Strathcona TSA

VRI Statistical Analysis ADDENDUM:
Analysis of Model and Attribute-Related Components of Volume Bias

Prepared for:

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1.1 Background

A Vegetation Resources Inventory (VRI) statistical analysis was completed for the Strathcona TSA in the fall of 2011. Subsequent to the completion of the main report[1], further analysis was undertaken to examine the potential source of the observed total bias in inventory volume estimation for this management unit. The addendum herein provides the results of that analysis.

The volume ratios of means, comparing the mean Phase I inventory volume with the mean Phase II ground sample volume, provide an estimate of the total bias in volume estimation for the VT, 30+ years of age target population of interest in the Strathcona TSA. The results in Table 1, reproduced from the main report, suggest that the Phase I inventory in the Strathcona TSA underestimates volume by roughly 12.5%[2] relative to the Phase II ground volume (based on a ratio of ground to inventory volume of about 1.14).

Table 1: Assessment of Phase I inventory volume accuracy (assuming FIPSTART-generated basal area and trees/ha), based on the Phase II ground sample, by stratum for the 30+ years target population in the Strathcona TSA.

Assessment of Phase I inventory volume (m^3/ha) estimates @12.5cm+ dbh utilization net DWB					
Stratum	***n***	***Weighted Mean Phase II vol/ha***	***Weighted Mean Phase I (FIPSTART) inventory vol/ha***	***Estimated ratio of means volume comparison***	***Sampling error % for volume ratio (at 95% confidence level)***
Operable Cw-Yc	26	533	465	1.145	±18.5%
Operable Fd	26	460	384	1.198	±23.6%
Operable Other-Imm.	26	475	385	1.233	±18.8%
Operable Other-Mature	13	703	698	1.007	±31.4%
All Operable samples	*91*	*542*	*483*	*1.123*	*±12.2%*
Inoperable (all spp)	7	266	211	1.260	±49.1%
Overall (all samples)	*98*	*464*	*406*	*1.143*	*±17.1%*

The Phase II ground sample suggests that, on average, the VDYP7 volumes in the Strathcona TSA are consistently underestimated across all strata with the possible exception of the "Operable Other-Mature" (i.e. non-fir, non-cedar) stratum. Although the average volume estimation bias in the "Operable Other-Mature" stratum was minimal, the sampling error in this stratum was high, reflecting the smaller sample size and relatively high level of variability in this stratum.

In the other strata, the average volume underestimation bias, as represented by the ratio of means, ranged from about 1.145 for operable cedar samples to 1.26 for the inoperable samples. When this bias is expressed as a percentage of the ground volume, the volume underestimation in these strata ranged from about 13% to 21%.

[1] *"Strathcona TSA: Documentation of Vegetation Resources Inventory Statistical Analysis"*, Churlish Consulting Ltd. and Jahraus & Associates Consulting Inc., November 2011, 45pp.

[2] Computed as: ((Ground vol –Inventory vol)/Ground vol)X100% = (1- (Inventory vol/Ground vol))X100%

1.2 Model-Related and Attribute-Related Components of Volume Bias

In the VRI inventory, estimates of volume for a polygon are generated by the VDYP7 yield model, based on a set of input attributes that are typically photo-estimated. Where photo-estimates of basal area and trees/ha are not available (as in an "F-type" inventory), these attributes are generated by the FIPSTART module of VDYP7. As such, this creates two main sources or two potential underlying causes for the volume bias that we observe when we compare the Phase I inventory volume with the Phase II ground volume. These two underlying causes, which each contribute independently and in an additive fashion to the total volume bias, are:

1. Attribute-related volume bias: bias associated with providing the yield model with incorrect input attributes for a polygon i.e. biased photo-estimates of inventory attributes such as species composition, height, age, basal area, trees/ha and/or FIPSTART-generated basal area and trees/ha.
2. Model-related volume bias: bias associated with poor prediction by the VDYP7 yield model (independent of the input attributes i.e. assuming a correct set of input attributes).

Understanding the cause or source of the volume bias in a management unit may help to focus future efforts for improving volume estimation in the inventory.

Estimates of the relative contribution of each of these bias components to the total inventory volume bias can be inferred by creating a new volume estimate using the polygon attributes from the ground sample (to remove the bias associated with the photo-estimation of these attributes) as inputs to the VDYP7 yield model.

In this manner, the model-related volume bias can be approximated by computing the difference between the ground sample volume and the VDYP7 volume using the ground attributes as input[3]. Attribute-related volume bias can be approximated by computing the difference between the VDYP7 inventory volume (using the photo-estimated and/or FIPSTART-generated attributes as input) and the VDYP7 volume using the ground attributes as input[4]. In each case, either the "model" or the "attributes" are held constant to isolate their respective effects on volume estimation.

The results of the analysis of model-related and attribute-related volume bias for the target population in the Strathcona TSA are shown in Table 2. Note that due to concerns regarding the accuracy of photo-estimated values of basal area and trees/ha in the Strathcona TSA, FIPSTART was used to generate values for these attributes in the Phase I inventory[5].

All volumes in this analysis are based on a 12.5cm+ dbh utilization net dwb. A complete set of ground attributes (e.g. heights and ages) were not available for 5 samples[6]. As a result, the model and attribute analysis in this report was based on the set of 93 samples for which all ground attributes were available.

[3] To estimate model bias, the bias associated with the inputs to VDYP7 is removed by using the ground attributes, which are assumed to be "correct". Since the ground attributes are used as inputs for both volume computations (i.e. VDYP7 and the compiler), any resulting volume differences are then attributed to the "model". That is, volumes generated by the ground sample compiler (which are assumed to be accurate) are compared as directly as possible to volumes generated by the VDYP7 yield prediction model.

[4] To estimate the attribute-related bias component of the total volume bias, the same "model" is used (i.e. VDYP7 in both cases) but volumes using the ground attributes (which are assumed to be accurate) as inputs to VDYP7 are compared to volumes using the photo-estimated and/or FIPSTART-generated attributes as inputs to VDYP7.

[5] For comparison purposes, Appendix A shows summary results based on the photo-estimated values of basal area and trees/ha.

[6] Samples #4, 8, 18, 19 and 77 did not have complete ground sample data for height and/or age and hence could not be used to generate a VDYP7 volume based on ground attributes.

Table 2: Weighted mean volumes at 1.25cm+ dbh net dwb, by stratum for the 30+ years target population in the Strathcona TSA, based on the 93 samples for which a complete set of ground attributes was available.

Stratum	***n***	***Weighted mean volume (m^3/ha) estimates[7] @12.5cm+ dbh utilization net DWB***					
		Phase II Ground ***A***	*VDYP7 Phase I Inventory (FIPSTART attributes)* ***B***	*VDYP7 volume with ground attributes as input* ***C***	*Model-related volume bias* ***A-C***	*Attribute-related volume bias* ***C-B***	*Total volume bias* ***A-B***
Operable Cw-Yc	24	551	482	516	36	34	69
Operable Fd	26	460	384	490	-31	107	76
Operable Other-Imm.	25	493	396	508	-16	112	97
Operable Other-Mature	11	728	655	697	31	42	73
All Operable samples	**86**	**549**	**469**	**551**	**-1**	**82**	**81**
Inoperable (all spp)	7	266	211	245	22	33	55
Overall (all samples)	**93**	**465**	**392**	**460**	**6**	**67**	**73**

The difference between the ground volume and inventory volume (Table 2 column A – column B), referred to as the total volume bias, was 73 m3/ha, indicating that, on average, the inventory is underestimating the volume by about 73 m3/ha or about 16% relative to the ground volume, for the set of 93 samples upon which this analysis was based[8]. The model-related volume bias (column A – column C) was +6 m3/ha, indicating that the VDYP7 model (assuming correct input attributes) underestimates volume slightly, by about 1%. The attribute-related component of the volume bias (column C – column B), on the other hand, was 67 m3/ha, indicating that the photo-estimated and/or FIPSTART-generated input attributes account for the majority of the volume underestimation bias, about 14%.

Based on all samples (i.e. operable and inoperable) in the Strathcona TSA, it appears that the model-related bias and the attribute-related bias both work to underestimate volume. When the operable portion of the TSA is considered on its own, nearly all of the volume underestimation is related to attribute bias since the model itself appears to slightly overestimate volume. In all strata, bias related to the attributes contributes to a volume underestimation, to various degrees. However, trends in model bias, that is, the bias related directly to VDYP7 volume estimation (assuming no bias in input attributes), vary considerably among the strata. For example, this analysis of the samples suggests that the VDYP7 model overestimates volume in the operable fir leading stratum whereas the VDYP7 model itself appears to underestimate volume in the operable cedar stratum.

[7] All volumes in this table have been rounded to the nearest cubic metre.

[8] Note that this analysis excludes 5 samples for which ground heights and/or ages were not available. As a result, the mean Phase I and II volumes in Table 2 may not be the same as those reported in Table 1.

The relationship between model and attribute bias, over all samples, is shown pictorially in Figure 1. Although, in aggregate, model and attribute-related volume biases contribute to the total volume bias in the same direction (i.e. both work to underestimate volume), this is not the case in all strata. In some strata, like Operable Fd leading, for example, the model bias, which overestimates volume mitigates a portion of the attribute-related bias, which underestimates volume. However, the net effect of the combination of model and attribute-related volume bias (i.e., the total volume bias) is still a significant volume underestimation in this stratum.

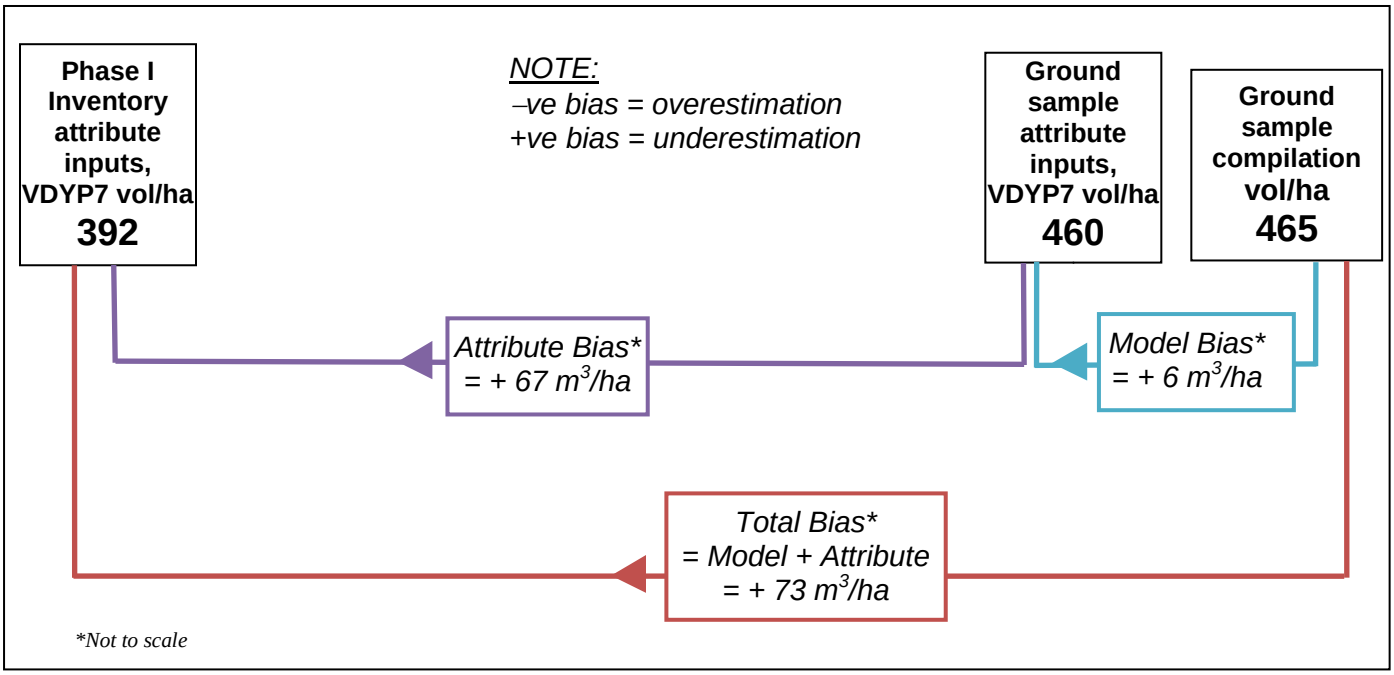

Figure 1: Relationship between the model and attribute-associated components of total volume bias for the target population in the Strathcona TSA over all samples (as per Table 2; n=93).

Graphs representing the total volume bias, as well as the model and attribute-related volume bias, by stratum, are provided in Appendix B. Table 3 shows the ratios of means corresponding with the total volume bias, and the model and attribute-related volume biases as well as their associated sampling errors.

The sample indicated that the Phase I inventory underestimated volume among all strata. This was consistent with the attribute-related volume bias, which also acted to underestimate volume in all strata. Trends in the VDYP7 model-related volume bias, however, varied across the strata. In the Operable Fd leading and Operable Other species leading strata, the model (assuming correct inputs) appeared to overestimate volume. However, the model appeared to underestimate volume in all other strata.

The model-related volume underestimation in the Operable Cedar leading and Operable Mature Other species leading strata could potentially be related to loss factor bias. The VDYP7 model was fit using data compiled using loss factors which commonly overestimate decay in cedar and and, to a lesser degree, hemlock (resulting in a potential net volume underestimation). In comparison, the compiled Phase II ground sample volumes have been adjusted with NVAF values to correct for bias in taper and loss.

Table 3: Ratios of mean volumes (12.5cm+ dbh net dwb) representing total, model and attribute bias, with associated sampling error % at a 95% confidence level. Note: all inventory volumes are based on FIPSTART-generated basal area and trees/ha.

Stratum	*n*	*Ratio of Weighted Mean Volume/ha net dwb at 7.5cm+ dbh*		
		***Total Bias**: Ground/Inventory (col A/B)*	***Model Bias**: Ground/ VDYP7(ground attributes) (col A/C)*	***Attribute Bias**: VDYP7 (ground attributes) / Inventory (col C/B)*
Operable Cw-Yc	24	1.144 (±18.9%)	1.069 (±15.6%)	1.070 (±23.2%)
Operable Fd	26	1.198 (±23.6%)	0.938 (±6.8%)	1.278 (±25.0%)
Operable Other-Imm.	25	1.244 (±18.8%)	0.969 (±6.7%)	1.283 (±18.2%)
Operable Other-Mature	11	1.111 (±32.5%)	1.044 (±22.0%)	1.064 (±24.2%)
All Operable samples	***86***	***1.172 (±12.3%)***	***0.998 (±6.8%)***	***1.175 (±11.7%)***
Inoperable (all spp)	7	1.260 (±49.1%)	1.089 (±18.7%)	1.157 (±43.9%)
Overall (all samples)	**93**	***1.186 (±17.5%)***	***1.012 (±7.5%)***	***1.172 (±15.2%)***

Basal area/ha is known to be an important driver of volume in the VDYP7 model. The magnitude of the contribution of basal area estimation to the attribute-related bias component of total volume bias was examined in two ways, from two slightly different perspectives. The overall results are provided in Table 4.

First, the VDYP7 volumes were computed using, as inputs, all ground attributes with the exception of FIPSTART-estimated basal area (see column D in Table 4). From this perspective, it appears that bias in the FIPSTART estimation of basal area is responsible for the vast majority of the overall volume underestimation.

Secondly, VDYP7 volumes were computed using all photo-estimated attributes[9] with the exception of ground-based basal area (see column E in Table 4). From this alternate perspective, it appears that the attribute-related volume underestimation bias virtually disappears by substituting the correct ground basal area.

It is hypothesized that the slight differences in the results from these two perspectives is due to the internal relationships in VDYP7 between basal area and other attributes. Nonetheless, these tests clearly indicate the dominant contribution of basal area estimation bias to the attribute bias component of the observed overall volume estimation bias. The remainder of the attribute bias, as it affects volume estimation, can be attributed to differences in species composition, age, height, trees/ha, crown closure, etc.[10].

Comparing columns B with D and columns C with E, it appears that the photo-estimated inventory attributes, other than basal area, may actually be working to overestimate volume. However, the impact of basal area appears to be dominating the observed volume bias, and is likely the primary cause of the overall volume underestimation in this management unit.

Note that on a stratum basis, the sample indicates slightly different trends in the Operable Fir leading stratum. Unlike other strata, where the influence of FIPSTART-generated basal area dominates the volume underestimation,

[9] including FIPSTART-generated trees/ha

[10] Also non-vegetated features such as rock% and vegetated features such as shrub/herb/bryoid %.

other photo-estimated attributes also appear to significantly contribute to the attribute-related volume underestimation in the Operable Fir leading stratum. It is suspected that the height underestimation observed in this stratum[11] may also be contributing to the observed volume underestimation.

Table 4: Influence of basal area on attribute-related volume bias.

Stratum	*n*	*Weighted Mean Volume/ha net dwb at 12.5cm+ dbh*			
		Phase I VDYP7 Inventory (FIPSTART attributes) ***B***	*VDYP7 with ground attributes* ***C***	*VDYP7 with ground attributes* ***except FIPSTART BA*** ***D***	*VDYP7 with FIPSTART attributes* ***except ground BA*** ***E***
Operable Cw-Yc	24	482	516	460	536
Operable Fd	26	384	490	393	451
Operable Other-Imm.	25	396	508	367	534
Operable Other-Mature	11	655	697	642	731
All Operable samples	***86***	***469***	***551***	***456***	***558***
Inoperable (all spp)	7	211	245	194	238
Overall (all samples)	***93***	***392***	***460***	***378***	***463***

[11] From Table 3 in the main Strathcona TSA analysis report, the ratio of means for height in the Operable Fir leading stratum was 1.06, suggesting an underestimation of height in this stratum.

APPENDIX A: RESULTS BASED ON PHOTO-INTERPRETED (VRISTART) PHASE I ATTRIBUTES

Due to concerns regarding the quality of the photo-interpreted basal area and trees/ha attributes, the audit analysis for the Strathcona TSA was based on FIPSTART-generated values for these attributes. However, for comparison, the results based on the photo-interpreted values are provided here.

Table A-1: Assessment of Phase I inventory volume accuracy, based on FIPSTART-generated attributes and photo-estimated attributes and VRISTART, based on the Phase II ground sample, by stratum for the 30+ years target population in the Strathcona TSA.

Assessment of Phase I inventory volume (m^3/ha) estimates @12.5cm+ dbh utilization net DWB: FIPSTART-generated vs. VRISTART (photo-estimated)						
Stratum	***n***	***Weighted Mean Phase II vol/ha***	***Weighted Mean Phase I (FIPSTART) inventory vol/ha***	***Estimated ratio of means volume comparison (and 95% CI for ratio) (FIPSTART)***	***Weighted Mean Phase I (photo-estimated attributes & VRISTART) inventory vol/ha***	***Estimated ratio of means volume comparison (and 95% CI for ratio) (VRISTART)***
Operable Cw-Yc	26	533	465	1.145 (±18.5%)	402	1.324 (±20.7%)
Operable Fd	26	460	384	1.198 (±23.6%)	462	0.996 (±23.2%)
Operable Other-Imm.	26	475	385	1.233 (±18.8%)	478	0.993 (±21.7%)
Operable Other-Mature	13	703	698	1.007 (±31.4%)	665	1.056 (±32.8%)
All Operable samples	***91***	***542***	***483***	***1.123 (±12.2%)***	***514***	**1.054 (±13.0%)**
Inoperable (all spp)	7	266	211	1.260 (±49.1%)	131	2.031 (±41.6%)
Overall (all samples)	***98***	***464***	***406***	***1.143 (±17.1%)***	***406***	**1.143 (±19.4%)**

Table A-2: Weighted mean volumes at 1.25cm+ dbh net dwb, by stratum for the 30+ years target population in the Strathcona TSA, based on the 93 samples for which a complete set of ground attributes was available. ***NOTE***: VDYP7 Phase I inventory volumes are based on photo-estimated values of basal area and trees/ha and volumes are produced in the VRISTART module of VDYP7.

Stratum	***n***	***Weighted mean volume (m^3/ha) estimates @12.5cm+ dbh utilization net DWB***					
		Phase II Ground ***A***	*VDYP7 Phase I Inventory (photo-estimated attributes)* ***B***	*VDYP7 volume with ground attributes as input* ***C***	*Model-related volume bias* ***A-C***	*Attribute-related volume bias* ***C-B***	*Total volume bias* ***A-B***
Operable Cw-Yc	24	551	418	516	36	98	134
Operable Fd	26	460	462	490	-31	29	-2
Operable Other-Imm.	25	493	496	508	-16	12	-3
Operable Other-Mature	11	728	614	697	31	83	113
All Operable samples	**86**	**549**	**504**	**551**	**-1**	**47**	**46**
Inoperable (all spp)	7	266	131	245	22	113	135
Overall (all samples)	**93**	**465**	**393**	**460**	**6**	**67**	**72**

APPENDIX B: GRAPHS OF TOTAL VOLUME BIAS, MODEL BIAS & ATTRIBUTE BIAS

(all volumes are 12.5cm+ dbh utilization net dwb)

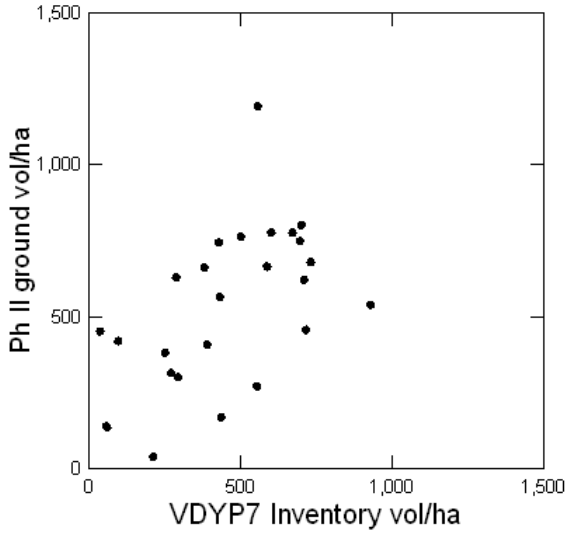

Fig B-1: Operable Cw-Yc leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

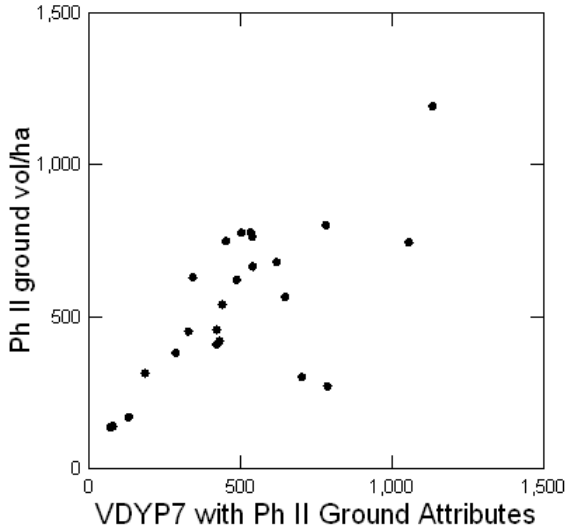

Fig B-2: Operable Cw-Yc: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

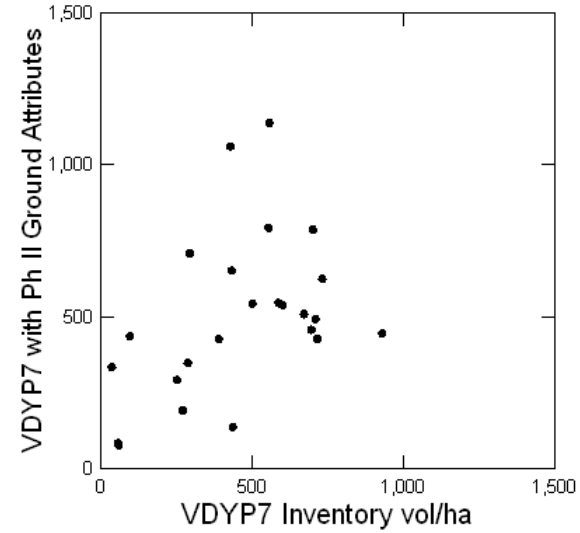

Fig B-3: Operable Cw-Yc: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

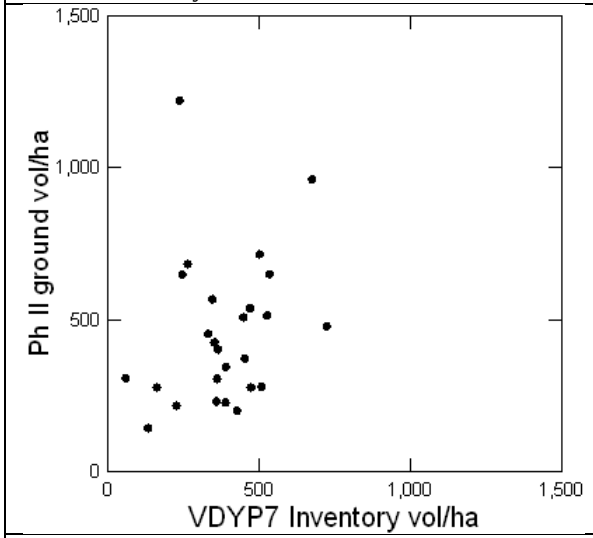

Fig B-4: Operable Fd leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

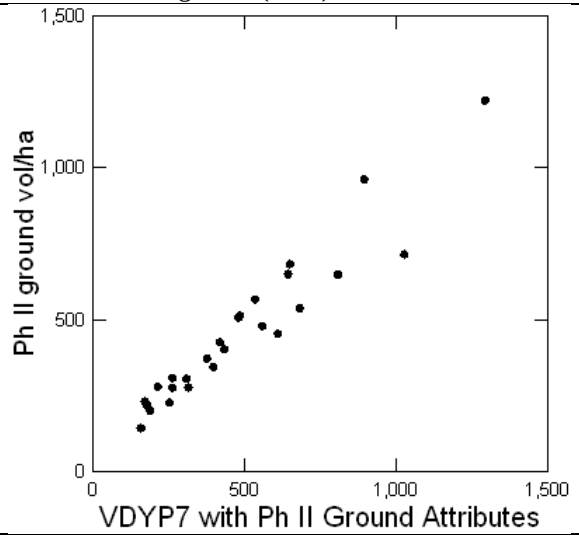

Fig B-5: Operable Fd: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

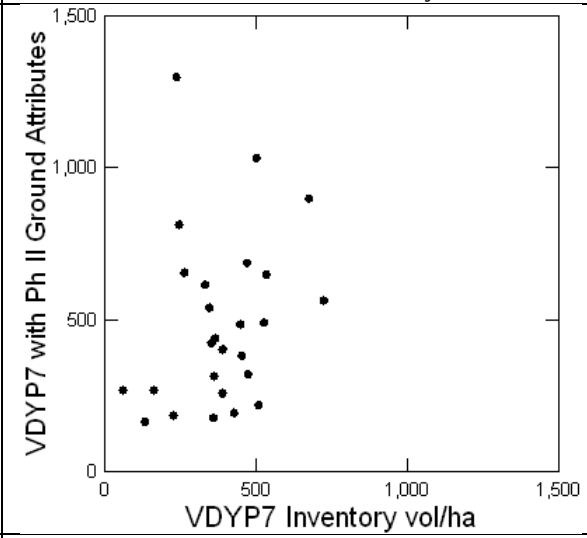

Fig B-6: Operable Fd: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

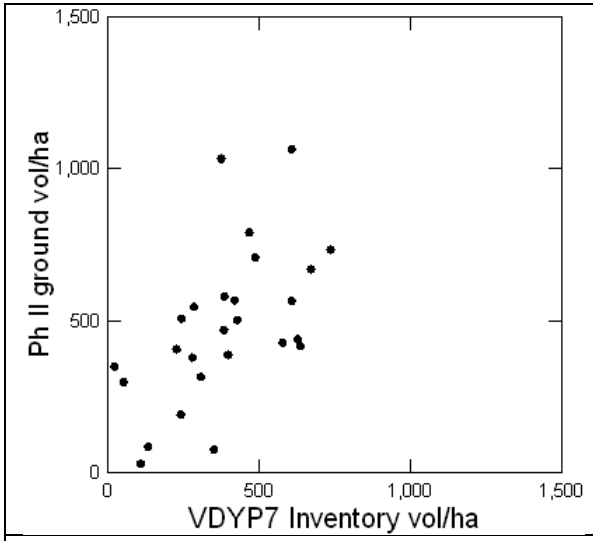

Fig B-7: Operable Other-Immature leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

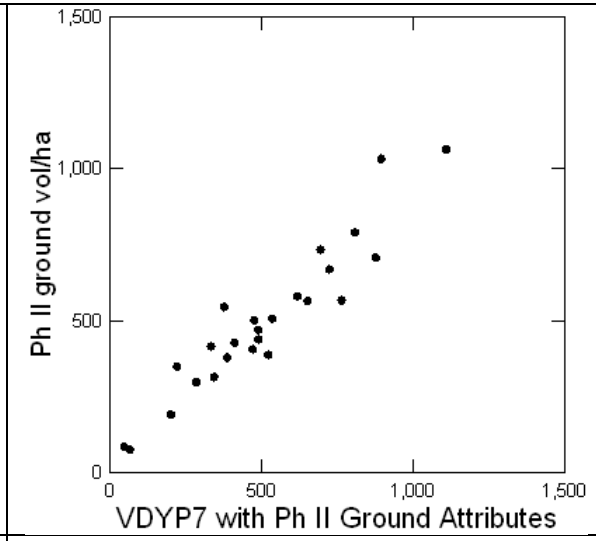

Fig B-8: Operable Other-Immature: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

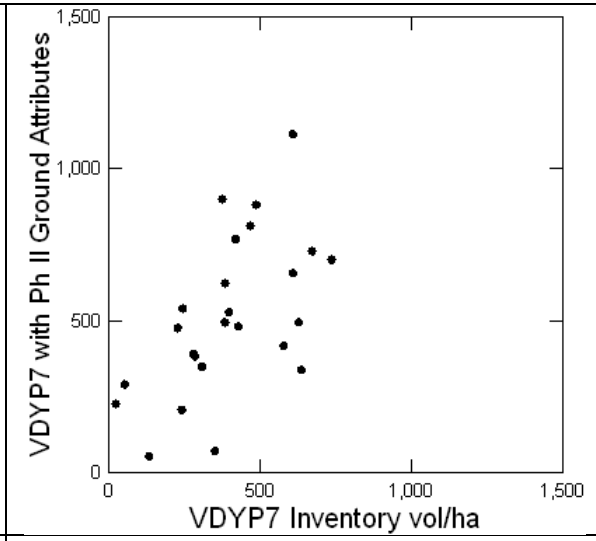

Fig B-9: Operable Other-Immature: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

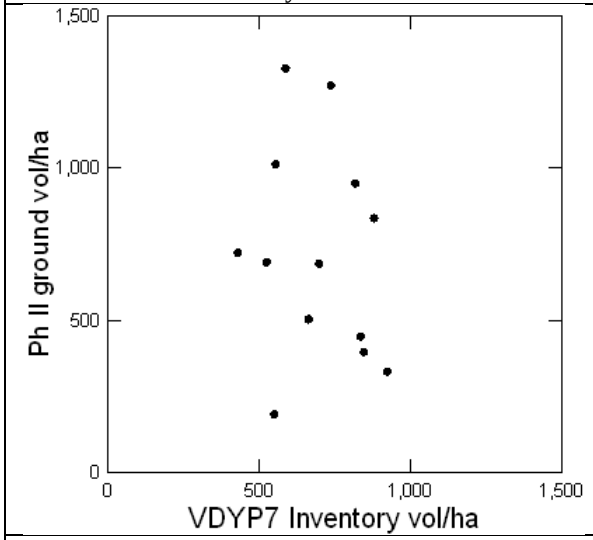

Fig B-10: Operable Other-Mature leading stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

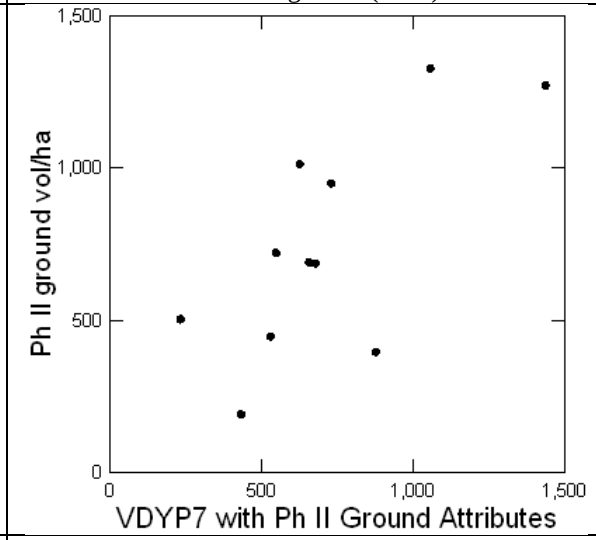

Fig B-11: Operable Other-Mature: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

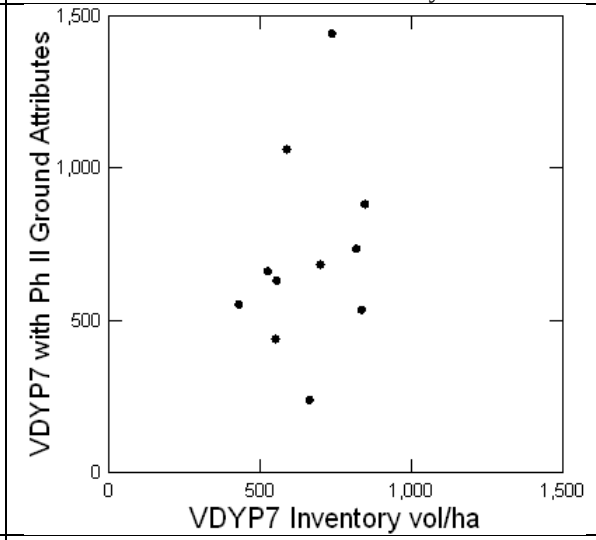

Fig B-12: Operable Other-Mature: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.

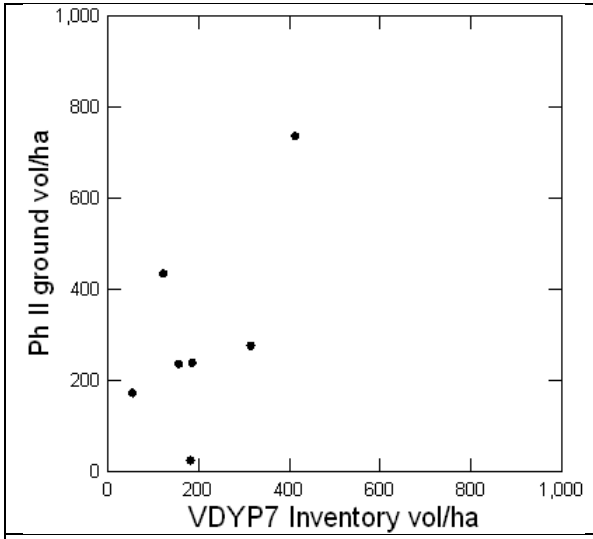

Fig B-13: Inoperable stratum: ***"total volume bias"*** i.e. Phase II compiled vol/ha vs. VDYP7 Phase I inventory vol/ha.

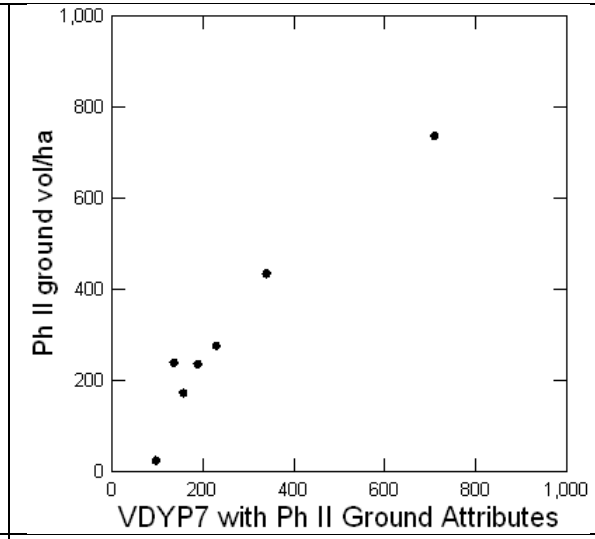

Fig B-14: Inoperable stratum: ***"model-related volume bias"*** i.e. Phase II compiled ground vol/ha vs. VDYP7 vol/ha based on ground (Ph II) attributes.

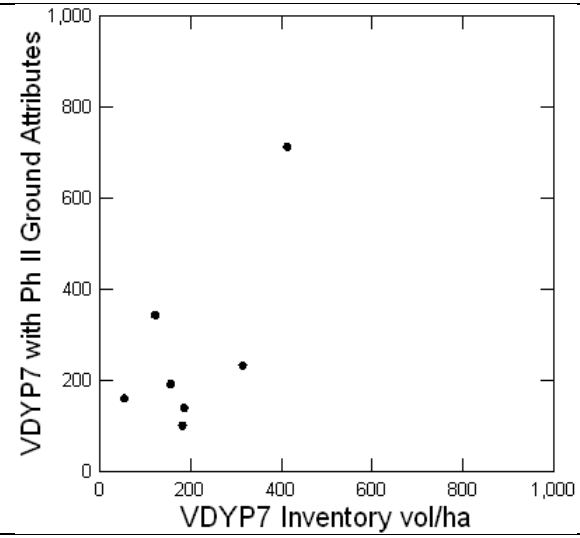

Fig B-15: Inoperable stratum: ***"attribute-related volume bias"*** i.e. VDYP7 vol/ha based on ground (Ph II) attributes vs. VDYP7 Phase I inventory vol/ha.