc3	PlB(S) 632-16/16	6	82.01%	40.31%	-1.74%	-28.34%	1.85%	11.27%

Table 4 – IDFdk3 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
3	IDFdk3	Pl 625-13/12	16	-12.04%	-28.65%	-4.44%	-50.95%		
10	IDFdk3	Pl 726-11/11	16	-2.52%	-29.72%	7.22%	-57.77%		
11	IDFdk3	Pl 735-15/14	8	-48.88%	-45.50%	-18.18%	-52.88%		
12	IDFdk3	Pl 735-16/16	7	-63.39%	-59.13%	-18.75%	-69.31%		
13	IDFdk3	Pl 735-17/16	21	-60.24%	-49.35%	-25.20%	-51.84%		
16	IDFdk3	Pl 725-10/10	15	14.66%	2.22%	-4.12%	17.77%		
18	IDFdk3	Pl 826-10/9	27	0.52%	-31.97%	7.65%	-59.92%		
20	IDFdk3	Pl 835-15/15	29	-16.31%	-4.99%	-17.50%	10.38%		
22	IDFdk3	Pl 833-12/12	6	21.05%	60.11%	-29.57%	36.76%		
24	IDFdk3	Pl 835-14/14	6	-49.76%	-27.93%	-35.20%	4.74%		
26	IDFdk3	Pl 836-11/12	5	-17.23%	-8.10%	-18.10%	29.68%		
32	IDFdk3	Pl(At) 735-17/16	37	-49.74%	-40.86%	-23.60%	-44.25%		
35	IDFdk3	Pl(Fd) 836-15/15	21	-18.62%	-2.86%	-22.92%	25.77%		
37	IDFdk3	Pl(S) 835-15/15	16	-3.08%	2.19%	-15.42%	-1.48%		
42	IDFdk3	PlAt 537-19/18	14	5.88%	-5.74%	-13.48%	-26.27%		
44	IDFdk3	PlAt 726-11/11	4	82.14%	-8.67%	17.78%	-53.14%	-12.89%	46.27%
45	IDFdk3	PlAt 736-17/16	15	-4.21%	-18.77%	-9.60%	-43.95%	-18.44%	11.16%
46	IDFdk3	PlAt 824-10/10	8	77.03%	-1.65%	8.33%	-46.39%		
48	IDFdk3	PlAt(S) 536-19/18	7	-12.97%	-18.07%	-16.52%	-19.14%		
			Average	**-8.30%**	**-16.71%**	**-12.19%**	**-23.80%**		
			Median	**-12.04%**	**-18.07%**	**-16.52%**	**-43.95%**	**-15.66%**	**28.72%**
			Standard Deviation	**39.66%**	**26.23%**	**14.22%**	**35.21%**	**3.92%**	**24.83%**

Table 5 – MSdm3 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
1	MSdm3	Pl(Se) 636-0/14	10	33.59%	-6.60%	12.86%	-40.00%		

Table 6 – MSxk2 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
2	MSxk2	Pl 526-0/13	8	23.72%	-21.59%	10.59%	-57.65%		
3	MSxk2	Pl 635-19/18	15	6.01%	15.02%	-17.31%	36.48%		
4	MSxk2	Pl 725-12/12	9	141.83%	59.14%	12.11%	1.31%		
8	MSxk2	Pl 635-0/18	5	15.81%	23.24%	-16.15%	25.13%		
10	MSxk2	Pl 735-17/16	32	22.26%	25.29%	-12.50%	18.51%		
11	MSxk2	Pl 635-0/15	5	6.82%	10.38%	-14.55%	-12.31%		
17	MSxk2	Pl 826-10/10	5	-7.93%	-48.57%	24.44%	-80.95%	-10.00%	57.85%
18	MSxk2	Pl 827-0/10	13	68.16%	16.22%	9.44%	-0.47%	-12.57%	14.50%
19	MSxk2	Pl 828-10/10	83	62.47%	5.44%	11.11%	-18.74%		
20	MSxk2	Pl 834-18/18	7	10.77%	19.24%	-19.26%	50.36%		
27	MSxk2	Pl 837-0/17	20	-14.81%	-9.01%	-15.77%	5.56%		
28	MSxk2	Pl(At) 735-0/17	6	7.42%	-4.13%	-5.60%	-47.82%		
29	MSxk2	Pl(At) 736-0/17	5	-11.20%	-19.89%	-6.80%	-33.07%		
			Average	**25.49%**	**5.44%**	**-3.10%**	**-8.74%**	**-11.28%**	**36.18%**
			Median	**10.77%**	**10.38%**	**-6.80%**	**-0.47%**	**-11.28%**	**36.18%**
			Standard Deviation	**43.00%**	**26.78%**	**14.63%**	**38.34%**	**1.82%**	**30.65%**

Table 7 – MSxk3 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
1	MSxk3	Pl(Fd) 735-0/19	6	-14.08%	-2.93%	-15.56%	15.09%		
2	MSxk3	Pl(Fd) 736-0/17	3	-33.12%	-5.53%	-30.40%	66.80%		
		Average		**-23.60%**	**-4.23%**	**-22.98%**	**40.94%**		

Table 8 – SBPSmk forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
4	SBPSmk	Pl 425-17/15	8	54.48%	3.72%	11.11%	-36.91%		
5	SBPSmk	Pl 626-13/12	13	31.45%	10.74%	-0.56%	-15.03%		
6	SBPSmk	Pl 723-11/11	21	114.69%	40.56%	27.78%	-26.96%		
8	SBPSmk	Pl 727-11/11	19	74.02%	17.89%	20.00%	-20.70%		
9	SBPSmk	Pl 728-11/11	29	73.96%	18.54%	17.22%		1.10%	41.82%
12	SBPSmk	Pl 636-0/14	5	50.16%	40.08%	-2.50%	40.74%	13.81%	4.57%
13	SBPSmk	Pl 737-17/16	15	-25.55%	-25.38%	-7.08%			
14	SBPSmk	Pl 737-19/18	21	-54.73%	-44.30%	-25.19%	-42.53%		
15	SBPSmk	Pl 738-17/16	20	35.19%	14.88%	3.33%	-1.81%	-6.13%	26.81%
16	SBPSmk	Pl 825-10/10	8	73.10%	8.70%	24.44%	-28.70%		
17	SBPSmk	Pl 826-10/10	8	91.63%	33.78%	12.22%	-9.85%		
20	SBPSmk	Pl 837-0/14	7	-40.58%	-36.46%	-12.61%	-44.67%	-34.51%	-2.50%
22	SBPSmk	Pl(At) 635-16/16	5	-19.59%	-9.81%	-20.87%	-6.80%		
23	SBPSmk	PlAt(S) 736-17/16	7	-20.29%	-39.80%	-4.40%			
26	SBPSmk	Pl(S) 836-15/15	17	16.16%	4.64%	0.42%			
27	SBPSmk	Pl(SAt) 836-15/15	6	7.40%	10.97%	-16.25%			
30	SBPSmk	Pl(Se) 737-0/18	26	27.26%	27.36%	-11.85%	14.52%		
33	SBPSmk	PlAt 735-0/18	5	22.48%	3.70%	-13.70%	-1.75%		
35	SBPSmk	PlAtS 635-19/18	14	43.96%	5.94%	4.40%			
37	SBPSmk	PlAtSe 537-0/16	6	61.50%	20.88%	-7.62%	17.76%		
38	SBPSmk	PlFd(At) 725-11/11	12	116.06%	23.36%	16.11%			
39	SBPSmk	PlS 836-12/12	11	-19.56%	-30.60%	-7.83%			
			Average	**32.42%**	**4.52%**	**0.30%**	**-11.62%**	**-6.43%**	**17.68%**
			Median	**33.32%**	**9.72%**	**-1.53%**	**-12.44%**	**-2.52%**	**15.69%**
			Standard Deviation	**48.63%**	**25.36%**	**14.87%**	**24.52%**	**20.45%**	**20.37%**

Table 9 – SBSdw2 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
3	SBSdw2	Pl(S) 736-17/16	8	-7.27%	-9.84%	-8.80%			

Table 10 – SBSmc1 forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
2	SBSmc1	PlS 645-23/22	8	-9.95%	-10.84%	-11.33%	-46.19%	8.48%	-8.47%

Table 11 – SBSmm forest cover type attribute differences

ID	Subzone	2011 Forest Cover type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
1	SBSmm	FdS(Pl) 647-19/19	10	58.22%	21.87%	0.34%	-17.52%		
7	SBSmm	SFd(At) 647-23/22	15	43.17%	19.89%	1.82%	-33.67%		
			Average	**50.70%**	**20.88%**	**1.08%**	**-25.59%**		

Table 12 – Age and site index differences

ID	Subzone	2011 Forest Cover Type	No. Plots	Volume	Basal Area	Height	Total Stems	Age	SI
3	ESSFdc3	PlSe 635-0/18	13	-27.40%	-25.96%	-11.15%	-66.23%	-1.96%	-6.22%
5	ESSFdc3	Se(Bl) 744-0/16	5	-15.95%	-15.13%	-22.07%	-28.54%	-23.66%	-1.34%
1	ESSFwc3	PlB(S) 632-16/16	6	82.01%	40.31%	-1.74%	-28.34%	1.85%	11.27%
3	ESSFwk1	PlS 645-23/22	20	0.87%	15.01%	-17.00%	-16.33%	3.20%	-19.83%
4	ESSFwk1	PlS 744-21/20	20	-2.48%	-3.04%	-13.45%	-14.78%	-16.92%	-1.93%
8	ESSFwk1	SPl 844-15/14	11	-0.60%	3.06%	-17.93%	-37.23%	-19.26%	17.87%
44	IDFdk3	PlAt 726-11/11	4	82.14%	-8.67%	17.78%	-53.14%	-12.89%	46.27%
45	IDFdk3	PlAt 736-17/16	15	-4.21%	-18.77%	-9.60%	-43.95%	-18.44%	11.16%
17	MSxk2	Pl 826-10/10	5	-7.93%	-48.57%	24.44%	-80.95%	-10.00%	57.85%
18	MSxk2	Pl 827-0/10	13	68.16%	16.22%	9.44%	-0.47%	-12.57%	14.50%
9	SBPSmk	Pl 728-11/11	29	73.96%	18.54%	17.22%		1.10%	41.82%
12	SBPSmk	Pl 636-0/14	5	50.16%	40.08%	-2.50%	40.74%	13.81%	4.57%
15	SBPSmk	Pl 738-17/16	20	35.19%	14.88%	3.33%	-1.81%	-6.13%	26.81%
20	SBPSmk	Pl 837-0/14	7	-40.58%	-36.46%	-12.61%	-44.67%	-34.51%	-2.50%
2	SBSmc1	PlS 645-23/22	8	-9.95%	-10.84%	-11.33%	-46.19%	8.48%	-8.47%
			Average	18.89%	-1.29%	-3.14%	-30.14%	-8.53%	12.79%
			Median	-0.60%	-3.04%	-9.60%	-32.89%	-10.00%	11.16%
			Standard Deviation	42.11%	25.93%	14.53%	30.71%	13.09%	22.07%

Appendix B - Forest Cover Type Attribute Differences

Figure 16 – IDF forest cover type attributes differences

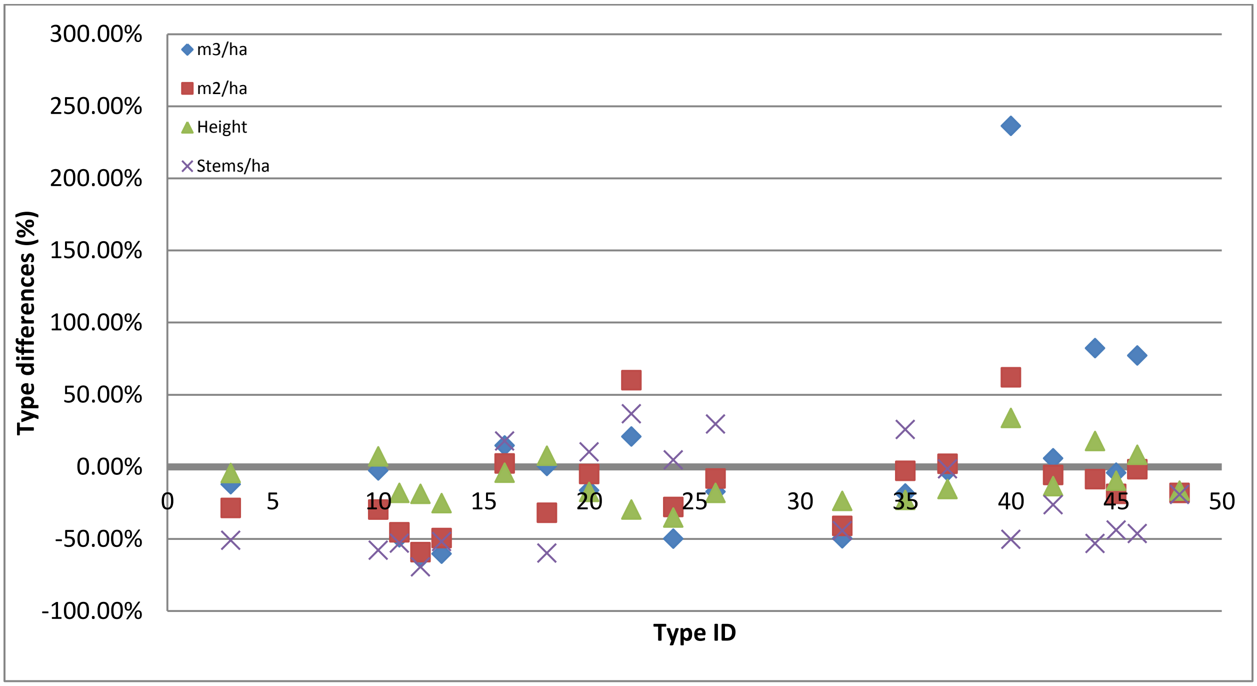


Figure 17 – MSxk2 forest cover type attributes differences

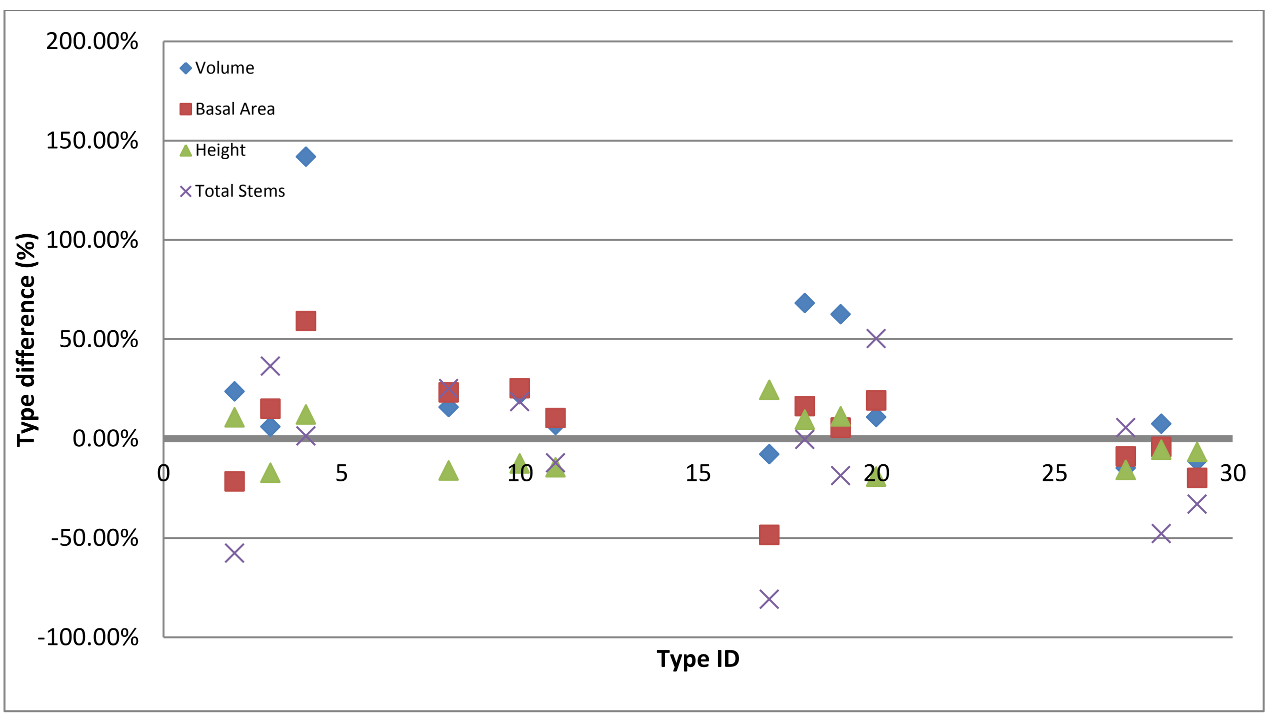


Figure 18 – SBPSmk forest cover type attributes differences

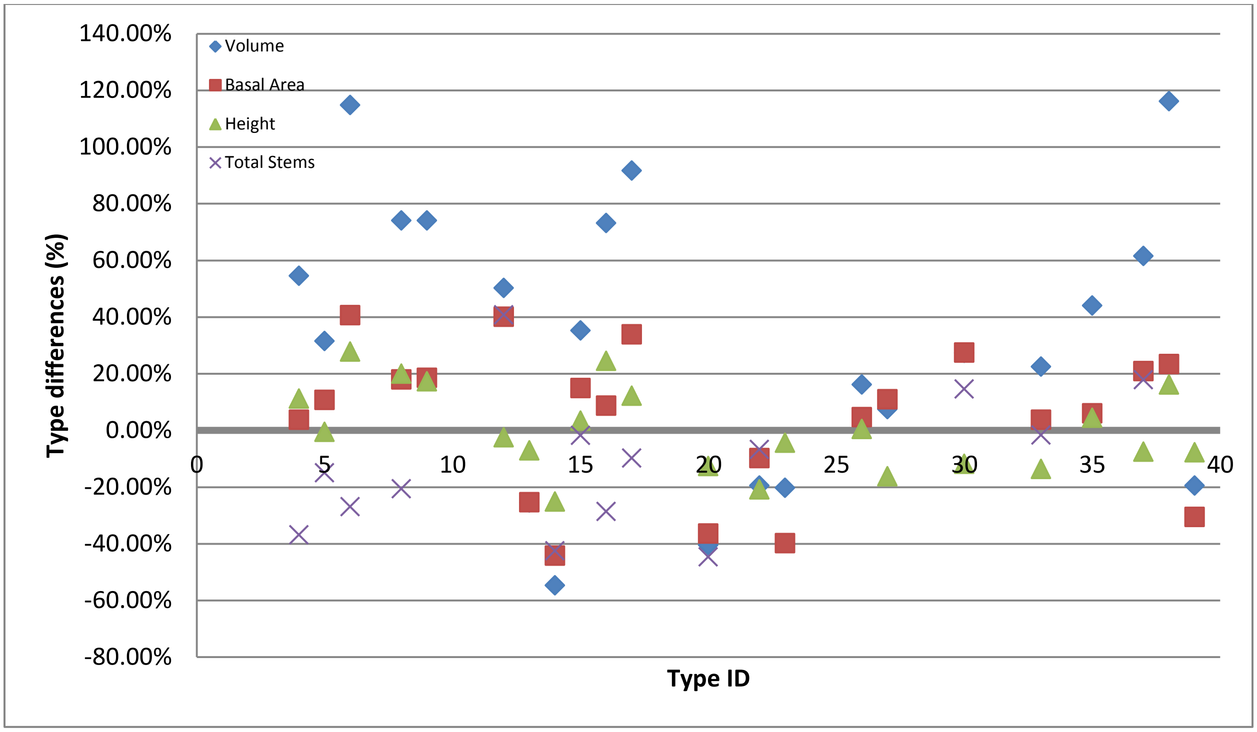


Figure 19 – Subzone volume differences

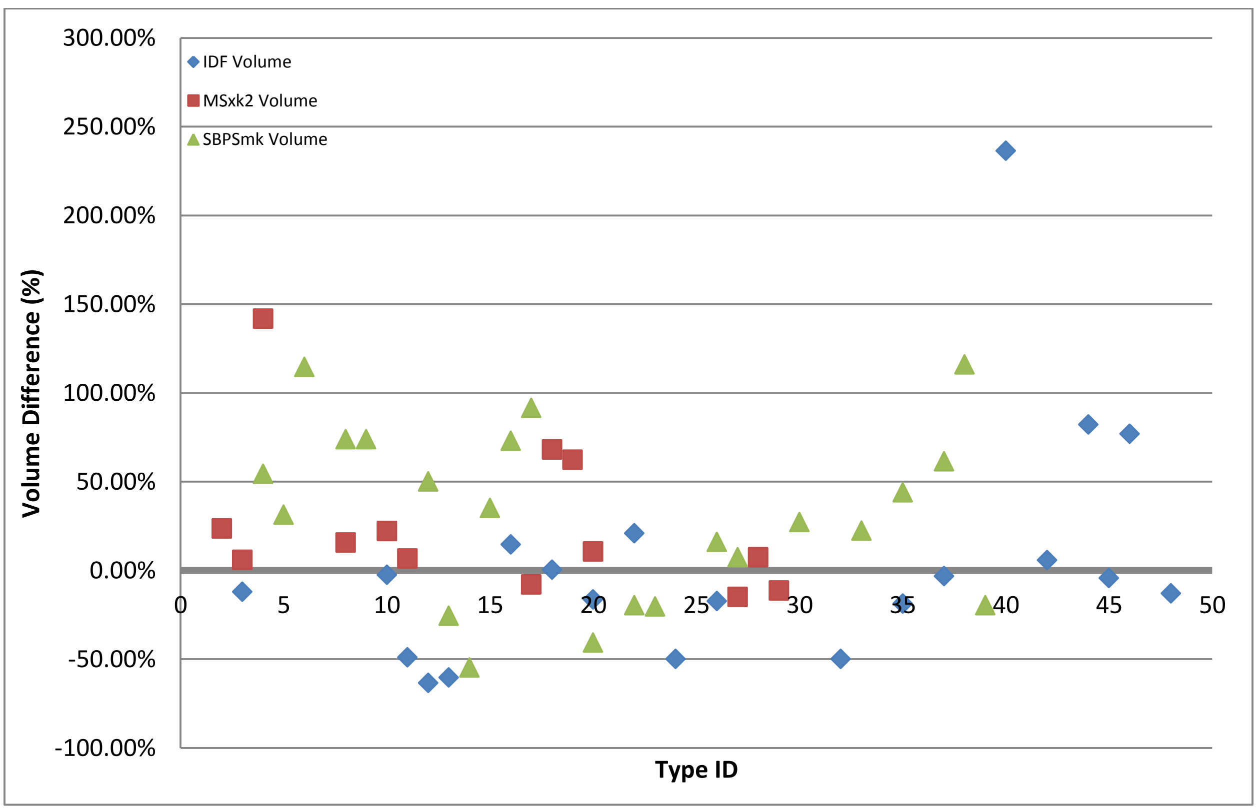


Figure 20 – Volume and site index difference vs cruise age

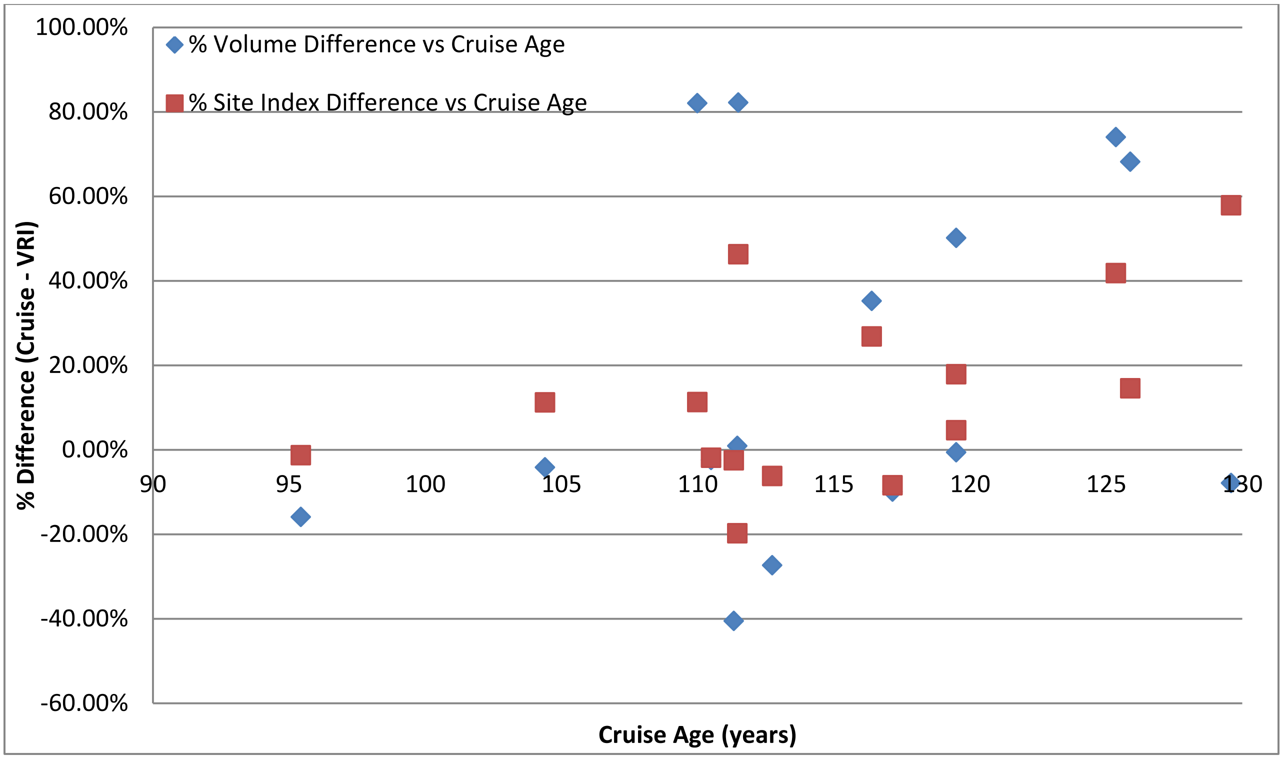
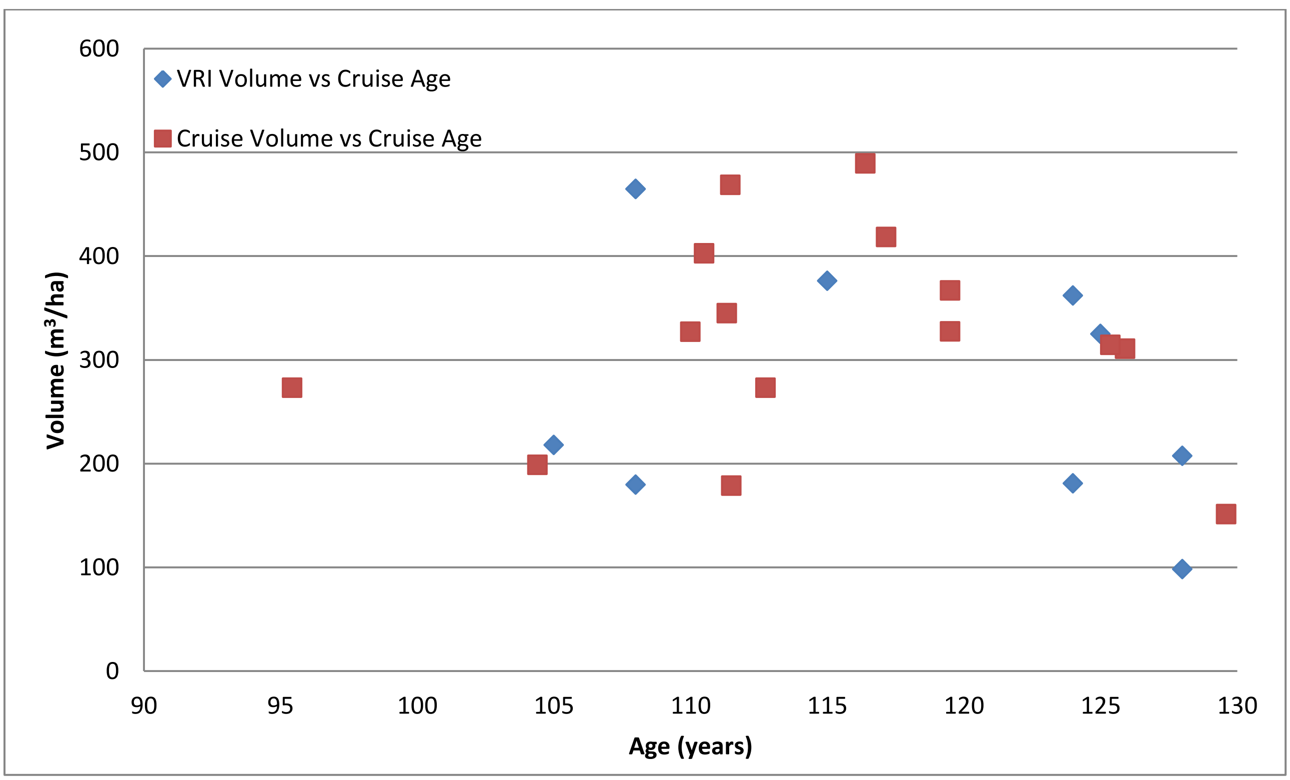


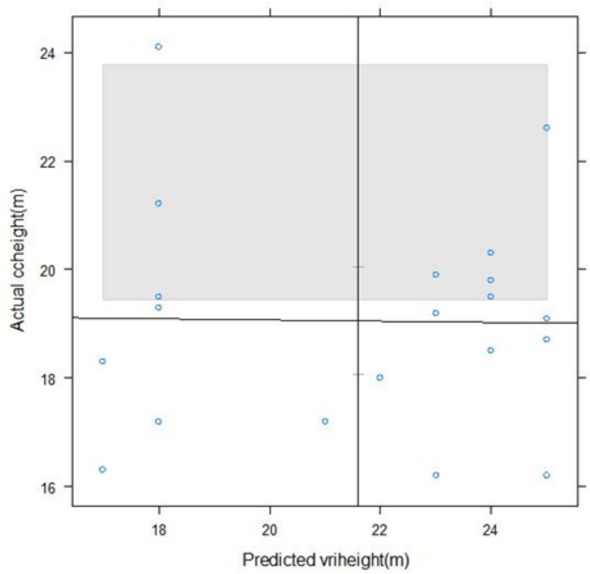
Figure 21 – Volume and age for cruise and VRI



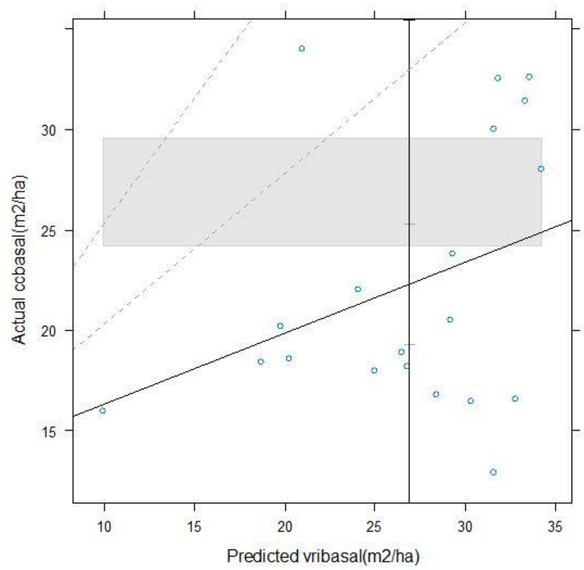
Appendix C – R-Equivalency Results

Figure 22 – IDFdk3 r-equivalency results

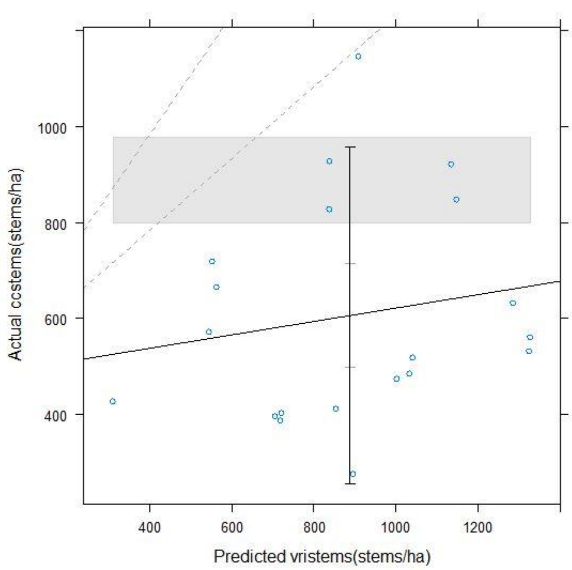
Height



Basal Area



Total Stems



Volume

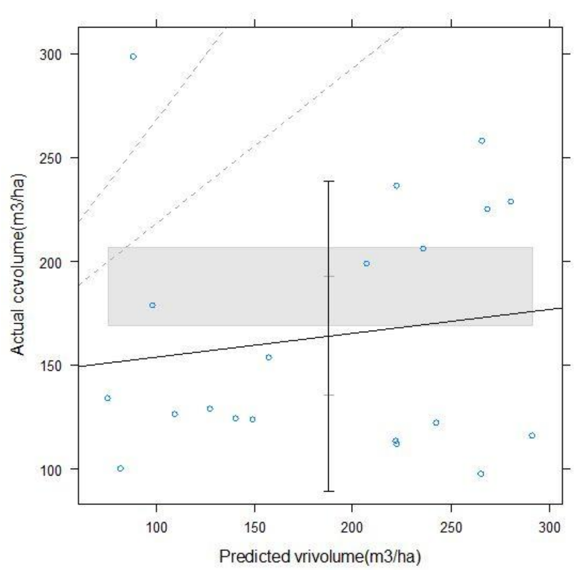


Figure 23 – MSxk2 r-equivalency results

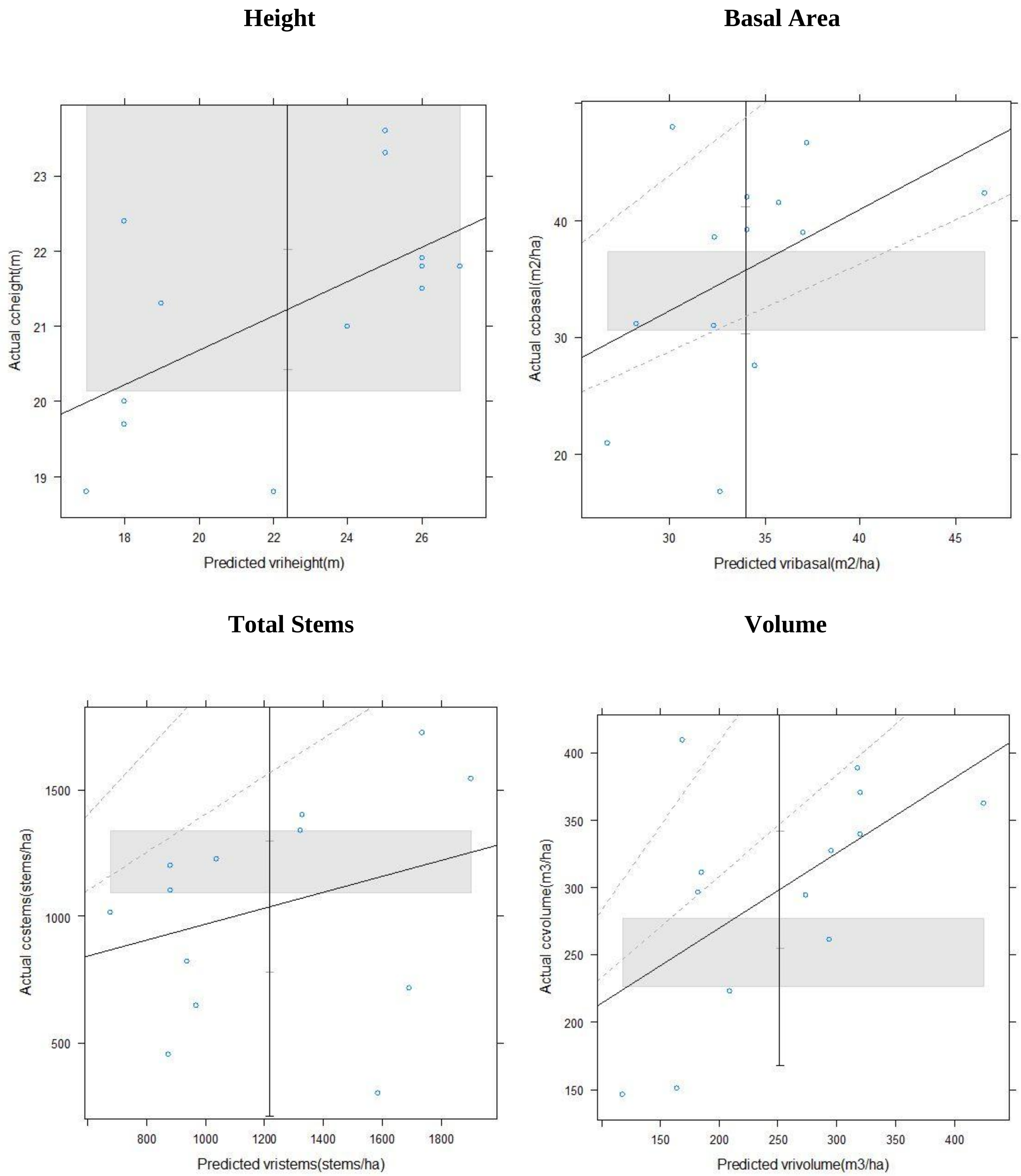
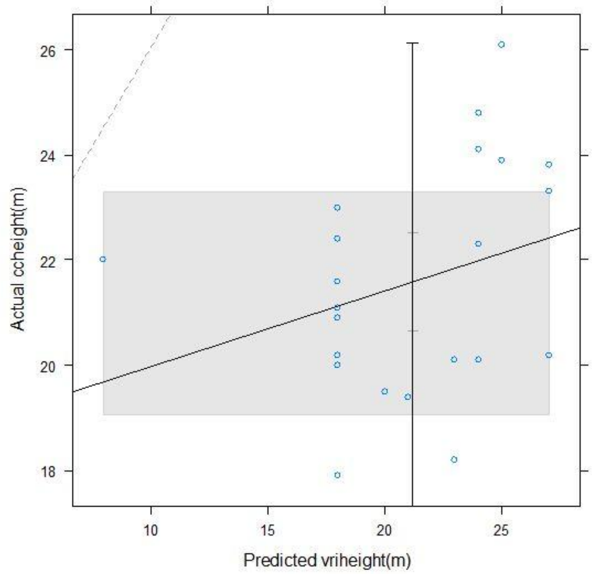
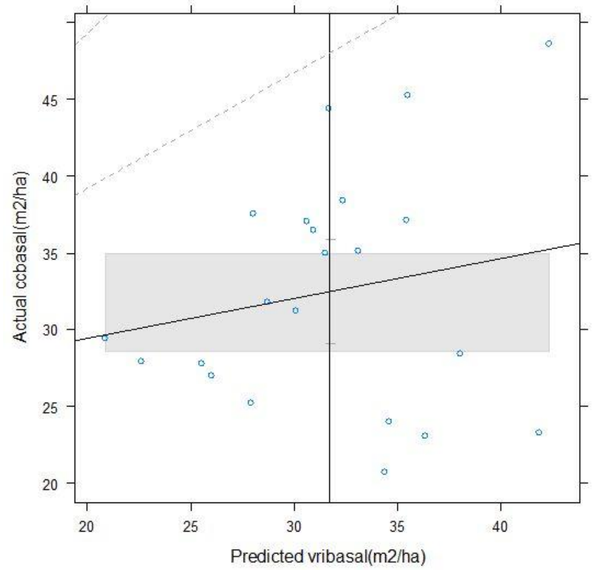


Figure 24 – SBPSmk r-equivalency results

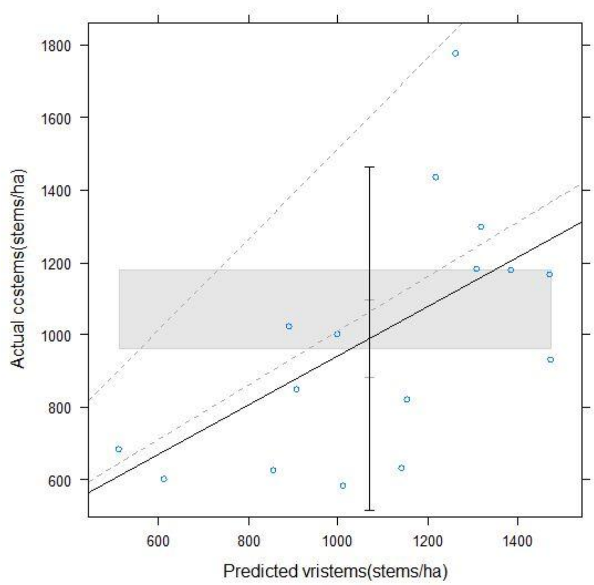
Height



Basal Area



Total Stems



Volume

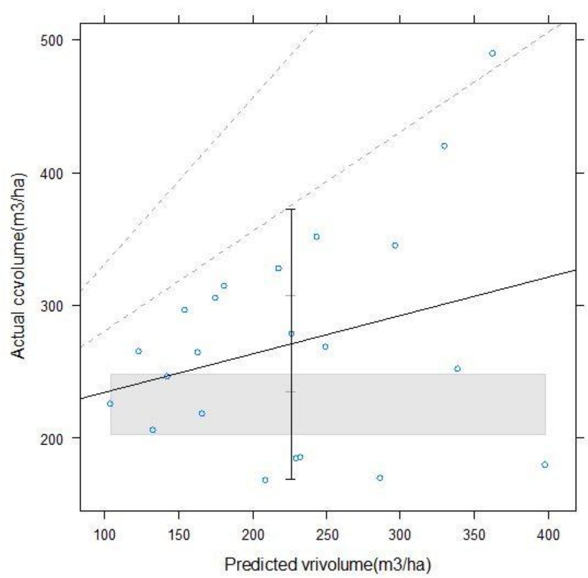
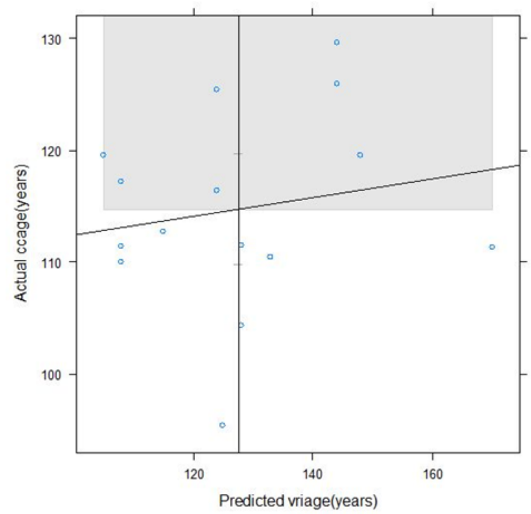


Figure 25 – Age and site index r-equivalency results

Age



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