# Validation of the Mixedwood Growth Model (MGM) against the Alberta Provincial Growth and Yield Initiative (PGYI) dataset

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**Abstract:**

In this report, we present results from validation of the Mixedwood Growth Model (MGM21 VS8.2.21.39 / Rev6378) using the 2020 Provincial Growth and Yield Initiative (PGYI) dataset. Results from this validation indicate good overall performance of MGM. MGM's primary species (i.e. white spruce, jack pine, lodgepole pine, aspen, and black spruce) validate well, individually or in mixture. Issues do remain when modelling secondary species (e.g. white birch, balsam fir, Douglas-fir, balsam poplar) and when species are minor components of stands (i.e. have low density or basal area). These issues reflect the need for additional species-specific submodels for secondary species, the influence of small sample sizes, and the use of small subplots. In addition, further refinement of MGM's growth functions may improve model behaviour. Errors in the validation dataset, the occurrence of stochastic events (e.g. insects, wind, flooding etc.), and undocumented stand tending are also suspected to negatively impact the validation in some cases. We recommend some future refinements to MGM to improve model behavior. While ingress was not modelled in MGM and PSP ingress data were not included in the validation, its presence influences stand dynamics. The need to model ingress is recognized and will be a focus of ongoing MGM development.

**Introduction:**

In this report, we present results from a validation of the Mixedwood Growth Model (MGM) using the 2020 Provincial Growth and Yield Initiative (PGYI) dataset.

The procedures used for this validation follow the methods and evaluation metrics outlined in the published validation manuscript "*The Validation of the Mixedwood Growth Model (MGM) for Use in Forest Management Decision Making", Forests 2013, 4(1), 1-27; doi:10.3390/f4010001* (Bokalo et. al., 2013). Bokalo et al. (2013) focused on pure and mixed stands of white spruce and aspen. Follow-up validations using the same procedures were carried out for lodgepole pine (Bokalo and Comeau, 2013), jack pine (Strimbu et al., 2015), juvenile PGYI data (Bokalo et al., 2015), and black spruce (Oboite, 2018). These procedures were also used in validation of MGM18 (Bokalo et al., 2019).

In this report, we evaluate MGM's performance against re-measured permanent sample plot (PSP) data and examine overall model performance. This validation also indicates where the model requires refinement, in relation to stand types and species. Model performance was evaluated for all species found in the dataset, even though MGM is parameterized only for aspen, white spruce, black spruce, lodgepole pine, and jack pine. Other species (e.g. white birch, balsam fir, Douglas-fir, balsam poplar) are modelled as surrogates of the primary species.

**The Mixedwood Growth Model:**

This validation references a new version of MGM: MGM21 (VS8.2.21.39 / Rev6378) which has been significantly modified from earlier versions and includes:

- A new climate and composition sensitive maximum size-density function for mature trees ≥ 4cm DBH (Comeau, 2021b)
- A new self-thinning system for mature trees ≥ 4cm DBH
- Revised survival functions for balsam fir, jack pine, lodgepole pine, and black spruce without a tagging limit variable (Comeau, 2021a)
- New height increment and diameter increment functions for black spruce (Oboite and Comeau, 2021)

- A new routine that solves for missing tree ages within MGM (i.e. Internal Age Solver)
- Improved tree age estimates on regenerated trees
- A modified approach to estimate white spruce tree age
- The updating of tree age estimates after stand establishment or thinning
- New site index functions for SK, MB, and BC
- Updated diameter estimates in MGM's Treelist Generator for untended deciduous trees
- Streamlined crop plans with fewer inputs
- Faster runtimes when using large Stand Workbooks
- 32-bit support for Microsoft Office 2016, Microsoft Office 2019, and local installations of Microsoft Office 365
- 64-bit support for Microsoft Office 2019 and local installations of Microsoft Office 365

**Validation Data:**

The Provincial Growth and Yield Initiative dataset from July 10, 2020 was used for this analysis (hereafter the 2020 PGYI dataset). This dataset contains 4903 plots and included 2915 plots that met the minimum requirements for MGM validation:

1. Known stand ages
2. Repeated tree-level measurements after Performance Survey Age (i.e. 12 years)
3. Treelists with more than 1 tree
4. Plot location coordinates that are required for calculating Climate Moisture Index (CMI)
5. No documented treatments after stand establishment (e.g. thinning, replanting, or site preparation)
6. No unusual data trends. Specifically, plots where individual trees regressed from large subplots into smaller subplots over time, suggesting changes to the measurement protocol, plot size, or tree numbering strategy.

Dramatic and unusual changes in basal area and density were observed on 282 plots. These changes included:

1. Basal area losses where more than 1/3 of the plot basal area was lost in 1 measurement interval (215 Plots)
2. Density losses where average conifer mortality exceeded 15% per year for each year of the projection period (35 Plots)

3. Extreme density losses that were identified through manual inspection of the plot data (32 Plots)

Although severe mortality events exist on the landscape, MGM is a deterministic model and does not model stochastic events such as insect attack, wind damage, or wildlife damage. Including plots with severe stochastic events has a strong negative impact on validation results. Since validation attempts to evaluate model performance of stands undergoing normal stand dynamics, these 282 plots were removed.

The final validation dataset included 2633 plots from the following sixteen sources:

1. Alberta Newsprint (125 Plots)
2. Alberta-Pacific Forest Industries Inc. (76 Plots)
3. Canadian Forest Products Ltd. (149 Plots)
4. Canadian Forest Service – Alberta (288 Plots)
5. Government of Alberta (1321 Plots)
6. Mercer Peace River (35 Plots)
7. Millar Western Forest Products Ltd. (39 Plots)
8. Spray Lake Sawmills (1980) Ltd. (17 Plots)
9. Tolko Industries Ltd. – Slave Lake (19 Plots)
10. West Fraser – Blue Ridge Lumber (50 Plots)
11. West Fraser – Edson Forest Products (63 Plots)
12. West Fraser – Manning Forest Products (42 Plots)
13. West Fraser – Slave Lake Pulp (38 Plots)
14. West Fraser – Sundre Forest Products (168 Plots)
15. Weyerhaeuser Company Ltd. – Grande Prairie (126 Plots)
16. Weyerhaeuser Company Ltd. – Pembina Timberland (77 Plots)

This dataset represents a range of forest stand types (species mixtures and structures; Tables 4 to 7), including a range of stand productivities (site index), stand ages (juvenile, mid-rotation and mature), and projection lengths (Table 1) across much of the working forest in Alberta (Figure 1). It should be noted that the 2020 PGYI dataset is the largest and most comprehensive dataset ever used to validate MGM.

**Table 1:** Plot characteristics for the validation dataset by primary species group (AW, PJ, PL, SB, and SW) and white spruce dominated stands arranged by natural subregion (SW-CM, SW-LF, and SW-UF). N = number of plots; BHAge = breast height age

| | | Site Index (m@50 years BHAge) | | | Initialization Age (years) | | | End Age (years) | | | Projection Length (years) | | | CMI | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | N | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max | Min | Mean | Max |
| AW | 387 | 10.49 | 19.43 | 26.88 | 12 | 52 | 144 | 17 | 73 | 175 | 4 | 20 | 56 | -7.97 | 8.29 | 33.88 |
| PJ | 30 | 12.38 | 16.55 | 21.68 | 16 | 54 | 135 | 21 | 72 | 150 | 5 | 18 | 37 | -5.76 | 0.25 | 6.75 |
| PL | 1195 | 7.65 | 15.49 | 24.60 | 12 | 57 | 239 | 15 | 83 | 249 | 3 | 26 | 59 | 2.08 | 20.79 | 69.66 |
| SB | 175 | 5.82 | 9.83 | 17.15 | 13 | 102 | 212 | 20 | 116 | 217 | 4 | 14 | 53 | -6.86 | 18.20 | 39.29 |
| SW | 462 | 6.07 | 16.55 | 25.05 | 12 | 88 | 261 | 17 | 112 | 272 | 4 | 24 | 57 | -9.15 | 13.16 | 59.83 |
| SW-CM | 210 | 10.47 | 17.10 | 25.05 | 12 | 88 | 207 | 17 | 115 | 247 | 4 | 27 | 55 | -9.15 | 4.68 | 17.33 |
| SW-LF | 145 | 10.08 | 17.66 | 23.95 | 12 | 78 | 216 | 19 | 99 | 226 | 4 | 21 | 55 | 2.39 | 16.91 | 32.37 |
| SW-UF | 107 | 6.07 | 13.98 | 22.63 | 12 | 100 | 261 | 18 | 123 | 272 | 4 | 23 | 57 | 14.22 | 24.71 | 59.83 |

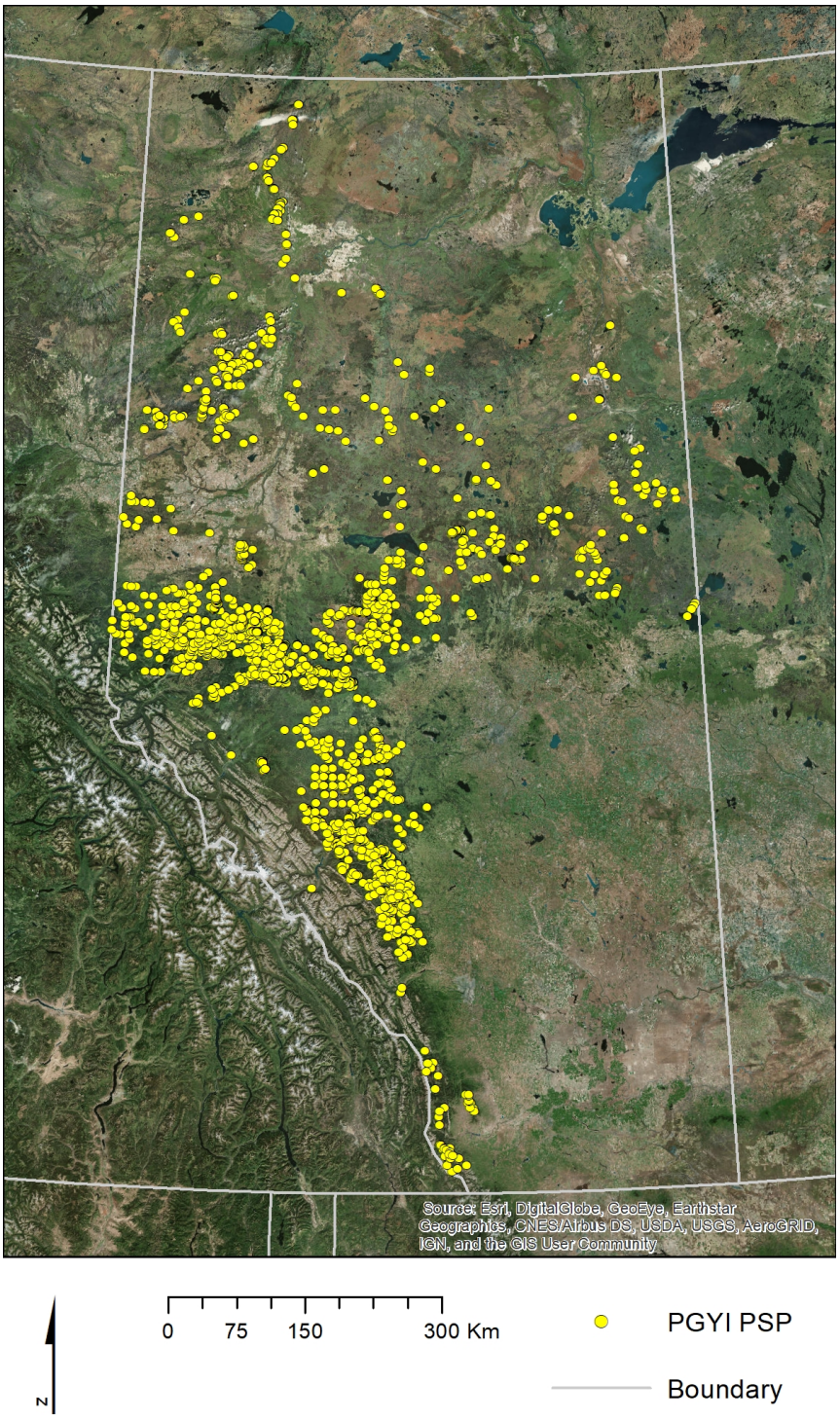


Figure 1. Distribution of the 2633 plots from the 2020 PGYI dataset.

Boundary: Open Government Licence – Canada; NRC (2017); Imagery: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

**Methods:**

For this validation, the first plot measurement greater than or equal to Performance Survey Age (i.e. 12 years) was used to initialize MGM. Then, each treelist was projected to the final measurement where the observed stand conditions were evaluated against the MGM predictions. Using the final measurement for validation provided the longest possible growth interval and eliminated autocorrelation issues that arise when multiple measurements from individual plots are used. (This approach also avoids issues associated with having variable numbers of measurements between plots.)

*Data Preparation*

The 2020 PGYI dataset was initially compiled by Alberta Agriculture and Forestry (Stadt, 2020; Froese and Stadt, 2020) and included stand ages, site indices (Huang et al., 2009), tree volumes (Huang et al., 1994), and estimates for missing tree heights and tree diameters. Then, these data were filtered using the approach outlined in the *Validation Data* section. Ingress from new germinants, trees crossing PSP diameter thresholds, and plot expansion was removed. Treefactors for individual trees were standardized over time, ensuring that treefactors from the first measurement matched treefactors from the final measurement when calculating summary statistics. Veteran trees were also retained to evaluate MGM's ability to model uneven-aged and multi-cohort stands.

In situations where site index could not be calculated from height-age information (Huang et al., 2009), PGYI ecosite information and ecosite-based site index values were used to define missing site index. Bjelanovic and Comeau (2019) was used as the primary reference for ecosite-based site index values in Northern and West-Central Alberta. Beckingham and Archibald (1996) and Beckingham, Corns, and Archibald (1996) were also used as references for ecosite-based site index values when species (e.g. SB) or ecosites were not supported by Bjelanovic and Comeau (2019). In Southwest Alberta, Archibald, Klappstein, and Corns (1996) was used as the primary reference for ecosite-based site index values. Calculated site index values from height-age information that fell outside an expected range (Table 2) were replaced with ecosite-based site index values.

Table 2. Expected site index range (m @ 50 years breast height age) by primary species group.

| Species | Minimum (m) | Maximum (m) | Source Range |
|---|---|---|---|
| AW | 9.0 | 28.5 | ASRD (2009)* |
| PJ | 7.5 | 26.0 | Strimbu et al. (2017) |
| PL | 7.5 | 26.0 | ASRD (2009)* |
| SB | 5.5 | 18.5 | ASRD (2009)* |
| SW | 6.0 | 25.5 | ASRD (2009)* |

* Total Age Site Index range converted to Breast Height Age Site Index.

Plots with missing elevations were assigned elevation values from the Canadian Digital Elevation Model (NRC 2016). In addition, elevations from the PGYI database that differed from the Canadian Digital Elevation Model (CDEM) by more than 45m (i.e. the maximum estimated error of the CDEM) were assigned elevation values from the CDEM. Climate Moisture Index (Hogg et al., 2013) was calculated for the 30-year reference period 1981-2010 using plot coordinates, plot elevations, and ClimateNA Version 6.11 (Wang et al., 2016).

*Hierarchical Analysis*

A hierarchical approach was used to evaluate model performance. To do this, the PGYI dataset was partitioned into: 1) broad cover groups, 2) species groups, and 3) broad cover groups by species. This approach enables identification of where problems with either the model or validation data are occurring. This approach also aids in defining where the model works well and where it may need further refinement. Broad cover groups represent dominant stand types: pure conifer (C), conifer leading (CD), deciduous leading (DC), and pure deciduous (D). Pure types were defined as having 80% or greater basal area of the primary species, while mixed types had between 50% and 80% of their basal area represented by the primary type. Data were also organized into one of 13 dominant species groups: AW, BW, FA, FB, FD, LT, PB, PJ, PL, SB, SE, SW, and MX. (MX was used if there were no dominant leading species.) Species groups were defined as having 50% or greater basal area of the primary species, while mixed types had no single species

greater than 50% basal area. The broad cover group by species category was a combination of the broad cover group (stand type) and the species groupings. Since basal area proportions vary over time and plots with long-term observations are subject to succession, plots were categorized using observed data from the final measurement. It should be noted that the broad cover group by species validation was not examined in this document.

*MGM Settings*

MGM projections did not apply gap loss (i.e. GapArea% = 0). The maximum size-density adjustment was enabled for all species (i.e. MaxDenAdj = 1 1 1 1). No merchantability criteria were set (i.e. Stump Height = 0m, Minimum DBH = 0cm, Top Diameter Inside Bark = 0cm, and Volume Loss = 0%). MGM's Internal Age Solver was used to calculate missing tree ages relative to tree height and site index. Observed tree ages in the PGYI dataset were not overwritten by MGM's Internal Age Solver. All MGM projections were standardized by growing season. As a result, measurements that occurred after July 31$^{st}$ were assigned to the next calendar year, and stand age was incremented by 1 year. There were no removals or harvests over the projection periods. (Note: Gap loss and the MaxDenAdj were available in MGM18 but are no longer a user-selectable options.)

*Validation Metrics*

The model was validated for stand volume ($m^3ha^{-1}$), basal area ($m^2ha^{-1}$), average DBH (cm), average height (m), top height (m) and density (stems $ha^{-1}$). Top height was defined as the average height of the 100 thickest (largest DBH) stems $ha^{-1}$ of each species. Basal area, density, and top height are readily measurable in the field and are useful for tracking stand performance against the model. Average height and DBH are additional metrics of tree size.

In order to assess the validity of the predictions, both graphical methods and statistical metrics were used. Plots of the observed (Y) versus predicted ($\hat{Y}$), with a Y= $\hat{Y}$ line

representing the perfect fit, were used to graphically evaluate the goodness of fit and identify any model biases (Bokalo et al. 2013). All plotting was performed in R.

As statistical measures, we calculated average mean bias (AMB), relative model bias (RMB) and efficiency (EF) (Vanclay and Skovsgaard 1997). AMB, RMB, EF, and all summary statistics were prepared using R. Residuals (difference between actual and predicted) for conifer and deciduous volume were also calculated and plotted against 12 variables: Initial conifer and deciduous density, initial conifer and deciduous volume, predicted conifer and deciduous volume, initial conifer and deciduous DBH, initial stand age, projection length, and CMI. Volume residuals were also plotted against site index for MGM's primary species groups (AW, PJ, PL, SB, SW). These residuals enable the identification of trends associated with a number of related stand variables. All plotting was performed in R.

**Results:**

**Full Dataset:**

The validation results for the full PGYI dataset are shown in Table 3. The scatterplots for these are presented in Appendix A (pages 1-2). The RMB values for the conifer component (volume, basal area, DBH, average height, density and top height) range from -7.18% to 10.22% in the full dataset. Conifer density is tending to be overpredicted (RMB=-7.18) while DBH is underestimated (RMB=10.22) and volume and basal area show only small RMB values (6.9 and 6.74, respectively). For the deciduous components (volume, basal area, DBH, average height, density and top height) RMB ranges between -2.01% and 4.21%. Efficiency is above 0.85 for both conifer and deciduous, indicating excellent model performance. Graphs (Appendix A, pages 1-2) show reasonable fit around the 1:1 line.

**Data Categorized into Broad Cover Groups**

The validation results, categorized into broad cover groups (C, CD, DC, D) are shown in Table 4. The scatterplots for these are presented in Appendix A (pages 3-10).

Conifer Broad Cover Group (C)

The RMB values for the conifer component (volume, basal area, DBH, average height, density and top height) range from -6.03 to 10.27%%, with DBH having being the only component exceeding +/- 10%. For the secondary deciduous component, volume, basal area, and density are overestimated by the model RMB values of -26.2%, -21.09% and -15.97%. Deciduous DBH (RMB=-0.23%) has a very small bias, while height and top height have RMB values of -7.9% and -7.28%, respectively. It is important to recognize that the average deciduous volume (19.4 $m^3$ $ha^{-1}$), basal area (2.4 m2 ha-1), and density (59 sph) are all low, indicating that the deciduous component does not have a significant role in this broad cover group. Moreover, such large relative biases are not surprising, given the small absolute values that are associated with these. AMB for deciduous density was -28.0 sph. Efficiency ranged between 0 and 0.85 for the deciduous component.

**Table 3.** Summary of observed stand parameters (number of plots (N), volume ($m^3$), basal area ($m^2$), DBH (cm), height (m), density (stems/ha) and top height (m)) as well as the validation statistics (average mean bias (AMB), standard deviation of residuals (SD Resid), relative model bias (RMB), efficiency (EF) for the conifer and deciduous components for the PGYI dataset. Highlighted bolded cells have RMB exceeding ±10%.

| | | | Conifer | | | | | | | | Deciduous | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Observed | | | | Validation Statistics | | | | Observed | | | | Validation Statistics | | | |
| Cover Group | N | Variable | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF |
| ALL | 2633 | Volume ($m^3$/ha) | 206.6 | 0 | 673.2 | 153.5 | 13.62 | 52.9 | 6.59 | 0.87 | 107.4 | 0 | 849.9 | 115.3 | 3.05 | 40.1 | 2.84 | 0.88 |
| | | Basal Area ($m^2$/ha) | 25.4 | 0 | 89.8 | 15.33 | 1.71 | 5.8 | 6.74 | 0.85 | 12.72 | 0 | 95.86 | 11.99 | 0.43 | 4.34 | 3.4 | 0.87 |
| | | Mean DBH (cm) | 17.9 | 0.75 | 67.2 | 8.97 | 1.83 | 2.9 | **10.22** | 0.85 | 20.9 | 0.4 | 60.7 | 12.52 | 0.88 | 4.49 | 4.21 | 0.87 |
| | | Mean Height (m) | 14.9 | 1.54 | 31.0 | 6.4 | 0.65 | 1.9 | 4.35 | 0.9 | 17.04 | 1.4 | 37.09 | 7.47 | -0.34 | 2.63 | -2.01 | 0.87 |
| | | Density (sph) | 1532 | 0 | 40000 | 2327 | -115 | 854 | -7.18 | 0.87 | 501 | 0 | 18387 | 1504 | 31 | 752.3 | 3.46 | 0.85 |
| | | Top Height (m) | 19.3 | 1.54 | 36.4 | 6.85 | 0.49 | 1.9 | 2.54 | 0.92 | 19.58 | 1.4 | 37.09 | 6.96 | -0.38 | 2.51 | -1.96 | 0.87 |

**Table 4.** Summary of observed stand parameters (number of plots (N),volume ($m^3$), basal area ($m^2$), DBH (cm), height (m), density (stems/ha) and top height (m)) as well as the validation statistics (average mean bias (AMB), standard deviation of residuals (SD Resid), relative model bias (RMB), efficiency (EF) for the conifer and deciduous components by broad cover group for the PGYI dataset. Highlighted cells have RMB exceeding ±10%.

| | | | Conifer | | | | | | | | Deciduous | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Observed | | | | Validation Statistics | | | | Observed | | | | Validation Statistics | | | |
| Cover Group | N | Variable | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF |
| C | 1747 | Volume ($m^3$/ha) | 246.5 | 0.4 | 673.2 | 151.6 | 18.32 | 56.0 | 7.43 | 0.85 | 19.4 | 0.0 | 116.5 | 22.6 | -5.09 | 20.9 | **-26.20** | 0.09 |
| | | Basal Area ($m^2$/ha) | 30.7 | 0.2 | 89.8 | 14.0 | 2.36 | 6.1 | 7.69 | 0.78 | 2.4 | 0.0 | 10.8 | 2.3 | -0.50 | 2.2 | **-21.09** | 0.00 |
| | | Mean DBH (cm) | 17.3 | 1.9 | 44.6 | 7.5 | 1.77 | 2.5 | **10.27** | 0.84 | 20.3 | 0.4 | 60.7 | 12.8 | -0.05 | 5.0 | -0.23 | 0.85 |
| | | Mean Height (m) | 14.9 | 2.2 | 31.0 | 5.9 | 0.67 | 1.6 | 4.48 | 0.92 | 16.0 | 1.4 | 37.1 | 7.7 | -1.25 | 2.9 | -7.80 | 0.84 |
| | | Density (sph) | 1918 | 25 | 40000 | 2569 | -116 | 900.7 | -6.03 | 0.88 | 59 | 0 | 7800 | 368 | -28 | 393 | **-15.97** | 0.59 |
| | | Top Height (m) | 19.3 | 2.6 | 36.4 | 6.4 | 0.43 | 1.6 | 2.23 | 0.93 | 16.6 | 1.4 | 37.1 | 7.3 | -1.21 | 3.0 | -7.28 | 0.81 |
| CD | 334 | Volume ($m^3$/ha) | 195.7 | 2.6 | 450.4 | 112.2 | 6.66 | 51.8 | 3.40 | 0.78 | 98.5 | 0.9 | 309.3 | 63.2 | -1.54 | 40.8 | -1.56 | 0.58 |
| | | Basal Area ($m^2$/ha) | 21.6 | 1.3 | 48.6 | 8.9 | 0.81 | 5.1 | 3.74 | 0.66 | 11.1 | 0.4 | 29.0 | 5.3 | 0.04 | 4.0 | 0.35 | 0.43 |
| | | Mean DBH (cm) | 20.8 | 2.9 | 44.8 | 9.5 | 1.51 | 2.8 | 7.27 | 0.89 | 24.2 | 1.8 | 58.5 | 13.1 | 1.61 | 4.2 | 6.66 | 0.88 |
| | | Mean Height (m) | 17.1 | 3.3 | 28.6 | 7.0 | 0.47 | 2.2 | 2.75 | 0.89 | 18.7 | 3.0 | 32.1 | 7.5 | -0.19 | 2.4 | -1.02 | 0.90 |
| | | Density (sph) | 1085 | 50 | 20400 | 1697 | -80 | 497.1 | -7.35 | 0.91 | 603 | 25 | 10900 | 1083 | 25 | 512.4 | 4.19 | 0.78 |
| | | Top Height (m) | 22.4 | 4.8 | 34.8 | 7.4 | 0.44 | 1.9 | 1.95 | 0.93 | 21.3 | 5.1 | 32.1 | 6.0 | -0.25 | 2.1 | -1.19 | 0.87 |
| D | 324 | Volume ($m^3$/ha) | 14.4 | 0.0 | 76.1 | 16.0 | -1.04 | 17.5 | -7.23 | -0.20 | 219.6 | 1.6 | 849.9 | 136.9 | 17.15 | 51.1 | 7.81 | 0.84 |
| | | Basal Area ($m^2$/ha) | 2.3 | 0.0 | 11.3 | 2.0 | -0.44 | 2.7 | **-19.03** | -0.84 | 26.5 | 0.4 | 95.9 | 12.0 | 1.91 | 5.7 | 7.22 | 0.75 |
| | | Mean DBH (cm) | 17.8 | 0.8 | 67.2 | 14.3 | 2.86 | 4.7 | **16.11** | 0.85 | 18.5 | 2.7 | 49.4 | 10.7 | 0.99 | 4.1 | 5.34 | 0.85 |
| | | Mean Height (m) | 12.1 | 1.5 | 30.6 | 7.3 | 0.83 | 2.8 | 6.85 | 0.84 | 16.7 | 3.5 | 30.3 | 6.8 | 0.37 | 2.3 | 2.23 | 0.88 |
| | | Density (sph) | 335 | 0 | 10030 | 1009 | -234 | 904.0 | **-46.80** | 0.39 | 2207 | 50 | 18387 | 2981 | 65 | 1092 | 2.95 | 0.87 |
| | | Top Height (m) | 14.3 | 1.5 | 30.6 | 6.3 | 0.91 | 3.0 | 6.33 | 0.75 | 21.7 | 6.9 | 32.8 | 6.0 | 0.39 | 2.0 | 1.80 | 0.88 |
| DC | 228 | Volume ($m^3$/ha) | 78.4 | 0.2 | 340.9 | 63.3 | 0.05 | 43.7 | 0.06 | 0.52 | 155.0 | 0.1 | 472.6 | 100.5 | 7.70 | 47.2 | 4.97 | 0.77 |
| | | Basal Area ($m^2$/ha) | 9.9 | 0.2 | 25.7 | 5.5 | -0.11 | 4.6 | -1.10 | 0.30 | 18.3 | 0.2 | 47.2 | 8.8 | 0.96 | 5.4 | 5.22 | 0.61 |
| | | Mean DBH (cm) | 18.5 | 1.9 | 51.0 | 11.6 | 1.84 | 4.0 | 9.95 | 0.86 | 20.8 | 1.9 | 51.6 | 12.6 | 1.70 | 4.0 | 8.19 | 0.88 |
| | | Mean Height (m) | 14.2 | 2.4 | 29.1 | 7.4 | 0.62 | 2.4 | 4.37 | 0.89 | 17.3 | 1.8 | 31.0 | 7.3 | 0.41 | 2.3 | 2.37 | 0.90 |
| | | Density (sph) | 931 | 40 | 12775 | 1586 | -44 | 843.8 | -4.71 | 0.72 | 1312 | 40 | 13320 | 2119 | 143 | 1084 | **10.90** | 0.73 |
| | | Top Height (m) | 18.5 | 3.5 | 31.3 | 7.1 | 0.69 | 2.7 | 3.74 | 0.84 | 21.1 | 1.5 | 32.7 | 6.3 | 0.30 | 1.8 | 1.42 | 0.91 |

Conifer Dominated Mixedwood (CD)

In the CD broad cover group, the performance of both conifer and deciduous are important. For the CD conifer and deciduous components, all RMB values are less than ±7.35%. Scatterplots in Appendix A (pages 5-6) show small model biases for this cover group. Efficiency exceeded 0.43 for the conifer and deciduous components.

Deciduous Broad Cover Group (D)

The RMB values for the deciduous component (volume, basal area, DBH, average height, density and top height) are all less than ±7.81%. The secondary conifer component in this cover group shows a slight overestimate of volume (RMB=-7.23%, AMB=-1.04 $m^3ha^{-1}$), larger overestimates of basal area (RMB=-19.03%, AMB=0.-0.44 $m^2ha^{-1}$), and density (RMB=-46.8%, AMB=-234 sph) while DBH is underestimated (RMB=16.11%, AMB=2.86 cm). Several points regarding the secondary conifer results should be noted. First, this is a pure deciduous broad cover group with average conifer volumes of only 14.4 $m^3$ $ha^{-1}$. (Conifer volumes in this cover group range between 0.0 and 76.1 $m^3ha^{-1}$ with a standard deviation of 16.0 $m^3ha^{-1}$.) Second, AMB values are small. By overestimating density, there is a tendency to maintain smaller trees; this results in underestimates of DBH. The figures in Appendix A (pages7-8) 2 also show a small number of plots with low (<500 sph) observed densities (Appendix A, Figure D-6, page 7) where predicted conifer densities are high; this is probably related to undocumented mortality events or tree removals.

Deciduous Dominated Mixedwood (DC)

In the DC broad cover group, the performance of both conifer and deciduous are important. For the dominant deciduous component, all RMB values except for density are less than ±8.19%. (Table 4). Deciduous density is underestimated by 10.9%. In the secondary conifer component, all RMB values are smaller than ±9.95% with the DBH having the largest value (RMB=-9.95%). Plots of predicted vs observed shown in Appendix A (pages 8-10) illustrate generally close relationships reflecting efficiencies above 0.52 for all variables except for conifer basal area (efficiency=0.30).

**Table 5.** Summary of observed stand parameters (number of plots (N), volume ($m^3$), basal area ($m^2$), DBH (cm), height (m), density (stems/ha) and top height (m)) as well as the validation statistics (average mean bias (AMB), standard deviation of residuals (SD Resid), relative model bias (RMB), efficiency (EF) for the conifer and deciduous components by species group for the PGYI dataset. Highlighted cells have RMB exceeding ±10%. (Species groups with fewer than 10 plots have been omitted).

| | | | Conifer | | | | | | | | Deciduous | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Observed | | | | Validation Statistics | | | | Observed | | | | Validation Statistics | | | |
| Species Group | N | Variable | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF |
| AW | 387 | Volume ($m^3$/ha) | 46.7 | 0.0 | 340.9 | 53.9 | -0.86 | 35.5 | -1.85 | 0.57 | 213.8 | 0.1 | 679.3 | 127.2 | 14.86 | 53.7 | 6.95 | 0.81 |
| | | Basal Area ($m^2$/ha) | 6.1 | 0.0 | 25.7 | 5.5 | -0.26 | 3.9 | -4.35 | 0.50 | 24.8 | 0.2 | 72.2 | 11.2 | 1.38 | 5.9 | 5.58 | 0.71 |
| | | Mean DBH (cm) | 17.9 | 0.8 | 65.9 | 12.0 | 2.39 | 4.5 | **13.35** | 0.82 | 19.5 | 1.9 | 51.6 | 11.2 | 1.37 | 3.6 | 7.02 | 0.88 |
| | | Mean Height (m) | 13.4 | 1.5 | 29.1 | 7.2 | 0.82 | 2.7 | 6.17 | 0.84 | 17.6 | 1.8 | 31.0 | 6.9 | 0.60 | 2.2 | 3.38 | 0.89 |
| | | Density (sph) | 527 | 0 | 10800 | 1158 | -73 | 726 | **-10.85** | 0.67 | 1926 | 50 | 18387 | 2789 | 88 | 1120 | 4.55 | 0.84 |
| | | Top Height (m) | 16.5 | 1.5 | 31.3 | 6.9 | 0.82 | 3.0 | 4.97 | 0.80 | 21.9 | 1.5 | 32.8 | 5.9 | 0.37 | 1.8 | 1.70 | 0.90 |
| BW | 19 | Volume ($m^3$/ha) | 29.2 | 0.1 | 121.6 | 33.6 | -4.87 | 20.3 | **-16.70** | 0.61 | 75.2 | 8.2 | 146.5 | 44.0 | 2.10 | 30.2 | 2.79 | 0.53 |
| | | Basal Area ($m^2$/ha) | 5.9 | 0.1 | 16.2 | 5.1 | -2.93 | 6.8 | **-49.72** | -1.14 | 14.3 | 3.0 | 25.0 | 6.8 | 0.73 | 4.7 | 5.08 | 0.52 |
| | | Mean DBH (cm) | 10.2 | 0.8 | 27.7 | 8.5 | 0.49 | 3.9 | 4.81 | 0.79 | 10.3 | 3.6 | 18.8 | 3.9 | 0.58 | 2.5 | 5.66 | 0.58 |
| | | Mean Height (m) | 8.1 | 1.6 | 19.1 | 5.3 | 0.53 | 3.4 | 6.52 | 0.58 | 10.7 | 4.9 | 16.6 | 3.3 | -0.35 | 2.2 | -3.26 | 0.56 |
| | | Density (sph) | 1365 | 0 | 12775 | 3005 | -733 | 2445 | **-45.23** | 0.37 | 2373 | 200 | 9355 | 2661 | -21 | 1116 | -0.89 | 0.82 |
| | | Top Height (m) | 13.7 | 7.8 | 22.5 | 4.4 | 0.78 | 5.2 | 5.65 | -0.39 | 15.6 | 10.7 | 19.9 | 2.8 | 0.02 | 1.6 | 0.14 | 0.69 |
| FB | 39 | Volume ($m^3$/ha) | 157.0 | 0.7 | 417.9 | 99.3 | -6.76 | 62.8 | -4.31 | 0.59 | 24.6 | 0.0 | 88.9 | 30.3 | 4.71 | 8.9 | **19.15** | 0.89 |
| | | Basal Area ($m^2$/ha) | 24.2 | 0.4 | 54.4 | 11.8 | 0.20 | 6.9 | 0.81 | 0.66 | 4.6 | 0.0 | 15.1 | 5.3 | 0.94 | 1.7 | **20.60** | 0.86 |
| | | Mean DBH (cm) | 16.0 | 2.2 | 33.0 | 8.2 | 1.29 | 4.0 | 8.07 | 0.73 | 8.3 | 1.4 | 20.0 | 5.6 | -0.27 | 2.1 | -3.24 | 0.86 |
| | | Mean Height (m) | 12.0 | 2.3 | 21.2 | 5.1 | 0.54 | 2.6 | 4.51 | 0.74 | 8.5 | 2.5 | 18.3 | 4.4 | -1.02 | 2.6 | **-11.90** | 0.60 |
| | | Density (sph) | 1816 | 200 | 8775 | 1970 | -136 | 518.8 | -7.47 | 0.93 | 243 | 0 | 3825 | 732 | 107 | 493.7 | **14.61** | 0.80 |
| | | Top Height (m) | 16.9 | 3.4 | 27.6 | 5.7 | -0.98 | 2.7 | -5.83 | 0.75 | 9.6 | 3.1 | 15.7 | 4.8 | -0.26 | 2.8 | -2.66 | 0.66 |
| MX | 213 | Volume ($m^3$/ha) | 183.6 | 2.2 | 534.7 | 129.6 | -1.07 | 47.7 | -0.58 | 0.86 | 108.5 | 1.0 | 334.2 | 81.2 | 3.70 | 34.2 | 3.41 | 0.82 |
| | | Basal Area ($m^2$/ha) | 21.2 | 0.6 | 59.0 | 12.9 | 0.17 | 4.7 | 0.81 | 0.87 | 12.9 | 0.2 | 44.3 | 8.0 | 0.68 | 3.6 | 5.23 | 0.79 |
| | | Mean DBH (cm) | 20.6 | 1.3 | 59.8 | 10.1 | 1.65 | 3.3 | 8.00 | 0.87 | 23.2 | 2.5 | 49.3 | 12.7 | 1.43 | 3.8 | 6.15 | 0.90 |
| | | Mean Height (m) | 16.0 | 2.2 | 30.6 | 6.7 | 0.33 | 2.2 | 2.04 | 0.89 | 18.3 | 3.8 | 30.6 | 7.5 | -0.21 | 2.2 | -1.13 | 0.91 |
| | | Density (sph) | 985 | 15 | 10030 | 1260 | -85 | 433.2 | -8.68 | 0.88 | 837 | 0 | 13225 | 1876 | 62 | 739.9 | 6.45 | 0.86 |
| | | Top Height (m) | 21.4 | 5.3 | 33.5 | 6.9 | 0.23 | 1.9 | 1.09 | 0.93 | 21.2 | 6.4 | 31.8 | 6.2 | -0.15 | 2.0 | -0.69 | 0.89 |
| PB | 81 | Volume ($m^3$/ha) | 35.6 | 0.1 | 264.8 | 51.4 | 5.87 | 22.5 | **16.47** | 0.79 | 169.0 | 3.1 | 849.9 | 131.9 | 14.92 | 44.2 | 8.83 | 0.87 |
| | | Basal Area ($m^2$/ha) | 4.8 | 0.1 | 21.5 | 4.7 | 0.26 | 3.0 | 5.46 | 0.59 | 21.9 | 1.2 | 95.9 | 13.3 | 2.58 | 5.3 | **11.79** | 0.81 |
| | | Mean DBH (cm) | 20.0 | 1.9 | 67.2 | 15.8 | 2.44 | 4.0 | 12.18 | 0.91 | 22.0 | 2.7 | 47.8 | 11.9 | 1.47 | 6.6 | 6.67 | 0.68 |
| | | Mean Height (m) | 12.9 | 2.4 | 27.5 | 8.2 | 0.43 | 2.1 | 3.33 | 0.93 | 16.8 | 3.5 | 30.3 | 7.0 | 0.29 | 2.9 | 1.70 | 0.83 |
| | | Density (sph) | 421 | 0 | 8920 | 1188 | -371 | 1103 | **-65.19** | 0.26 | 1156 | 40 | 9825 | 1762 | 38 | 1030 | 3.27 | 0.66 |
| | | Top Height (m) | 16.1 | 4.2 | 30.3 | 7.8 | 0.81 | 2.2 | 5.00 | 0.91 | 21.3 | 6.8 | 32.5 | 6.4 | 0.39 | 2.5 | 1.81 | 0.85 |
| PJ | 30 | Volume ($m^3$/ha) | 144.3 | 13.1 | 312.8 | 78.8 | -17.89 | 31.0 | **-12.40** | 0.79 | 20.1 | 0.8 | 63.3 | 21.5 | -6.01 | 11.7 | **-29.97** | 0.62 |
| | | Basal Area ($m^2$/ha) | 19.4 | 5.2 | 36.3 | 7.8 | -2.00 | 3.8 | **-10.30** | 0.69 | 3.1 | 0.3 | 9.6 | 2.9 | -0.97 | 1.6 | **-31.32** | 0.58 |
| | | Mean DBH (cm) | 16.5 | 5.2 | 30.3 | 6.0 | 1.01 | 1.7 | 6.16 | 0.89 | 13.1 | 1.7 | 20.9 | 5.1 | -0.22 | 2.0 | -1.71 | 0.85 |
| | | Mean Height (m) | 15.2 | 4.7 | 22.3 | 4.9 | 0.61 | 1.7 | 3.99 | 0.85 | 13.4 | 3.1 | 19.0 | 5.1 | -0.81 | 2.5 | -6.01 | 0.74 |
| | | Density (sph) | 1176 | 310 | 5075 | 1009 | -135 | 258.3 | -11.52 | 0.92 | 246 | 0 | 3300 | 663 | -2 | 330.2 | -0.55 | 0.85 |
| | | Top Height (m) | 17.7 | 6.3 | 23.4 | 4.5 | -0.72 | 1.3 | -4.05 | 0.88 | 14.2 | 5.1 | 20.3 | 5.2 | -1.67 | 2.1 | **-11.76** | 0.73 |

| | | | Conifer | | | | | | | | Deciduous | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Observed | | | | Validation Statistics | | | | Observed | | | | Validation Statistics | | | |
| Species Group | N | Variable | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF |
| PL | 1195 | Volume (m³/ha) | 246.0 | 0.6 | 657.4 | 153.4 | 24.84 | 54.0 | **10.10** | 0.85 | 32.3 | 0.0 | 228.2 | 46.2 | -1.58 | 21.3 | -4.90 | 0.79 |
| | | Basal Area (m²/ha) | 30.0 | 0.5 | 68.7 | 13.5 | 2.79 | 5.9 | 9.29 | 0.76 | 4.0 | 0.0 | 23.5 | 4.8 | -0.20 | 2.4 | -5.06 | 0.74 |
| | | Mean DBH (cm) | 16.6 | 1.9 | 40.0 | 6.9 | 2.05 | 2.2 | **12.35** | 0.81 | 17.8 | 0.4 | 60.7 | 12.9 | -0.22 | 4.8 | -1.21 | 0.86 |
| | | Mean Height (m) | 15.0 | 2.2 | 28.9 | 5.7 | 0.79 | 1.4 | 5.27 | 0.92 | 14.7 | 1.4 | 29.8 | 7.8 | -1.00 | 2.8 | -6.80 | 0.85 |
| | | Density (sph) | 2018 | 80 | 40000 | 2819 | -184 | 983.1 | -9.10 | 0.87 | 113 | 0 | 8000 | 560 | 20 | 493.4 | 5.43 | 0.73 |
| | | Top Height (m) | 18.7 | 2.6 | 32.8 | 5.9 | 0.77 | 1.5 | 4.10 | 0.92 | 16.1 | 1.4 | 30.6 | 7.4 | -0.79 | 2.9 | -4.90 | 0.83 |
| SB | 175 | Volume (m³/ha) | 190.1 | 0.4 | 457.7 | 114.5 | 18.84 | 41.0 | 9.91 | 0.84 | 15.5 | 0.0 | 102.3 | 21.8 | -4.12 | 14.2 | **-26.54** | 0.54 |
| | | Basal Area (m²/ha) | 31.9 | 0.2 | 61.3 | 15.4 | 3.27 | 5.6 | **10.26** | 0.82 | 2.5 | 0.0 | 16.1 | 3.2 | -0.47 | 2.3 | **-18.98** | 0.46 |
| | | Mean DBH (cm) | 11.7 | 2.3 | 24.5 | 4.4 | 0.59 | 1.5 | 5.08 | 0.86 | 15.3 | 1.1 | 38.4 | 10.3 | -2.43 | 2.7 | **-15.95** | 0.87 |
| | | Mean Height (m) | 10.7 | 2.3 | 21.3 | 3.9 | 0.57 | 1.2 | 5.38 | 0.88 | 12.3 | 2.0 | 24.9 | 6.7 | -2.72 | 2.2 | **-22.12** | 0.72 |
| | | Density (sph) | 3434 | 38 | 17325 | 2837 | 235 | 1112 | 6.84 | 0.84 | 61.0 | 0.0 | 1600 | 221.0 | 36.0 | 177.7 | **15.38** | 0.78 |
| | | Top Height (m) | 16.1 | 3.7 | 26.8 | 4.5 | -0.21 | 1.3 | -1.34 | 0.92 | 13.3 | 2.5 | 24.9 | 6.3 | -2.41 | 2.4 | **-18.16** | 0.70 |
| SW | 462 | Volume (m³/ha) | 252.4 | 1.5 | 624.9 | 146.4 | 2.52 | 59.8 | 1.00 | 0.83 | 60.1 | 0.1 | 271.2 | 56.3 | -8.25 | 37.5 | **-13.74** | 0.53 |
| | | Basal Area (m²/ha) | 27.8 | 0.9 | 60.0 | 13.4 | 0.81 | 6.0 | 2.92 | 0.80 | 6.6 | 0.0 | 29.0 | 5.4 | -0.58 | 3.6 | -8.86 | 0.55 |
| | | Mean DBH (cm) | 22.5 | 3.3 | 44.8 | 9.0 | 1.53 | 3.0 | 6.80 | 0.86 | 26.2 | 1.2 | 58.5 | 12.4 | 1.42 | 5.0 | 5.44 | 0.83 |
| | | Mean Height (m) | 17.7 | 2.8 | 31.0 | 6.8 | 0.38 | 2.1 | 2.16 | 0.91 | 19.5 | 2.2 | 37.1 | 7.0 | -0.70 | 2.8 | -3.57 | 0.83 |
| | | Density (sph) | 853 | 25 | 8740 | 800 | -52 | 326.6 | -6.13 | 0.83 | 203 | 0 | 10900 | 716 | -36 | 350.3 | **-13.38** | 0.81 |
| | | Top Height (m) | 23.9 | 3.6 | 36.4 | 7.4 | 0.16 | 1.9 | 0.68 | 0.93 | 20.7 | 3.2 | 37.1 | 6.2 | -0.80 | 2.8 | -3.87 | 0.79 |

## Data Categorized by Dominant Species

The validation results for the PGYI dataset, categorized by species are shown in Table 5. The scatterplots for these are presented in Appendix A (pages 11-36).

### Aspen (AW)

There are 387 plots categorized as aspen dominated. For the deciduous component of these stands, all RMB values are less than ±7.02%. Figure 2 shows the aspen group scatterplots of observed vs predicted for deciduous volume, basal area, DBH and density. Deciduous efficiencies are all above 0.71. With respect to the conifer component within the aspen group, there is a tendency to slightly overestimate volume (RMB=-1.85%) and basal area (-4.35%) while DBH was underestimated (RMB=13.35%) and density was overestimated (-10.85%). It should be noted that conifer volume and densities are low (46.7 $m^3ha^{-1}$ and 527 sph) and may be from any of the conifer species. (This may include conifer species that are only partially modelled in MGM (e.g. FB).) One outlier with very high observed (10,800 sph) and low predicted (4,000 sph) conifer density is evident in Appendix A (page 11).

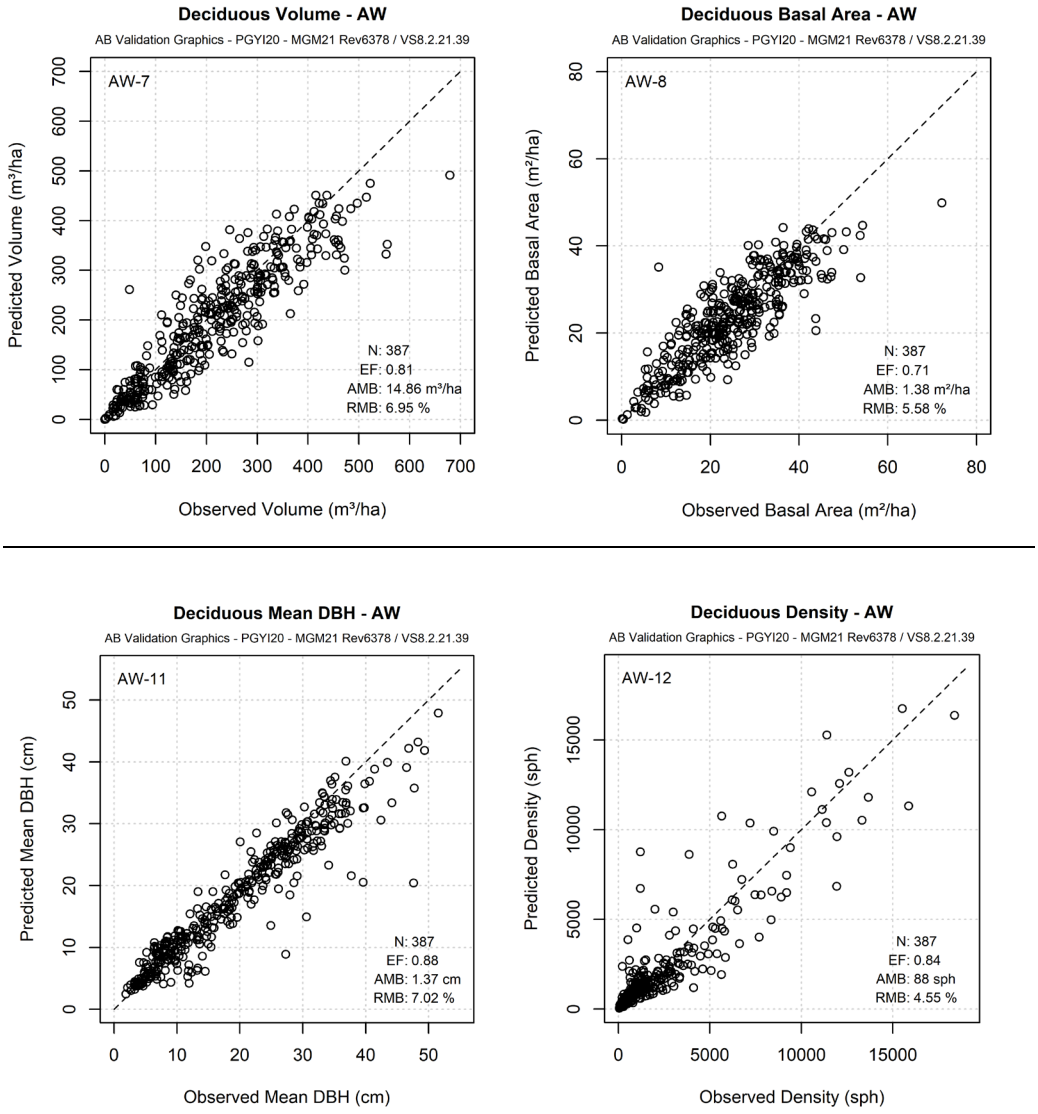


Figure 2. Scatterplots of observed and predicted stand volume, basal area, diameter and density for the deciduous component in the aspen (AW) species group.

White Birch (BW)

There are 19 plots dominated by white birch. For the deciduous component RMB is below +/- 5.66% and efficiency is above 0.52. Plots show good correspondence between predicted and observed for the deciduous component (Appendix A, page 14). White birch is modelled in MGM using aspen growth functions, aspen site index curves, and balsam poplar survival probability models. This surrogate approach is necessary, given the lack of available data to build birch submodels; however, the overall results may not be ideal. Predictions of the conifer component in these plots are poor, reflecting the small amount of conifer present (Table 5) and the substantial variation in behavior of conifer in these stands. (Birch dominated stands are often wet and subject to flooding).

Balsam Fir (FB)

There are 39 plots dominated by balsam fir. The results show that conifer volume, basal area, DBH, average height, top height and density are modelled well with a RMB of less than ±8.07%. This low RMB value is achieved, despite balsam fir using white spruce functions for height growth, diameter growth, and site index. The minor deciduous component is modelled poorly in these plots with deciduous volume underestimated by 19.15%, deciduous basal area underestimated by 20.60% and density underestimated by 14.61%. These underestimates reflect the narrow ranges of deciduous volume and basal area in the balsam fir dominated plots and the effects of a small sample size.

Mixedwoods (MX)

In this category, there are 213 plots representing stands with no single, dominant conifer or deciduous species. With respect to the deciduous component, all RMB values are less than ±6.45%. With respect to conifer component, all RMB values are less than ±8.68%. The scatterplots in Appendix A (pages 23 and 24) do not indicate any clear problems with outliers for this grouping.

Balsam Poplar (PB)

There are 81 plots dominated by balsam poplar. Volume, DBH and density of deciduous are modelled well with a RMB less than ±8.83%, while basal area has an RMB of

11.79%. RMB for conifer volume was 16.47% while an RMB of -65.19% for conifer density indicates substantial overestimation, which results from the small number of datapoints and the small amount of conifer in the dataset for this species group (Appendix A, page 25).

Jack Pine (PJ)

There are 30 plots dominated by jack pine in the dataset. The jack pine conifer component validated adequately with all RMB values below ±12.4%, with volume, basal area and density being overestimated. Scatterplots do not indicate any clear issues (Appendix A, pages 27 and 28) with the exception of one plot showing much higher actual deciduous density than predicted. However, the minor deciduous component has RMB of -29.97% for volume, -31.32% for basal area. These biases are associated with the small basal area of the deciduous component and a small sample size.

Lodgepole Pine (PL)

There are 1195 plots dominated by lodgepole pine in the validation dataset. Lodgepole pine validated adequately (Figure 3) with all RMB values below ±12.35%. Conifer volume was generally underestimated by 10.1% and DBH by 12.35% in this group while there was a slight tendency to overestimate conifer density (RMB=-9.1%). Efficiency for both conifer and deciduous ranged from 0.73 to 0.92. RMB values for deciduous are below 6.8%.

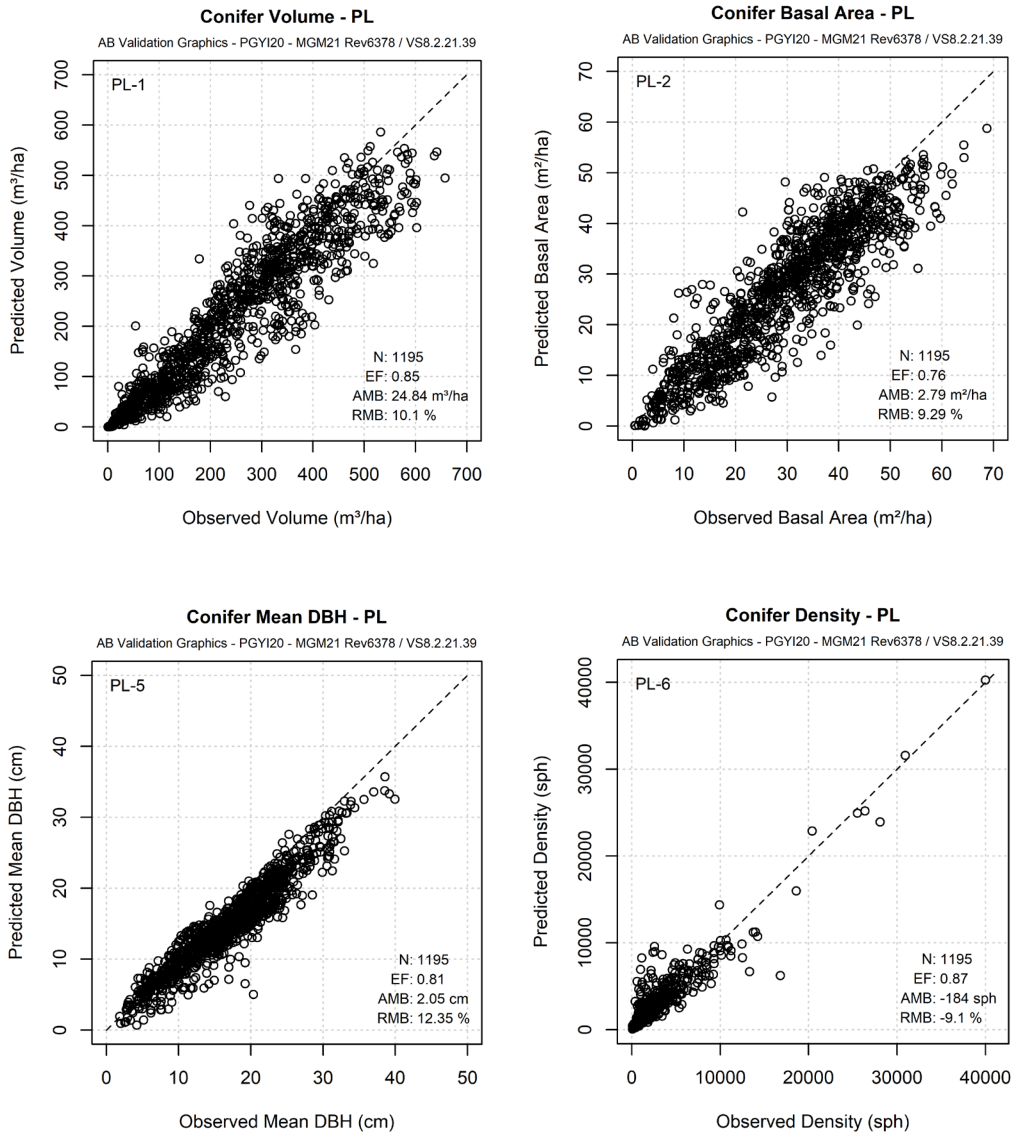


Figure 3. Scatterplots of observed and predicted stand volume, basal area, diameter and density for the conifer component in the Lodgepole Pine (PL) species group.

Black Spruce (SB)

175 black spruce plots were available for validation in this dataset. The conifer component of the black spruce group performed well with all RMB values below ±9.91% with the exception of basal area (RMB=10.26%). The minor deciduous component of these black spruce stands have large RMB values for volume (-26.54%) and density (15.38%); however, these large RMB values are associated with small AMB values (-4.122 $m^3ha^{-1}$ for volume and 36.0 sph for density). Scatter plots for the SB group are provided in Appendix A (pages 31 and 32).

White Spruce (SW)

There are 462 plots dominated by white spruce in the validation dataset. The model validated very well for the conifer component of these stands with RMB values less than ±6.80% (Figure 4). The deciduous component is also modelled adequately, with RMB values below ±13.74% and small values for AMB (volume AMB=-8.25, density AMB=-36). The scatterplots in Figure 4 and in Appendix A (pages 35 and 36) illustrate the generally strong correspondence between MGM predictions and observed.

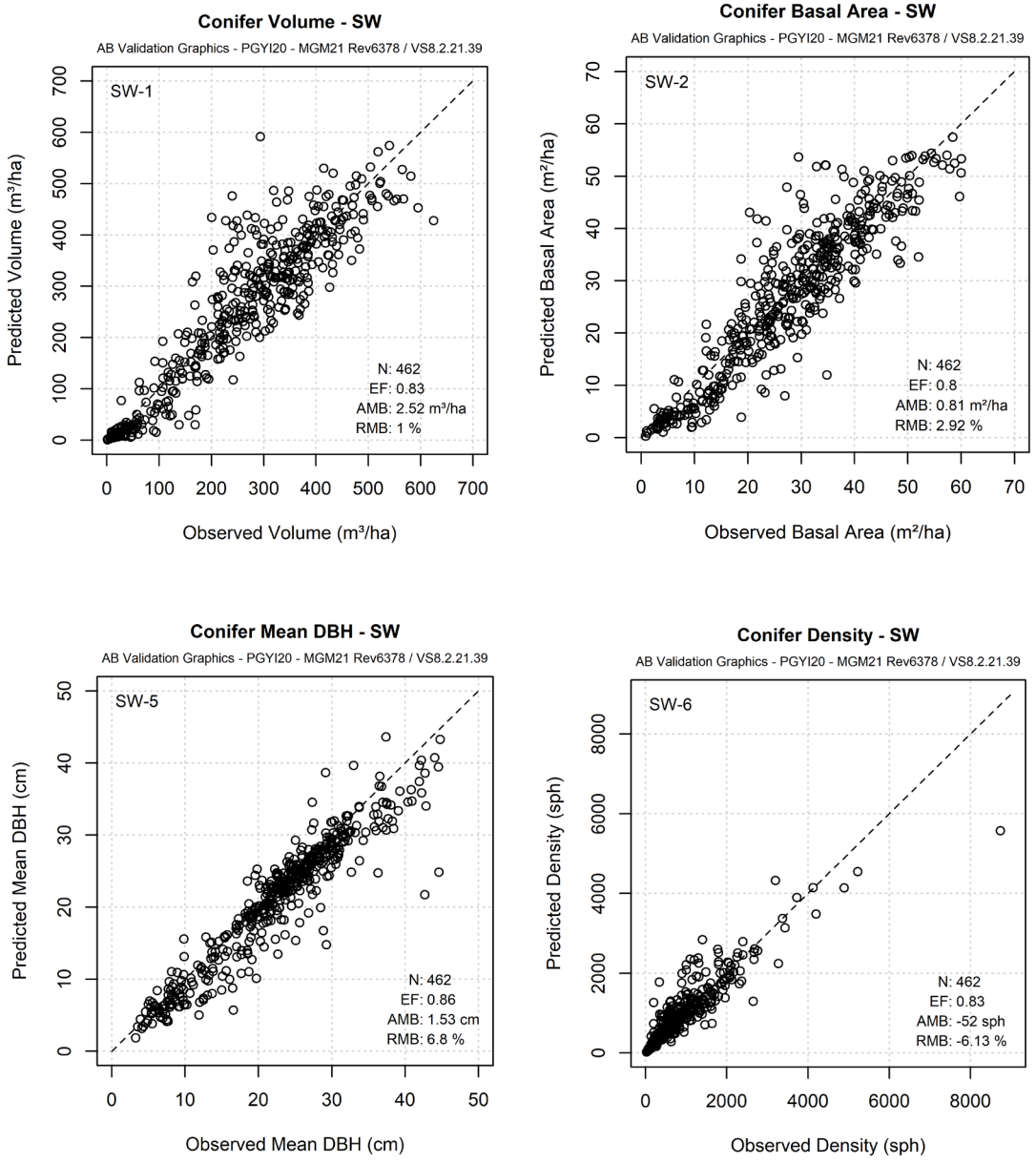


Figure 4. Scatterplots of observed and predicted stand volume, basal area, diameter and density for the conifer component in the white spruce (SW) species group.

**Table 6.** Summary of observed stand parameters (volume ($m^3$), basal area ($m^2$), DBH (cm), height (m), density (stems/ha) and top height (m)) as well as the validation statistics (average mean bias (AMB), standard deviation of residuals (SD Resid), relative model bias (RMB), efficiency (EF) for the conifer and deciduous components by broad cover group and species for the PGYI dataset. Highlighted cells have RMB exceeding ±10%. (Groups with fewer than 10 plots have been omitted).

| | | | Conifer | | | | | | | | Deciduous | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Observed | | | | Validation Statistics | | | | Observed | | | | Validation Statistics | | | |
| Group | N | Variable | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF |
| CPL | 1113 | Volume ($m^3$/ha) | 250.7 | 0.6 | 657.4 | 154.9 | 25.35 | 54.8 | **10.11** | 0.85 | 14.7 | 0.0 | 114.6 | 19.2 | -3.71 | 14.7 | **-25.28** | 0.37 |
| | | Basal Area ($m^2$/ha) | 30.7 | 0.5 | 68.7 | 13.6 | 2.93 | 6.0 | 9.55 | 0.76 | 1.9 | 0.0 | 10.6 | 1.9 | -0.46 | 1.9 | **-24.32** | 0.02 |
| | | Mean DBH (cm) | 16.6 | 1.9 | 40.0 | 6.7 | 2.04 | 2.2 | **12.31** | 0.80 | 17.5 | 0.4 | 60.7 | 13.3 | -0.59 | 4.9 | -3.40 | 0.86 |
| | | Mean Height (m) | 14.9 | 2.2 | 28.9 | 5.6 | 0.76 | 1.4 | 5.06 | 0.92 | 14.3 | 1.4 | 29.8 | 7.9 | -1.30 | 2.9 | -9.12 | 0.84 |
| | | Density (sph) | 2045 | 80 | 40000 | 2832 | -174 | 1002 | -8.53 | 0.87 | 56 | 0 | 7800 | 419 | -18 | 467.4 | -8.38 | 0.66 |
| | | Top Height (m) | 18.6 | 2.6 | 32.4 | 5.8 | 0.76 | 1.5 | 4.06 | 0.92 | 15.1 | 1.4 | 29.8 | 7.4 | -1.14 | 3.1 | -7.59 | 0.80 |
| CSB | 169 | Volume ($m^3$/ha) | 192.2 | 0.4 | 457.7 | 114.3 | 18.69 | 40.4 | 9.73 | 0.85 | 10.8 | 0.0 | 60.6 | 12.7 | -4.39 | 14.2 | **-40.60** | -0.38 |
| | | Basal Area ($m^2$/ha) | 32.3 | 0.2 | 61.3 | 15.3 | 3.30 | 5.6 | **10.22** | 0.82 | 1.7 | 0.0 | 6.3 | 1.6 | -0.63 | 2.2 | **-37.12** | -1.05 |
| | | Mean DBH (cm) | 11.6 | 2.3 | 24.5 | 4.5 | 0.57 | 1.5 | 4.88 | 0.88 | 15.2 | 1.1 | 38.4 | 10.6 | -2.52 | 2.5 | **-16.58** | 0.89 |
| | | Mean Height (m) | 10.6 | 2.3 | 21.3 | 4.0 | 0.55 | 1.2 | 5.14 | 0.90 | 12.3 | 2.0 | 24.9 | 6.9 | -2.60 | 2.2 | **-21.08** | 0.75 |
| | | Density (sph) | 3518 | 38 | 17325 | 2846 | 245 | 1129 | 6.96 | 0.84 | 51 | 0 | 1600 | 216 | 33 | 174.1 | **15.12** | 0.81 |
| | | Top Height (m) | 16.1 | 3.7 | 26.8 | 4.5 | -0.26 | 1.3 | -1.63 | 0.92 | 13.1 | 2.5 | 24.9 | 6.4 | -2.35 | 2.6 | **-17.91** | 0.70 |
| CSW | 307 | Volume ($m^3$/ha) | 272.6 | 1.5 | 624.9 | 156.1 | 2.95 | 59.5 | 1.08 | 0.85 | 25.6 | 0.1 | 116.5 | 25.8 | -6.95 | 29.3 | **-27.16** | -0.36 |
| | | Basal Area ($m^2$/ha) | 30.6 | 0.9 | 60.0 | 14.3 | 0.83 | 6.0 | 2.70 | 0.82 | 2.9 | 0.0 | 10.5 | 2.4 | -0.53 | 2.8 | **-18.52** | -0.32 |
| | | Mean DBH (cm) | 22.1 | 3.3 | 44.6 | 8.6 | 1.69 | 3.1 | 7.64 | 0.83 | 25.1 | 1.2 | 54.2 | 11.4 | 0.94 | 5.3 | 3.75 | 0.77 |
| | | Mean Height (m) | 17.2 | 2.8 | 31.0 | 6.6 | 0.51 | 1.9 | 2.97 | 0.91 | 18.9 | 2.2 | 37.1 | 6.8 | -0.96 | 3.0 | -5.09 | 0.78 |
| | | Density (sph) | 897 | 25 | 5225 | 705 | -81 | 290.0 | -9.04 | 0.82 | 71 | 0 | 2725 | 281 | -58 | 349.7 | **-51.50** | -0.04 |
| | | Top Height (m) | 23.6 | 3.6 | 36.4 | 7.4 | 0.10 | 1.7 | 0.43 | 0.95 | 19.3 | 3.2 | 37.1 | 6.4 | -1.01 | 3.1 | -5.23 | 0.75 |
| CDPL | 82 | Volume ($m^3$/ha) | 181.6 | 2.6 | 416.0 | 113.6 | 17.87 | 41.7 | 9.84 | 0.84 | 82.7 | 0.9 | 228.2 | 61.3 | 4.47 | 33.0 | 5.41 | 0.70 |
| | | Basal Area ($m^2$/ha) | 20.9 | 1.5 | 39.7 | 8.6 | 0.89 | 4.1 | 4.25 | 0.76 | 10.2 | 0.4 | 23.5 | 5.2 | 0.51 | 3.5 | 5.03 | 0.52 |
| | | Mean DBH (cm) | 17.5 | 2.9 | 34.4 | 8.9 | 2.24 | 2.5 | **12.81** | 0.86 | 18.9 | 2.4 | 41.1 | 11.6 | 0.86 | 4.2 | 4.56 | 0.86 |
| | | Mean Height (m) | 15.3 | 3.7 | 27.2 | 7.0 | 1.23 | 1.8 | 8.03 | 0.90 | 16.0 | 4.2 | 28.7 | 7.4 | -0.14 | 2.3 | -0.90 | 0.90 |
| | | Density (sph) | 1642 | 80 | 20400 | 2628 | -310 | 672.0 | **-18.85** | 0.92 | 890 | 30 | 8000 | 1248 | 153 | 559.0 | **17.23** | 0.78 |
| | | Top Height (m) | 19.1 | 4.8 | 32.8 | 7.1 | 0.88 | 1.3 | 4.59 | 0.95 | 19.1 | 6.4 | 30.6 | 6.3 | 0.23 | 1.9 | 1.22 | 0.91 |
| CDSB | 6 | Volume ($m^3$/ha) | 130.7 | 4.8 | 304.7 | 116.7 | 22.93 | 61.2 | **17.54** | 0.68 | 45.4 | 1.3 | 102.3 | 40.9 | -2.42 | 15.7 | -5.33 | 0.85 |
| | | Basal Area ($m^2$/ha) | 19.2 | 1.3 | 43.2 | 15.9 | 2.31 | 6.4 | **12.03** | 0.81 | 7.5 | 0.4 | 16.1 | 5.7 | 0.54 | 2.8 | 7.25 | 0.75 |
| | | Mean DBH (cm) | 14.0 | 10.4 | 17.0 | 2.2 | 1.37 | 3.1 | 9.83 | -1.45 | 15.6 | 4.4 | 30.6 | 9.2 | -1.88 | 4.2 | **-12.07** | 0.74 |
| | | Mean Height (m) | 12.2 | 8.4 | 15.0 | 2.9 | 1.36 | 2.4 | **11.21** | 0.04 | 12.2 | 6.1 | 21.4 | 6.0 | -3.52 | 2.4 | **-28.80** | 0.44 |
| | | Density (sph) | 1074 | 100 | 2642 | 951 | -49 | 220.8 | -4.55 | 0.94 | 332 | 150 | 675 | 200 | 55 | 216.9 | **16.52** | -0.26 |
| | | Top Height (m) | 17.0 | 8.4 | 22.3 | 5.3 | 1.38 | 1.6 | 8.12 | 0.82 | 14.5 | 6.9 | 21.9 | 5.8 | -2.88 | 1.1 | **-19.83** | 0.65 |
| CDSW | 155 | Volume ($m^3$/ha) | 212.4 | 9.7 | 450.4 | 115.2 | 1.66 | 60.6 | 0.78 | 0.72 | 98.1 | 4.6 | 271.2 | 56.4 | -9.68 | 45.0 | -9.87 | 0.33 |
| | | Basal Area ($m^2$/ha) | 22.3 | 3.1 | 48.6 | 9.2 | 0.79 | 6.0 | 3.52 | 0.57 | 10.7 | 0.9 | 29.0 | 4.8 | -0.64 | 4.4 | -5.98 | 0.17 |
| | | Mean DBH (cm) | 23.4 | 5.0 | 44.8 | 9.9 | 1.22 | 2.8 | 5.23 | 0.91 | 27.3 | 1.8 | 58.5 | 13.3 | 1.95 | 4.5 | 7.15 | 0.86 |
| | | Mean Height (m) | 18.7 | 4.6 | 28.6 | 7.1 | 0.13 | 2.2 | 0.69 | 0.90 | 20.2 | 3.0 | 32.1 | 7.3 | -0.40 | 2.5 | -2.00 | 0.88 |

| | | | Conifer | | | | | | | | Deciduous | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Observed | | | | Validation Statistics | | | | Observed | | | | Validation Statistics | | | |
| Group | N | Variable | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF |
| | | Density (sph) | 767 | 50 | 8740 | 958 | 5 | 383.7 | 0.60 | 0.84 | 465 | 25 | 10900 | 1128 | -9 | 350.2 | -1.85 | 0.90 |
| | | Top Height (m) | 24.3 | 6.1 | 34.8 | 7.4 | 0.28 | 2.2 | 1.14 | 0.91 | 22.3 | 7.0 | 32.1 | 5.5 | -0.58 | 2.3 | -2.58 | 0.81 |
| DAW | 244 | Volume (m³/ha) | 14.4 | 0.0 | 76.1 | 16.1 | -0.61 | 16.2 | -4.24 | -0.01 | 236.9 | 1.6 | 679.3 | 134.9 | 19.51 | 53.4 | 8.23 | 0.82 |
| | | Basal Area (m²/ha) | 2.3 | 0.0 | 10.3 | 2.0 | -0.36 | 2.5 | **-15.75** | -0.58 | 27.9 | 0.4 | 72.2 | 11.3 | 1.86 | 5.9 | 6.67 | 0.70 |
| | | Mean DBH (cm) | 17.3 | 0.8 | 65.9 | 13.2 | 2.95 | 4.8 | **17.05** | 0.82 | 18.1 | 2.7 | 49.4 | 10.2 | 0.98 | 2.9 | 5.39 | 0.91 |
| | | Mean Height (m) | 12.1 | 1.5 | 28.6 | 7.0 | 0.94 | 2.9 | 7.77 | 0.81 | 17.1 | 4.1 | 30.0 | 6.7 | 0.54 | 2.1 | 3.13 | 0.89 |
| | | Density (sph) | 296 | 0 | 7400 | 765 | -132 | 671.0 | **-29.41** | 0.43 | 2369 | 50 | 18387 | 3119 | 107 | 1090 | 4.53 | 0.88 |
| | | Top Height (m) | 14.1 | 1.5 | 28.6 | 6.0 | 0.96 | 3.1 | 6.81 | 0.72 | 21.9 | 6.9 | 32.8 | 5.8 | 0.45 | 1.9 | 2.08 | 0.89 |
| DBW | 12 | Volume (m³/ha) | 7.3 | 0.1 | 16.0 | 6.4 | -0.07 | 7.9 | -0.92 | -0.51 | 64.8 | 8.2 | 146.5 | 49.3 | 3.00 | 21.0 | 4.64 | 0.81 |
| | | Basal Area (m²/ha) | 1.8 | 0.1 | 3.8 | 1.7 | -2.02 | 5.8 | **-110.8** | -12.85 | 12.9 | 3.0 | 25.0 | 8.0 | 0.54 | 3.2 | 4.20 | 0.84 |
| | | Mean DBH (cm) | 8.8 | 0.8 | 24.4 | 9.0 | -0.91 | 2.9 | **-10.31** | 0.89 | 8.8 | 3.6 | 13.9 | 3.5 | 0.41 | 2.9 | 4.65 | 0.32 |
| | | Mean Height (m) | 7.1 | 1.6 | 16.6 | 5.7 | -0.97 | 3.8 | **-13.60** | 0.51 | 9.5 | 4.9 | 15.9 | 3.1 | -0.41 | 2.0 | -4.29 | 0.54 |
| | | Density (sph) | 408 | 0 | 2000 | 705 | -979 | 1913 | **-179.9** | -6.89 | 2969 | 200 | 9355 | 3225 | 48 | 1265 | 1.62 | 0.85 |
| | | Top Height (m) | 12.1 | 7.8 | 16.6 | 3.2 | 1.56 | 6.2 | **12.88** | -3.04 | 14.6 | 10.7 | 17.7 | 2.6 | -0.03 | 1.7 | -0.20 | 0.56 |
| DPB | 55 | Volume (m³/ha) | 14.6 | 0.1 | 68.6 | 17.1 | -0.87 | 12.2 | -5.96 | 0.49 | 194.6 | 5.5 | 849.9 | 138.9 | 13.42 | 48.8 | 6.90 | 0.87 |
| | | Basal Area (m²/ha) | 2.2 | 0.1 | 11.3 | 2.3 | -0.31 | 2.5 | **-13.73** | -0.12 | 24.3 | 1.8 | 95.9 | 13.9 | 2.52 | 5.6 | **10.36** | 0.80 |
| | | Mean DBH (cm) | 23.4 | 2.0 | 67.2 | 17.9 | 3.18 | 4.3 | **13.61** | 0.91 | 23.9 | 2.7 | 47.8 | 11.8 | 1.25 | 7.4 | 5.23 | 0.60 |
| | | Mean Height (m) | 13.9 | 2.5 | 27.5 | 8.3 | 0.51 | 2.4 | 3.68 | 0.91 | 17.8 | 3.5 | 30.3 | 6.6 | 0.10 | 2.9 | 0.54 | 0.80 |
| | | Density (sph) | 239 | 0 | 8920 | 1209 | -578 | 1368 | **-149.2** | 0.05 | 902 | 100 | 5950 | 1140 | -146 | 956.1 | **-16.21** | 0.28 |
| | | Top Height (m) | 16.0 | 5.0 | 27.5 | 7.7 | 0.45 | 2.3 | 2.84 | 0.91 | 22.6 | 8.2 | 32.5 | 6.1 | 0.14 | 2.5 | 0.60 | 0.83 |
| DCAW | 143 | Volume (m³/ha) | 78.9 | 0.2 | 340.9 | 59 | -1.11 | 47.7 | -1.41 | 0.35 | 174.4 | 0.1 | 472.6 | 101.7 | 6.92 | 53.4 | 3.97 | 0.72 |
| | | Basal Area (m²/ha) | 9.9 | 0.2 | 25.7 | 5.3 | -0.17 | 4.9 | -1.69 | 0.14 | 19.5 | 0.2 | 47.2 | 8.9 | 0.57 | 5.9 | 2.92 | 0.56 |
| | | Mean DBH (cm) | 18.5 | 2.3 | 43.7 | 10.8 | 1.82 | 4 | 9.87 | 0.83 | 21.9 | 1.9 | 51.6 | 12.5 | 2.04 | 4.4 | 9.32 | 0.85 |
| | | Mean Height (m) | 14.6 | 3 | 29.1 | 7.2 | 0.71 | 2.5 | 4.85 | 0.87 | 18.5 | 1.8 | 31 | 7.1 | 0.7 | 2.3 | 3.78 | 0.88 |
| | | Density (sph) | 921 | 44 | 10800 | 1549 | -6 | 780.2 | -0.66 | 0.75 | 1170 | 84 | 13320 | 1893 | 54 | 1174 | 4.63 | 0.61 |
| | | Top Height (m) | 18.9 | 3.5 | 31.3 | 6.8 | 0.68 | 2.9 | 3.6 | 0.81 | 21.9 | 1.5 | 32.7 | 6 | 0.24 | 1.7 | 1.08 | 0.92 |
| DCBW | 7 | Volume (m³/ha) | 47.9 | 14.0 | 121.6 | 36.6 | -8.98 | 27.1 | **-18.75** | 0.38 | 93.0 | 65.0 | 142.2 | 27.9 | 0.54 | 43.9 | 0.58 | -1.49 |
| | | Basal Area (m²/ha) | 9.4 | 4.5 | 16.2 | 4.3 | -3.71 | 7.9 | **-39.53** | -3.24 | 16.9 | 13.3 | 21.2 | 3.2 | 1.05 | 6.9 | 6.22 | -3.64 |
| | | Mean DBH (cm) | 11.4 | 2.9 | 27.7 | 8.6 | 1.70 | 4.4 | **14.85** | 0.69 | 12.8 | 9.3 | 18.8 | 3.4 | 0.87 | 1.7 | 6.85 | 0.68 |
| | | Mean Height (m) | 9.0 | 3.1 | 19.1 | 5.3 | 1.82 | 2.6 | **20.25** | 0.62 | 12.8 | 9.5 | 16.6 | 2.7 | -0.25 | 2.5 | -1.95 | 0.12 |
| | | Density (sph) | 3004 | 190 | 12775 | 4606 | -416 | 3141 | **-13.86** | 0.53 | 1351 | 600 | 2000 | 506 | -140 | 879.4 | **-10.33** | -2.10 |
| | | Top Height (m) | 15.8 | 10.3 | 22.5 | 5.4 | -0.20 | 4.3 | -1.25 | 0.35 | 17.6 | 15.0 | 19.9 | 2.2 | 0.13 | 1.3 | 0.72 | 0.64 |
| DCPB | 26 | Volume (m³/ha) | 59.1 | 0.4 | 264.8 | 65.5 | 13.38 | 28.7 | **22.64** | 0.77 | 114.9 | 3.1 | 360.9 | 97.3 | 18.07 | 32.8 | **15.74** | 0.85 |
| | | Basal Area (m²/ha) | 7.6 | 0.4 | 21.5 | 5.1 | 0.89 | 3.5 | **11.78** | 0.50 | 16.8 | 1.2 | 45.3 | 10.2 | 2.71 | 4.4 | **16.17** | 0.74 |
| | | Mean DBH (cm) | 16.2 | 1.9 | 44.5 | 12.3 | 1.60 | 3.4 | 9.89 | 0.91 | 18.1 | 3.4 | 39.3 | 11.4 | 1.94 | 4.7 | **10.68** | 0.80 |
| | | Mean Height (m) | 11.9 | 2.4 | 26.7 | 8.1 | 0.34 | 1.7 | 2.87 | 0.95 | 14.6 | 4.8 | 27.3 | 7.4 | 0.69 | 2.8 | 4.71 | 0.85 |
| | | Density (sph) | 805 | 50 | 5100 | 1065 | -99 | 515.0 | **-12.29** | 0.76 | 1695 | 40 | 9825 | 2585 | 427 | 1089 | **25.19** | 0.79 |
| | | Top Height (m) | 16.3 | 4.2 | 30.3 | 8.1 | 1.18 | 2.0 | 7.21 | 0.91 | 18.9 | 6.8 | 29.0 | 6.4 | 0.86 | 2.3 | 4.55 | 0.86 |

**Data Categorized by Broad Cover Group and Dominant Species**

The validation results for the PGYI dataset, categorized into broad cover groups (C, CD, DC, D) and by species are shown in Table 6. The scatterplots for these are presented in Appendix A (pages 37-84).

Conifer Broad Cover Group – Lodgepole Pine (CPL)

There are 1113 plots designated as pure conifer dominated by lodgepole pine (CPL). In this case, the model performed adequately in the conifer component with RMB values for volume and average DBH exceeding 10% (10.11 for volume and 12.31 for DBH) and indicating underestimation of these two variables. Efficiencies for the conifer component are all above 0.76. Deciduous volume and basal area are overestimated, with RMB's of -25.28 and -24.32, respectively, while deciduous DBH (RMB=-3.4%) and density (RMB=-8.38) are reasonable. Efficiency is very low for deciduous volume and basal area, due to the narrow range of volumes and densities included in the dataset and substantial variability. The secondary deciduous component is small in these stands with an average volume of 14.7 $m^3ha^{-1}$ and an average density of 56 sph.

Conifer Broad Cover Group – Black Spruce (CSB)

There are 169 plots designated as pure conifer, dominated by black spruce (CSB). In this case, the model performed well for the conifer component with RMB values less than ±10% for all characteristics except basal area which has an underestimate of 10.22%. Efficiencies for the conifer component are all above 0.82. Scatter plots suggest a slight tendency of MGM to underestimate conifer basal area when it is above 40 $m^2ha^{-1}$ (Appendix A, page 63). Secondary deciduous were a minor component of most stands in this groupcomponent was insignificant with an average volume of 10.8 $m^3ha^{-1}$ and an average density of 51 sph. The secondary deciduous component also has larger RMB values; however, the AMB values for these stand metrics are relatively small. Scatter plots (Appendix A, page 64) illustrate consistent overestimation of mean height and top height by the model, suggesting that overestimation of deciduous site index may be causing overestimation of deciduous DBH, volume and basal area for these plots.

Conifer Broad Cover Group – White Spruce (CSW)

There are 307 plots designated as pure conifer dominated by white spruce (CSW). In these white spruce dominated stands, all conifer characteristics are modelled well with RMB values less than ±9.04%, and efficiencies above 0.82. RMB values for the deciduous component range down to -51.5% for density, but this is associated with a small AMB (-58). However, the deciduous component plays a minor role in the plots with basal area averaging 2.9 $m^2ha^{-1}$.

Conifer Dominated Mixedwood Broad Cover Group – Lodgepole Pine (CDPL)

There are 82 plots in the CDPL category. Conifer volume, basal area, average height, and top height are modelled well with RMB values less than ±9.84%. Conifer DBH (RMB=12.81) is underestimated while density (RMB=-18.85) is underestimated. The scatter plot for conifer density (Appendix A, page 43) shows two plots with densities above 10,000 sph which are having large influence on the RMB value. MGM is underestimating density of the secondary deciduous component (RMB=17.23), with this being due to effects of a small number of data points with observed deciduous densities above 2,000 sph (Appendix A, page 44), but is performing well for other variables.

Conifer Dominated Mixedwood Broad Cover Group – Black Spruce (CDSB)

The CDSB group included only 6 plots which limits the ability to draw conclusions about model performance. However, the RMB for conifer volume is 17.54%, and RMB for density is -4.55. Deciduous volume (RMB=-5.33) and basal area (RMB=7.25) are predicted well while DBH and density had higher RMBs, and, as in the CSB group, overestimation of deciduous site index is suggested by overestimation of top height and average height.

Conifer Dominated Mixedwood Broad Cover Group – White Spruce (CDSW)

There are 155 plots designated as white spruce dominated mixedwoods (CDSW). All RMB values for the conifer component are below ±5.23% and efficiencies are above 0.57. The secondary deciduous species are modelled well with RMB values less than

±9.87%. Scatterplots in Appendix A (pages 47 and 48) illustrate the good overall fit of the model against observed values.

Deciduous Dominated Broad Cover Group – Aspen (DAW)

There are 244 plots designated as deciduous dominated by aspen (DAW). All deciduous characteristics have RMB values below ±8.23% and efficiencies above 0.70. The secondary conifer volumes are very small with an average volume of 14.4 $m^3ha^{-1}$ and an average density of 296 sph; RMB for conifer volume was -4.24, while density had an RMB of -29.41 and DBH had an RMB of 17.05 The conifer density scatterplot (Appendix A, page 69) shows that a small number of points, with either high (>4,000 sph) predicted or high observed densities are leading to these results.

Deciduous Dominated Broad Cover Group – Birch (DBW)

Only 12 plots were present in this group, with these indicating large RMB values for the conifer component. As noted previously for the larger BW group (table 5), predictions of the conifer component in these plots are poor, reflecting the small amount of conifer present (Table 6) and the substantial variation in behavior of conifer in these stands. (Birch dominated stands are often wet and subject to flooding).

Deciduous Dominated Broad Cover Group –Balsam Poplar (DPB)

There are 55 plots in this group, with conifer density being predicted very poorly and overestimated in this group (RMB=-149.2), as also noted earlier for the balsam poplar group (Table 6). This poor prediction of conifer density is associated with several datapoints where actual densities are near 0 (Appendix A, page 83) while predicted densities are above 1,000 sph and could reflect data errors in either the initial or final measurements or the effects of a stochastic event (eg. flooding) that has caused mortality of the spruce in the stand which is not included in model predictions. Deciduous density is overestimated (RMB=-16.21) and basal area is underestimated (RMB=-10.36), while deciduous volume and mean DBH appear to be estimated well.

Deciduous Dominated Mixedwood Broad Cover Group – Aspen (DCAW)

There are 143 plots designated as deciduous dominated mixedwood with aspen as the leading species (DCAW). All deciduous characteristics have RMB values below the ±9.3% and efficiencies above 0.56, with the largest RMB being associated with deciduous DBH (RMB=9.32%). The secondary conifer volume, basal area, DBH, height, density and top height are all modelled well with RMB values below ±9.97%. Scatterplots are provided in Appendix A, pages 73 and 74.

Deciduous Dominated Mixedwood Broad Cover Group – Birch (DCBW)

The 7 plots in this group show similar results to those observed for other stands with a major component of birch, with poor prediction of the conifer component and good prediction of the birch component (Table 6, Appendix A pages 75 and 76).

Deciduous Dominated Mixedwood Broad Cover Group –Balsam Poplar (DCPB)

While results from the 26 plots in this group indicate underestimation of conifer volume (RMB=22.64%) it should be noted that this is associated with an AMB of 13.38 $m^3ha^{-1}$ (Table 6). Deciduous volume (RMB=15.74), basal area (RMB=16.17), DBH (RMB=10.68), and density (RMB=25.19) are all underestimated by MGM. As mentioned previously, the application of aspen growth functions to estimation of balsam poplar growth is believed to be the primary cause of these behavioral problems.

Analysis of residuals for all groupings

Examining residuals can indicate where key factors may be influencing model behaviour and indicate areas where model refinement is needed. Plots of residuals for the groups described in the previous section are provided in Appendix B.

On the whole, residual plots do not indicate any major issues with MGM behaviour. It should be noted that volume may be weakly related to density in mature, low density stands. As a result, residual volume may exhibit high variation at low initial densities. Residual volume also exhibits high variation in species and group combinations where stocking is inherently low. For example, in pure conifer stands, deciduous densities and deciduous volumes are low. As a result, conifer residuals (in pure conifer stands) may exhibit clustering around zero (on the X axis) when plotted against deciduous variables. There is a tendency for volume residuals to increase with projection length and for residuals to decrease with increases in initial or predicted volumes (e.g. the plot of

Residual Deciduous Volume against Initial Deciduous Volume for the conifer broad cover group; Appendix B, page 7). These scatter plots also illustrate some of the biases described earlier.

White Spruce dominated stands

Further analysis of data from stands dominated by white spruce was done to evaluate how well MGM is performing in each of the major natural subregions. There were 210 stands in the Central Mixedwoods (CM) subregion, 145 stands in the Lower Foothills (LF) subregion, and 107 stands in the Upper Foothills (UF) subregion. As indicated in table 7, the model shows little bias for the conifer component, with RMB being below $\pm$8.66%, and with efficiency exceeding 0.72. Conifer volume is predicted well (RMB $<\pm$4.59%). Higher RMB values were obtained for the deciduous component of these stands, but are associated with small values for AMB and generally small observed values, as well as being associated with issues in the modeling of balsam poplar and white birch, as discussed previously. Plots of predicted against observed values (Appendix C) indicate very good performance of MGM for white spruce. Residual (predicted minus observed) plots shown in Appendix D indicate a tendency for some increase in underprediction with increasing volumes and projection length, but do not show any major trends.

**Table 7.** Summary of observed stand parameters (number of plots (N),volume ($m^3$), basal area ($m^2$), DBH (cm), height (m), density (stems/ha) and top height (m)) as well as the validation statistics (average mean bias (AMB), standard deviation of residuals (SD Resid), relative model bias (RMB), efficiency (EF) for white spruce dominated stands arranged by natural subregion for the PGYI dataset. Highlighted cells have RMB exceeding ±10%.

| | | | Conifer | | | | | | | | Deciduous | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Observed | | | | Validation Statistics | | | | Observed | | | | Validation Statistics | | | |
| Cover Group | N | Variable | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF | Mean | Min | Max | SD | AMB | SD Resid | RMB | EF |
| SW-CM | 210 | Volume ($m^3$/ha) | 251.7 | 6.54 | 624.9 | 144.0 | 11.57 | 59.73 | 4.59 | 0.82 | 60.17 | 0.14 | 247.4 | 55.46 | -7.98 | 37.21 | **-13.26** | 0.53 |
| | | Basal Area ($m^2$/ha) | 26.24 | 2.45 | 52.15 | 11.72 | 1.77 | 5.94 | 6.74 | 0.72 | 6.58 | 0.04 | 22.26 | 5.27 | -0.49 | 3.59 | -7.41 | 0.53 |
| | | Mean DBH (cm) | 22.63 | 4.32 | 42.72 | 8.97 | 1.96 | 2.68 | 8.66 | 0.86 | 24.77 | 1.83 | 58.49 | 11.68 | 0.74 | 4.99 | 2.99 | 0.81 |
| | | Mean Height (m) | 18.99 | 3.3 | 30.95 | 7.01 | 0.47 | 2.09 | 2.49 | 0.91 | 19.57 | 3.29 | 30.25 | 6.69 | -1.03 | 2.82 | -5.26 | 0.8 |
| | | Density (sph) | 812 | 109 | 8740 | 857 | -48 | 365.2 | -5.85 | 0.82 | 291 | 0 | 10900 | 950 | -45 | 424.8 | **-14.37** | 0.81 |
| | | Top Height (m) | 25.42 | 6.03 | 36.34 | 7.37 | 0.35 | 1.81 | 1.38 | 0.94 | 20.84 | 5 | 30.25 | 5.77 | -1.03 | 2.87 | -4.96 | 0.72 |
| SW-LF | 145 | Volume ($m^3$/ha) | 227.3 | 1.53 | 581.5 | 148.2 | -1.05 | 57.09 | -0.46 | 0.85 | 72.52 | 0.1 | 271.2 | 58.17 | -11.69 | 42.54 | **-16.12** | 0.42 |
| | | Basal Area ($m^2$/ha) | 24.71 | 0.87 | 57.86 | 12.81 | 0.63 | 5.56 | 2.57 | 0.81 | 7.86 | 0.06 | 29.01 | 5.59 | -1 | 4.03 | **-12.77** | 0.45 |
| | | Mean DBH (cm) | 22.52 | 3.28 | 44.77 | 10.94 | 1.59 | 3.63 | 7.05 | 0.87 | 28.64 | 1.2 | 54.81 | 14.18 | 2.15 | 5.14 | 7.51 | 0.85 |
| | | Mean Height (m) | 16.88 | 2.76 | 28.61 | 7.68 | 0.25 | 2.24 | 1.5 | 0.91 | 19.83 | 2.18 | 37.09 | 8.19 | -0.49 | 2.66 | -2.47 | 0.89 |
| | | Density (sph) | 893 | 25 | 4890 | 891 | -62 | 331.2 | -6.93 | 0.86 | 219 | 0 | 4450 | 540 | -33 | 250.8 | **-12.38** | 0.81 |
| | | Top Height (m) | 23.19 | 3.61 | 36.4 | 8.27 | 0.14 | 2.1 | 0.59 | 0.94 | 21.29 | 3.2 | 37.09 | 7.17 | -0.79 | 2.51 | -3.73 | 0.86 |
| SW-UF | 107 | Volume ($m^3$/ha) | 287.7 | 1.95 | 595.2 | 142.7 | -10.39 | 61.23 | -3.61 | 0.81 | 16.53 | 0.85 | 129.9 | 25.77 | 2.02 | 9.1 | 12.2 | 0.87 |
| | | Basal Area ($m^2$/ha) | 35.2 | 1.21 | 60.01 | 14.6 | -0.82 | 6.35 | -2.33 | 0.81 | 2.08 | 0.18 | 12.93 | 2.68 | 0.33 | 0.94 | **15.61** | 0.86 |
| | | Mean DBH (cm) | 22.27 | 4.12 | 36.3 | 5.71 | 0.62 | 2.49 | 2.78 | 0.8 | 25.58 | 13.47 | 52.2 | 8 | 2.83 | 3.43 | **11.08** | 0.69 |
| | | Mean Height (m) | 16.29 | 3.17 | 24.59 | 4.22 | 0.38 | 1.68 | 2.35 | 0.83 | 18.08 | 9.55 | 24.6 | 3.88 | 0.5 | 2.55 | 2.76 | 0.55 |
| | | Density (sph) | 881 | 50 | 2690 | 501 | -49 | 227.1 | -5.53 | 0.79 | 10 | 0 | 100 | 20 | 4 | 13.67 | **12.38** | 0.62 |
| | | Top Height (m) | 21.86 | 4.8 | 33.95 | 5.32 | -0.15 | 1.69 | -0.7 | 0.9 | 18.08 | 9.55 | 24.6 | 3.88 | 0.5 | 2.55 | 2.76 | 0.55 |

**Conclusions**

Results from this validation indicate that MGM's overall performance is strong. MGM's primary species (i.e. white spruce, jack pine, lodgepole pine, aspen, and black spruce) generally validate well, individually or in mixture. Issues do remain when modelling species that are minor components (i.e. have low density or basal area) of stands, or species whose growth is predicted using growth functions for other species (eg. balsam poplar, white birch, balsam fir). These issues reflect the influence of small sample sizes, small plot areas sampled, and the ability to predict tree-level behavior using a non-spatial (distance independent) model. MGM's purely deterministic approach may also contribute to some of the model bias. Errors in the validation dataset, the occurrence of stochastic events (e.g. insects, wind, flooding etc), and undocumented stand tending are also suspected in some cases.

Further refinements to MGM could improve model behavior. These improvements include: 1) incorporating climate into MGM's diameter and height growth models, 2) updating the diameter and height growth models for lodgepole pine, aspen and white spruce, 3) completely modelling secondary species such as balsam poplar, white birch, and balsam fir, 4) incorporation of genetic worth to allow modelling of plantations with improved stock, 5) addition of an ingress model, 6) inclusion of additional predictive variables (eg. soil moisture regime, aspect) in model functions to improve MGM's predictive ability and sensitivity, 7) development of tools to support generation of tree lists from Performance Survey Data collected following the Regeneration Standards of Alberta (and likewise for other provinces), and 8) others. Modelling secondary species would require the development and application of new height-age, mortality and growth equations which may be a challenge given the limited amount of PSP data available for these species. While ingress was not modelled in MGM and PSP ingress data was not included in the validation, its presence influences long-term stand dynamics. Ingress can also contribute to stand volumes and stand structure over extended periods. In addition to these functional refinements, refinements to the code to enhance performance or to accommodate Windows updates, as well as development of a version of MGM that can be run independently from Excel are important to ongoing use of the model.

**Acknowledgements:**

The MGM Development Team would like to thank Ken Stadt and Katrina Froese from Alberta Agriculture and Forestry for graciously providing their compilation of the 2020 PGYI dataset. Their work assigning stand ages, calculating site index, solving tree volume, and estimating missing tree heights and diameters substantially helped this analysis. We would also like to thank the government and industrial partners that support the PGYI dataset. This validation would not be possible without the uniform, province-wide PSP data that is provided by this dataset.

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# Appendices

**Appendix A.** Scatterplots of predicted vs observed stand parameters (volume (m3), basal area (m2), dbh (cm), height (m), density (sph) and top height (m) for the conifer and deciduous components for the full PGYI dataset. Results are presented for: 1) the full dataset (ALL, pages 1-2), 2) broad cover group (pages 3-10), 3) species (pages 11-36) , and 4) by combination of broad cover group and species (Pages 37-84).

Broad Cover Groups:

C – Conifer

CD – Conifer Dominated Mixedwood

D - Deciduous

DC – Deciduous Dominated Mixedwood

Species:

AW – trembling aspen (*Populus tremuloides* Michx.)

BW – white birch (*Betula papyrifera* Marsh.)

FA – alpine fir (*Abies lasiocarpa* (Hook.) Nutt.)

FB – balsam fir (*Abies balsamea* (L.) Mill.)

FD – Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)

LT – tamarack (*Larix laricina* (Du Roi) K. Koch)

MX – tree mixture without a clear dominant species

PB – balsam poplar (*Populus balsamifera* L.)

PJ – jack pine (*Pinus banksiana* Lamb.)

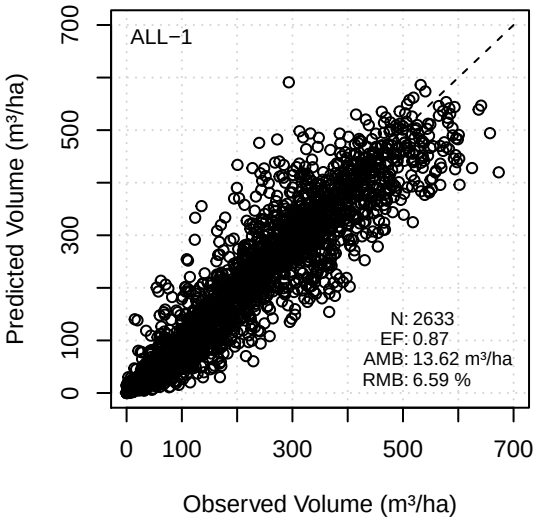
PL – lodgepole pine (*Pinus contorta* Loudon)

SB – black spruce (*Picea mariana* (Mill.) BSP.)

SE – Engelmann spruce (*Picea engelmannii* Parry ex Engelm.)

SW – white spruce (*Picea glauca* (Moench) Voss)

**Conifer Volume − ALL**

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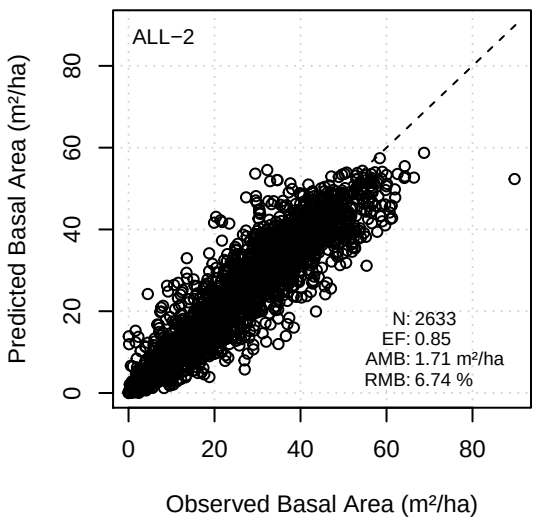


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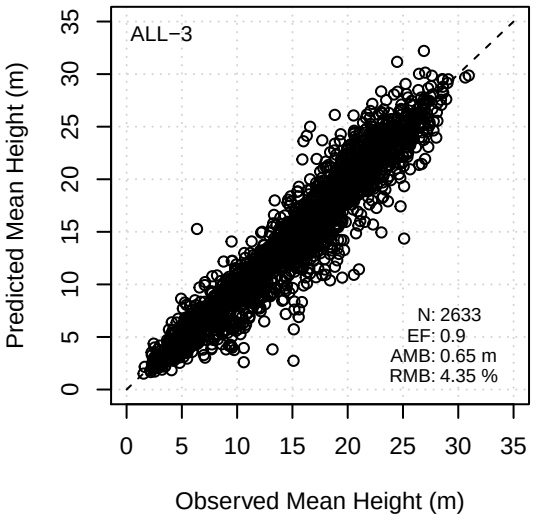


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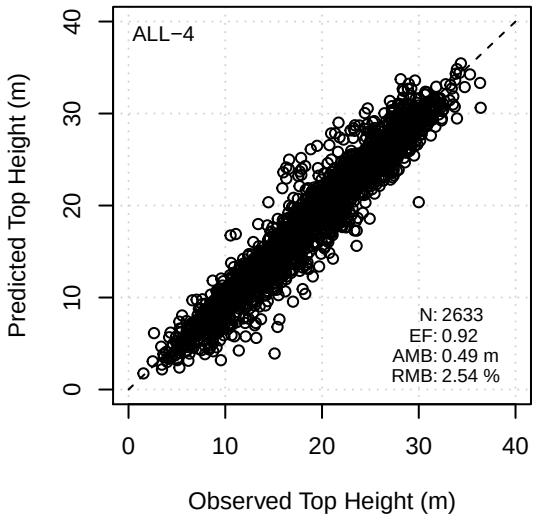


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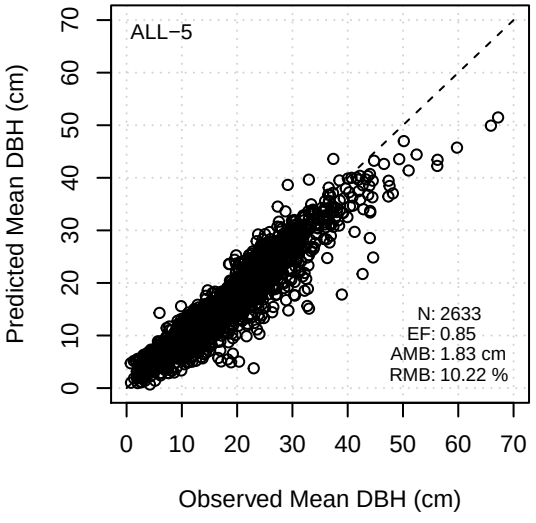
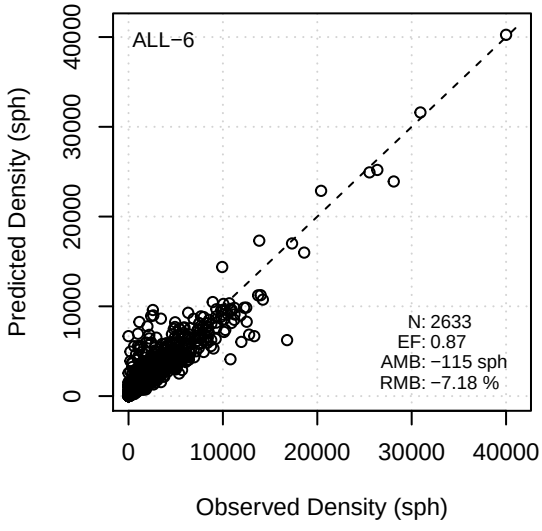
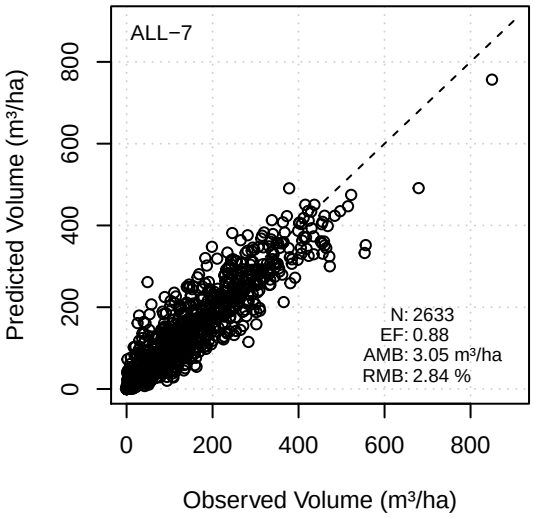



**Conifer Density − ALL**



**Deciduous Volume − ALL**

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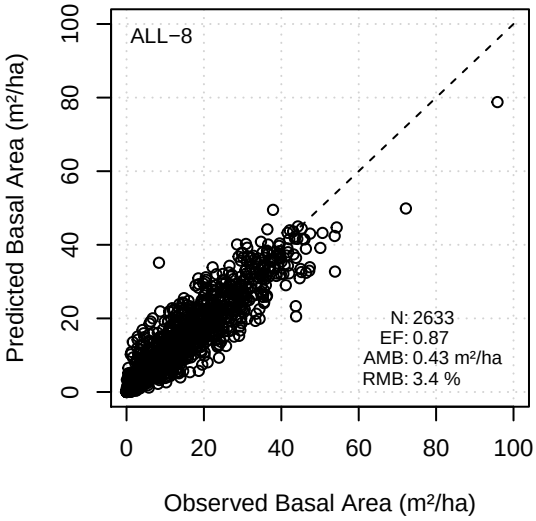


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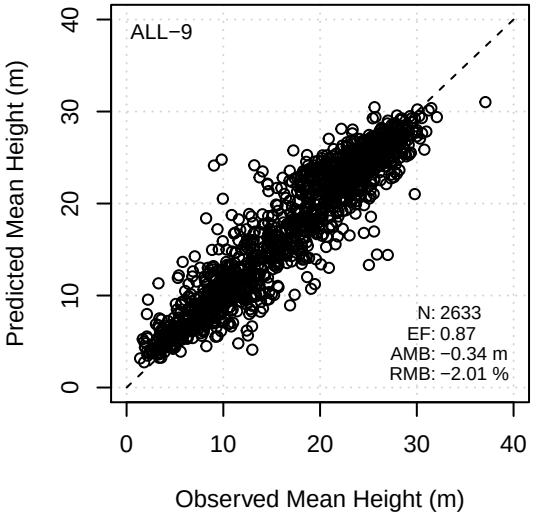


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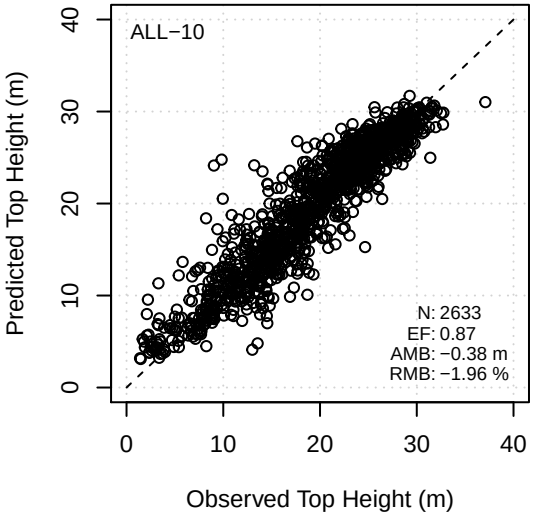


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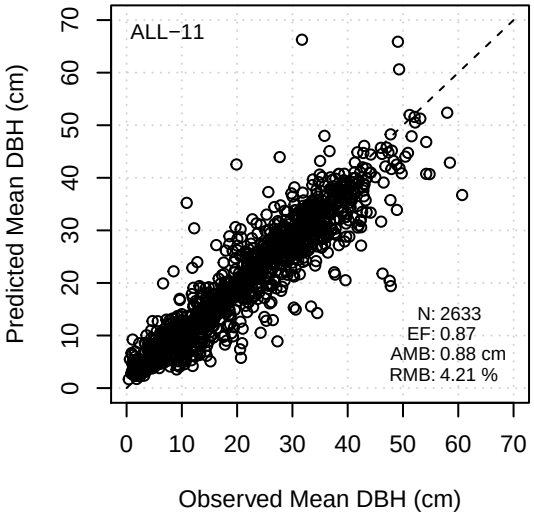


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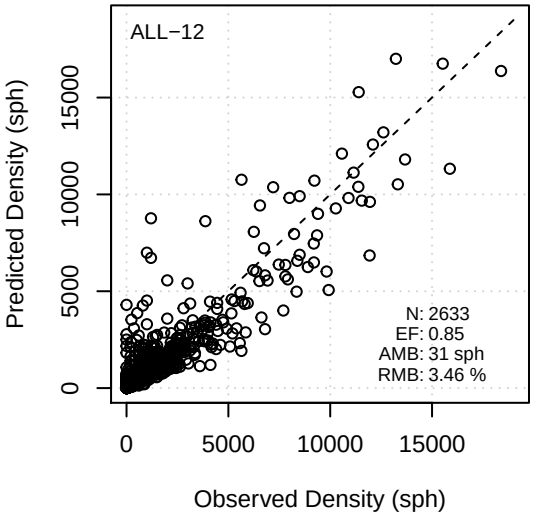

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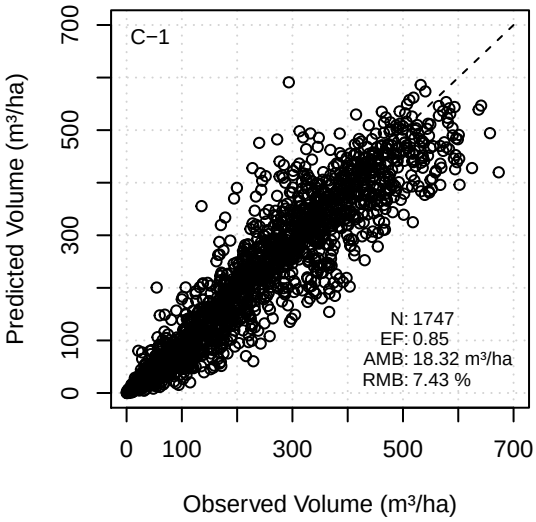


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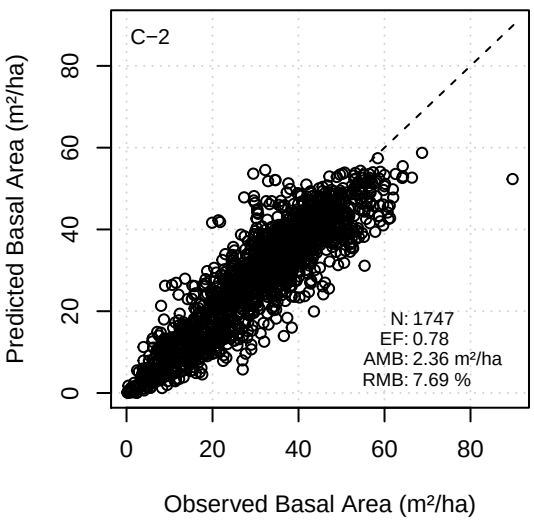


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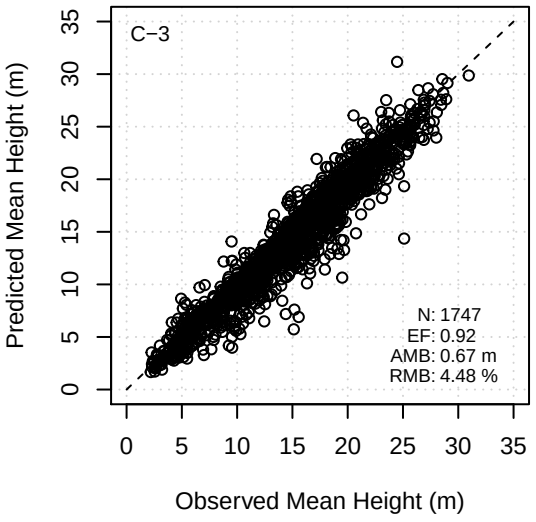


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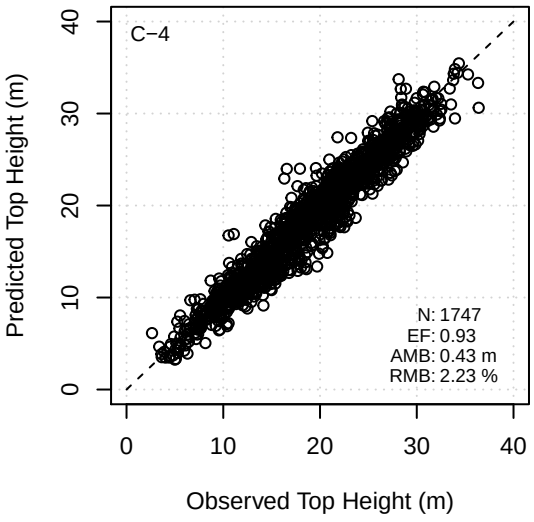


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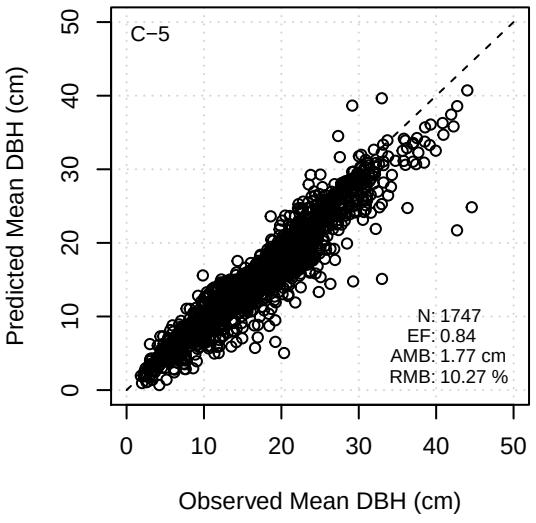


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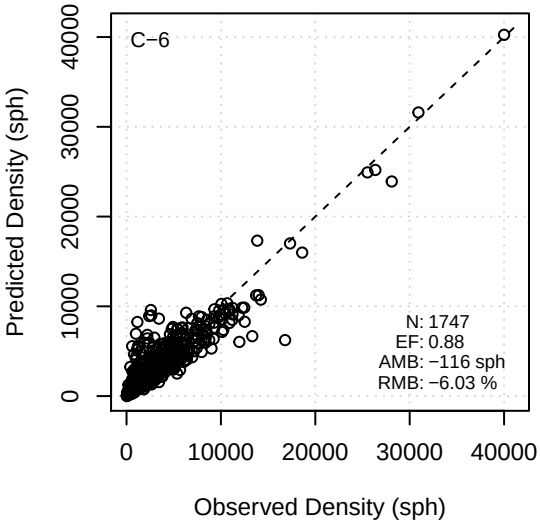

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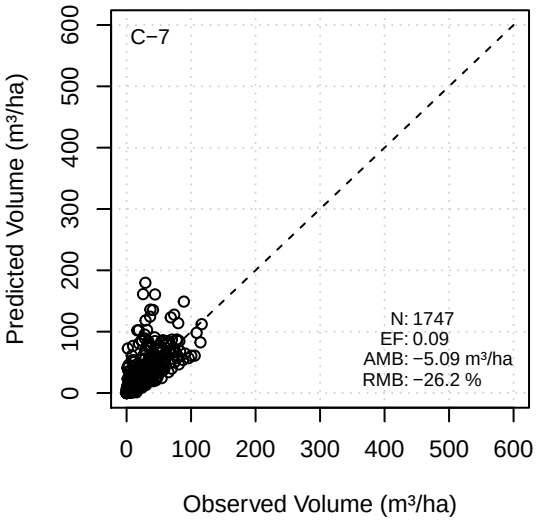


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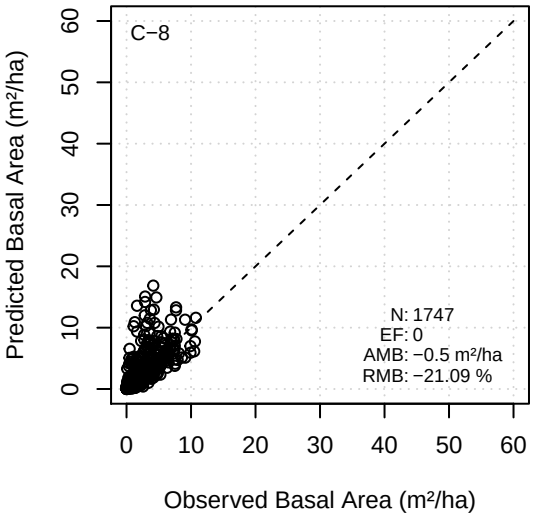


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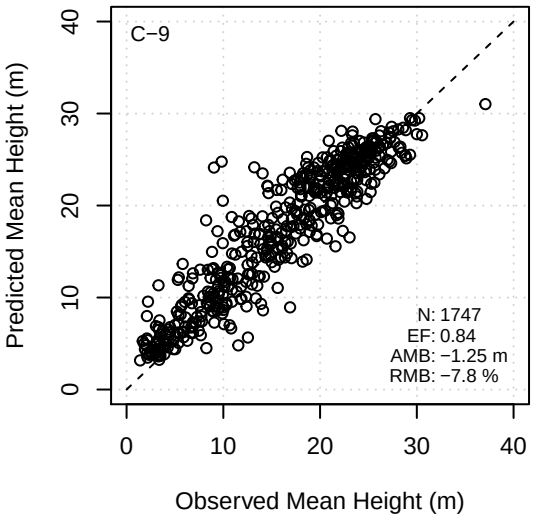


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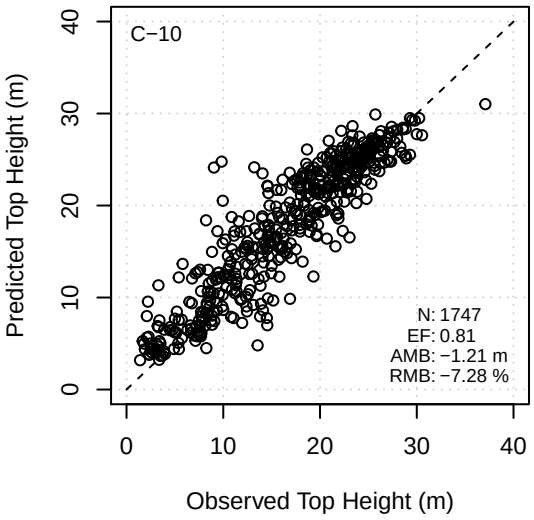


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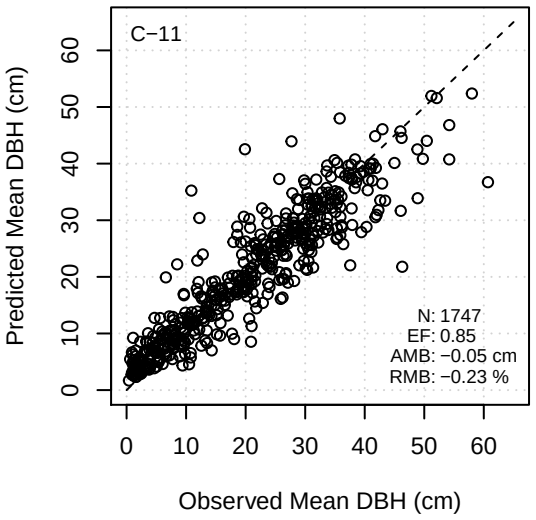


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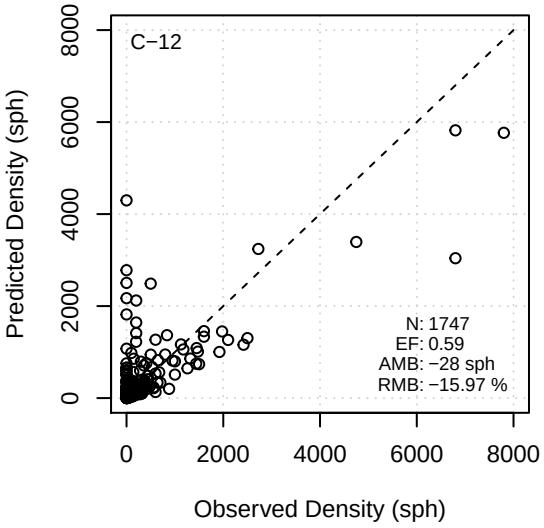

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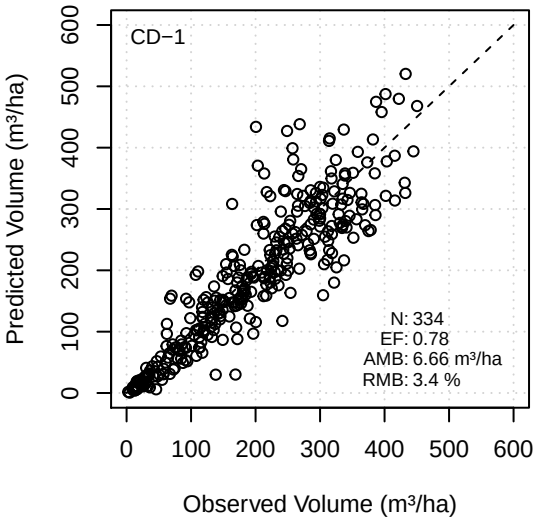


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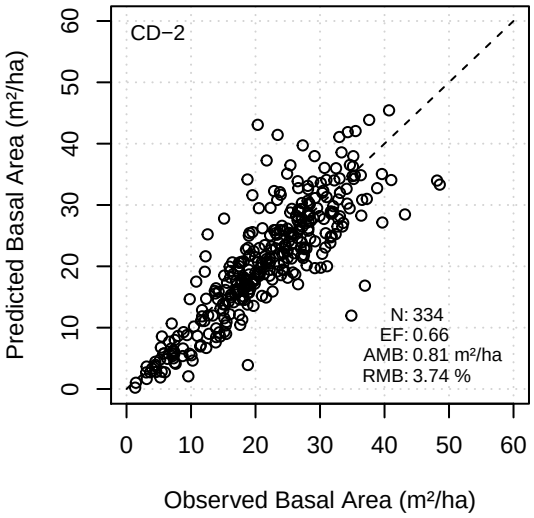


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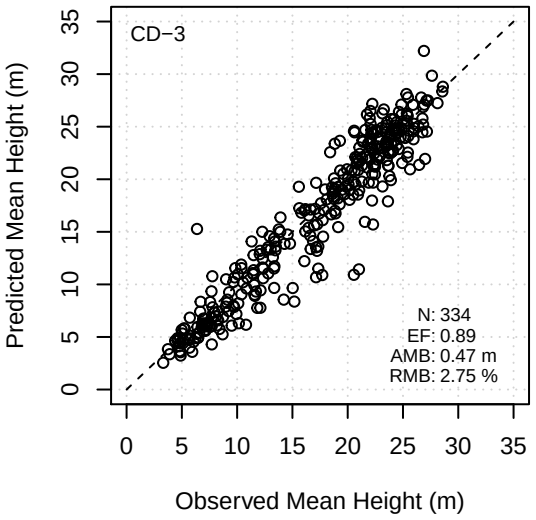


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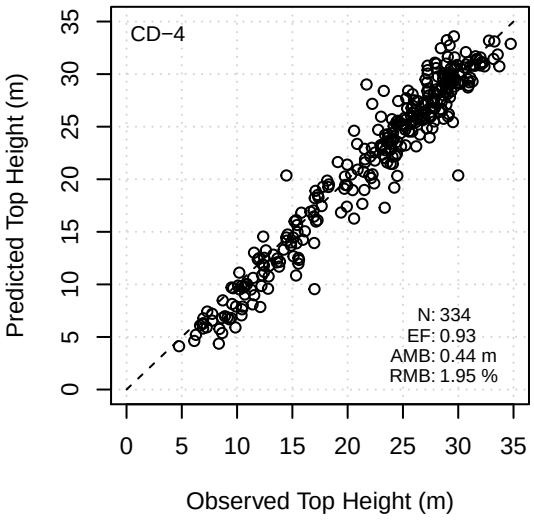


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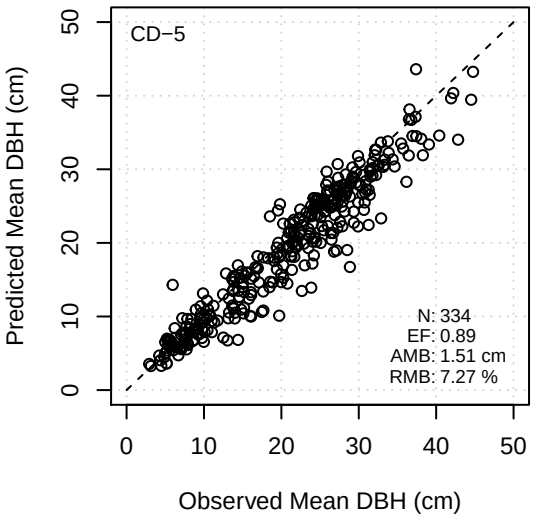


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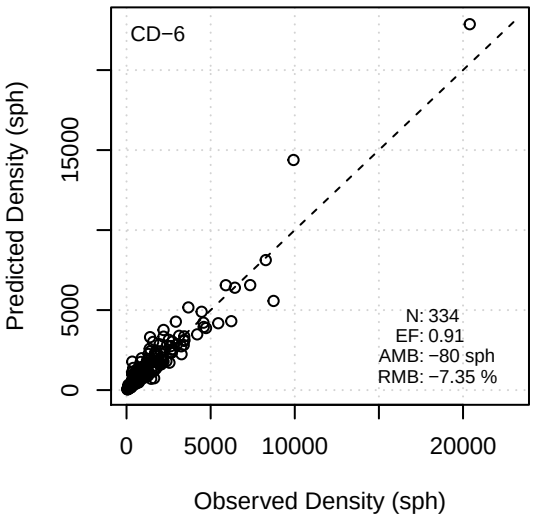

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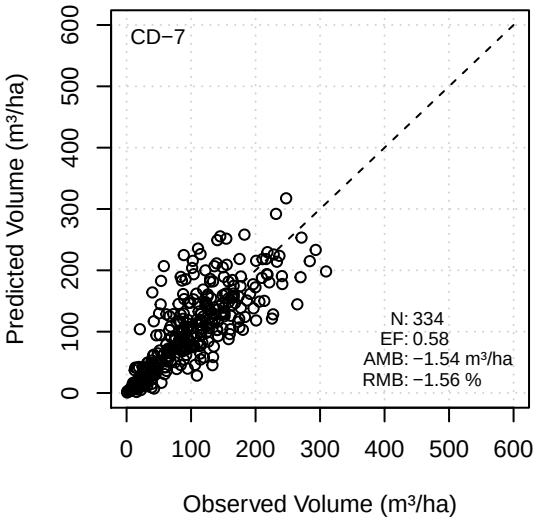


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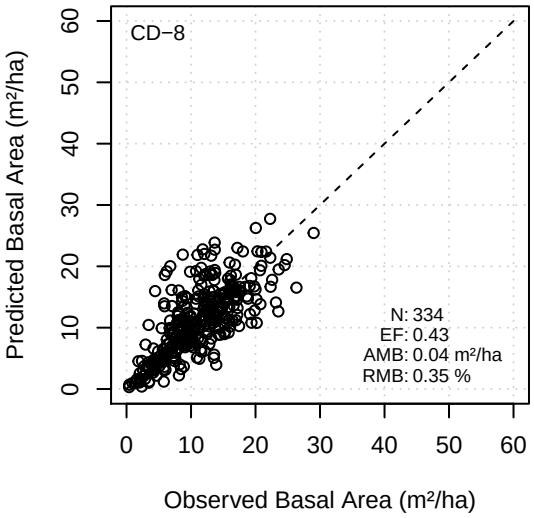


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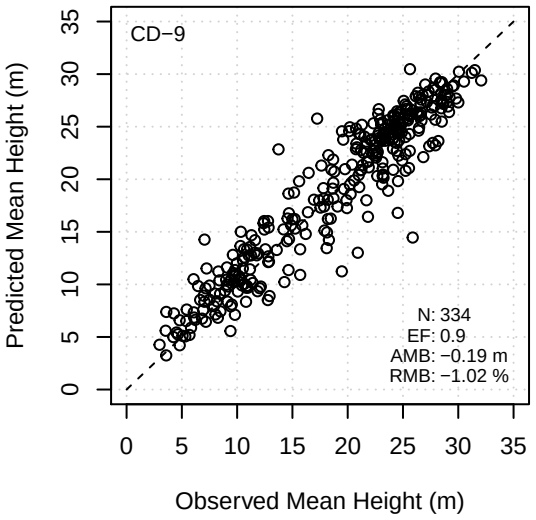


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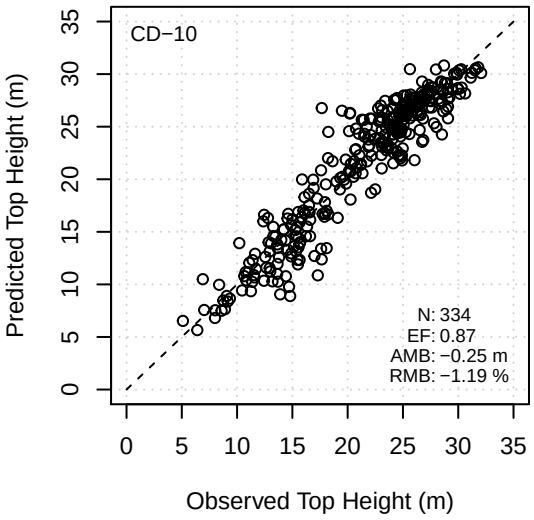


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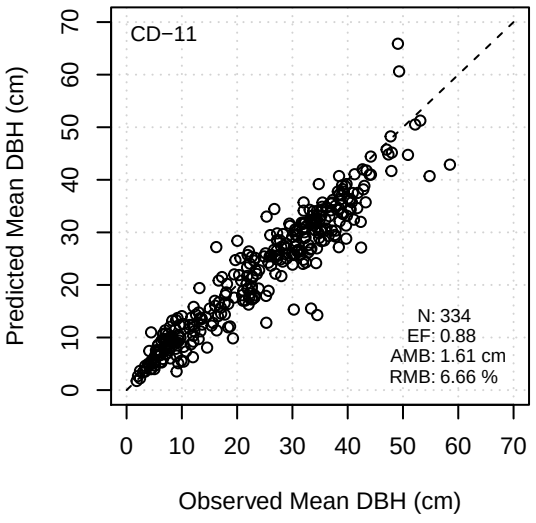


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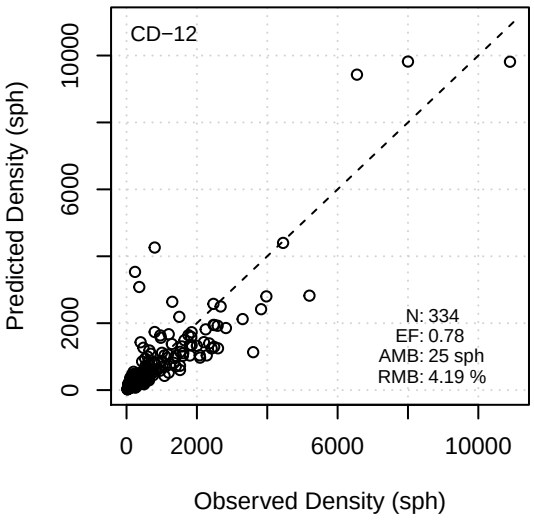

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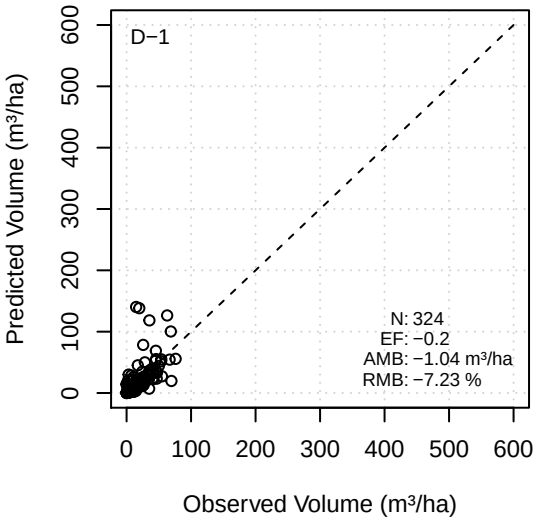
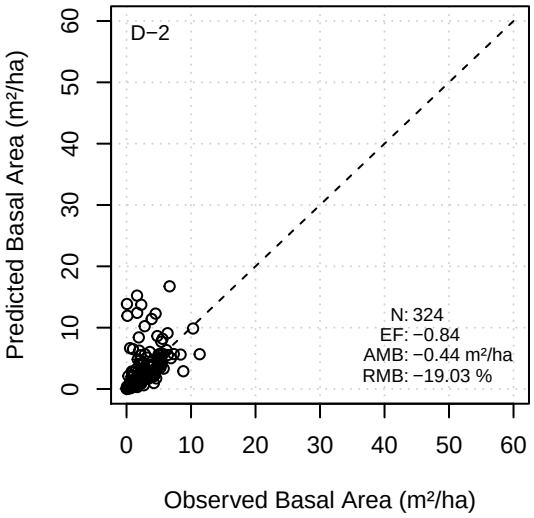
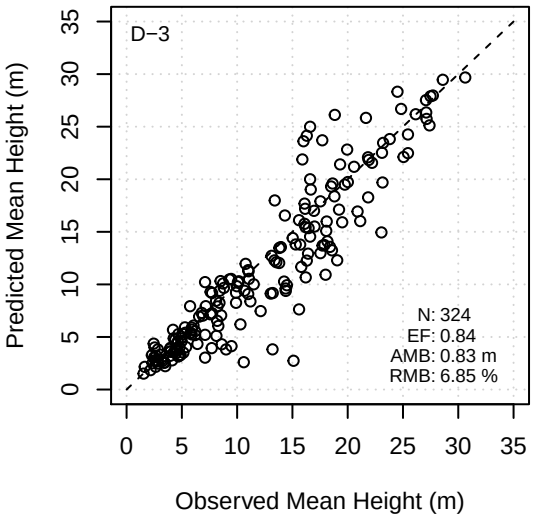


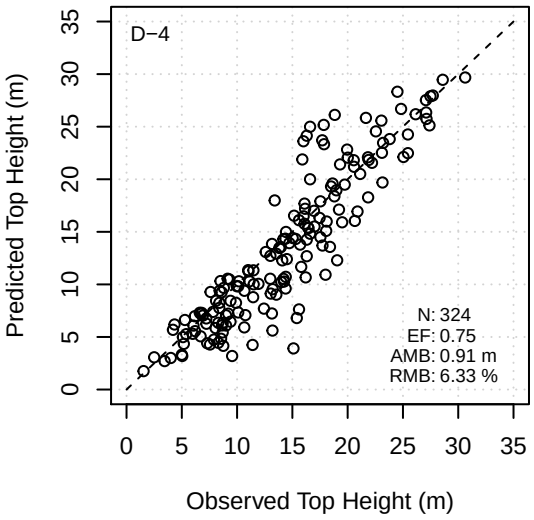

**Conifer Basal Area − D**



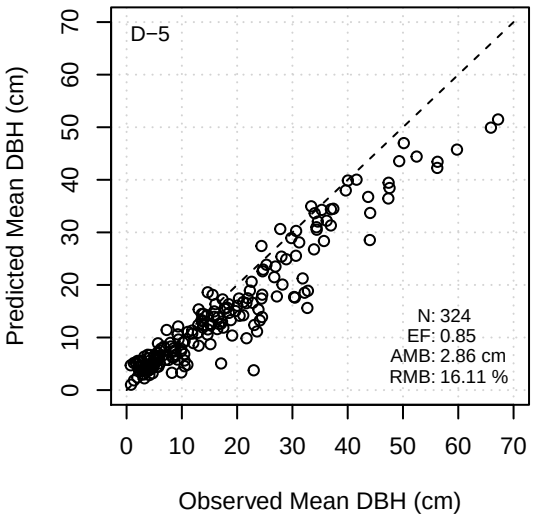

**Conifer Mean Height − D**



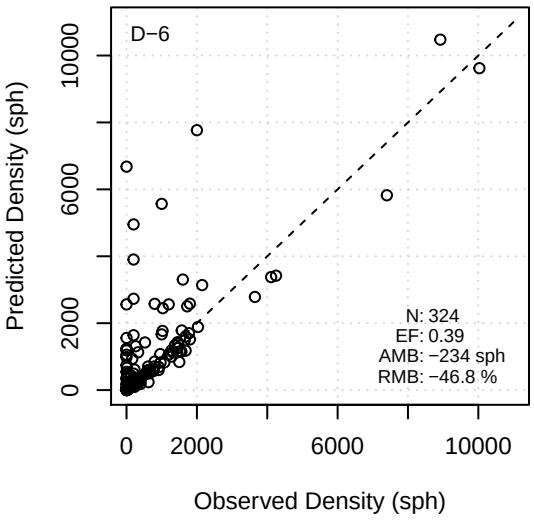

**Conifer Top Height − D**



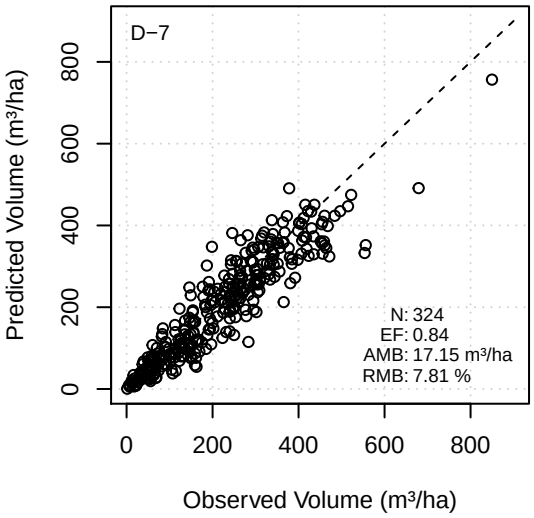

**Conifer Mean DBH − D**



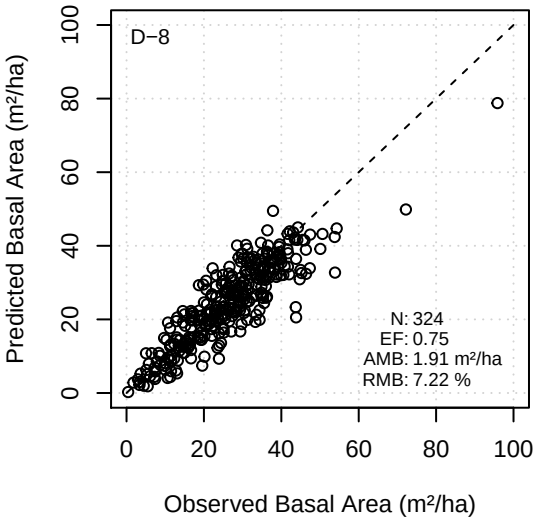

**Conifer Density − D**



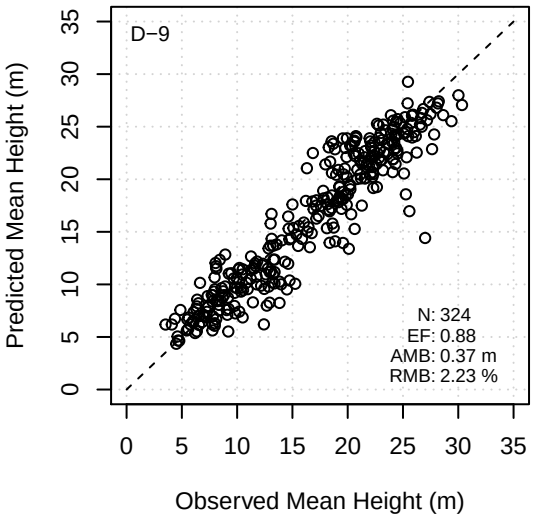
**Deciduous Volume − D**



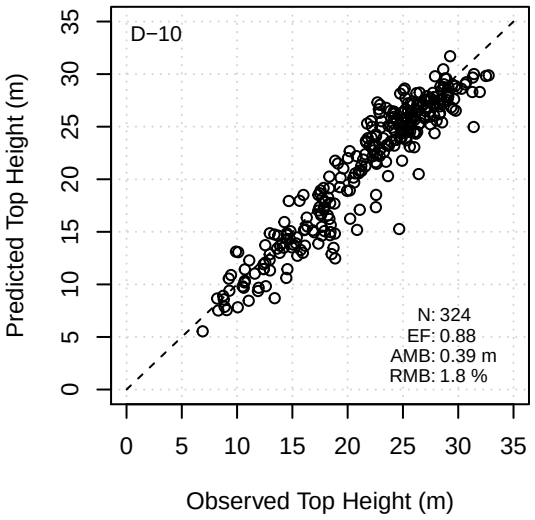

**Deciduous Basal Area − D**



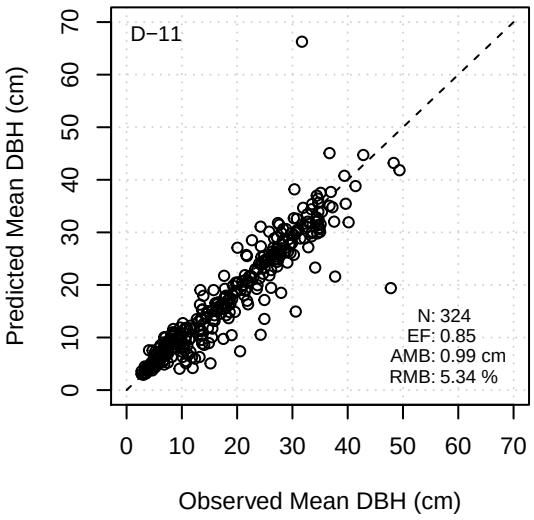

**Deciduous Mean Height − D**



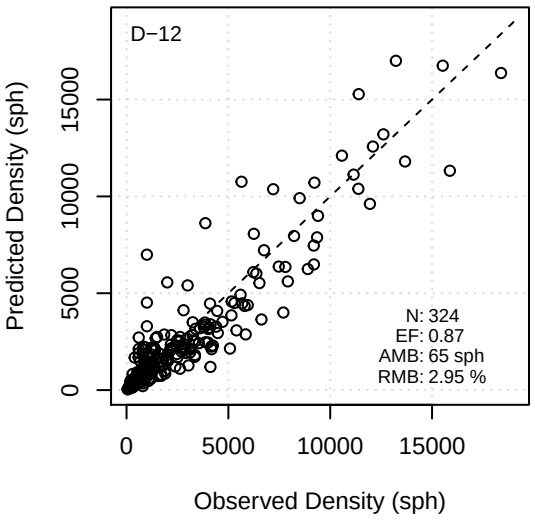

**Deciduous Top Height − D**



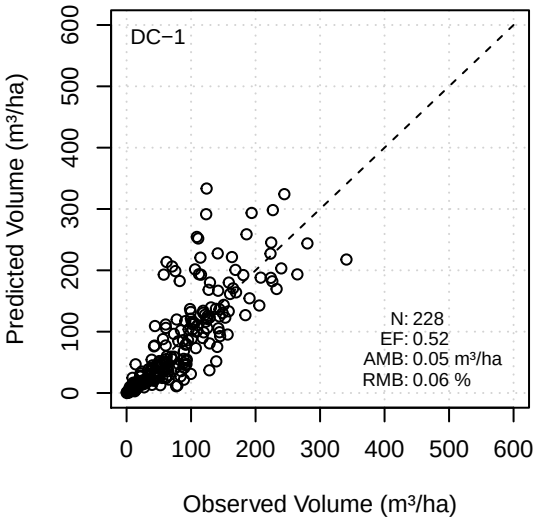

**Deciduous Mean DBH − D**



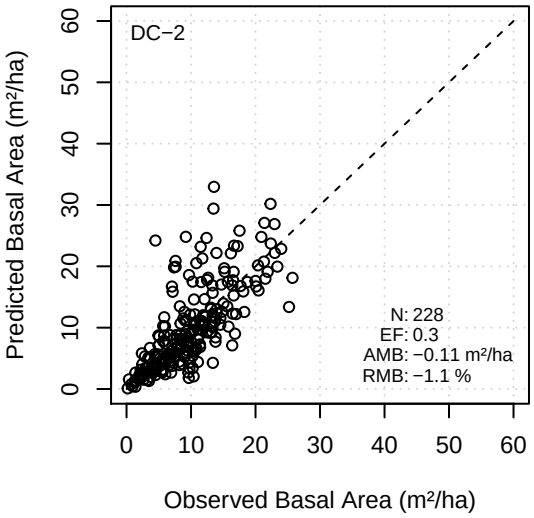

**Deciduous Density − D**



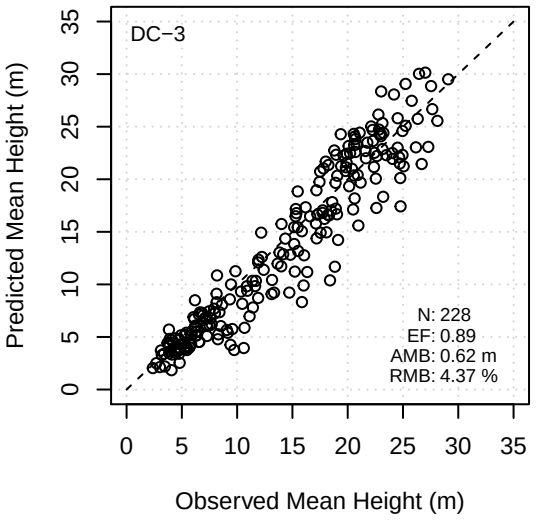
**Conifer Volume − DC**



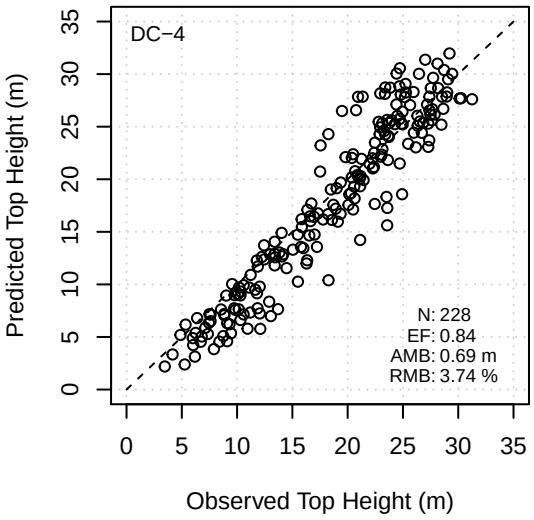

**Conifer Basal Area − DC**



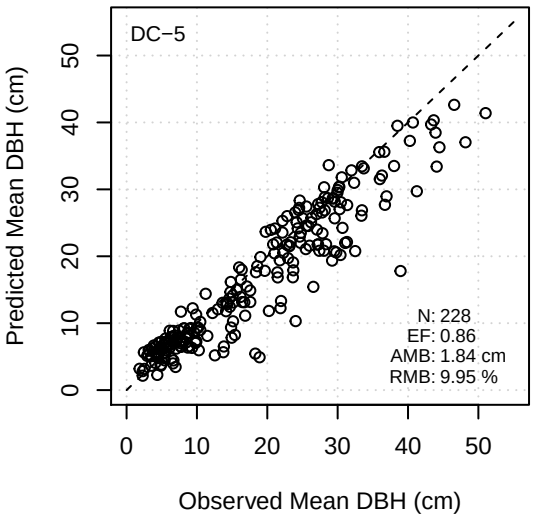

**Conifer Mean Height − DC**



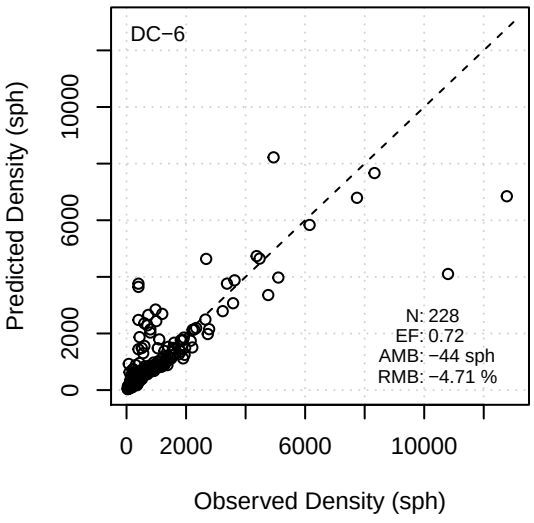

**Conifer Top Height − DC**



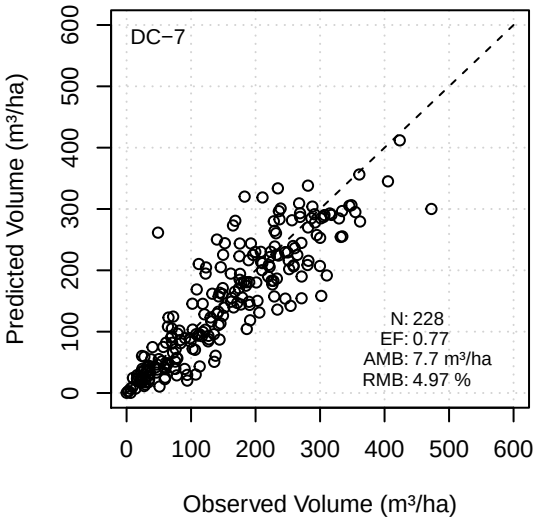

**Conifer Mean DBH − DC**



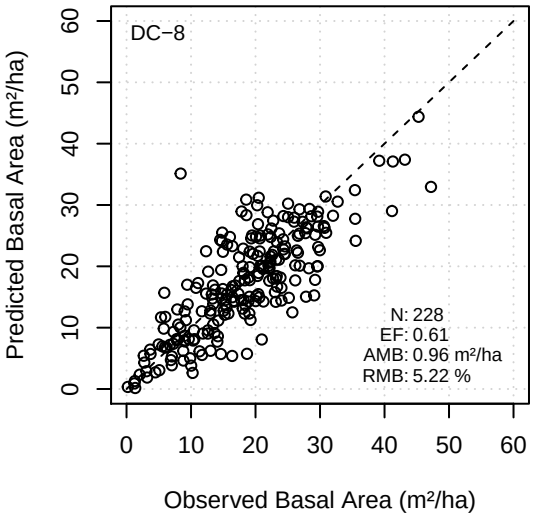

**Conifer Density − DC**



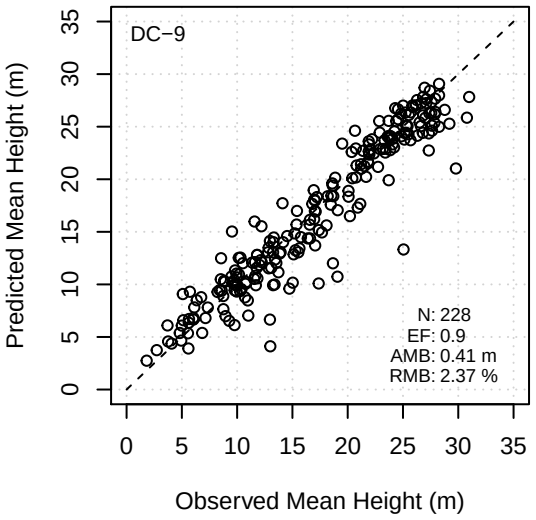
**Deciduous Volume − DC**



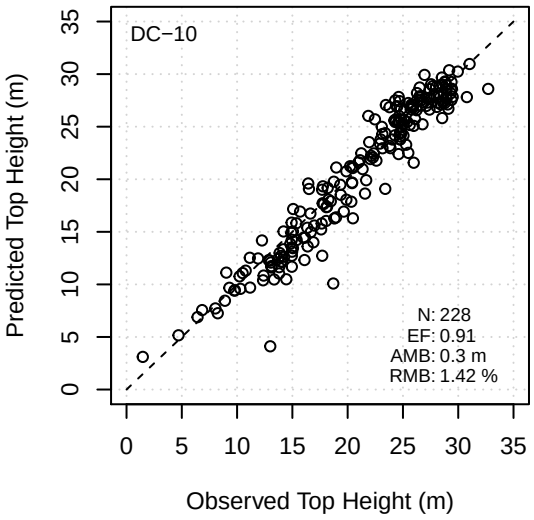

**Deciduous Basal Area − DC**



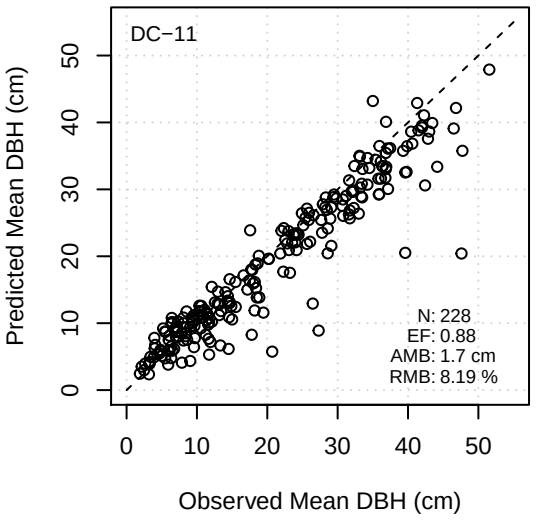

**Deciduous Mean Height − DC**



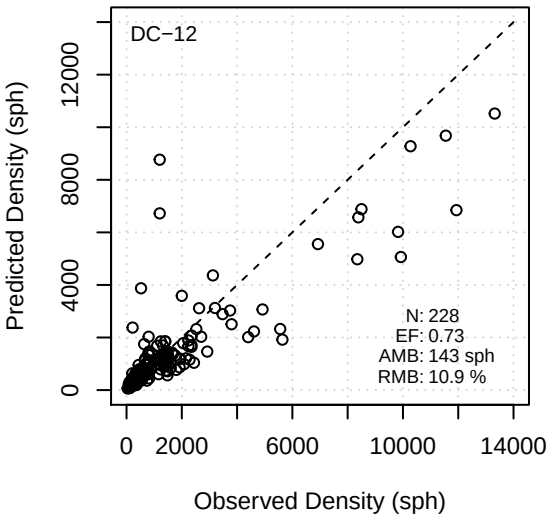

**Deciduous Top Height − DC**



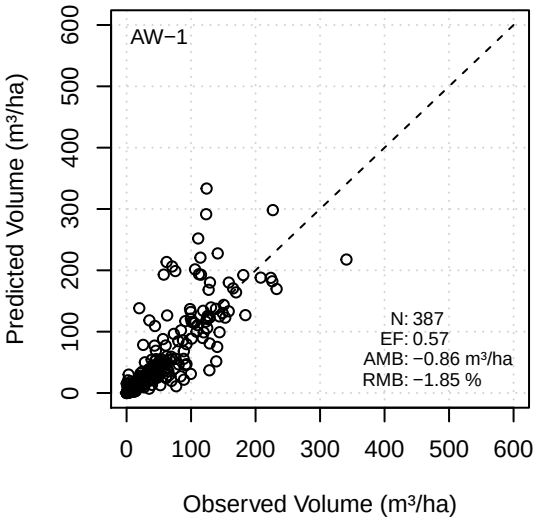

**Deciduous Mean DBH − DC**



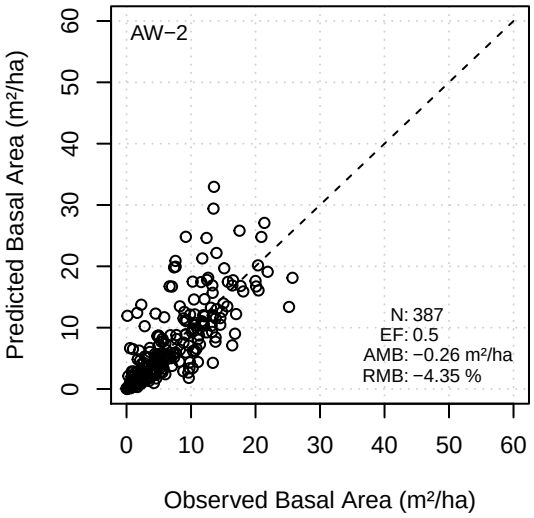

**Deciduous Density − DC**



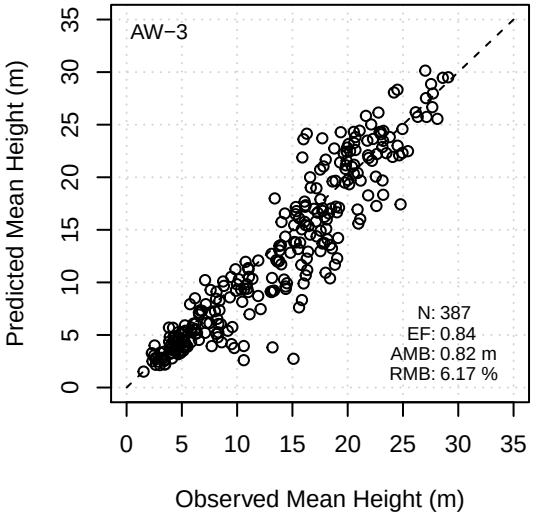
**Conifer Volume − AW**



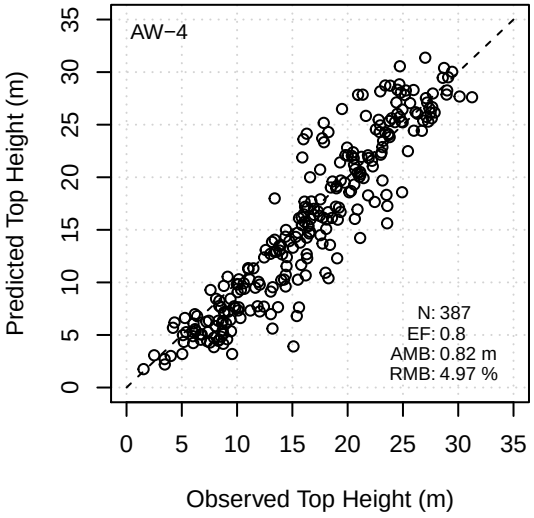

**Conifer Basal Area − AW**



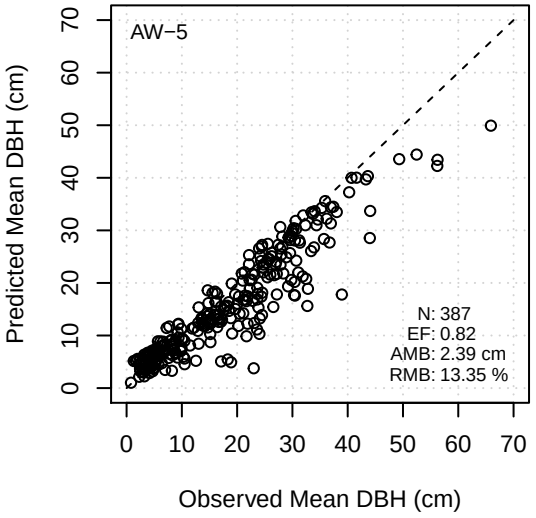

**Conifer Mean Height − AW**



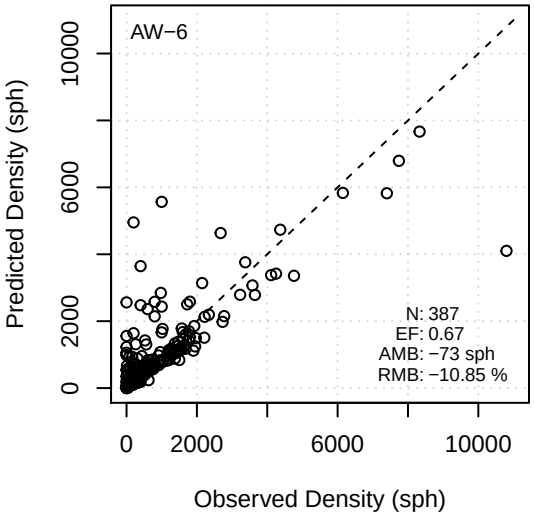

**Conifer Top Height − AW**



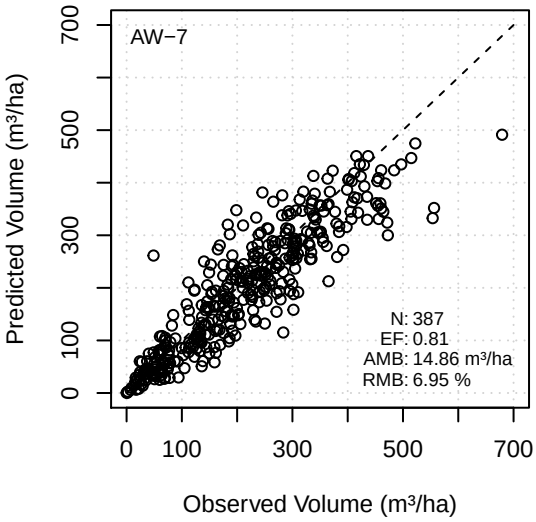

**Conifer Mean DBH − AW**



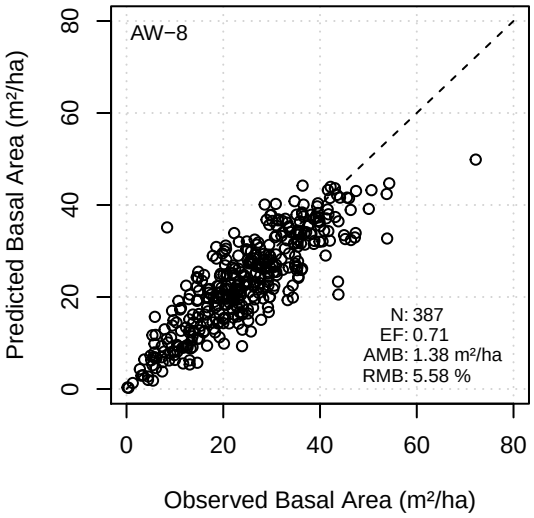

**Conifer Density − AW**



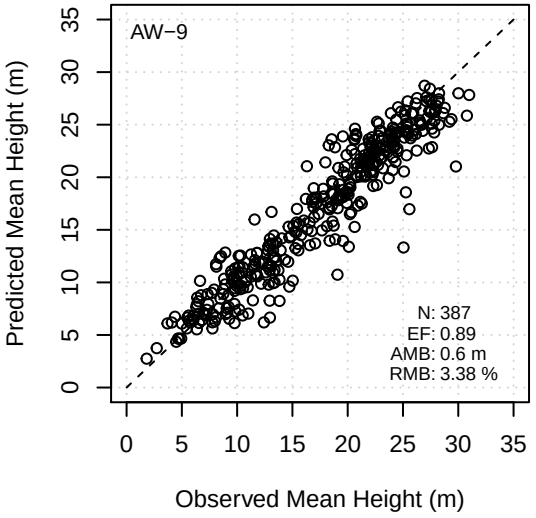
**Deciduous Volume − AW**



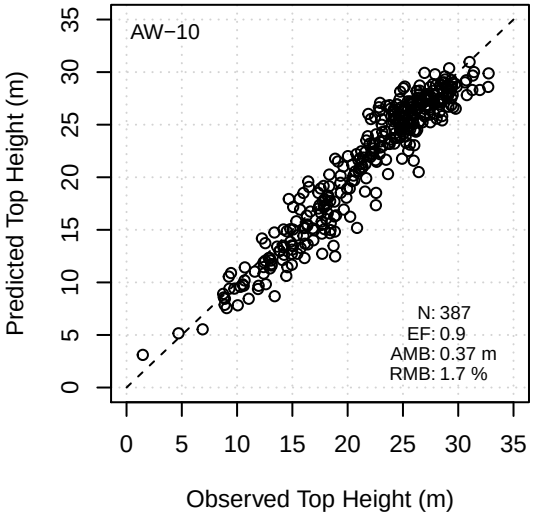

**Deciduous Basal Area − AW**



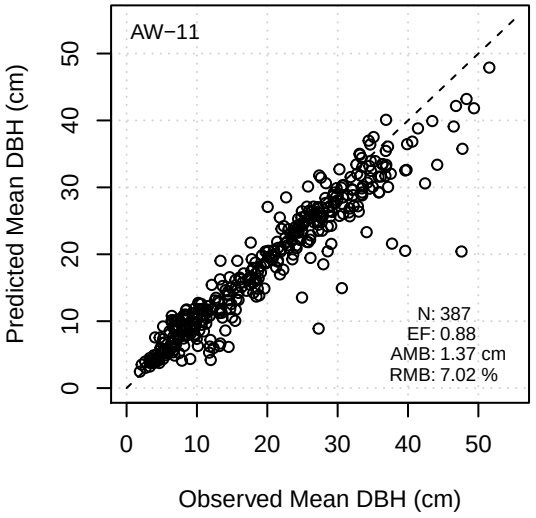

**Deciduous Mean Height − AW**



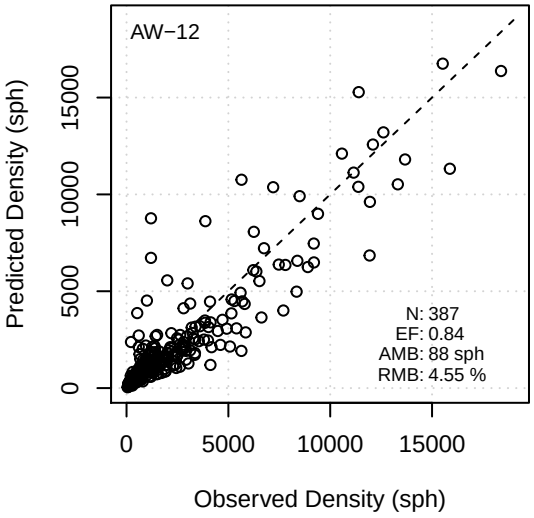

**Deciduous Top Height − AW**



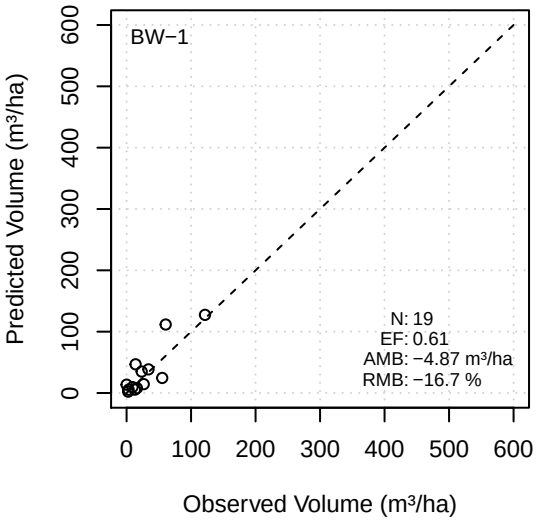

**Deciduous Mean DBH − AW**



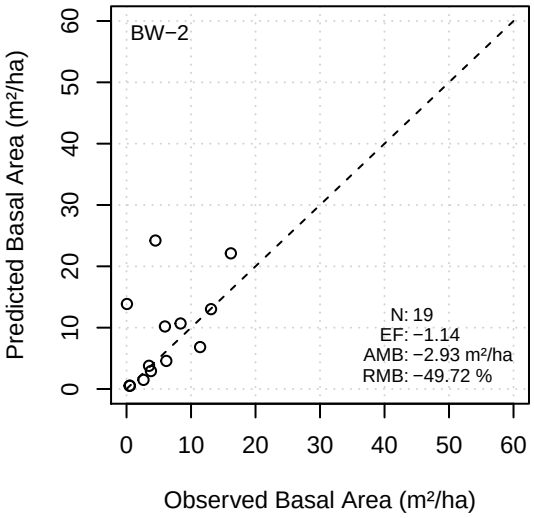

**Deciduous Density − AW**



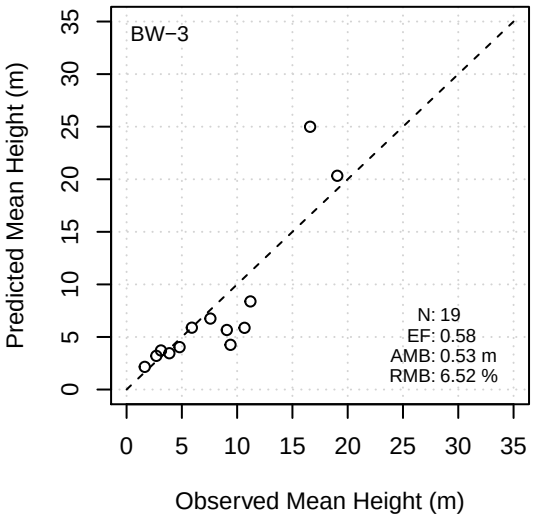
**Conifer Volume − BW**



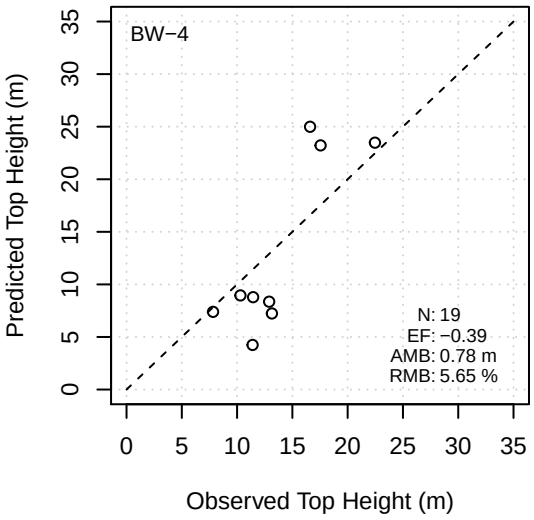

**Conifer Basal Area − BW**



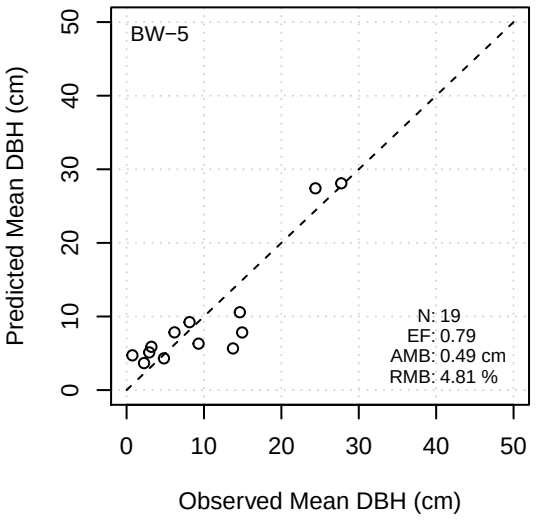

**Conifer Mean Height − BW**



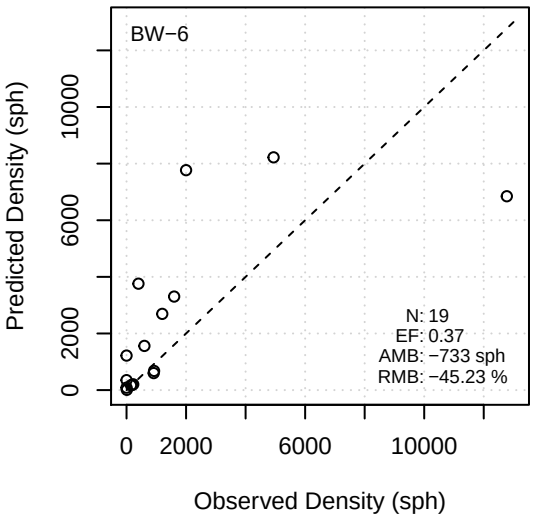

**Conifer Top Height − BW**



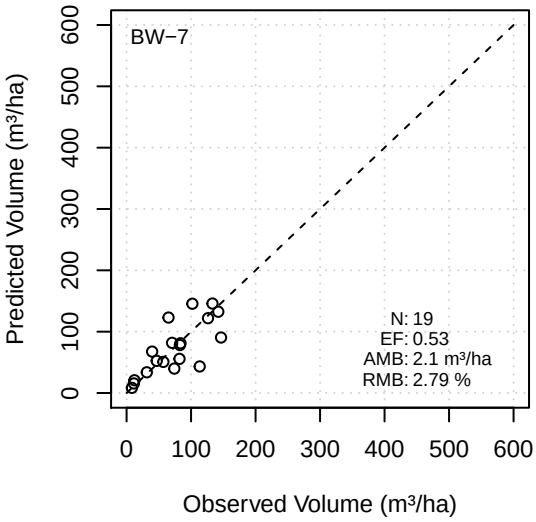

**Conifer Mean DBH − BW**



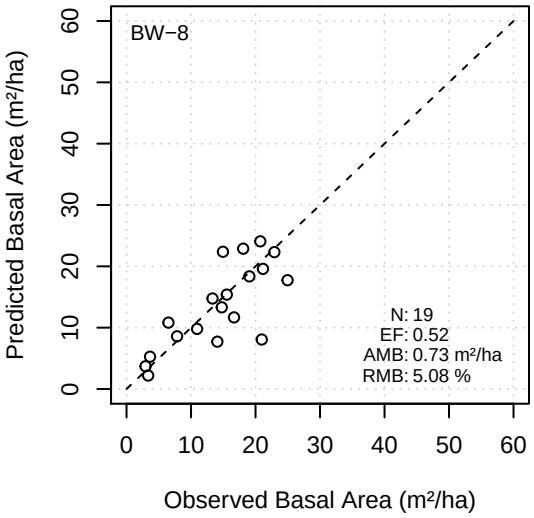

**Conifer Density − BW**



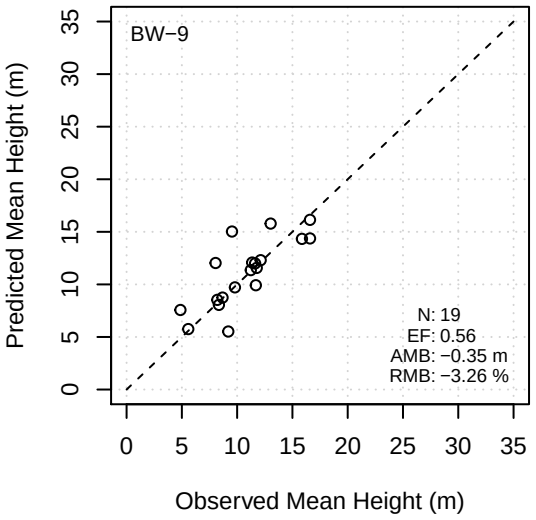
**Deciduous Volume − BW**



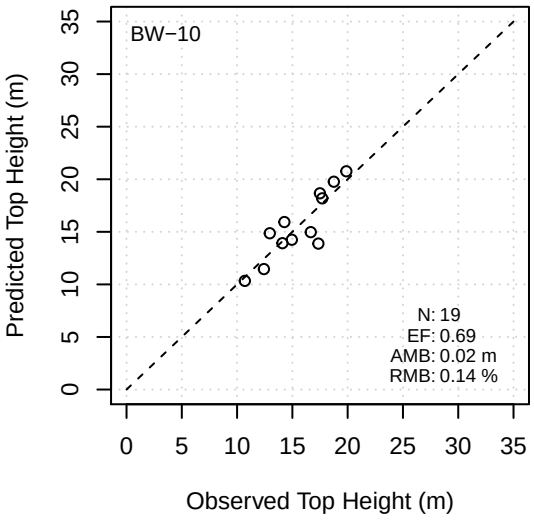

**Deciduous Basal Area − BW**



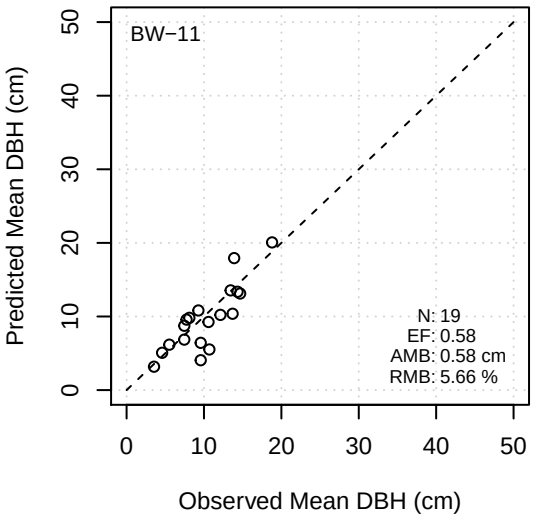

**Deciduous Mean Height − BW**



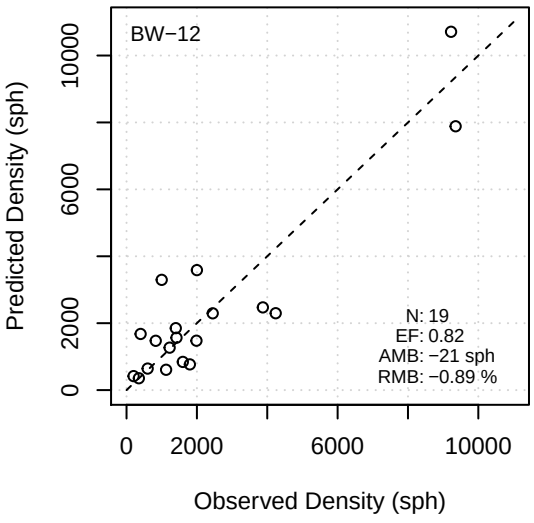

**Deciduous Top Height − BW**



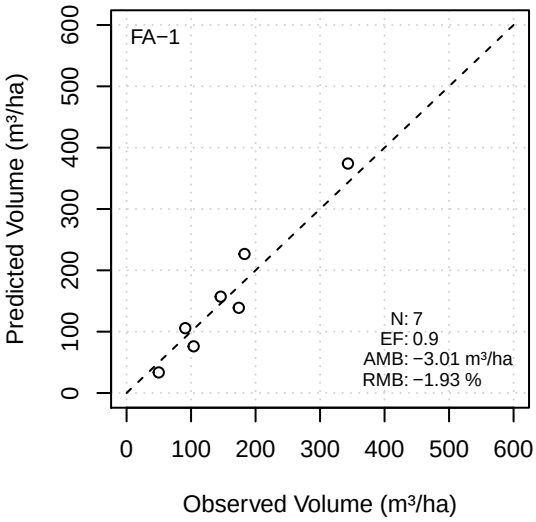

**Deciduous Mean DBH − BW**



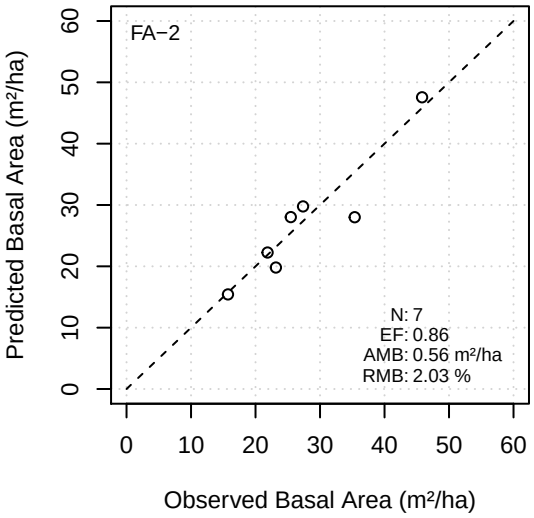

**Deciduous Density − BW**



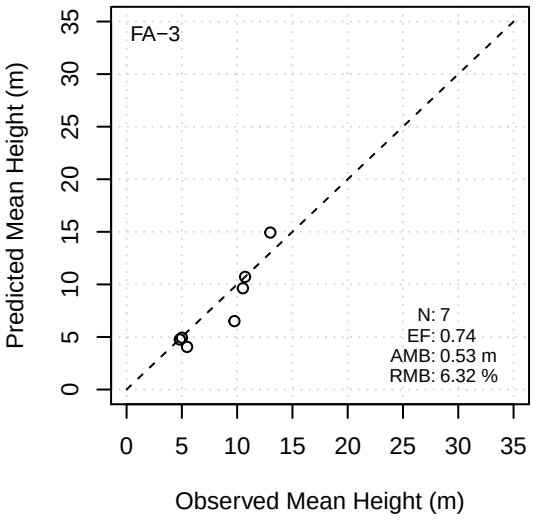
**Conifer Volume − FA**



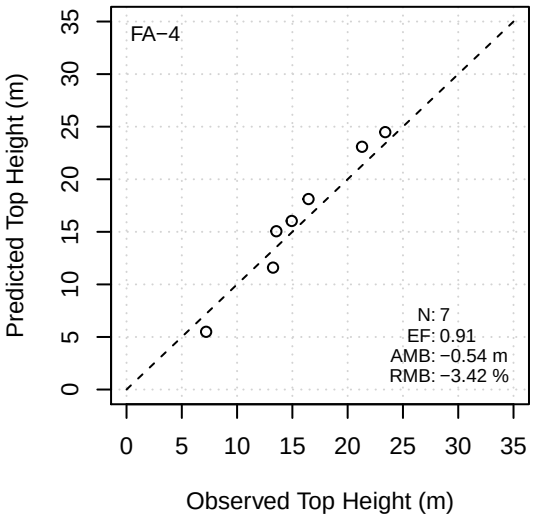

**Conifer Basal Area − FA**



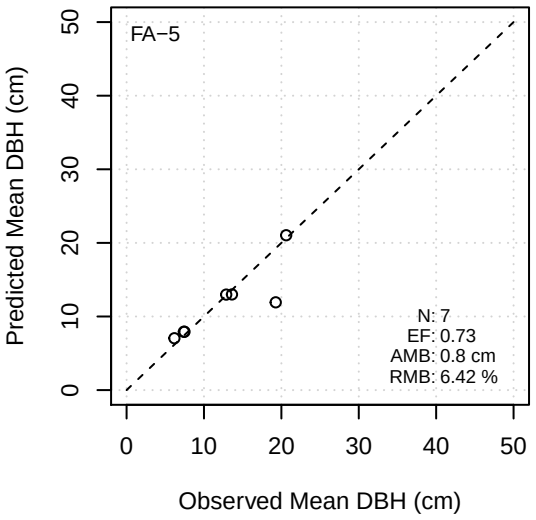

**Conifer Mean Height − FA**



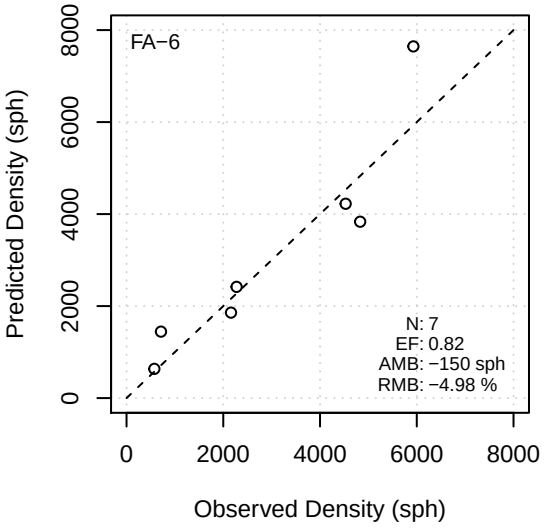

**Conifer Top Height − FA**



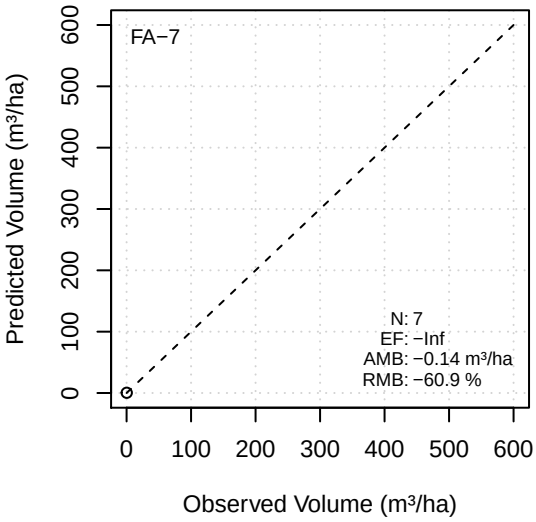

**Conifer Mean DBH − FA**



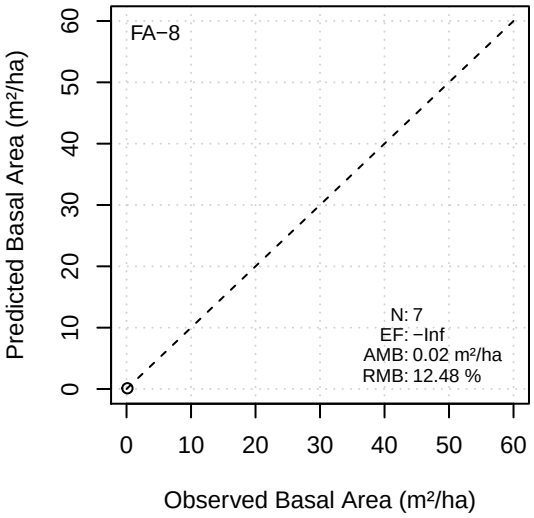

**Conifer Density − FA**



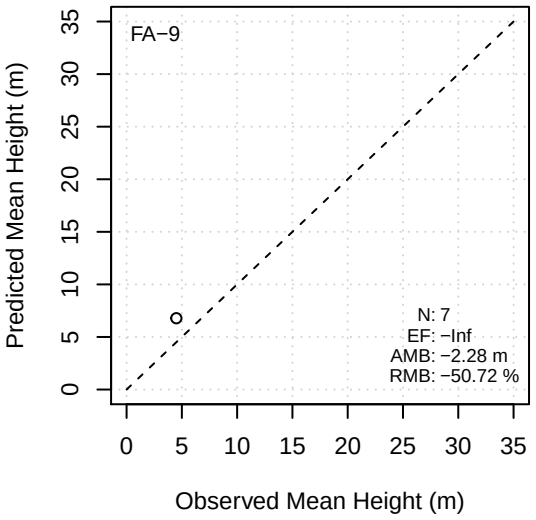
**Deciduous Volume − FA**



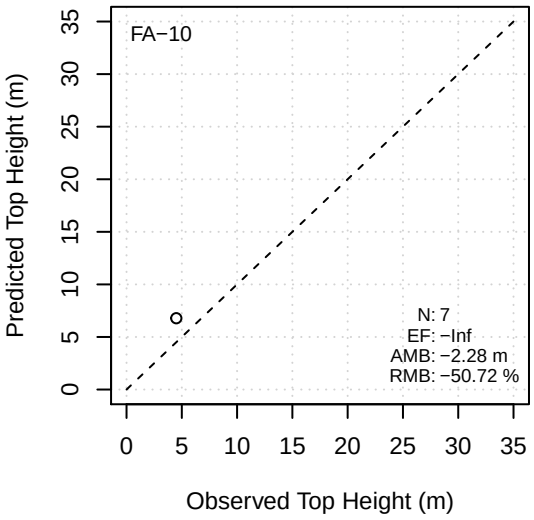

**Deciduous Basal Area − FA**



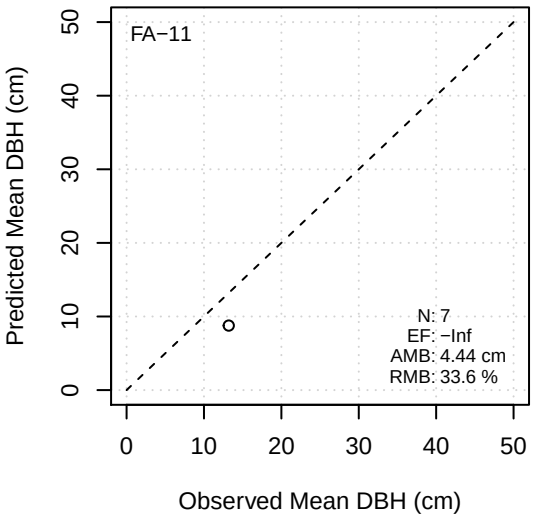

**Deciduous Mean Height − FA**



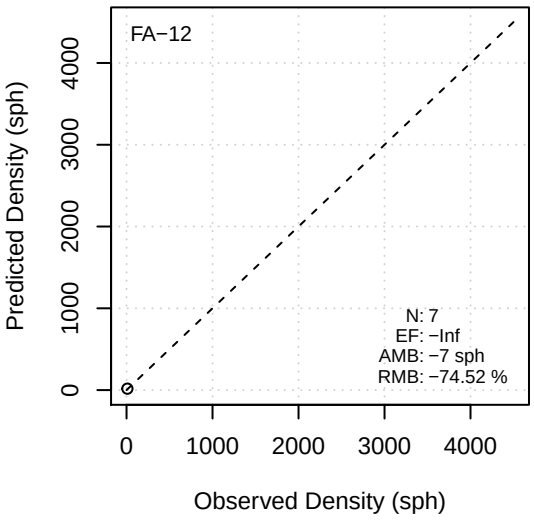

**Deciduous Top Height − FA**



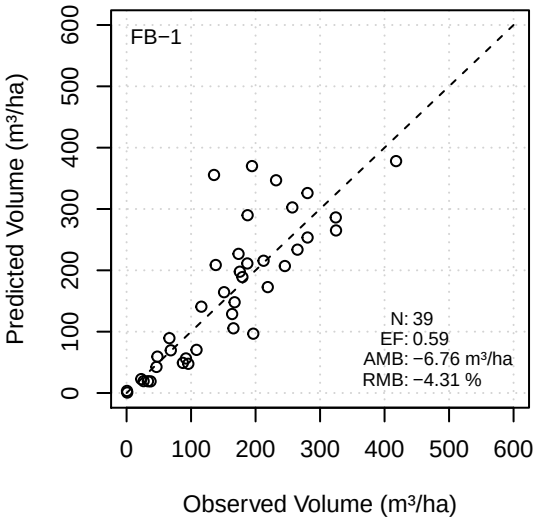

**Deciduous Mean DBH − FA**



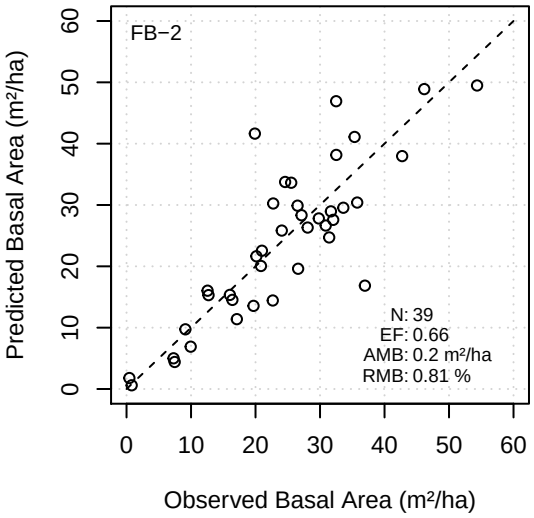

**Deciduous Density − FA**



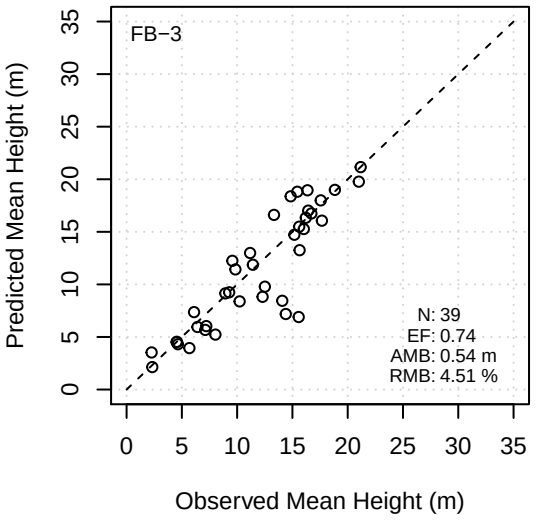
**Conifer Volume − FB**



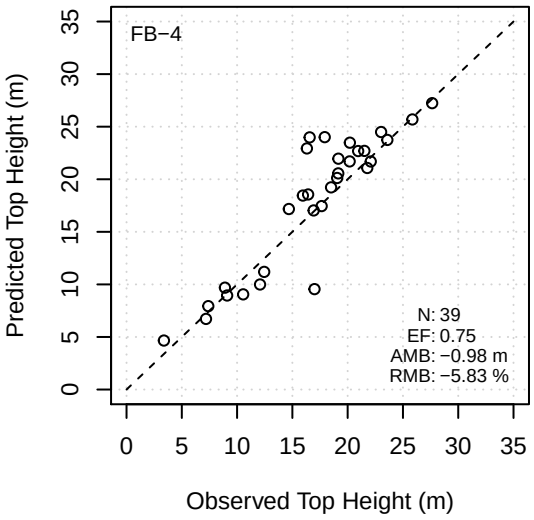

**Conifer Basal Area − FB**



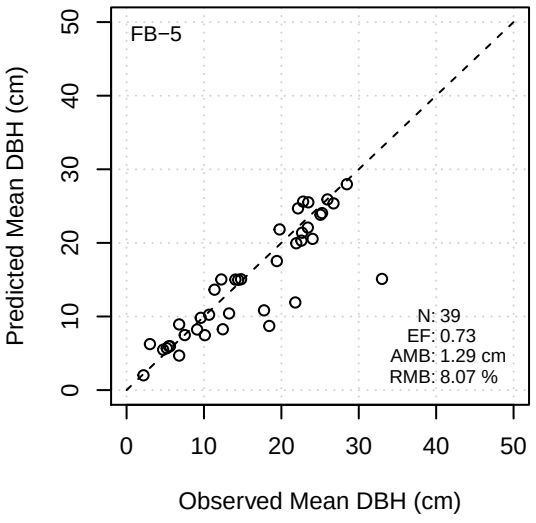

**Conifer Mean Height − FB**



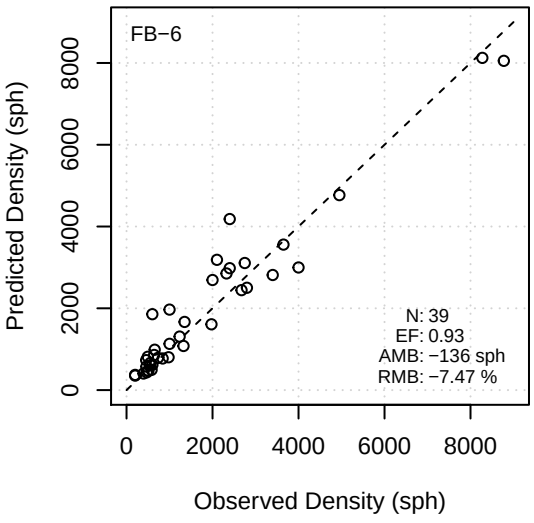

**Conifer Top Height − FB**



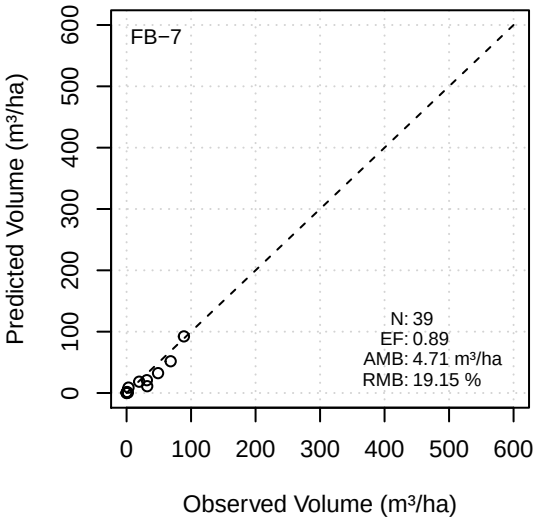

**Conifer Mean DBH − FB**



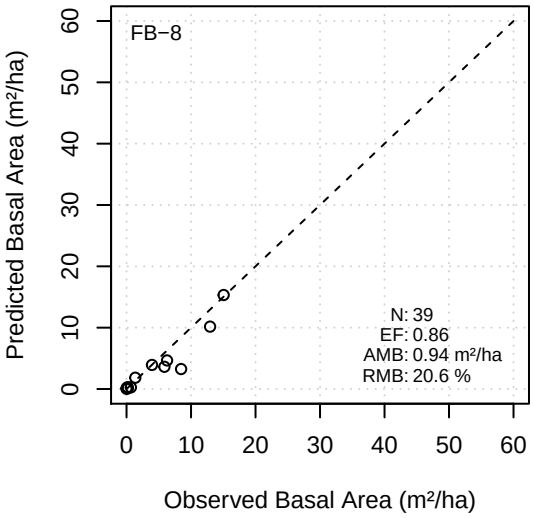

**Conifer Density − FB**



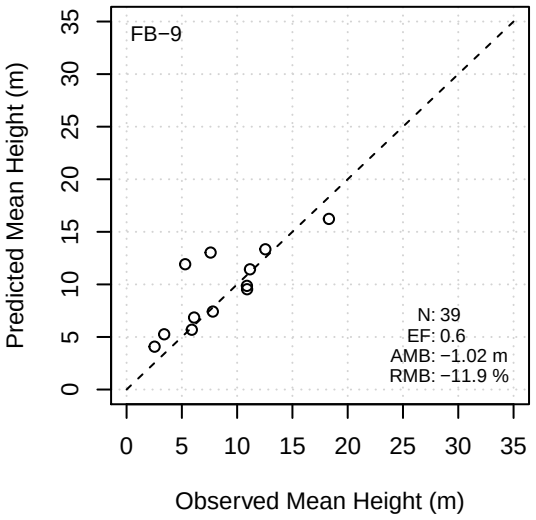
**Deciduous Volume − FB**



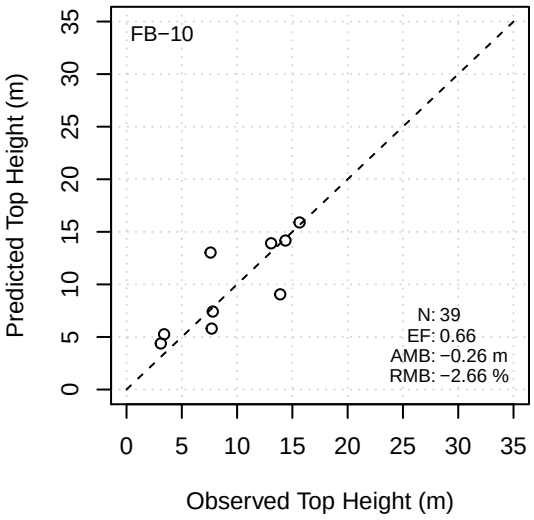

**Deciduous Basal Area − FB**



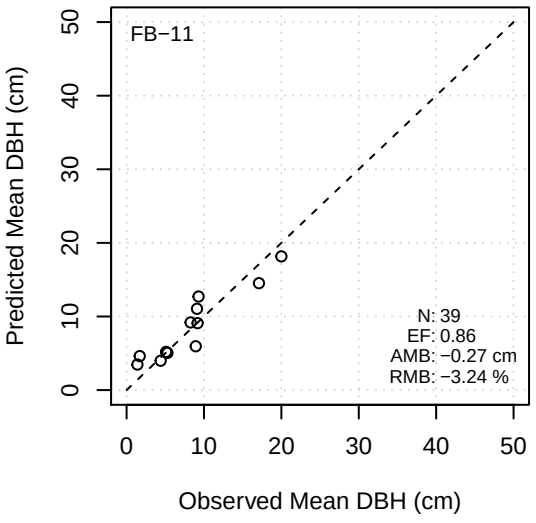

**Deciduous Mean Height − FB**



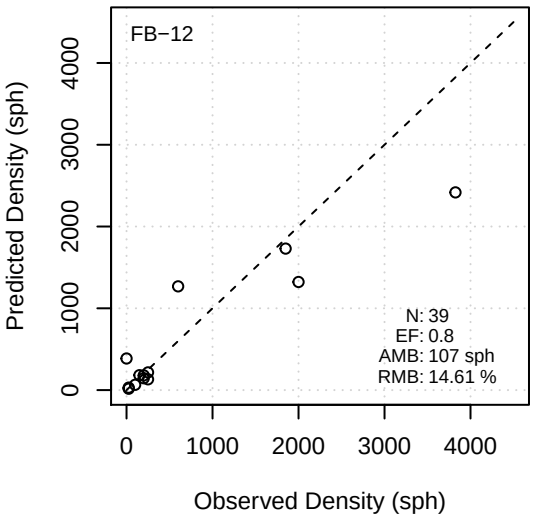

**Deciduous Top Height − FB**



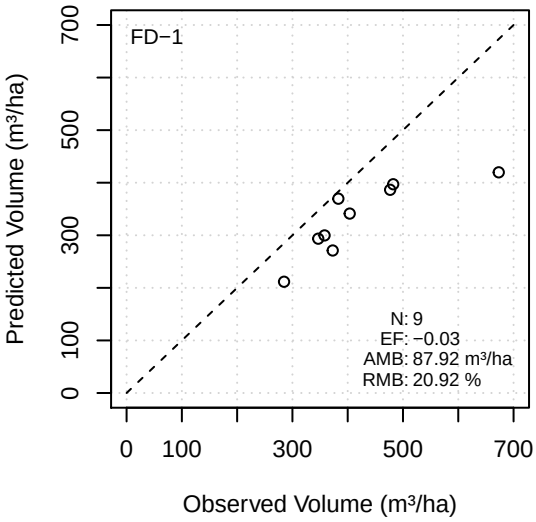

**Deciduous Mean DBH − FB**



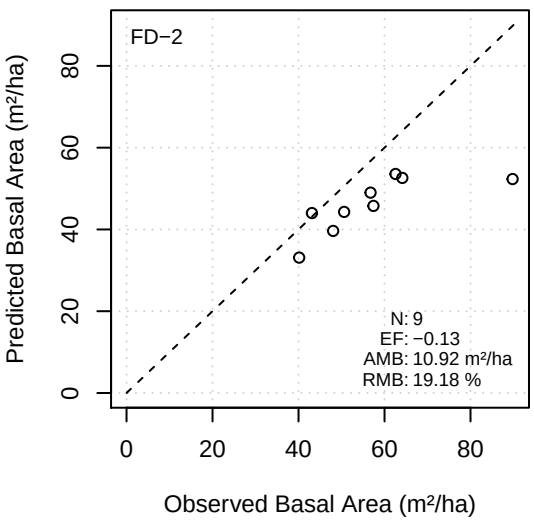

**Deciduous Density − FB**



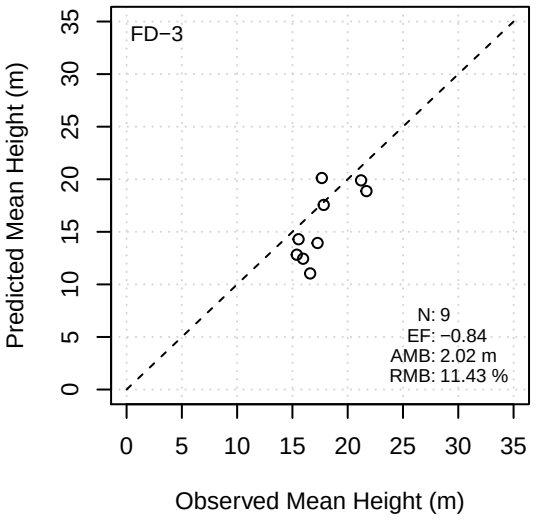
**Conifer Volume − FD**



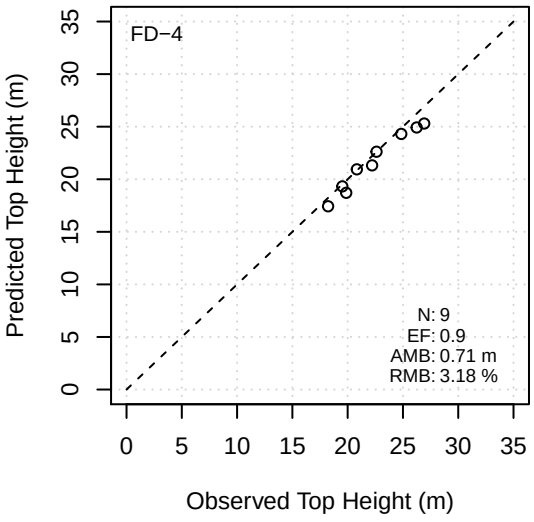

**Conifer Basal Area − FD**



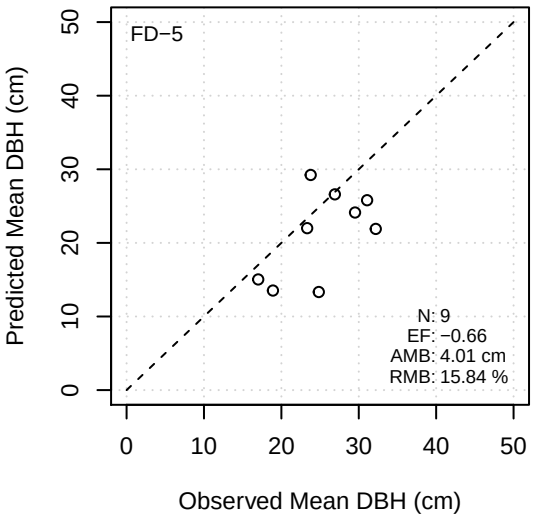

**Conifer Mean Height − FD**



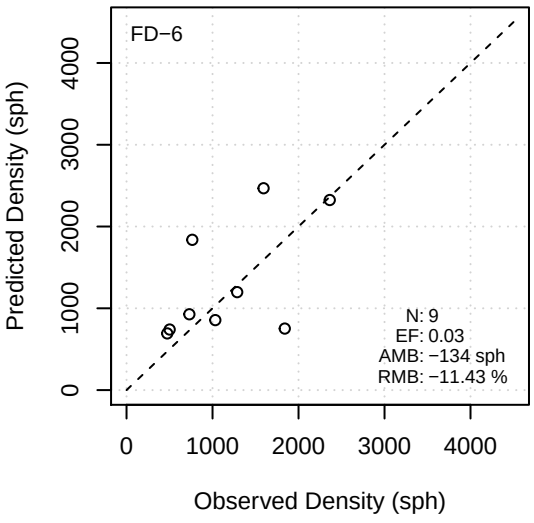

**Conifer Top Height − FD**



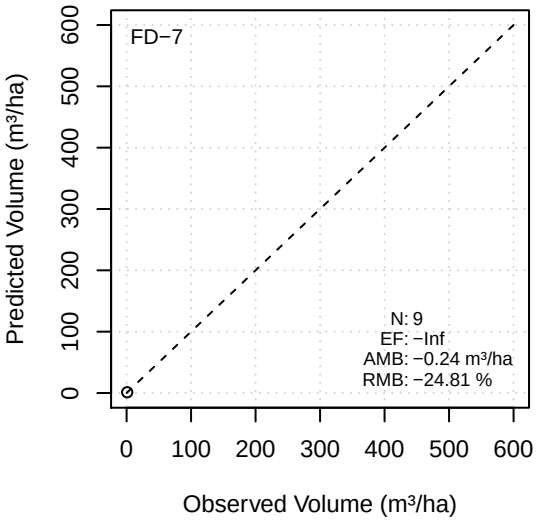

**Conifer Mean DBH − FD**



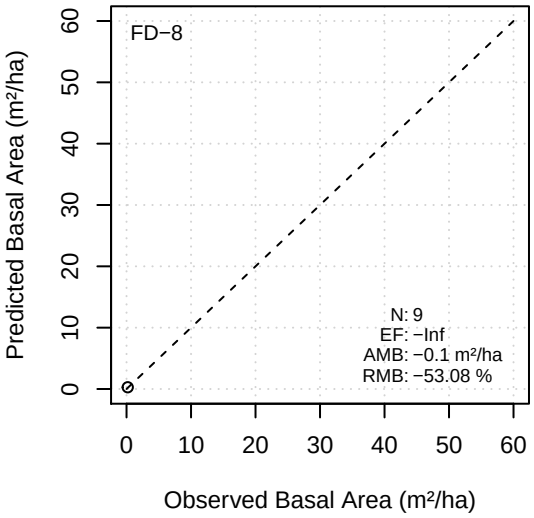

**Conifer Density − FD**



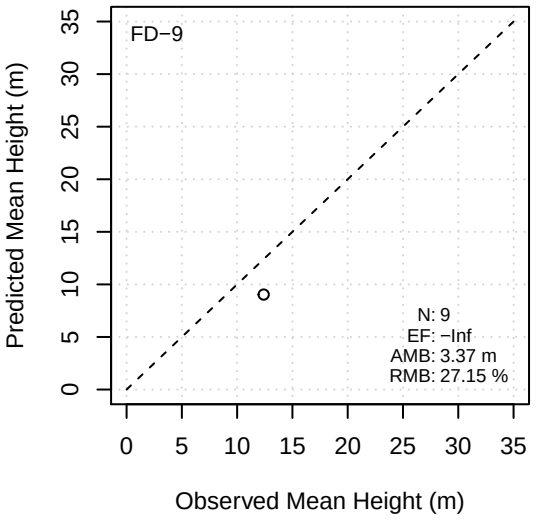
**Deciduous Volume − FD**



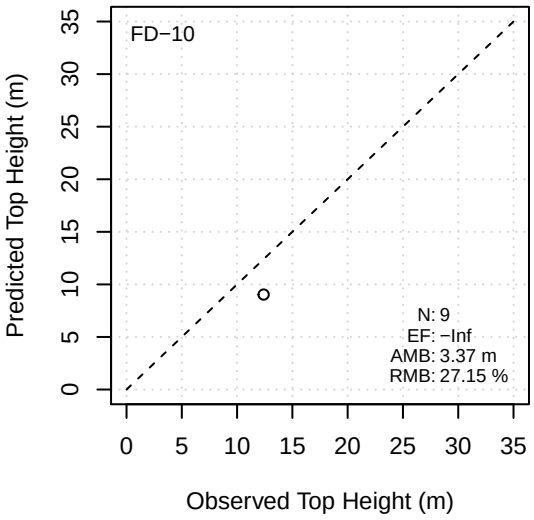

**Deciduous Basal Area − FD**



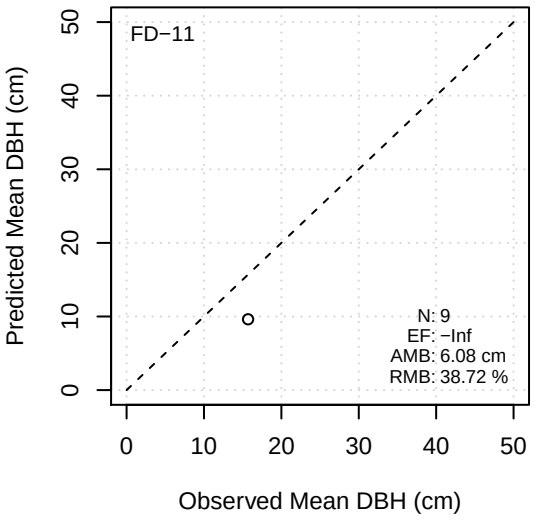

**Deciduous Mean Height − FD**



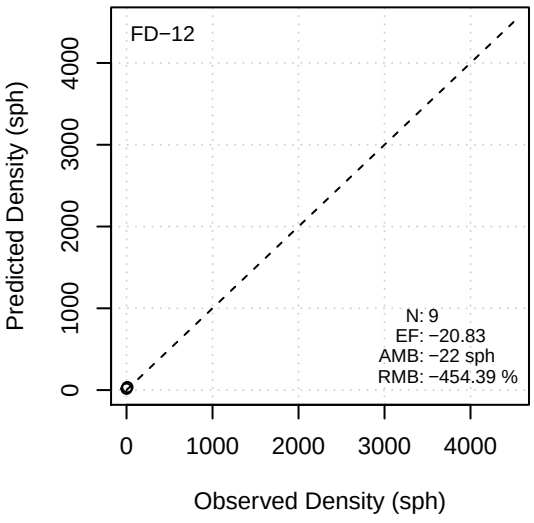

**Deciduous Top Height − FD**



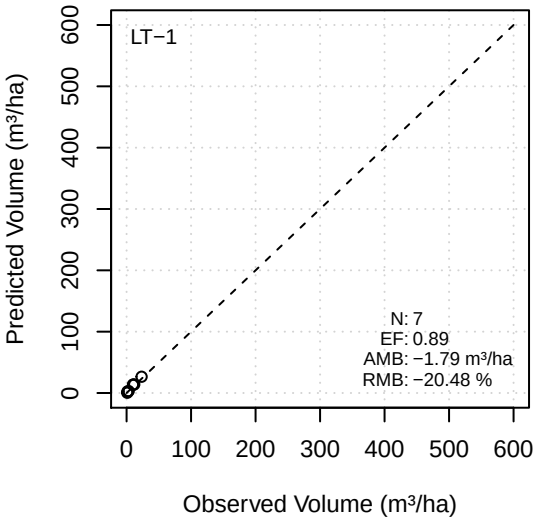

**Deciduous Mean DBH − FD**



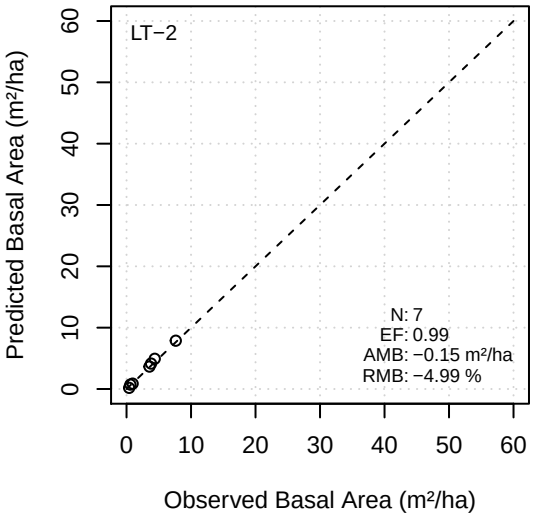

**Deciduous Density − FD**



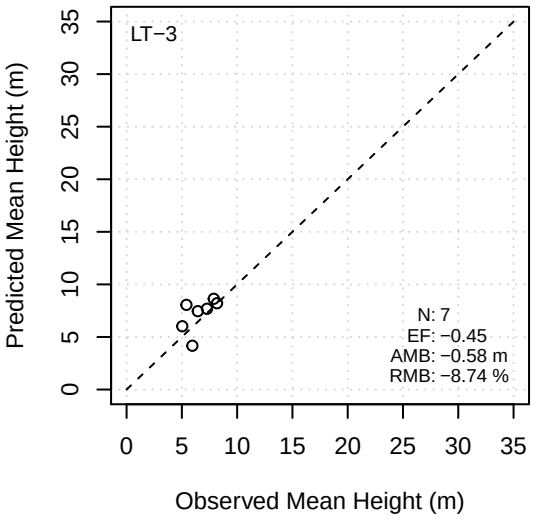
**Conifer Volume − LT**



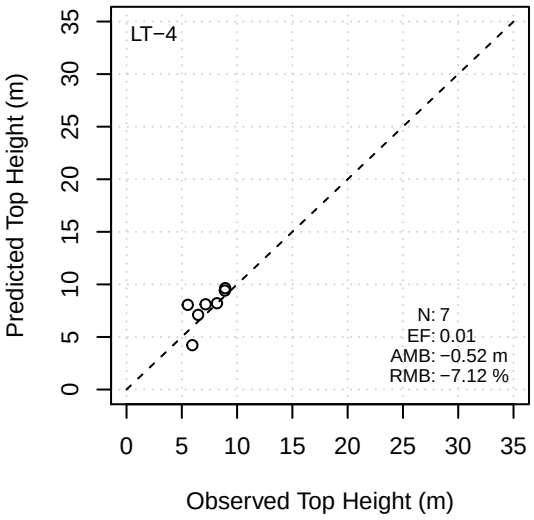

**Conifer Basal Area − LT**



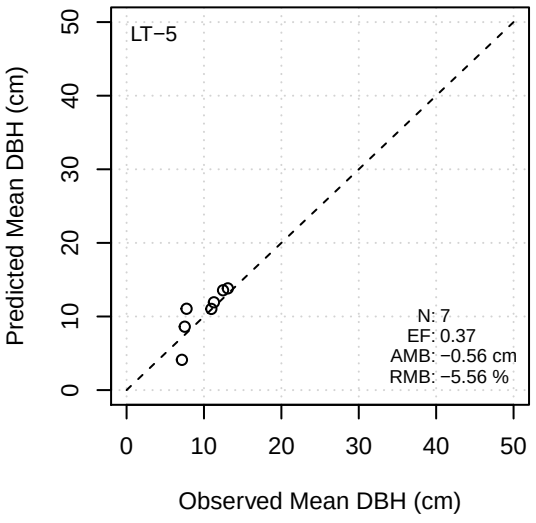

**Conifer Mean Height − LT**



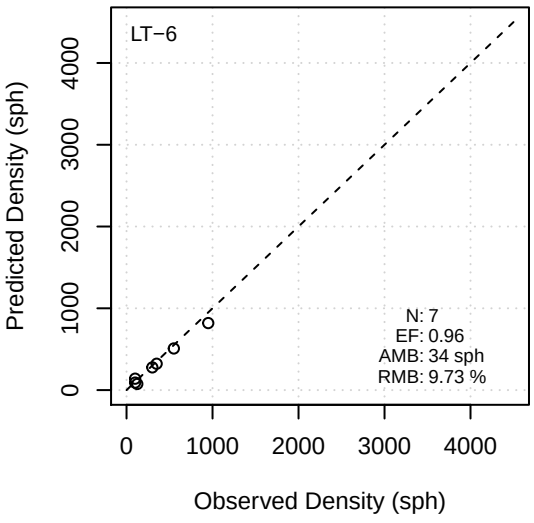

**Conifer Top Height − LT**



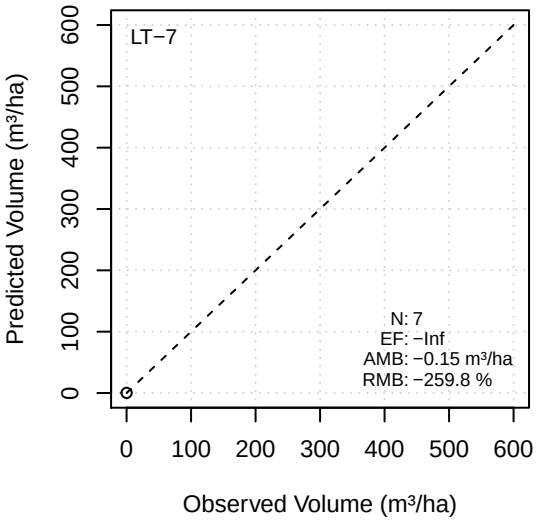

**Conifer Mean DBH − LT**



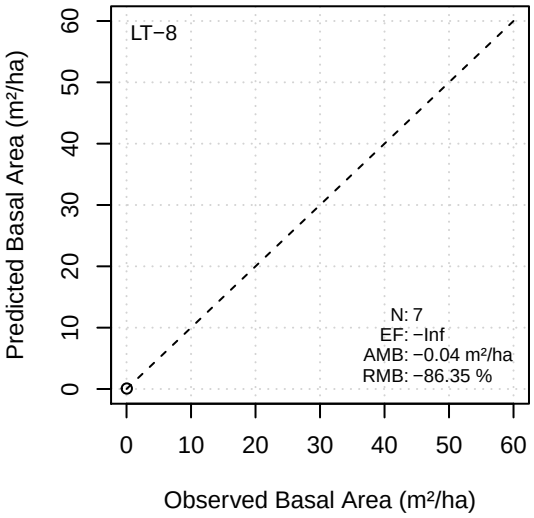

**Conifer Density − LT**



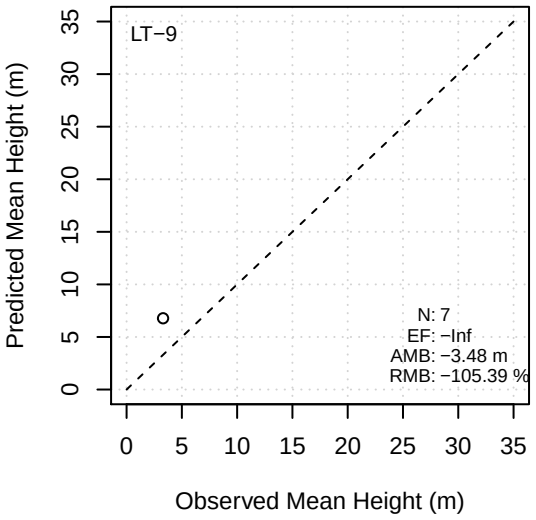
**Deciduous Volume − LT**



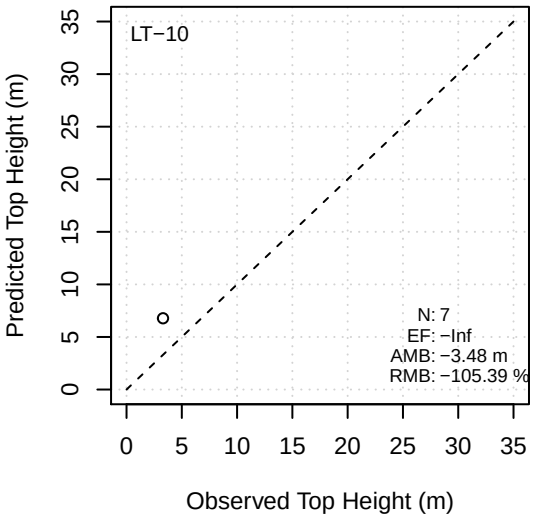

**Deciduous Basal Area − LT**



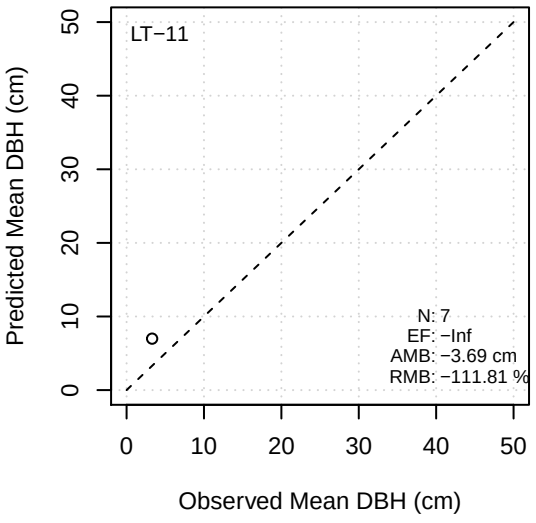

**Deciduous Mean Height − LT**



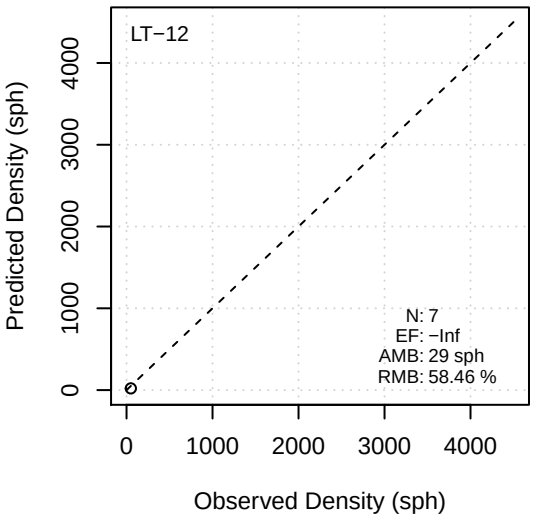

**Deciduous Top Height − LT**



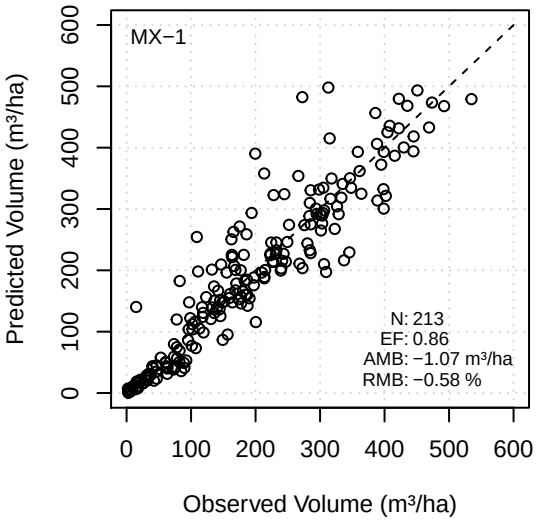

**Deciduous Mean DBH − LT**



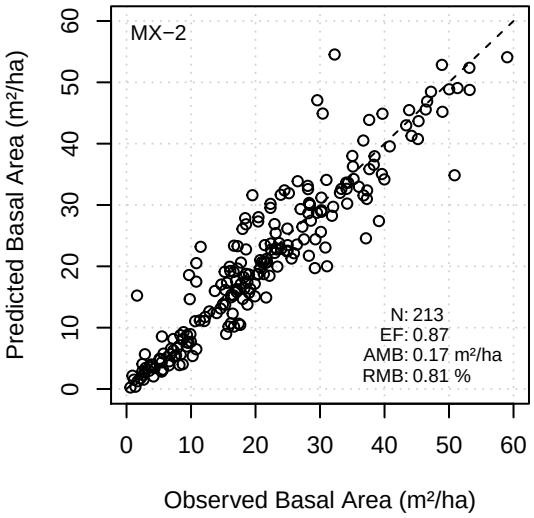

**Deciduous Density − LT**



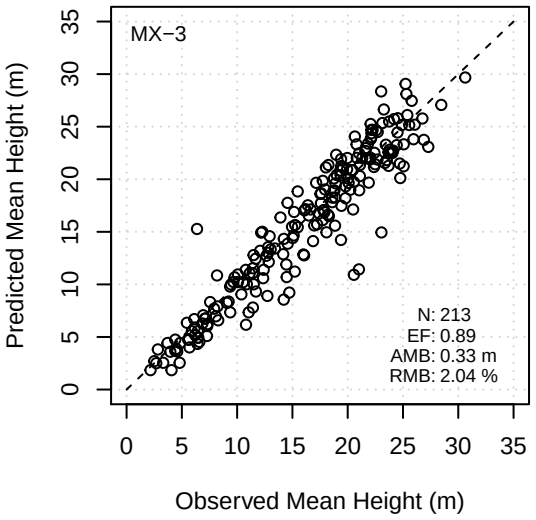
**Conifer Volume − MX**



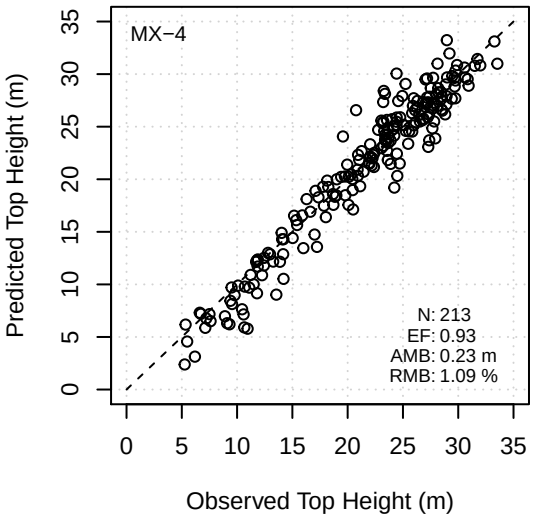

**Conifer Basal Area − MX**



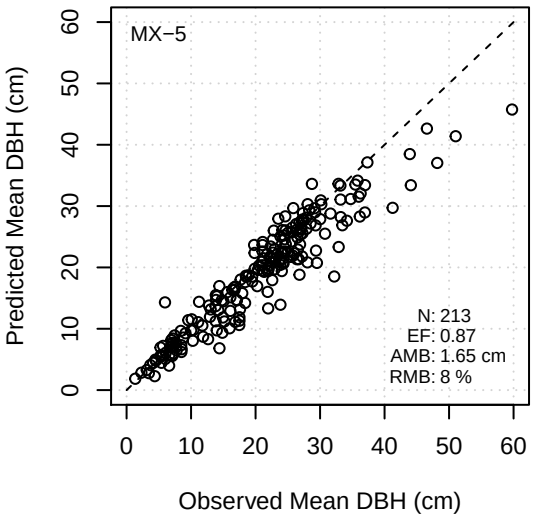

**Conifer Mean Height − MX**



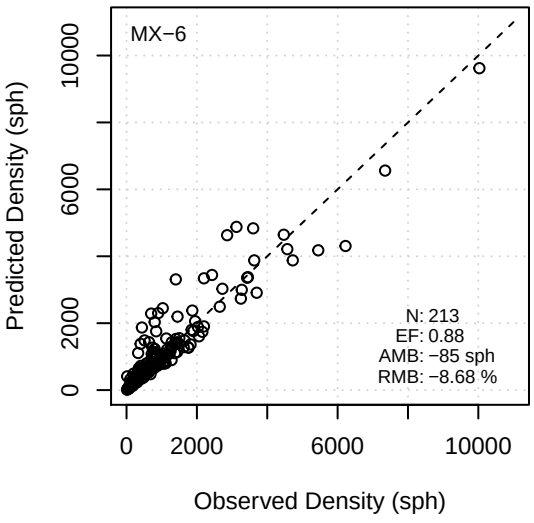

**Conifer Top Height − MX**



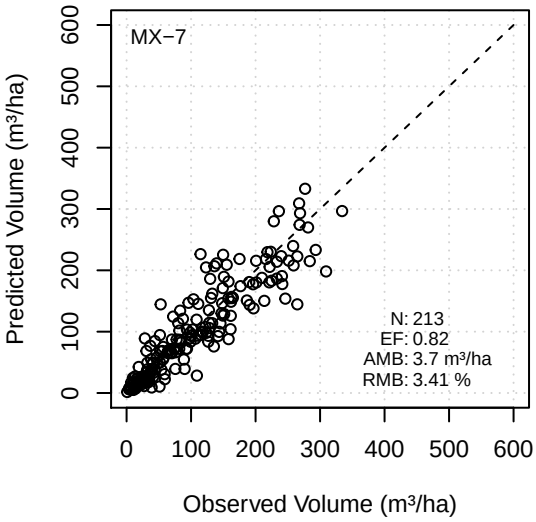

**Conifer Mean DBH − MX**



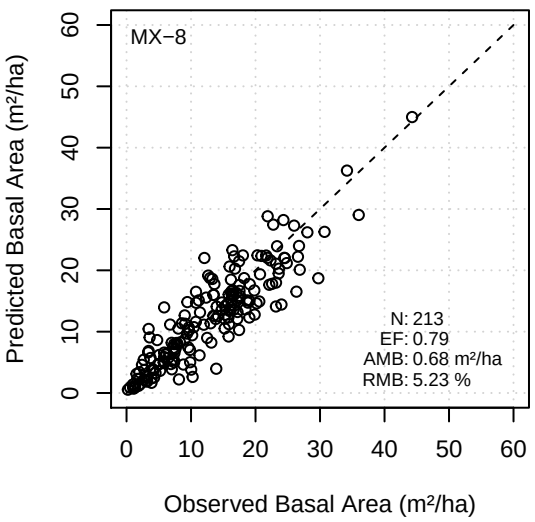

**Conifer Density − MX**



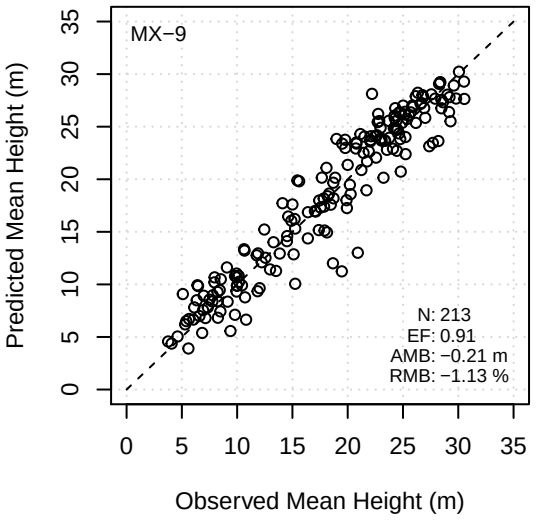
**Deciduous Volume − MX**



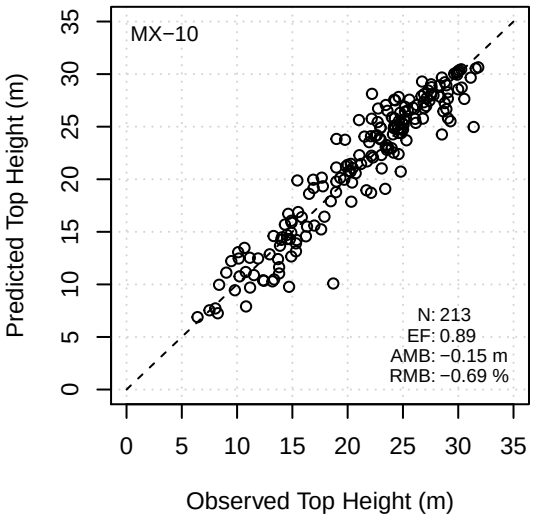

**Deciduous Basal Area − MX**



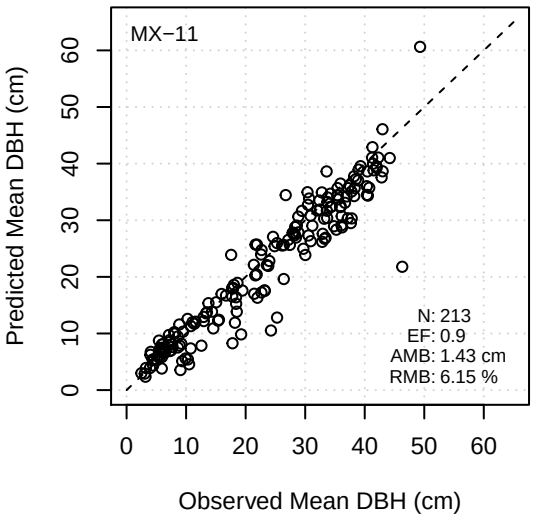

**Deciduous Mean Height − MX**



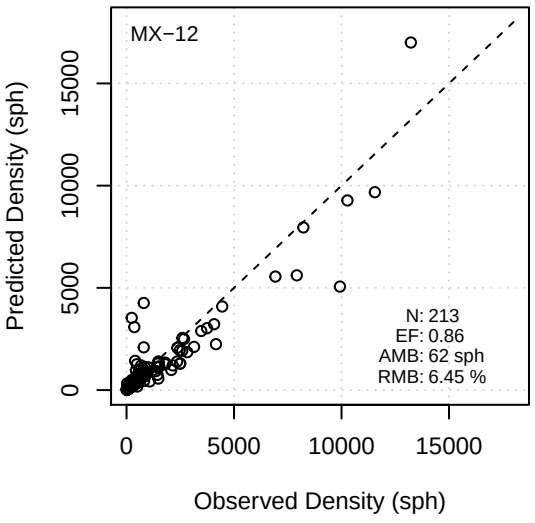

**Deciduous Top Height − MX**



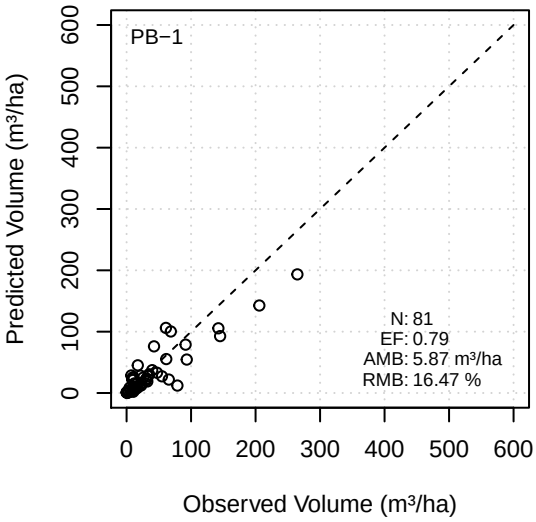

**Deciduous Mean DBH − MX**



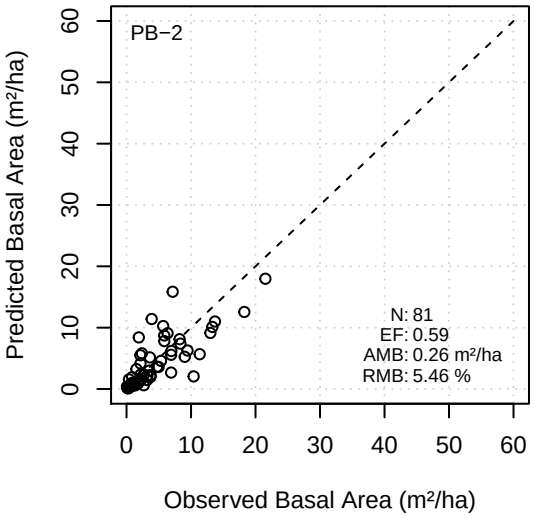

**Deciduous Density − MX**



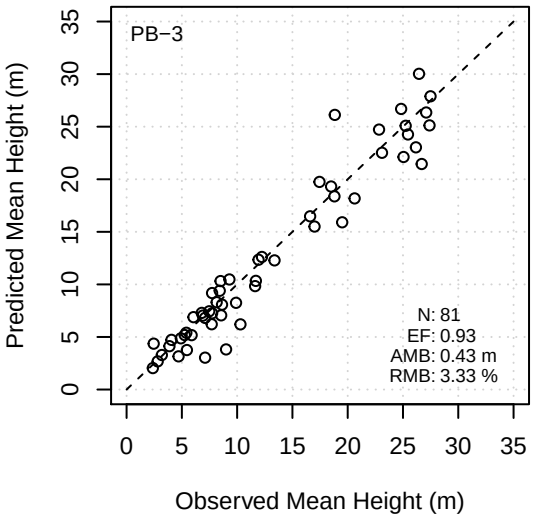
**Conifer Volume − PB**



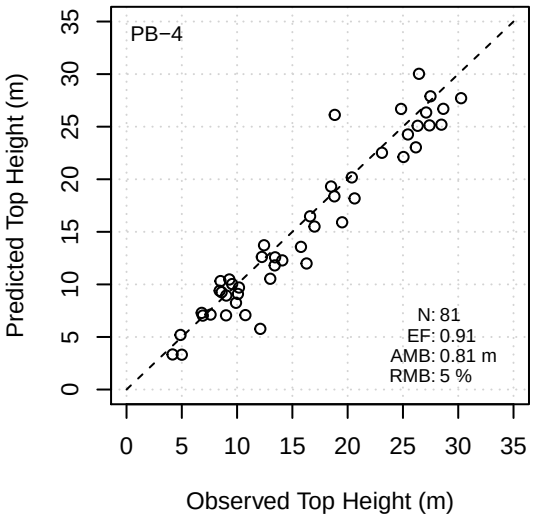

**Conifer Basal Area − PB**



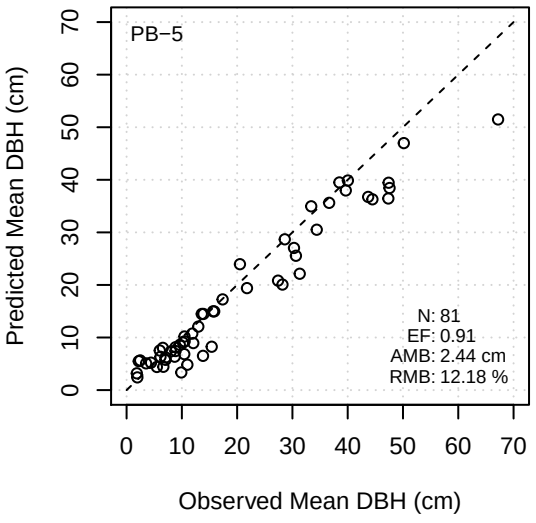

**Conifer Mean Height − PB**



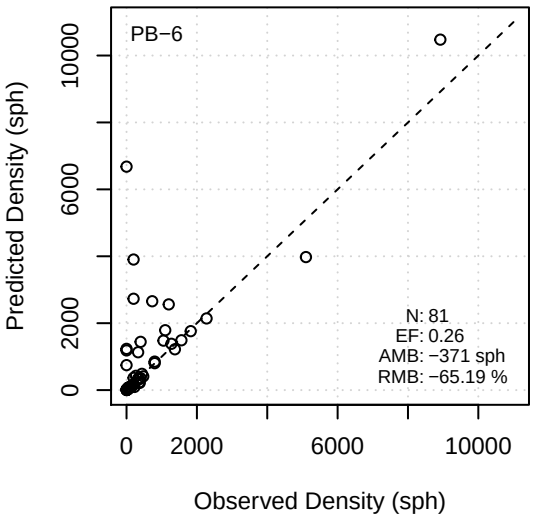

**Conifer Top Height − PB**



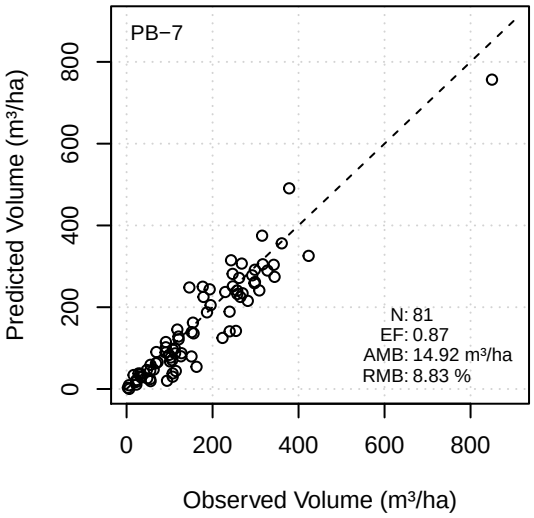

**Conifer Mean DBH − PB**



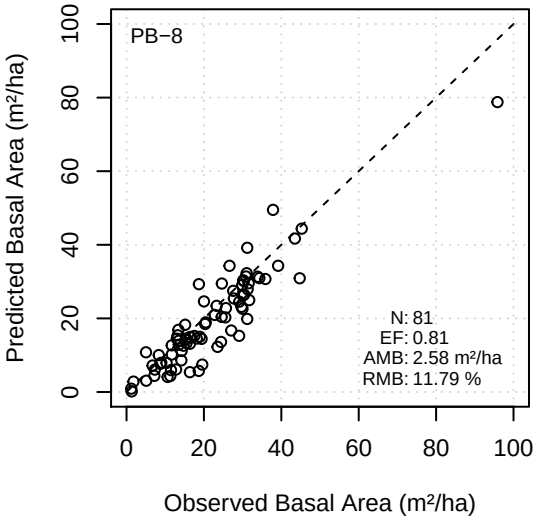

**Conifer Density − PB**



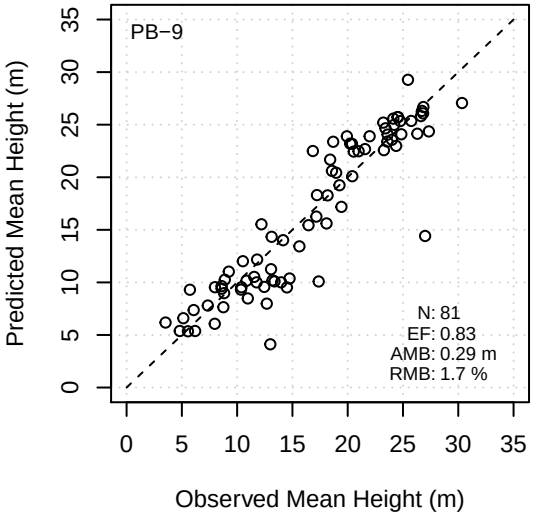
**Deciduous Volume − PB**



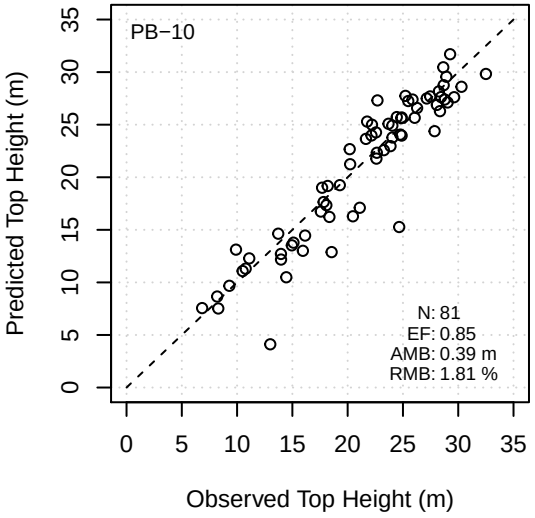

**Deciduous Basal Area − PB**



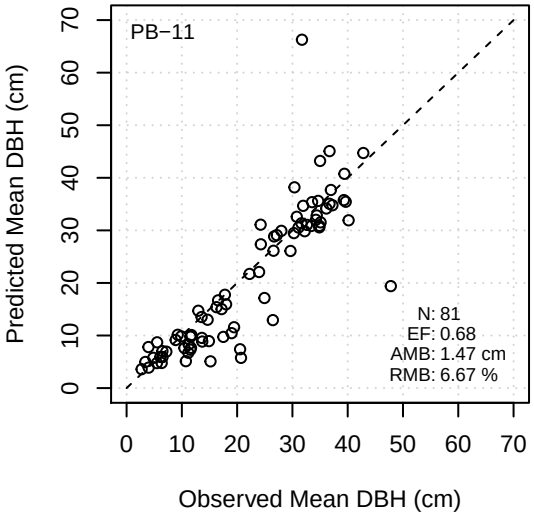

**Deciduous Mean Height − PB**



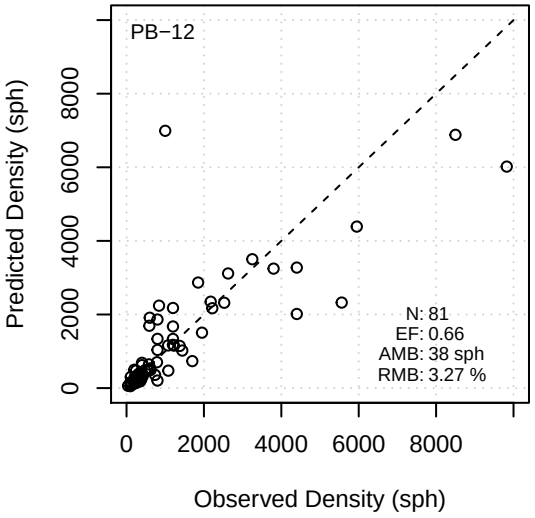

**Deciduous Top Height − PB**



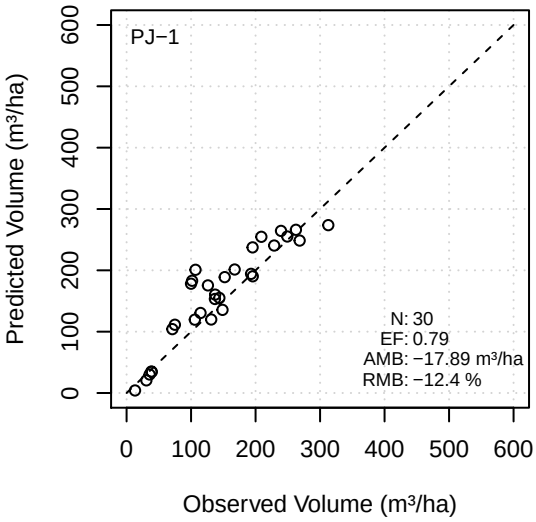

**Deciduous Mean DBH − PB**



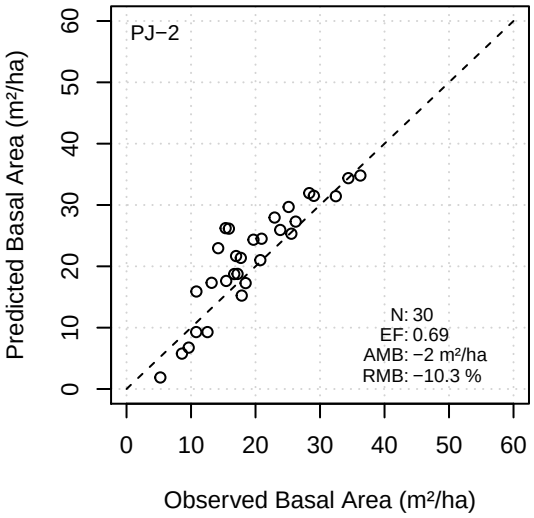

**Deciduous Density − PB**



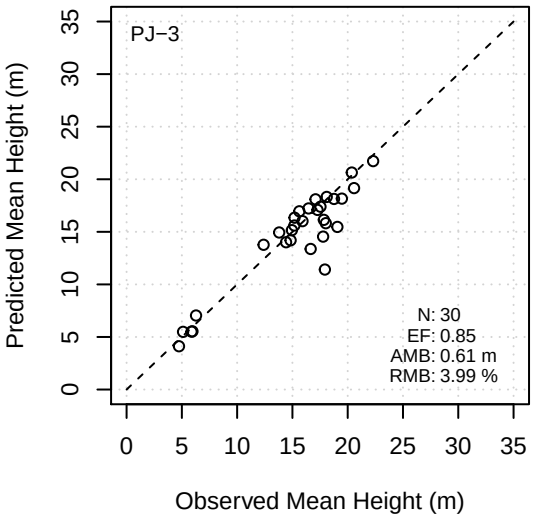
**Conifer Volume − PJ**



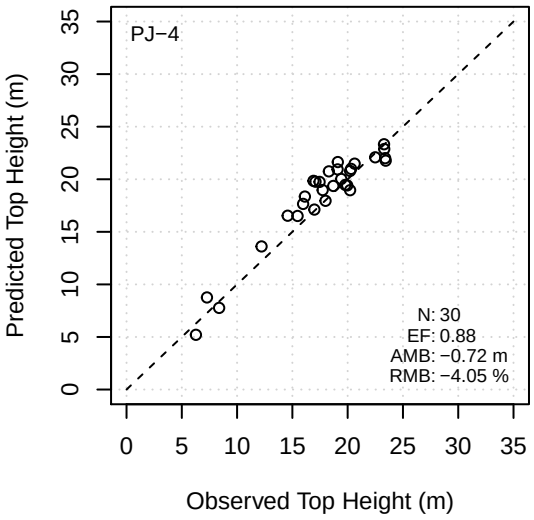

**Conifer Basal Area − PJ**



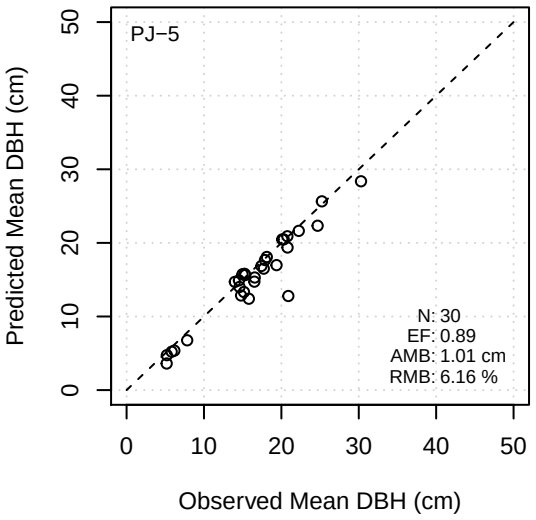

**Conifer Mean Height − PJ**



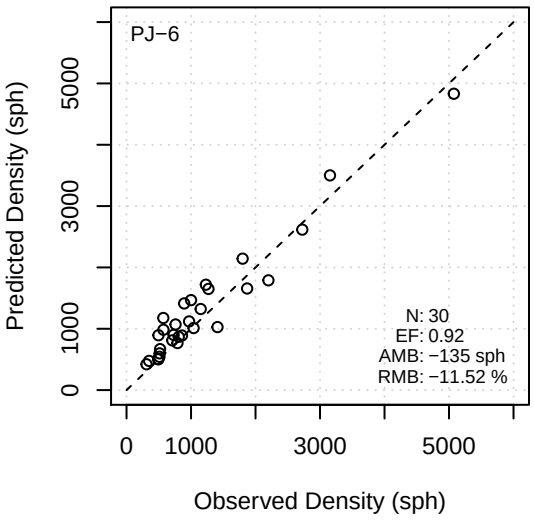

**Conifer Top Height − PJ**



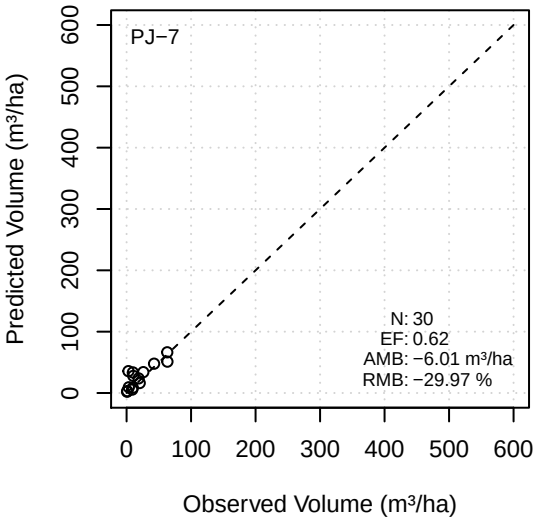

**Conifer Mean DBH − PJ**



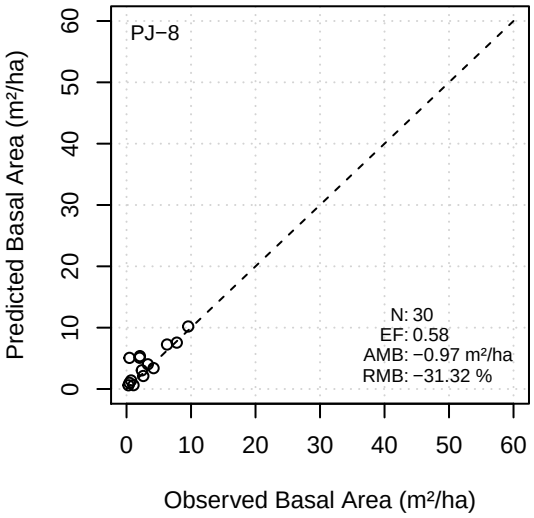

**Conifer Density − PJ**



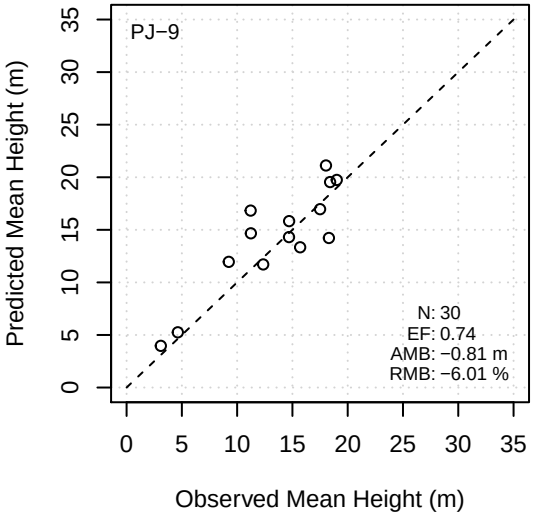
**Deciduous Volume − PJ**



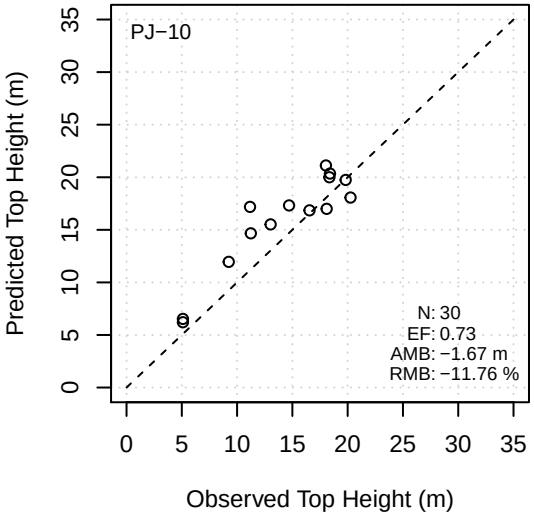

**Deciduous Basal Area − PJ**



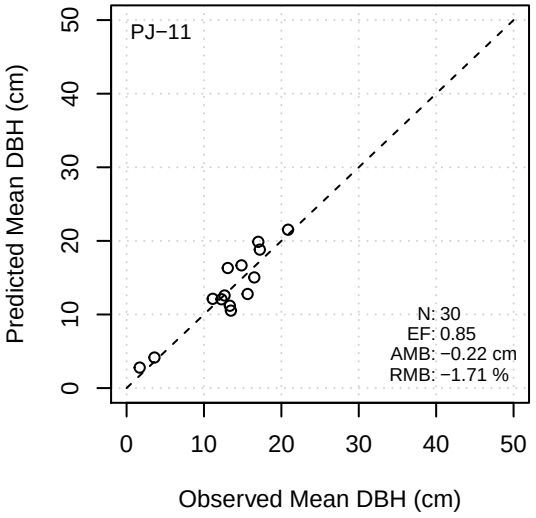

**Deciduous Mean Height − PJ**



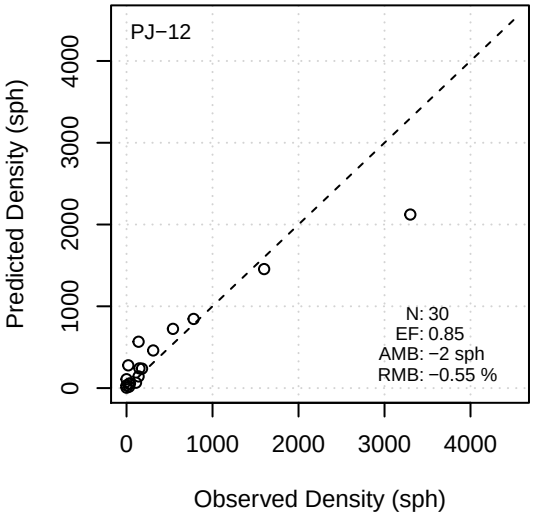

**Deciduous Top Height − PJ**



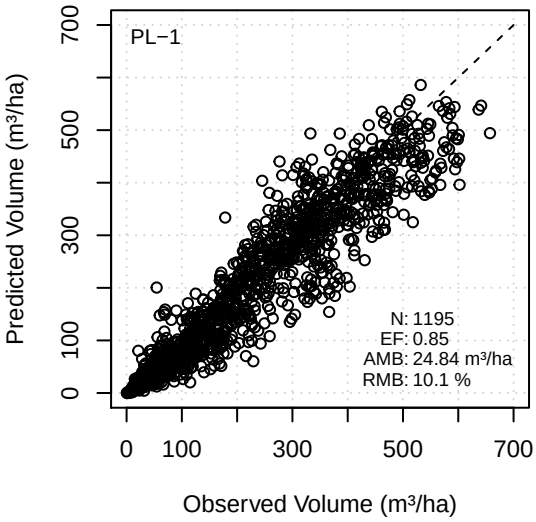

**Deciduous Mean DBH − PJ**



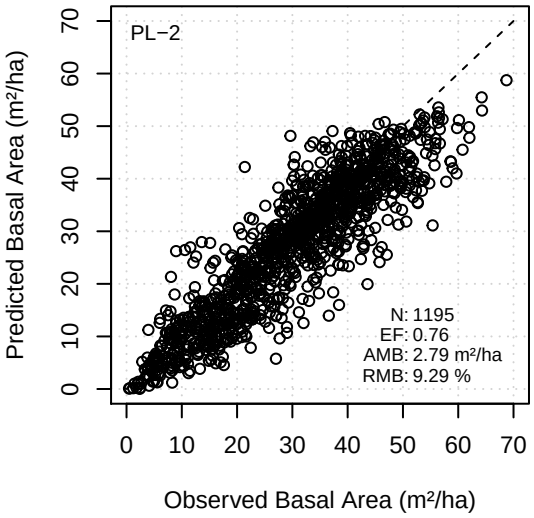

**Deciduous Density − PJ**



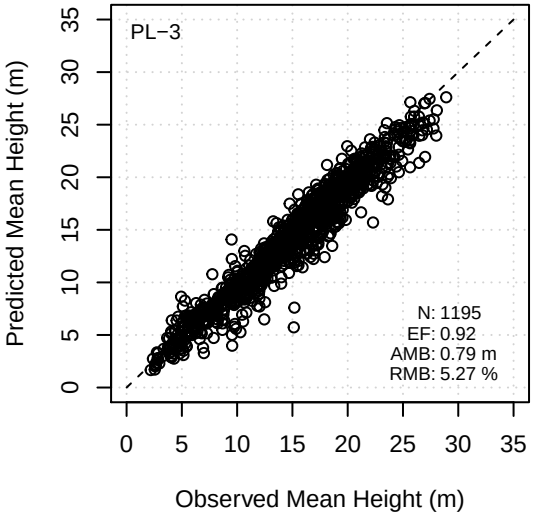
**Conifer Volume − PL**



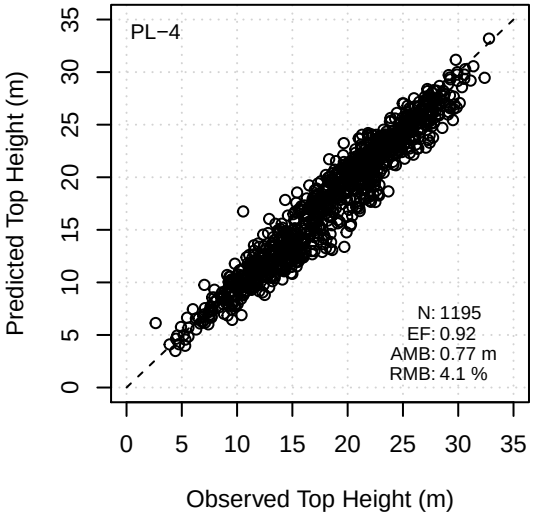

**Conifer Basal Area − PL**



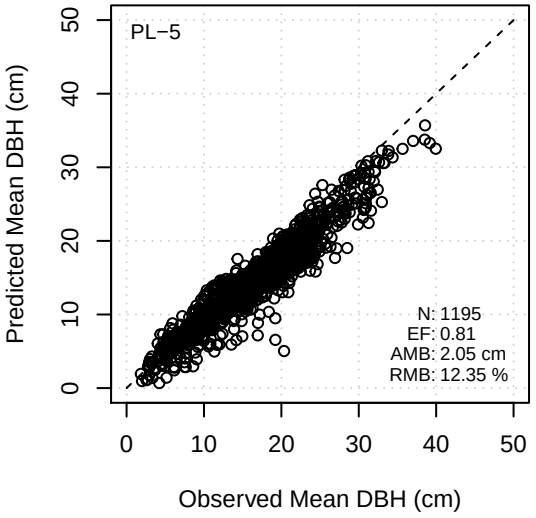

**Conifer Mean Height − PL**



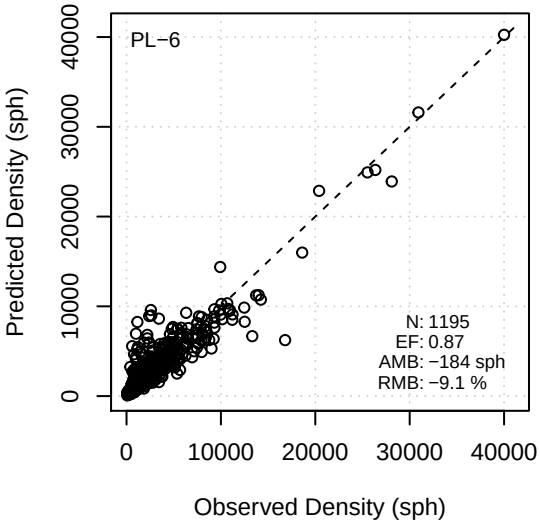

**Conifer Top Height − PL**



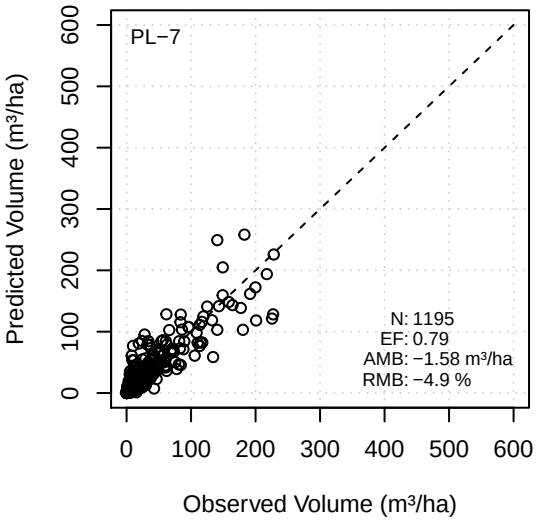

**Conifer Mean DBH − PL**



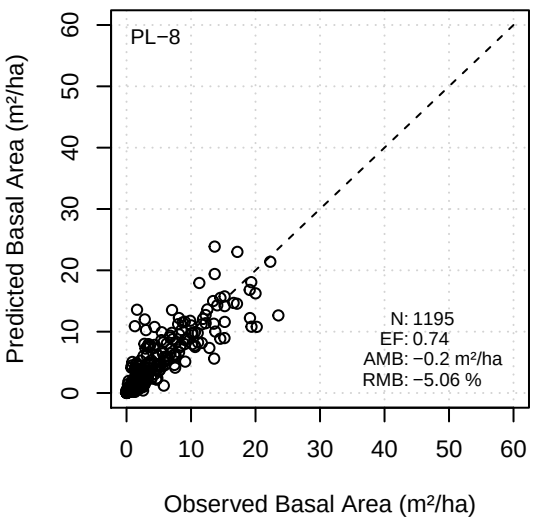

**Conifer Density − PL**



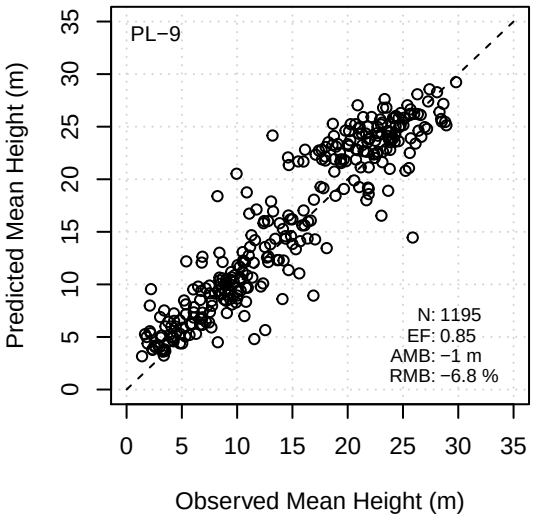
**Deciduous Volume − PL**



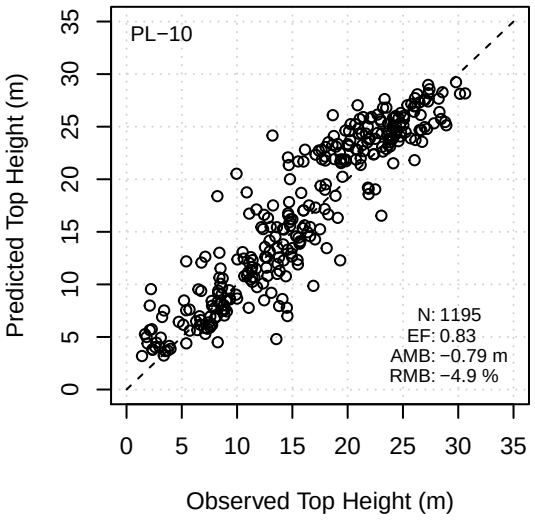

**Deciduous Basal Area − PL**



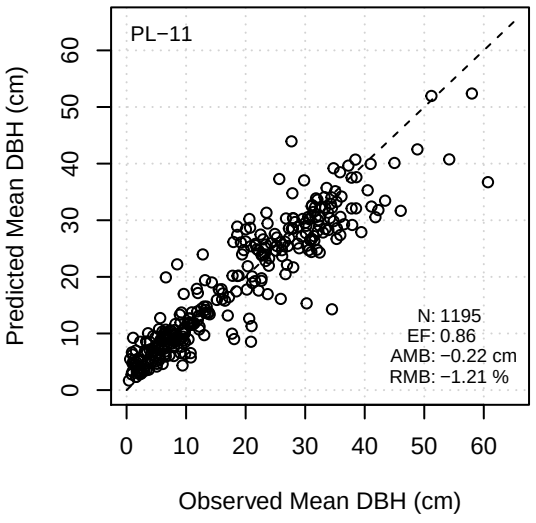

**Deciduous Mean Height − PL**



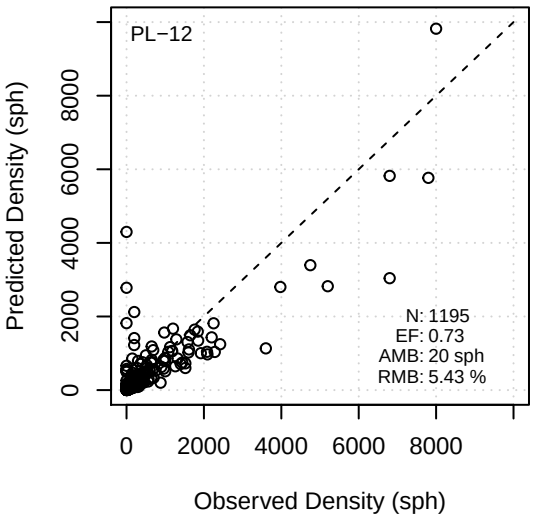

**Deciduous Top Height − PL**



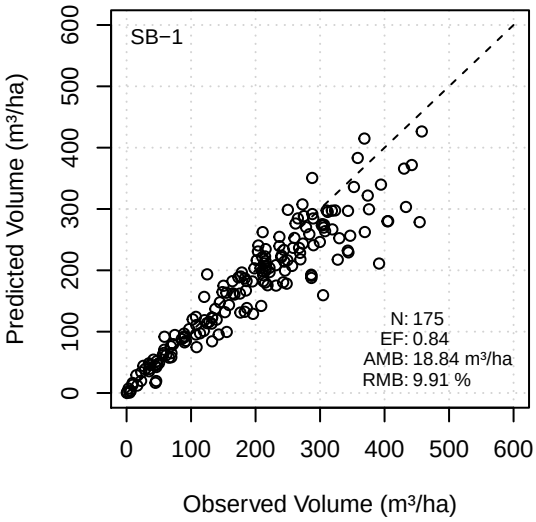

**Deciduous Mean DBH − PL**



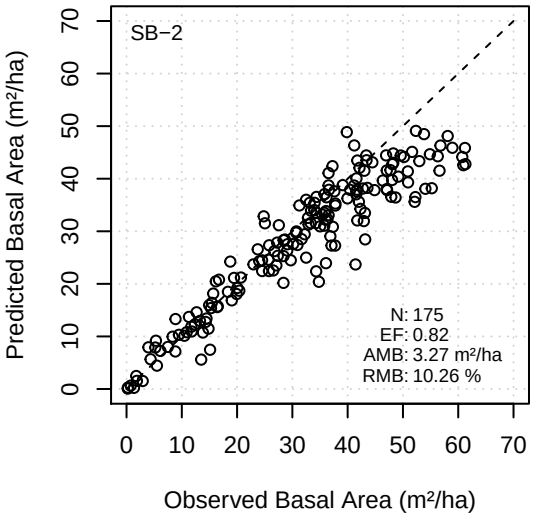

**Deciduous Density − PL**



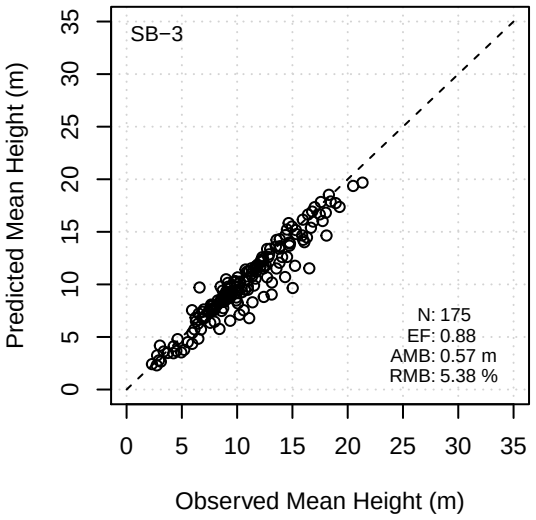
**Conifer Volume − SB**



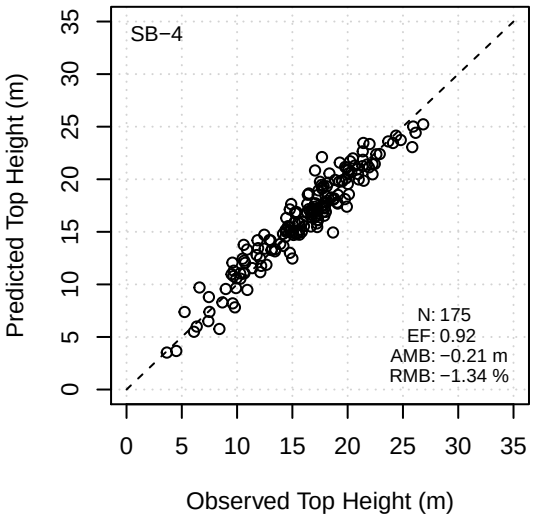

**Conifer Basal Area − SB**



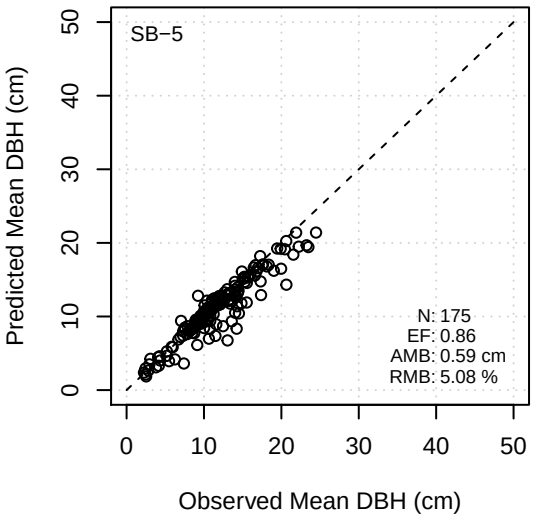

**Conifer Mean Height − SB**



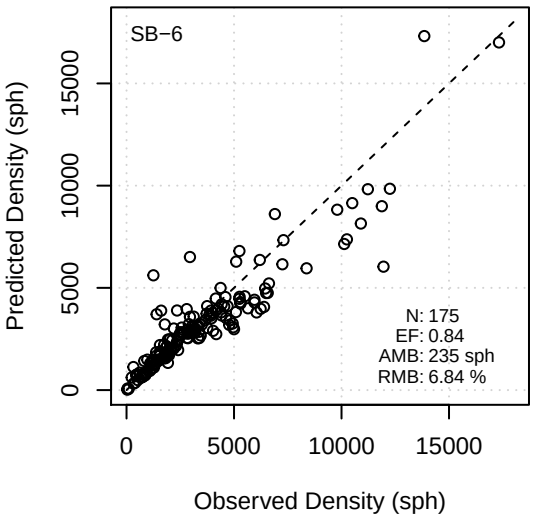

**Conifer Top Height − SB**



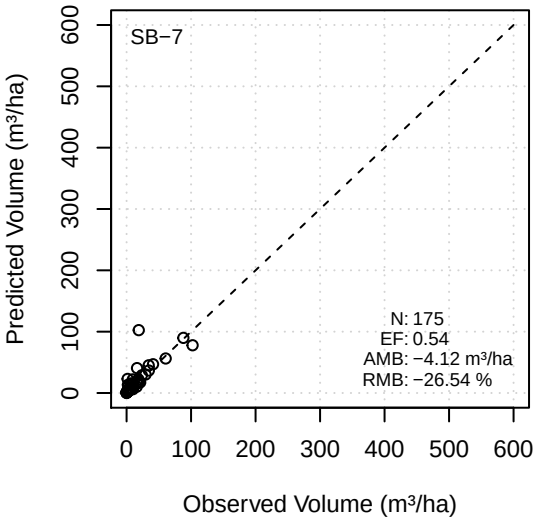

**Conifer Mean DBH − SB**



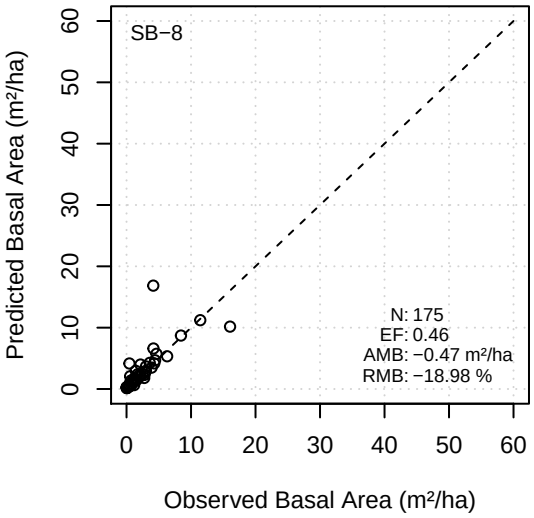

**Conifer Density − SB**



**Deciduous Volume − SB**




**Deciduous Basal Area − SB**

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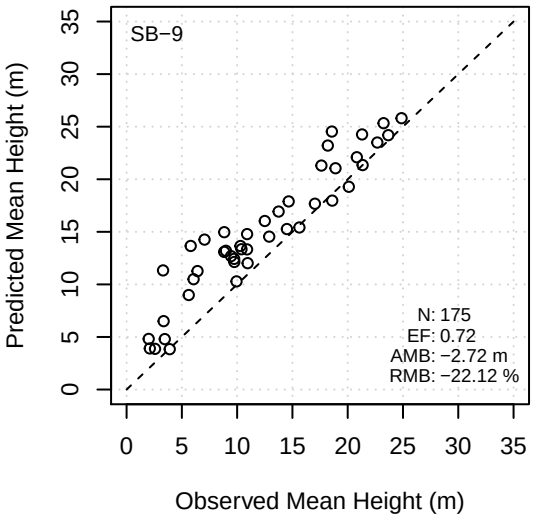
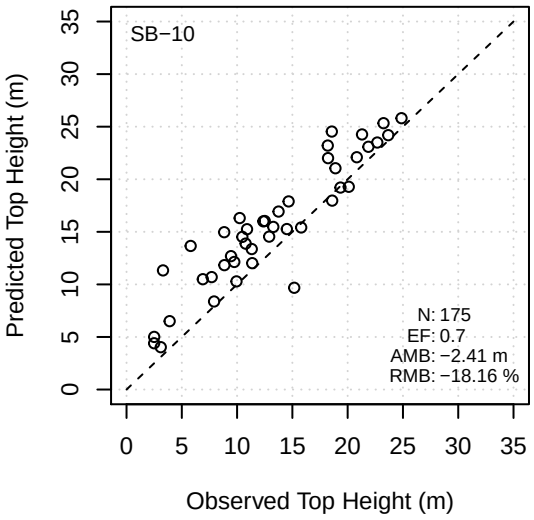
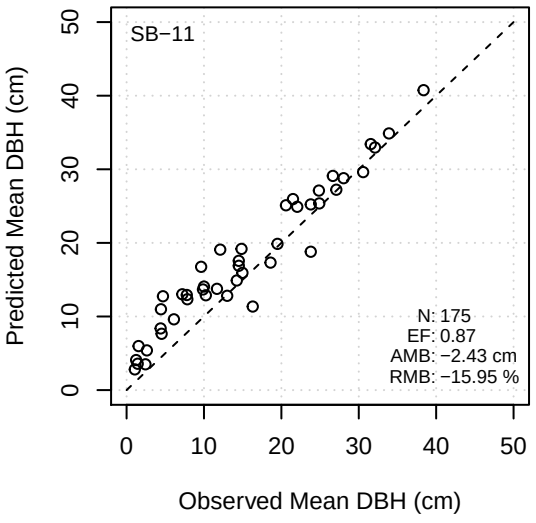


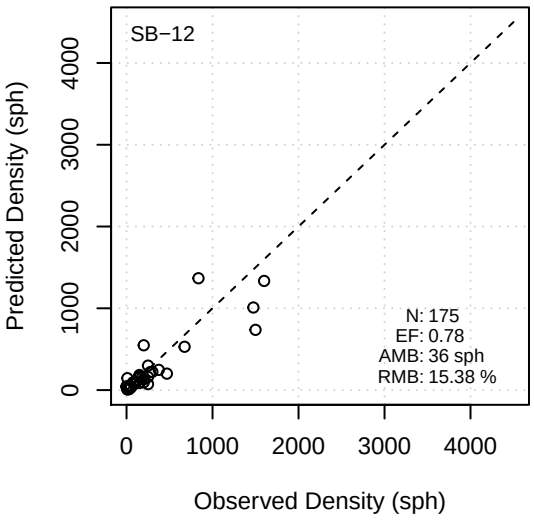

**Deciduous Top Height − SB**



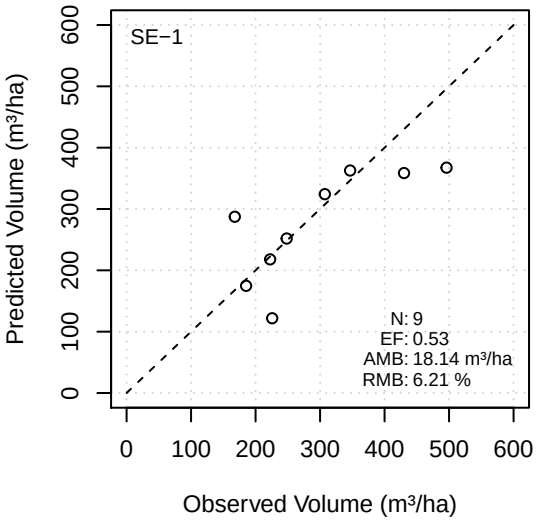

**Deciduous Mean DBH − SB**



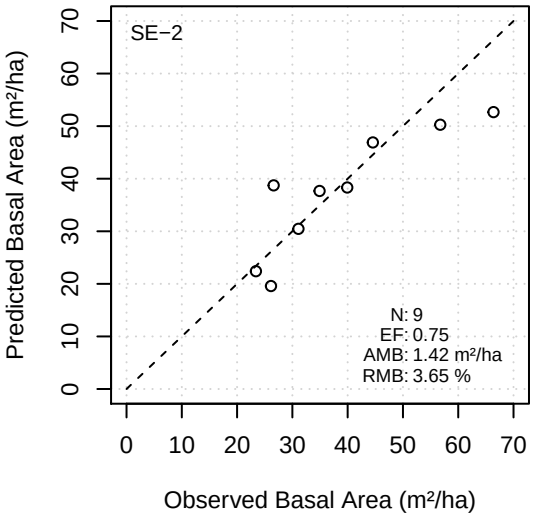

**Deciduous Density − SB**



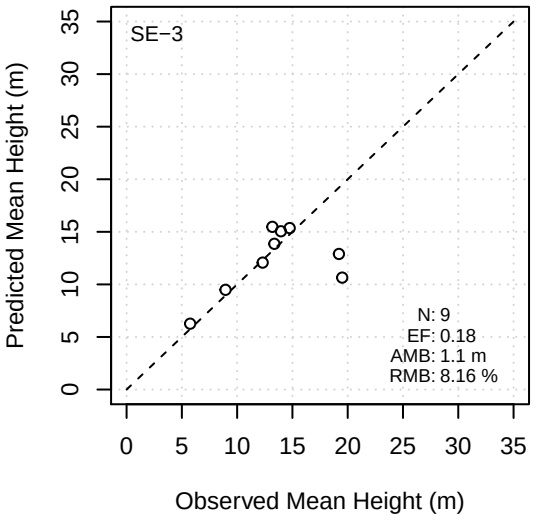
**Conifer Volume − SE**



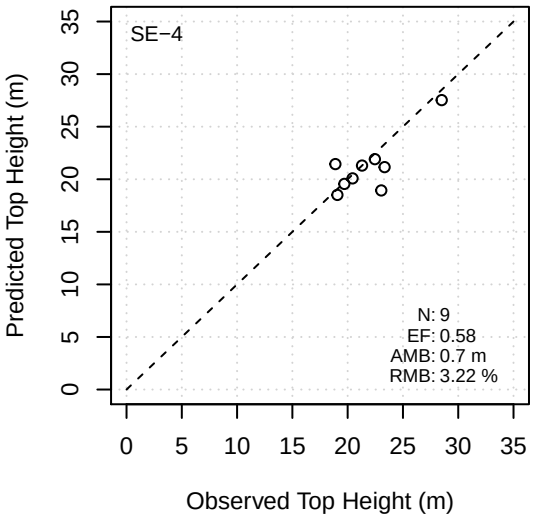

**Conifer Basal Area − SE**



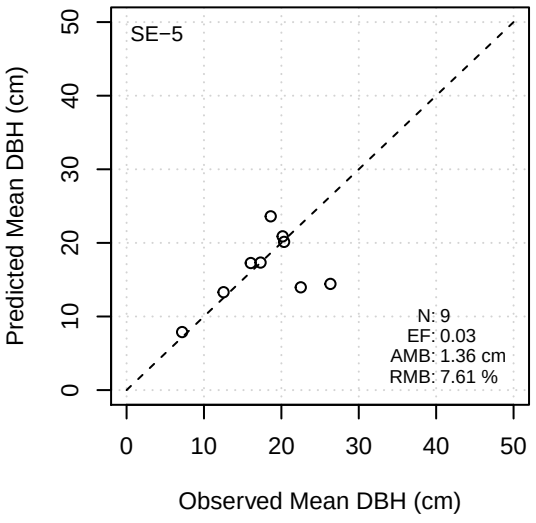

**Conifer Mean Height − SE**



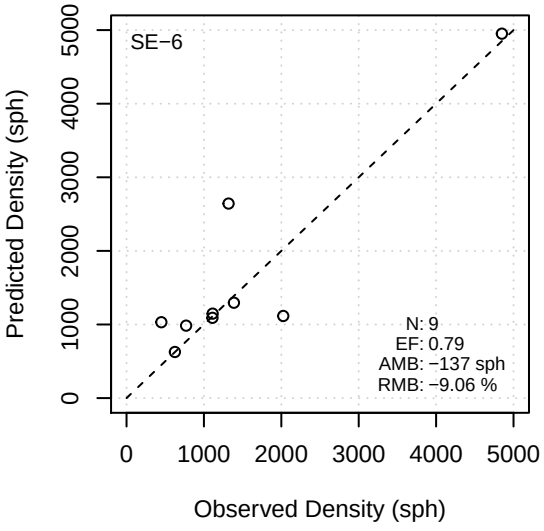

**Conifer Top Height − SE**



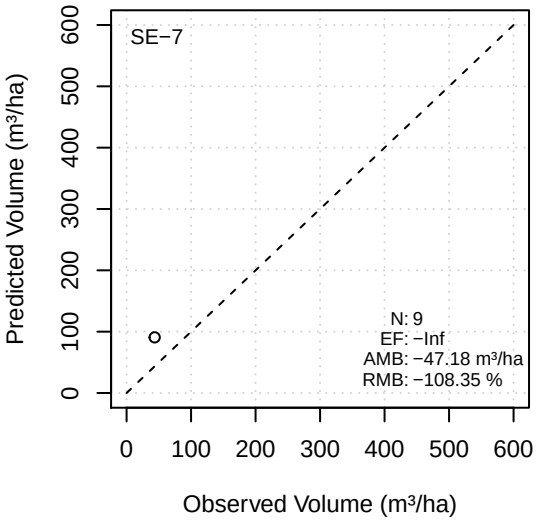

**Conifer Mean DBH − SE**



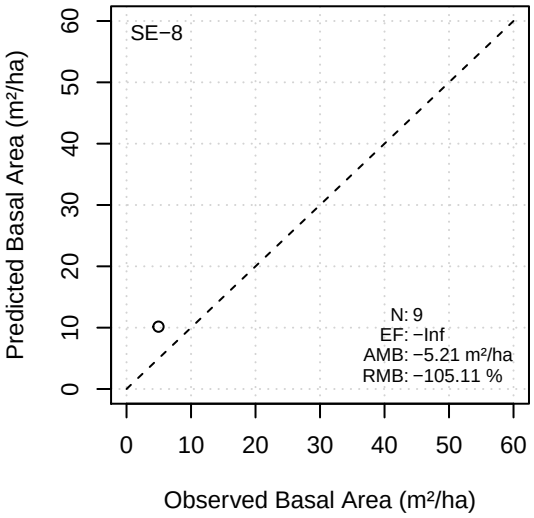

**Conifer Density − SE**



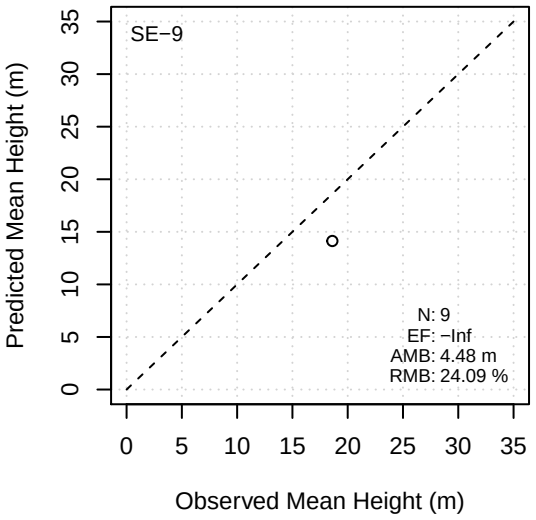
**Deciduous Volume − SE**



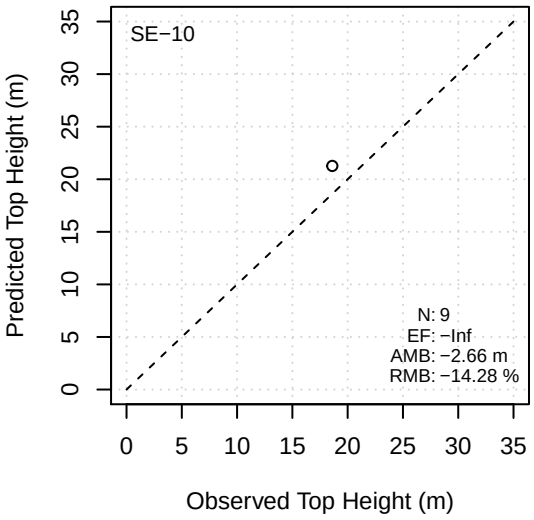

**Deciduous Basal Area − SE**



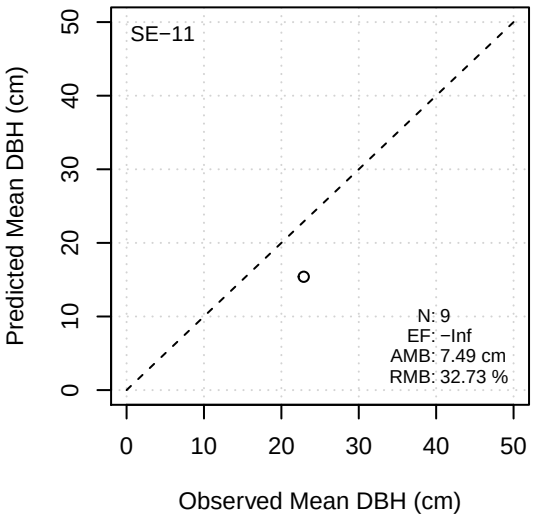

**Deciduous Mean Height − SE**



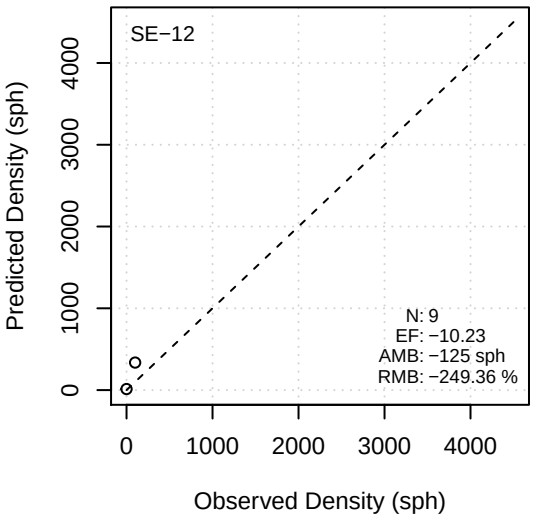

**Deciduous Top Height − SE**



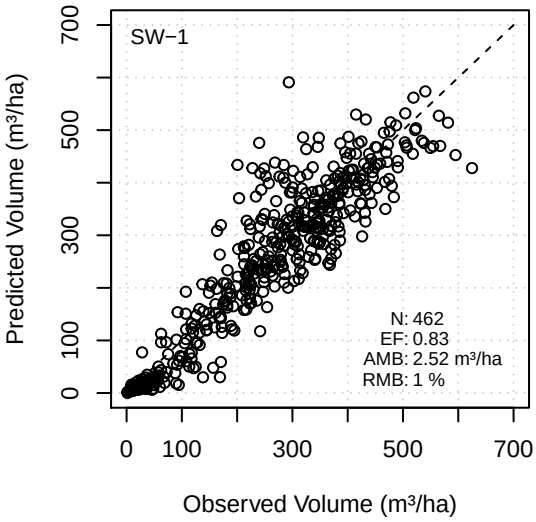

**Deciduous Mean DBH − SE**



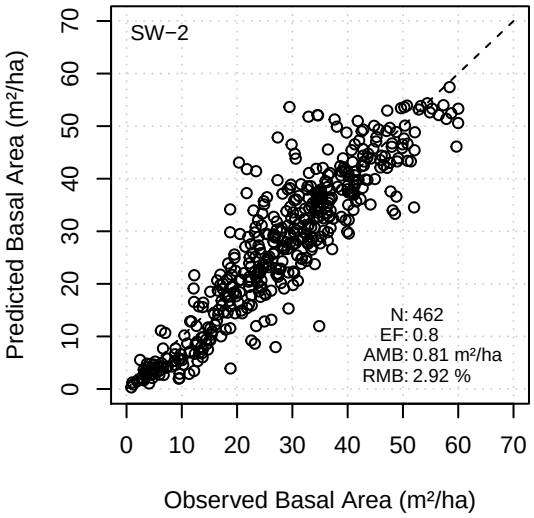

**Deciduous Density − SE**



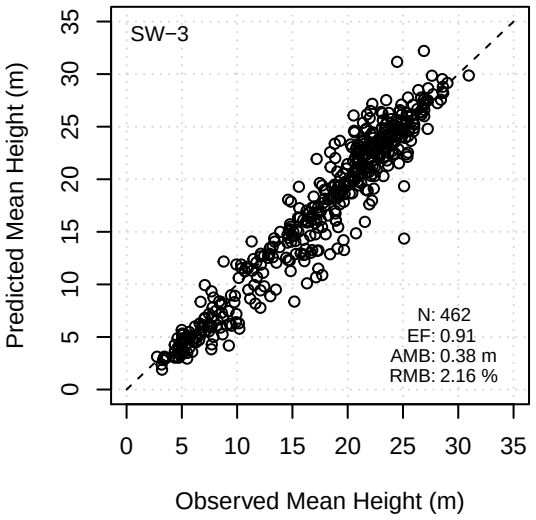
**Conifer Volume − SW**



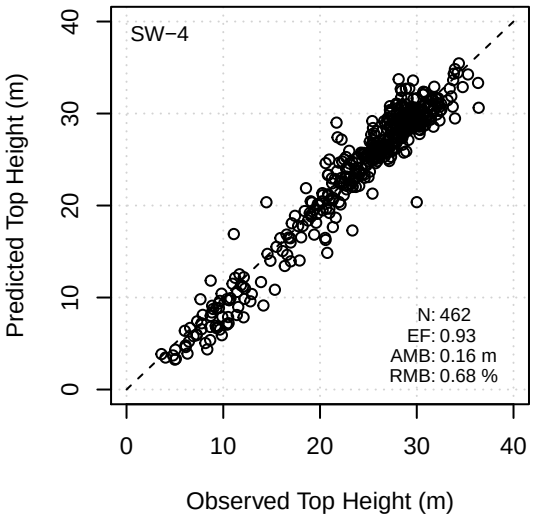

**Conifer Basal Area − SW**



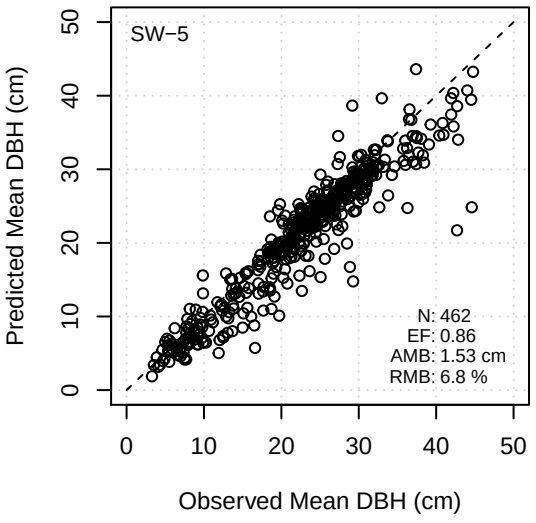

**Conifer Mean Height − SW**



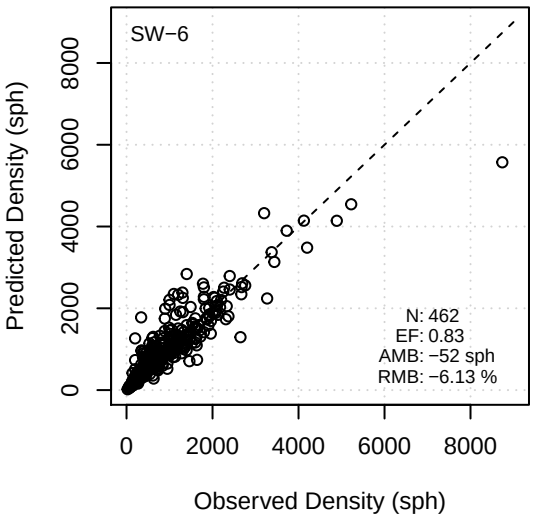

**Conifer Top Height − SW**



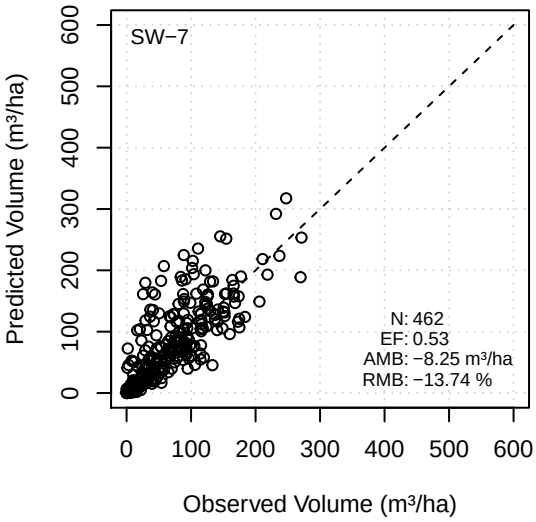

**Conifer Mean DBH − SW**



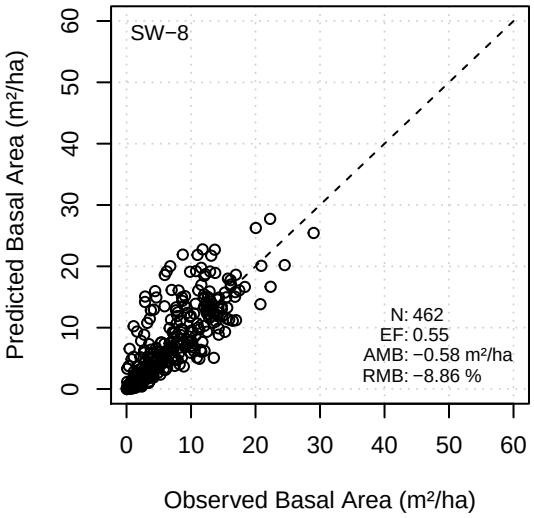

**Conifer Density − SW**



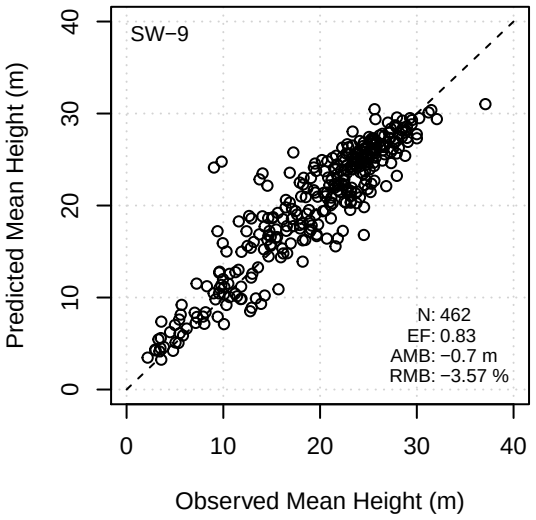
**Deciduous Volume − SW**



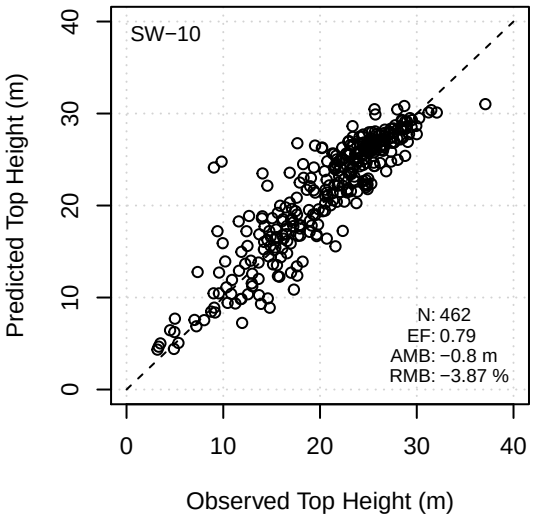

**Deciduous Basal Area − SW**



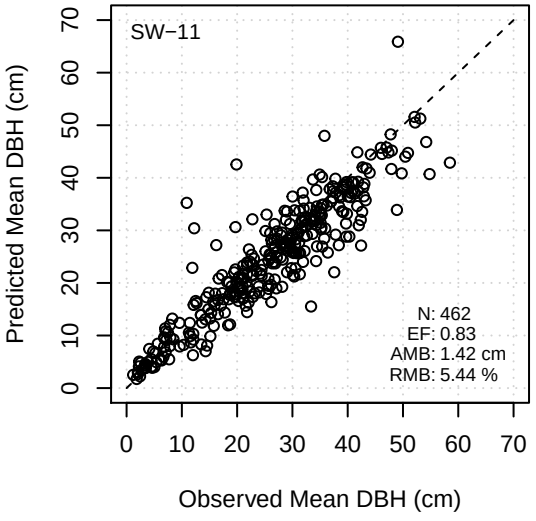

**Deciduous Mean Height − SW**



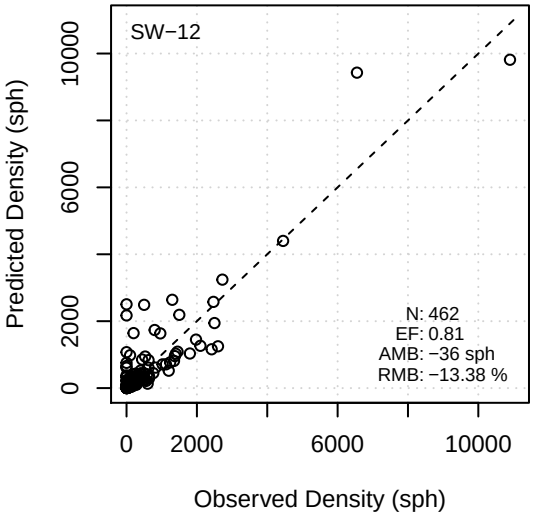

**Deciduous Top Height − SW**



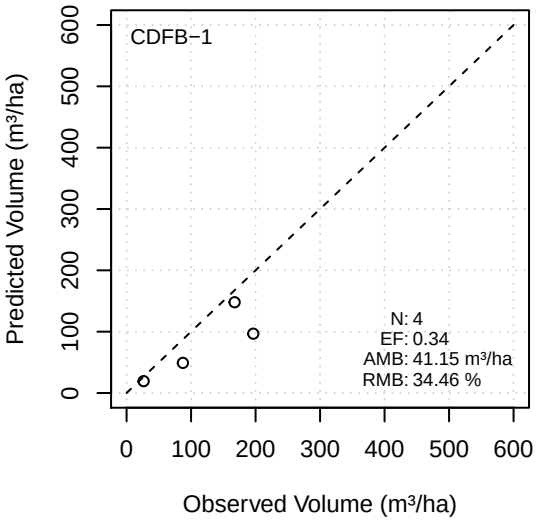

**Deciduous Mean DBH − SW**



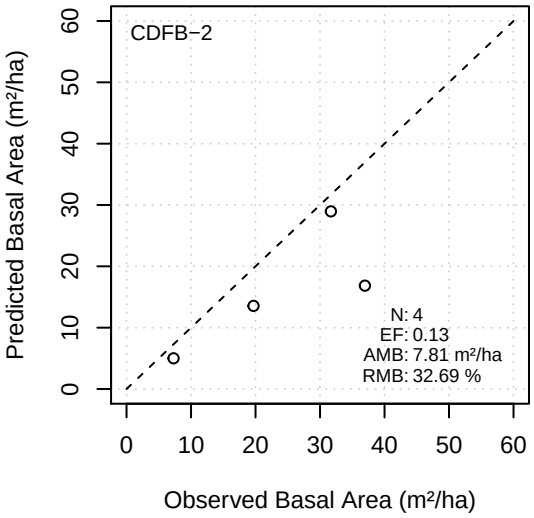

**Deciduous Density − SW**



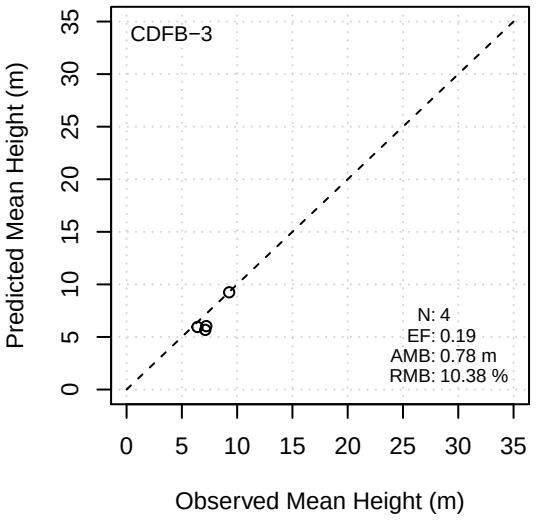
**Conifer Volume − CDFB**



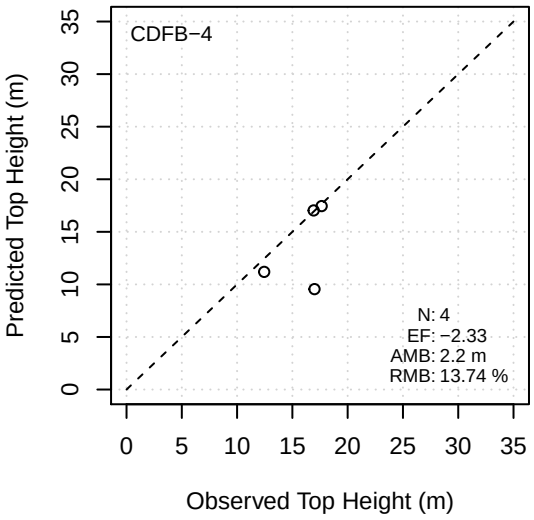

**Conifer Basal Area − CDFB**



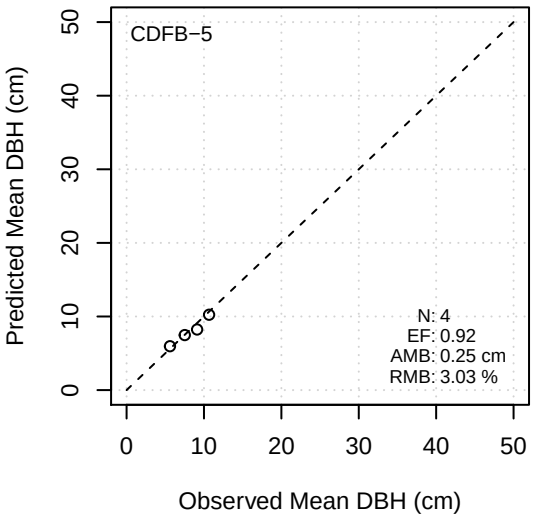

**Conifer Mean Height − CDFB**



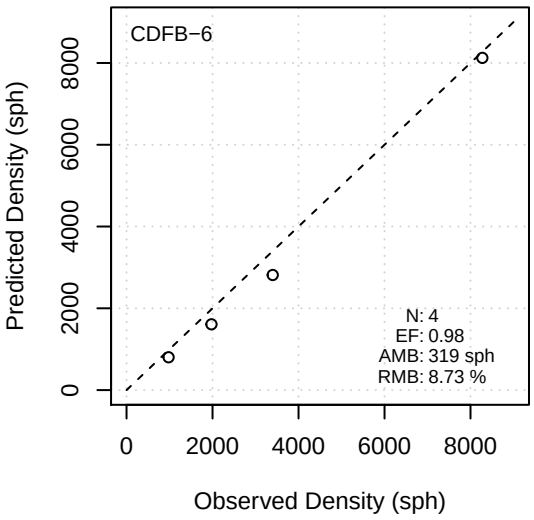

**Conifer Top Height − CDFB**



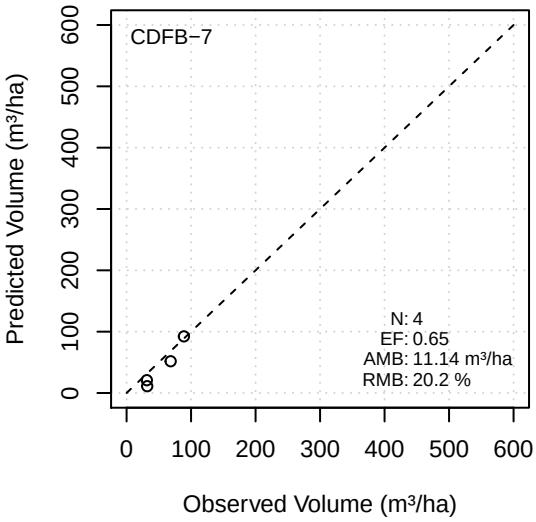

**Conifer Mean DBH − CDFB**



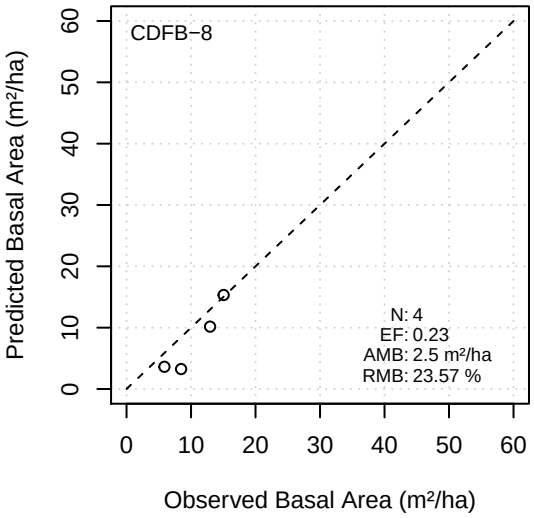

**Conifer Density − CDFB**



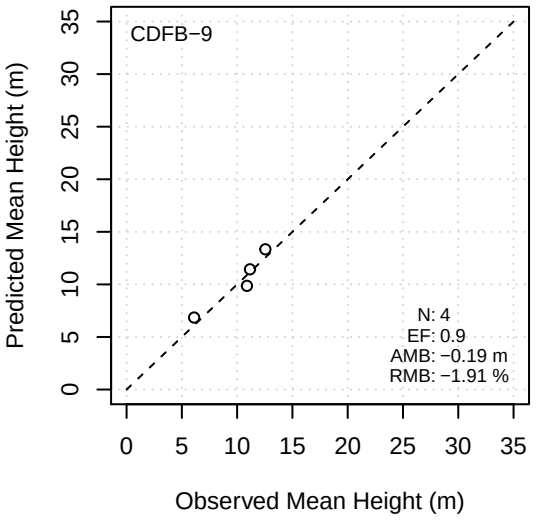
**Deciduous Volume − CDFB**



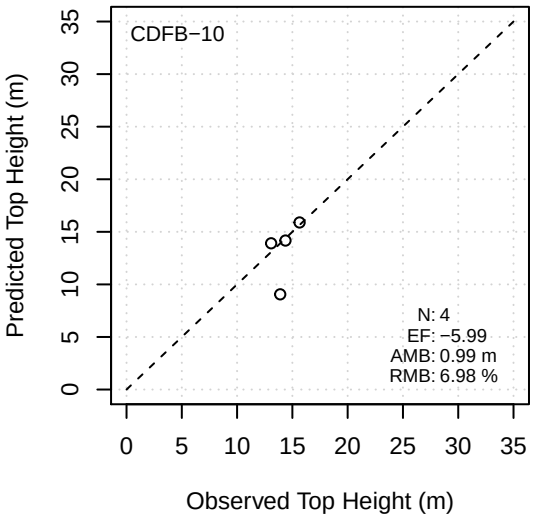

**Deciduous Basal Area − CDFB**



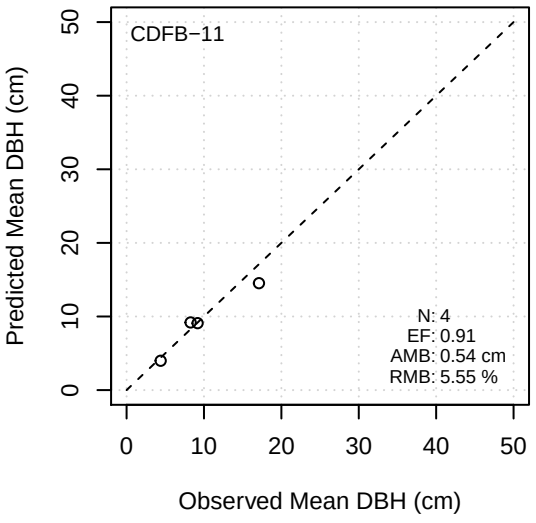

**Deciduous Mean Height − CDFB**



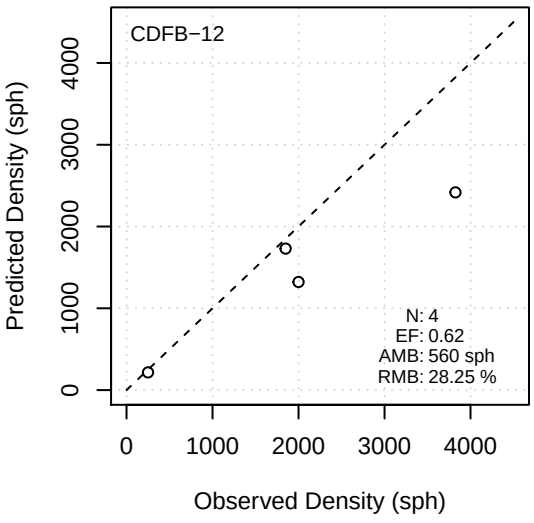

**Deciduous Top Height − CDFB**



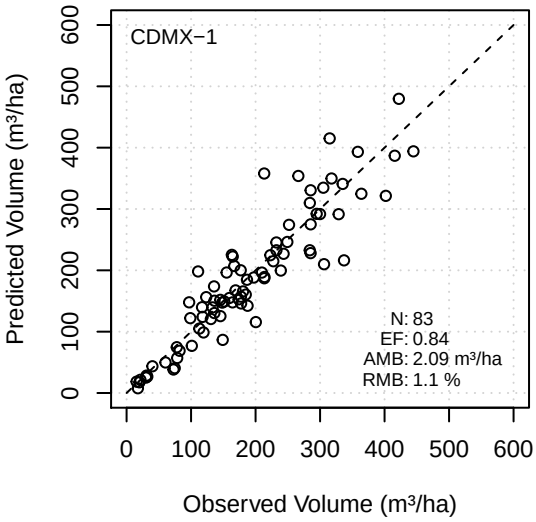

**Deciduous Mean DBH − CDFB**



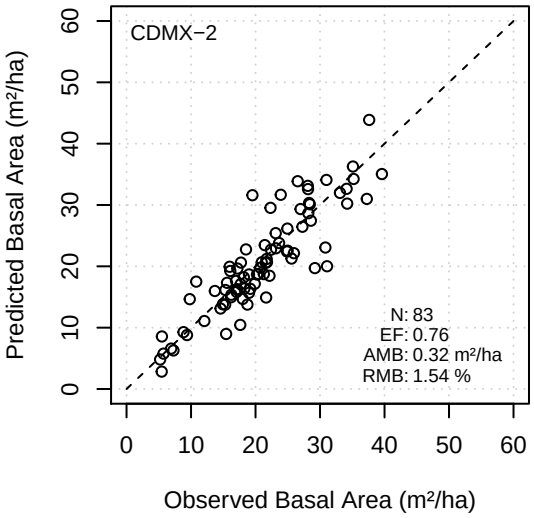

**Deciduous Density − CDFB**



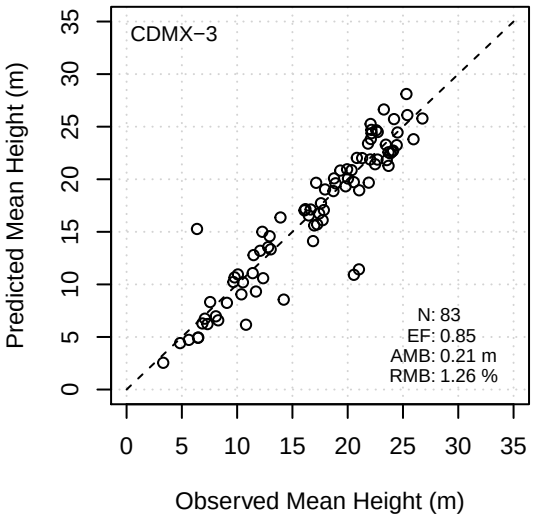
**Conifer Volume − CDMX**



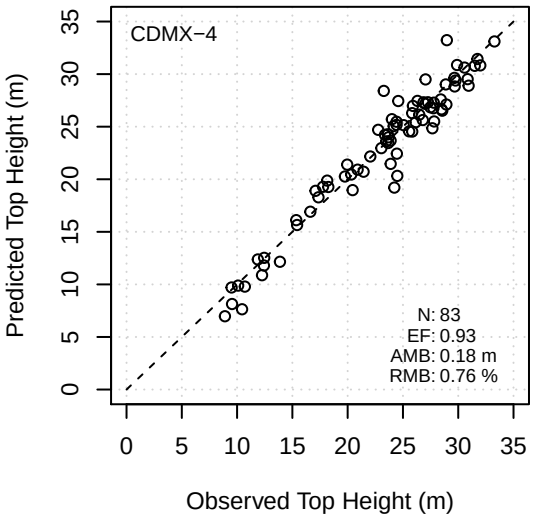

**Conifer Basal Area − CDMX**



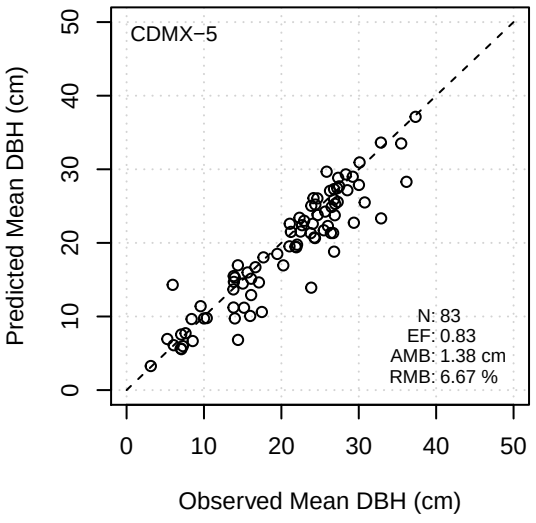

**Conifer Mean Height − CDMX**



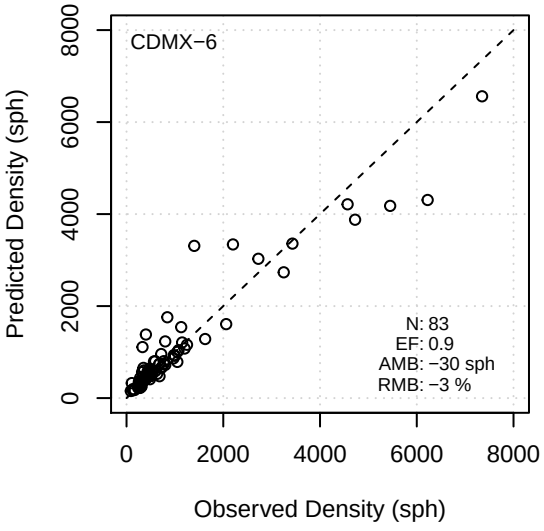

**Conifer Top Height − CDMX**



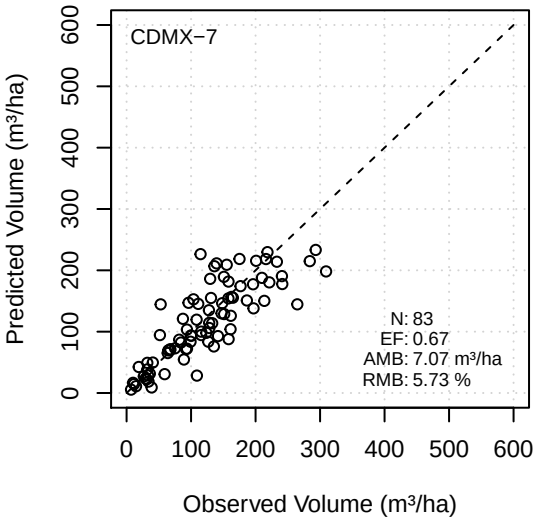

**Conifer Mean DBH − CDMX**



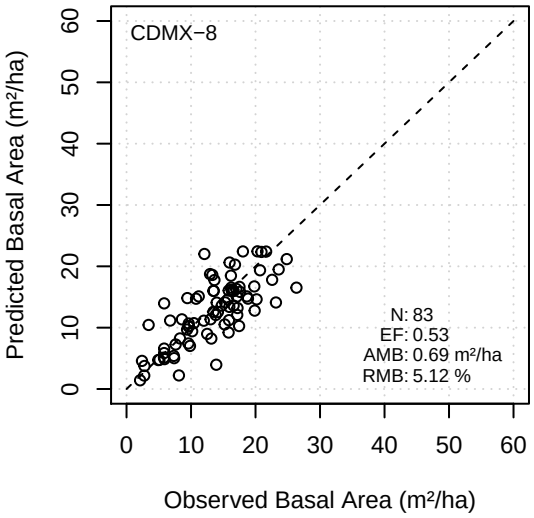

**Conifer Density − CDMX**



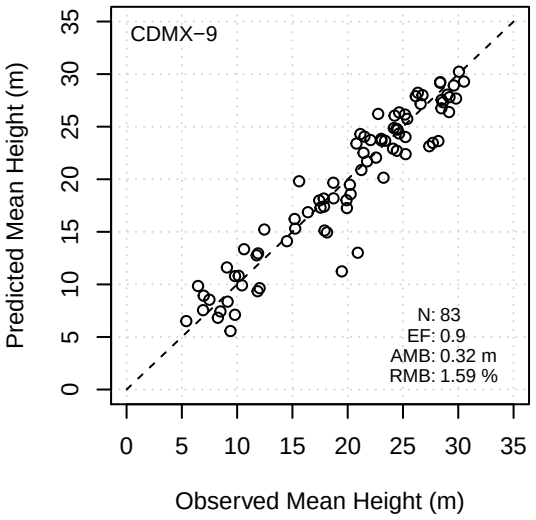
**Deciduous Volume − CDMX**



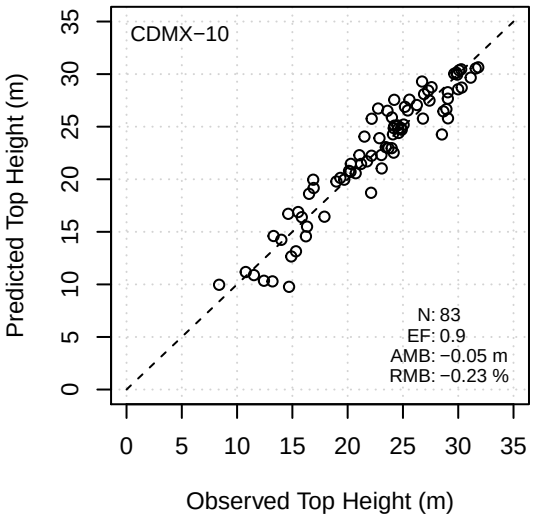

**Deciduous Basal Area − CDMX**



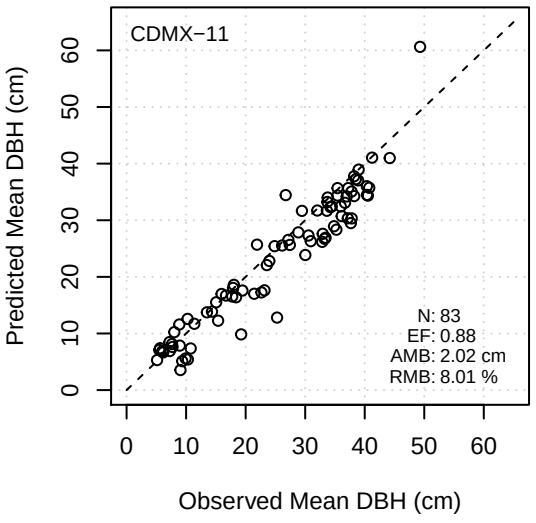

**Deciduous Mean Height − CDMX**



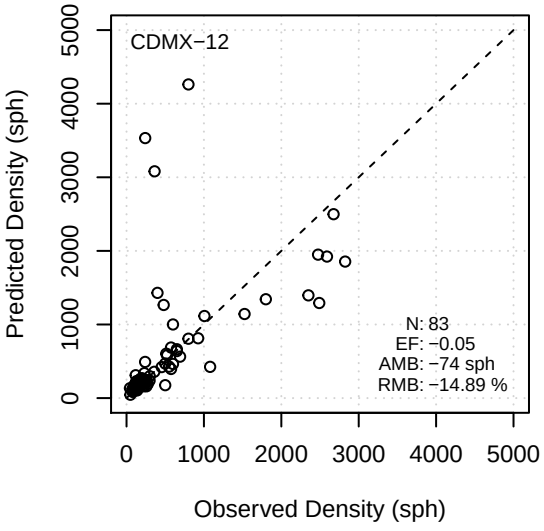

**Deciduous Top Height − CDMX**



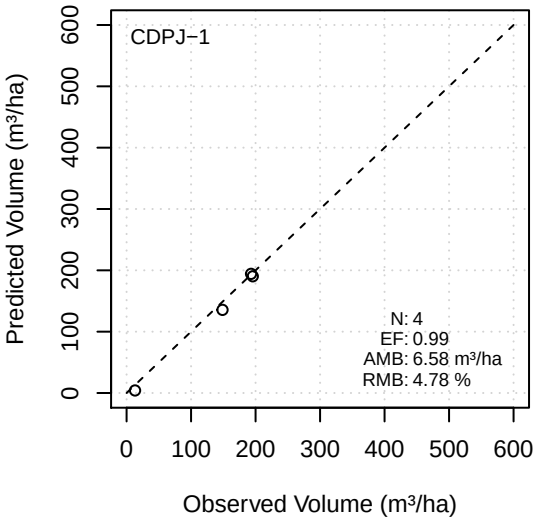

**Deciduous Mean DBH − CDMX**



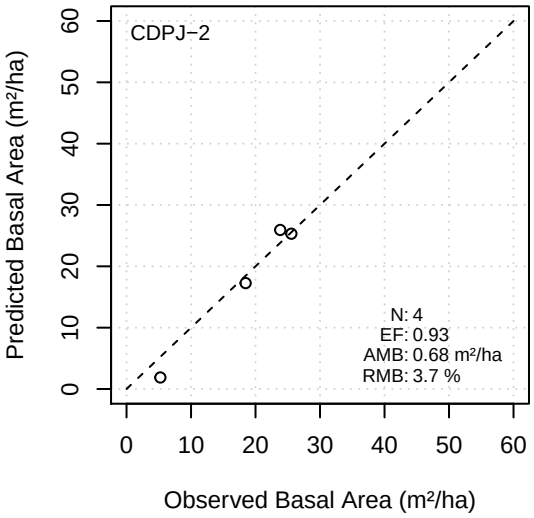

**Deciduous Density − CDMX**



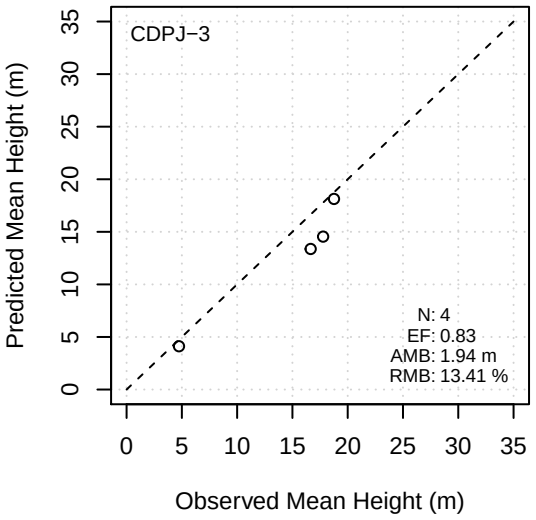
**Conifer Volume − CDPJ**



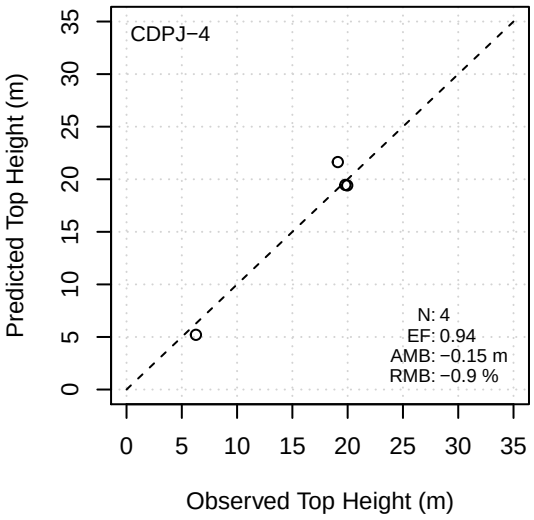

**Conifer Basal Area − CDPJ**



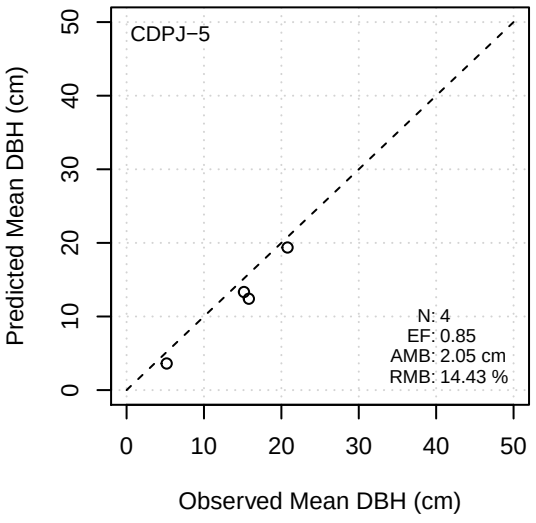

**Conifer Mean Height − CDPJ**



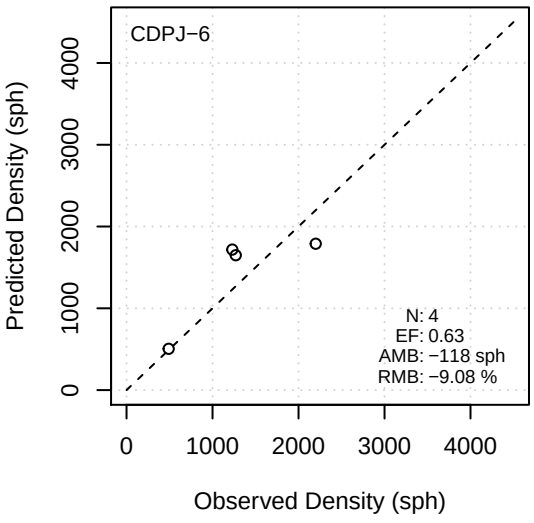

**Conifer Top Height − CDPJ**



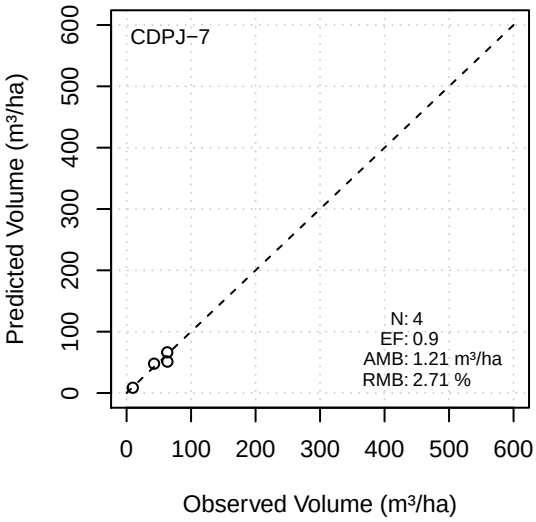

**Conifer Mean DBH − CDPJ**



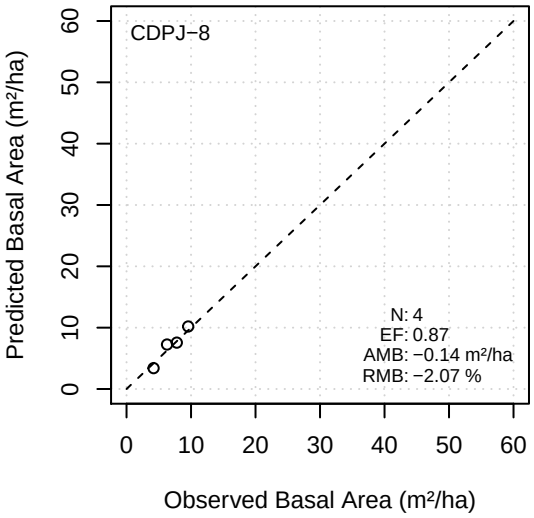

**Conifer Density − CDPJ**



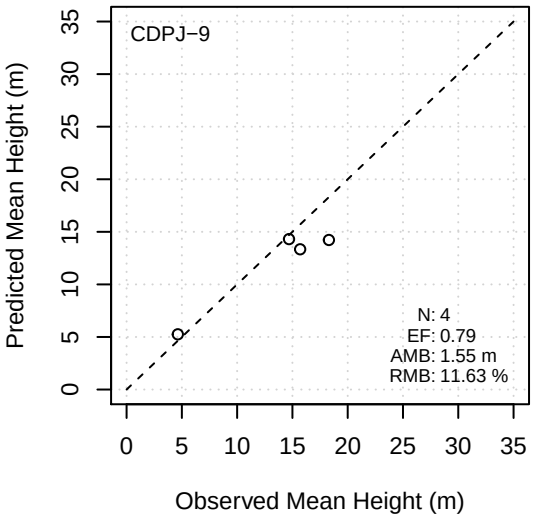
**Deciduous Volume − CDPJ**



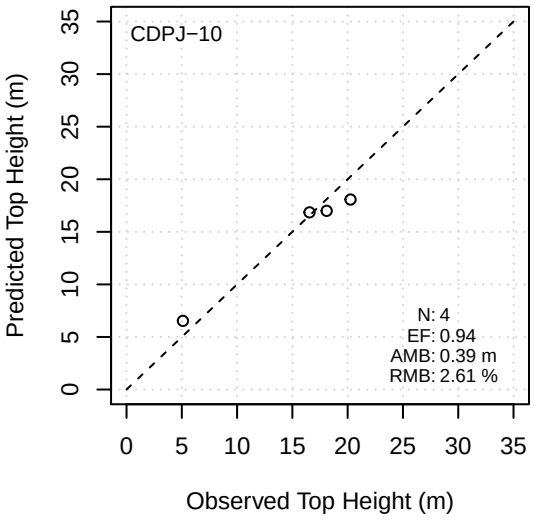

**Deciduous Basal Area − CDPJ**



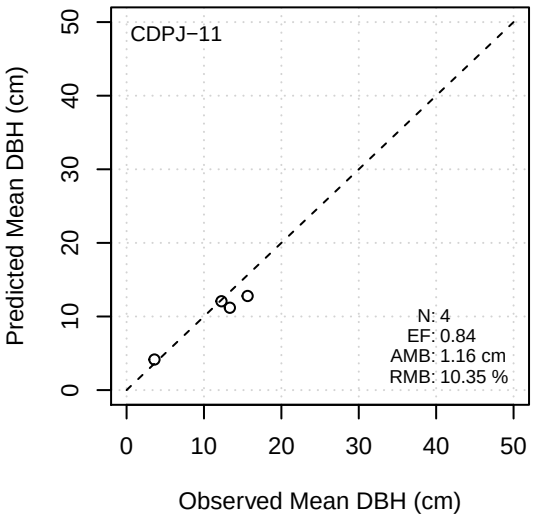

**Deciduous Mean Height − CDPJ**



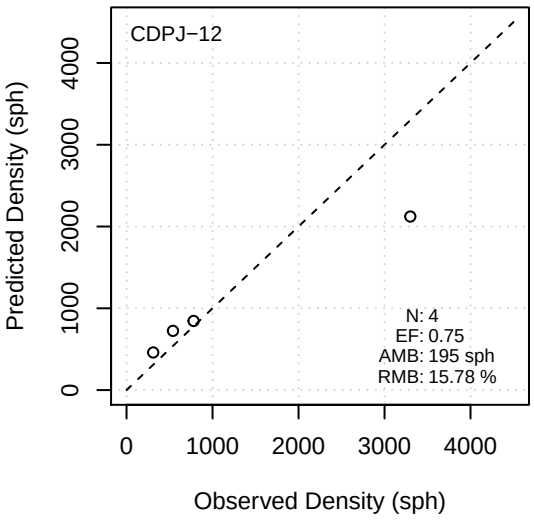

**Deciduous Top Height − CDPJ**



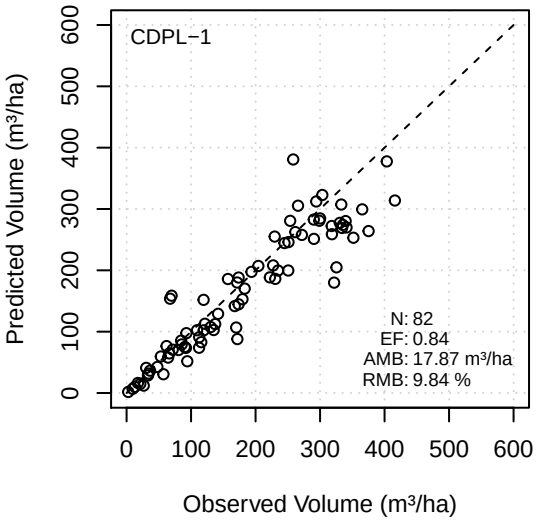

**Deciduous Mean DBH − CDPJ**



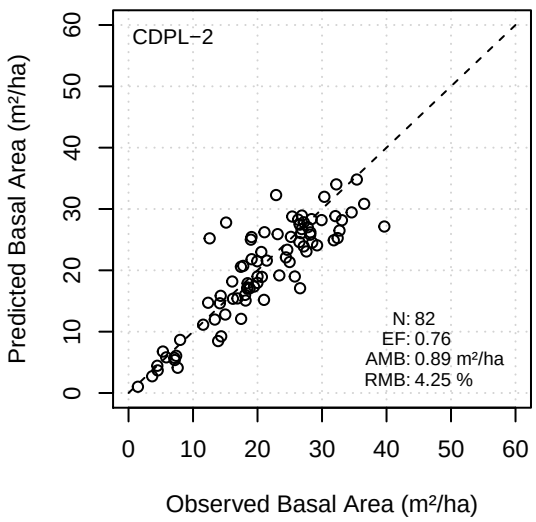

**Deciduous Density − CDPJ**



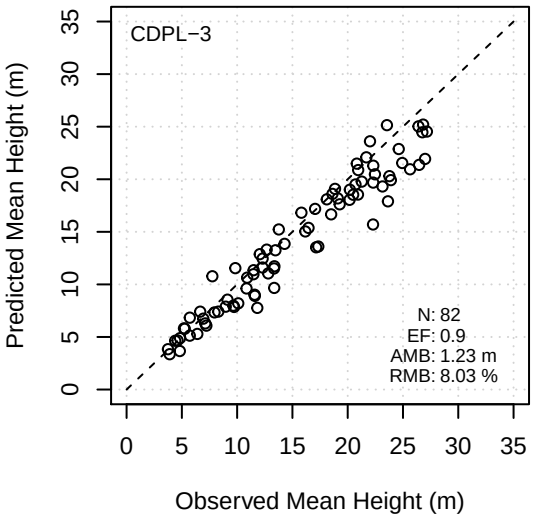
**Conifer Volume − CDPL**



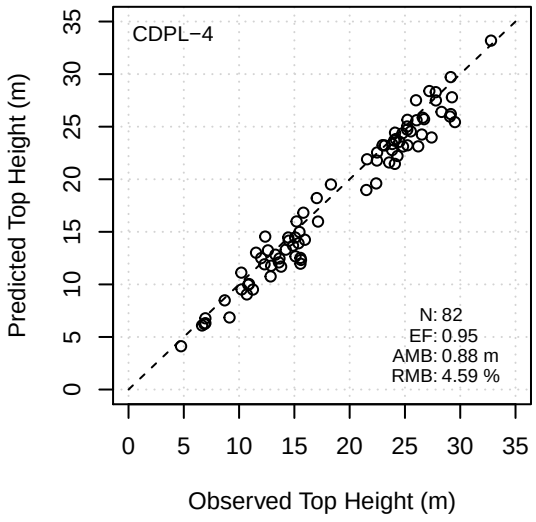

**Conifer Basal Area − CDPL**



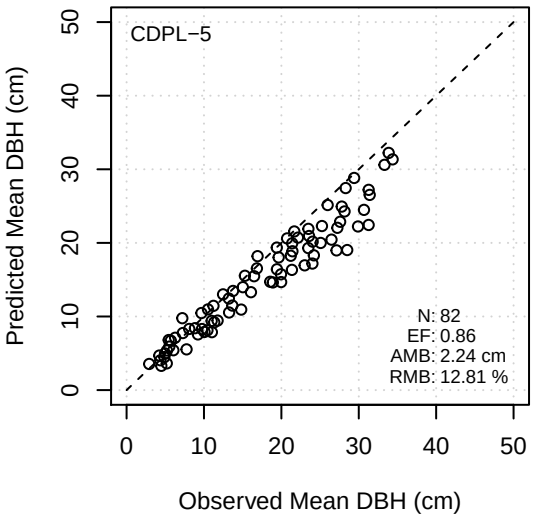

**Conifer Mean Height − CDPL**



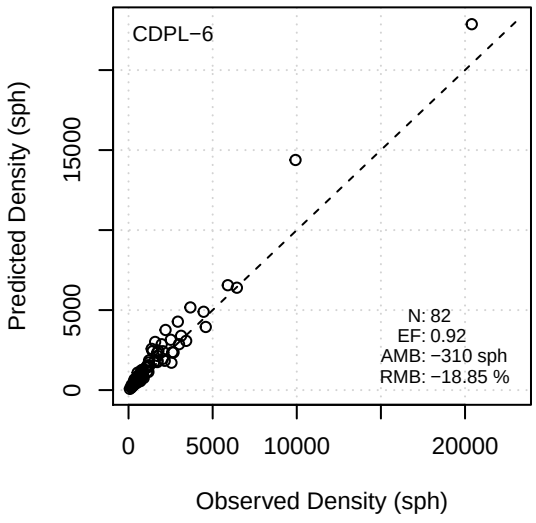

**Conifer Top Height − CDPL**



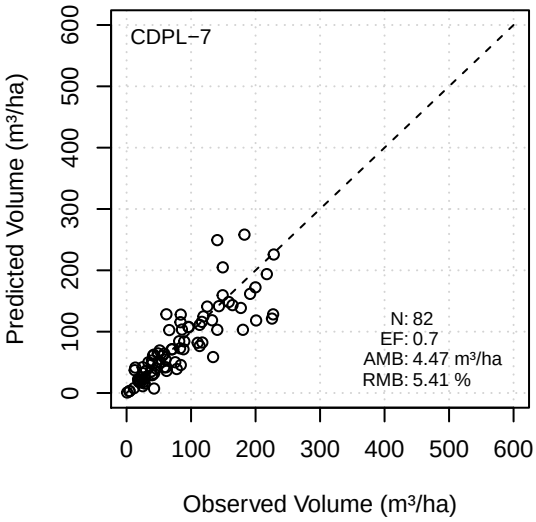

**Conifer Mean DBH − CDPL**



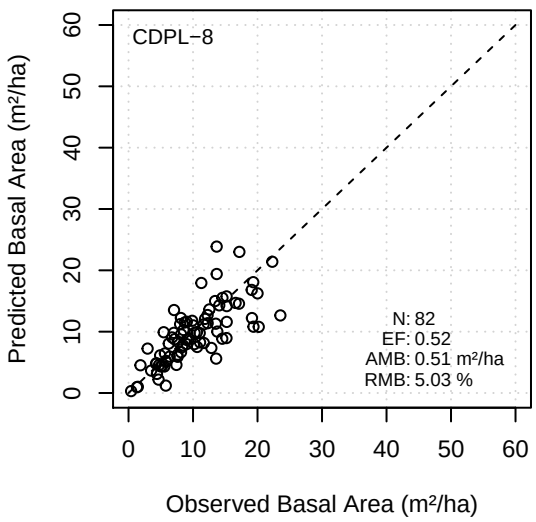

**Conifer Density − CDPL**



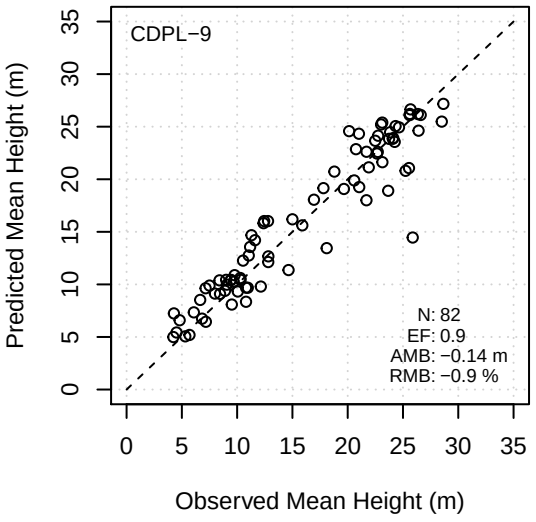
**Deciduous Volume − CDPL**



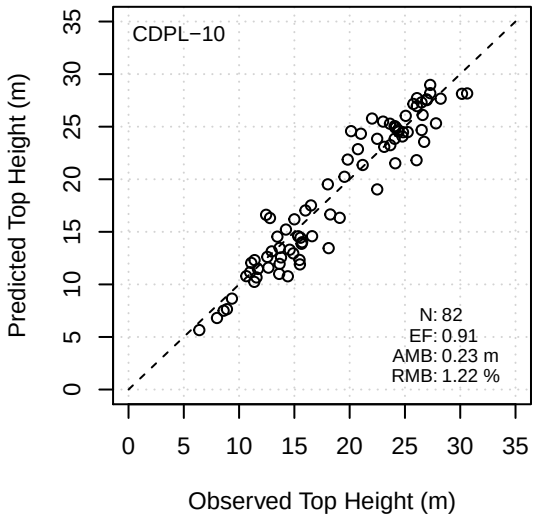

**Deciduous Basal Area − CDPL**



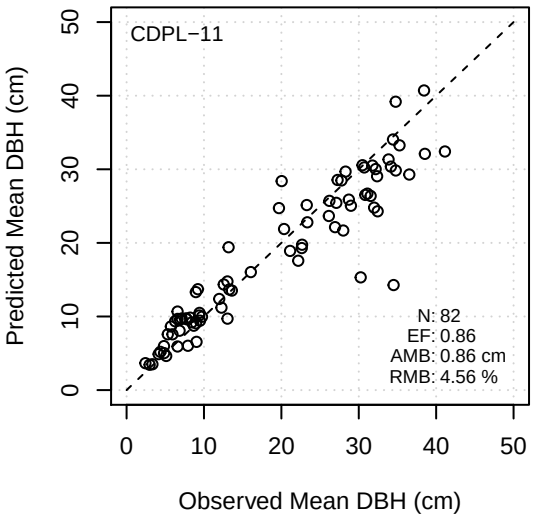

**Deciduous Mean Height − CDPL**



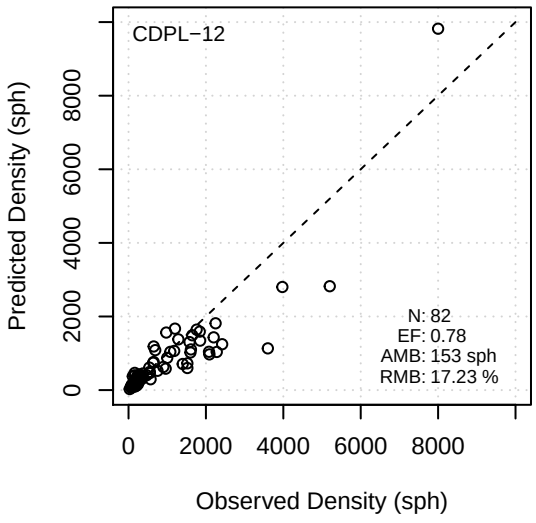

**Deciduous Top Height − CDPL**



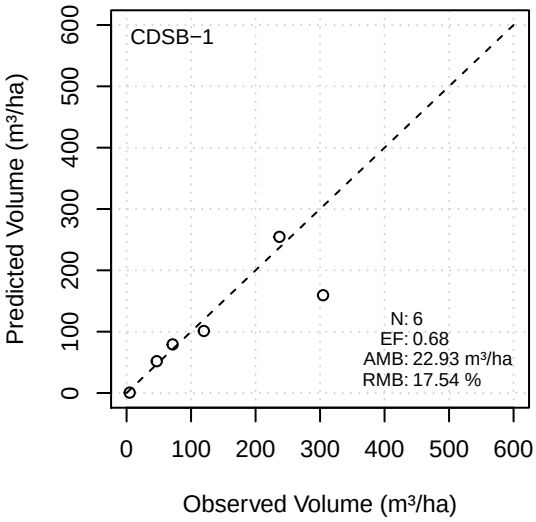

**Deciduous Mean DBH − CDPL**



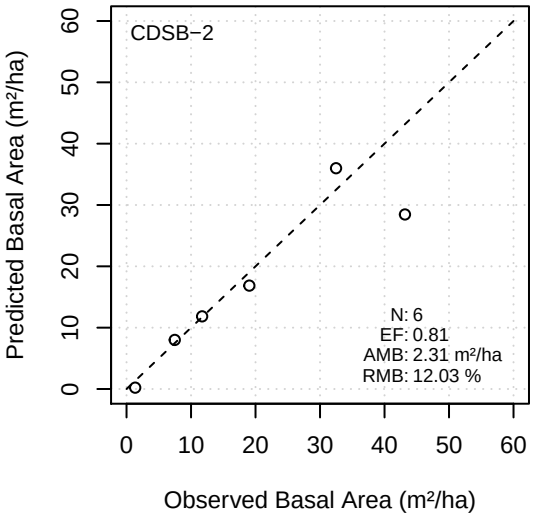

**Deciduous Density − CDPL**



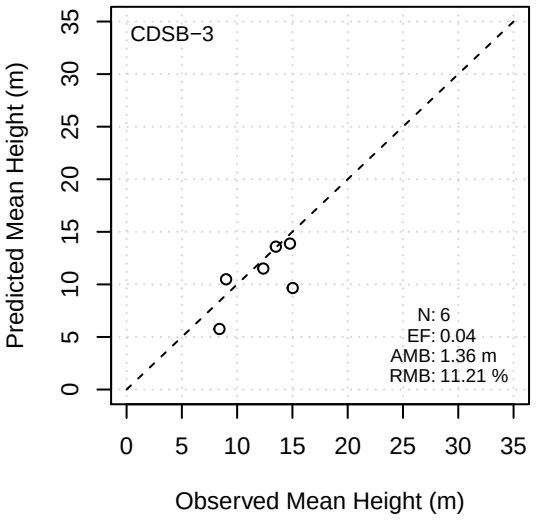
**Conifer Volume − CDSB**



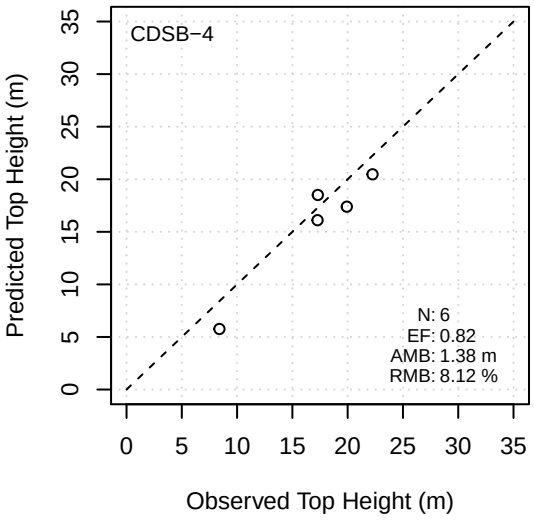

**Conifer Basal Area − CDSB**



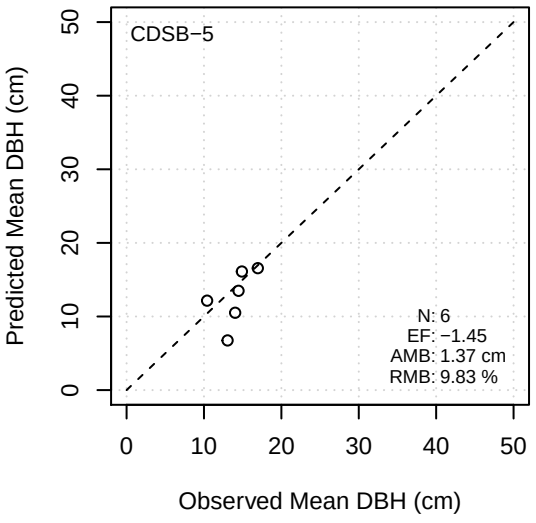

**Conifer Mean Height − CDSB**



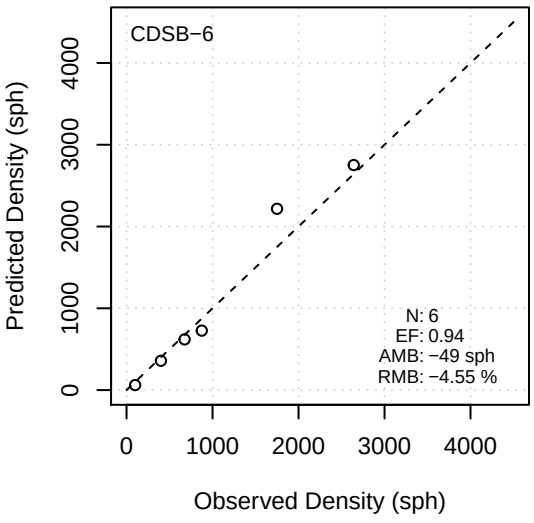

**Conifer Top Height − CDSB**



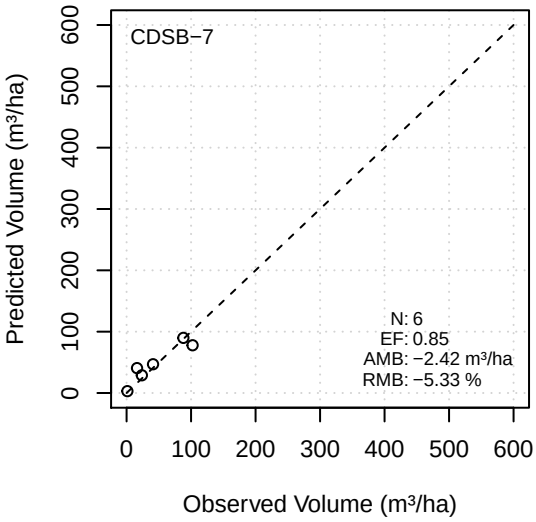

**Conifer Mean DBH − CDSB**



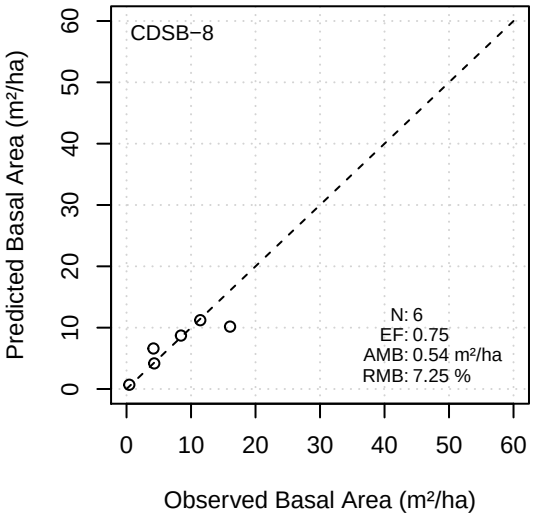

**Conifer Density − CDSB**



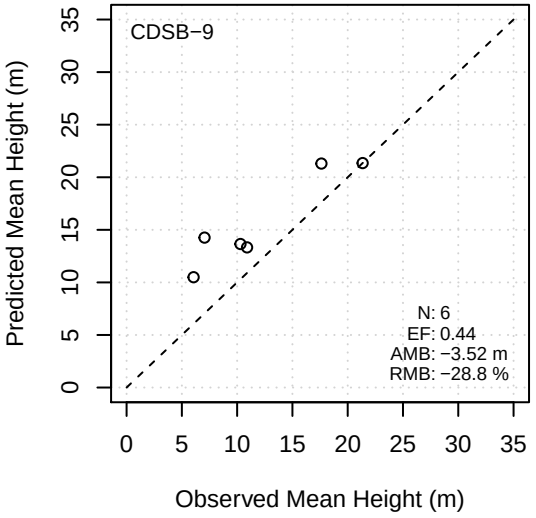
**Deciduous Volume − CDSB**



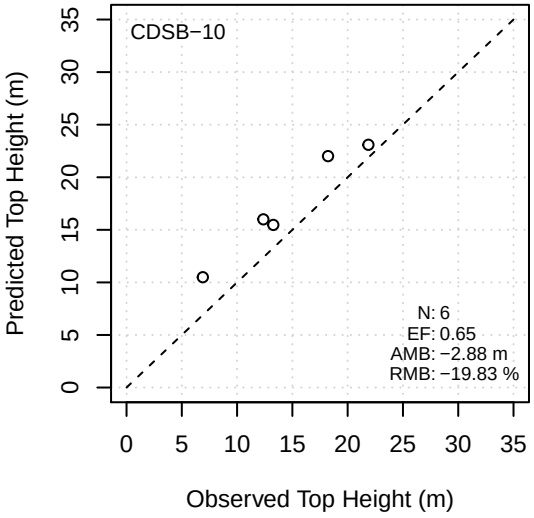

**Deciduous Basal Area − CDSB**



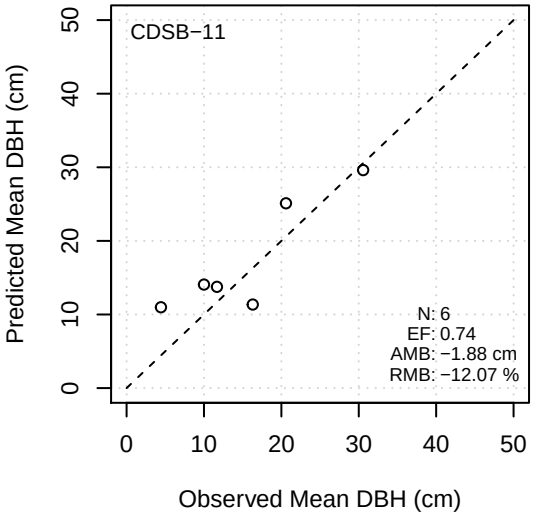

**Deciduous Mean Height − CDSB**



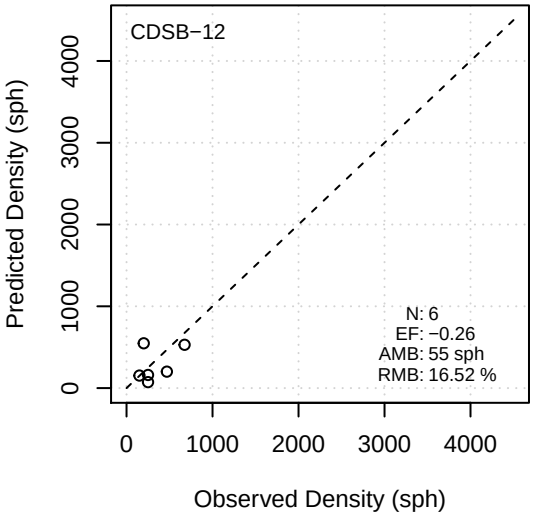

**Deciduous Top Height − CDSB**



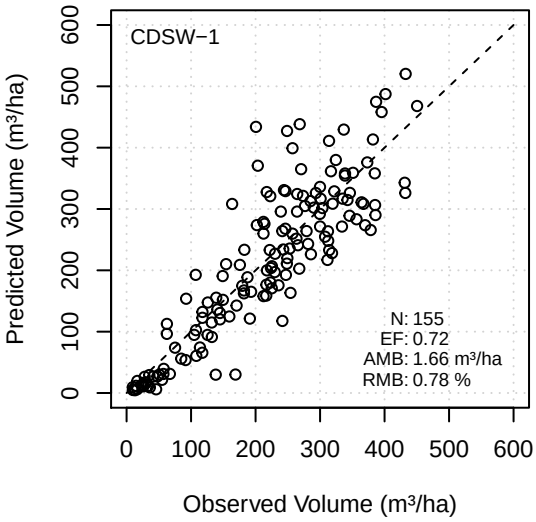

**Deciduous Mean DBH − CDSB**



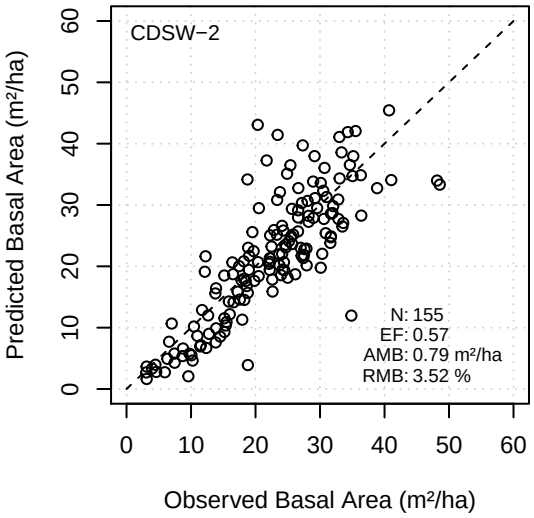

**Deciduous Density − CDSB**



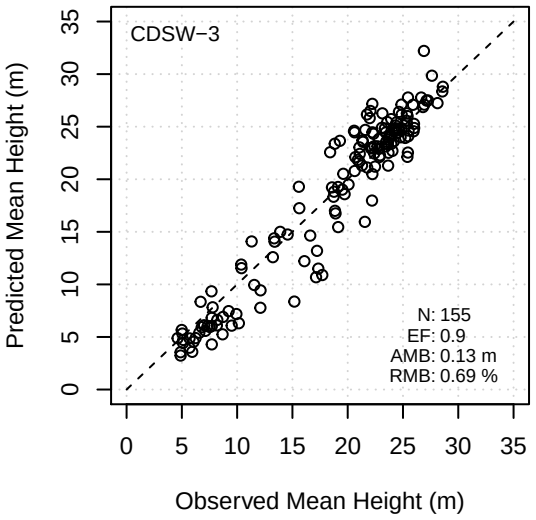
**Conifer Volume − CDSW**



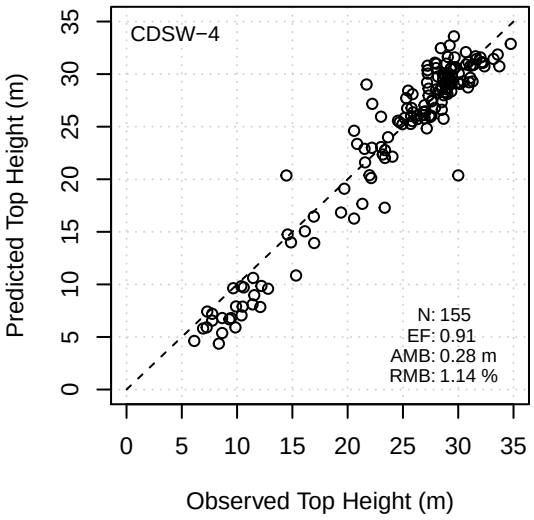

**Conifer Basal Area − CDSW**



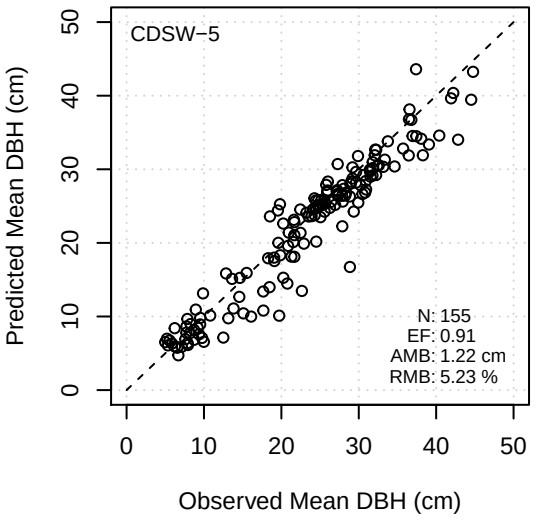

**Conifer Mean Height − CDSW**



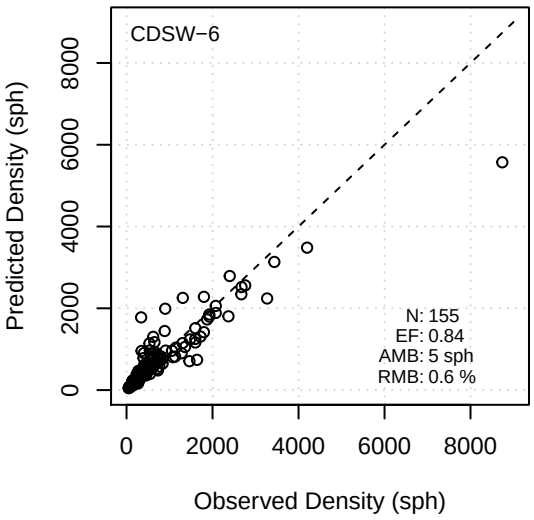

**Conifer Top Height − CDSW**



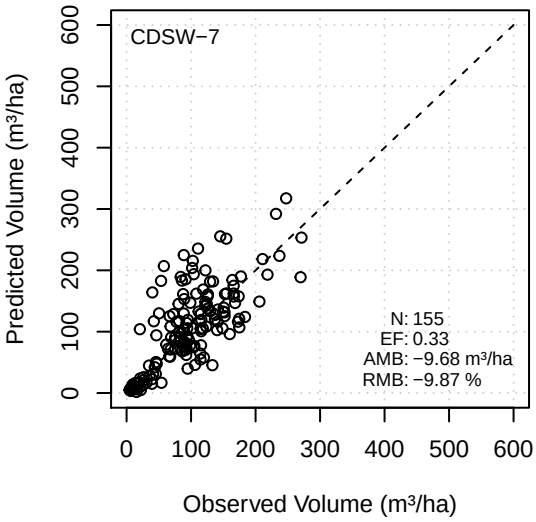

**Conifer Mean DBH − CDSW**



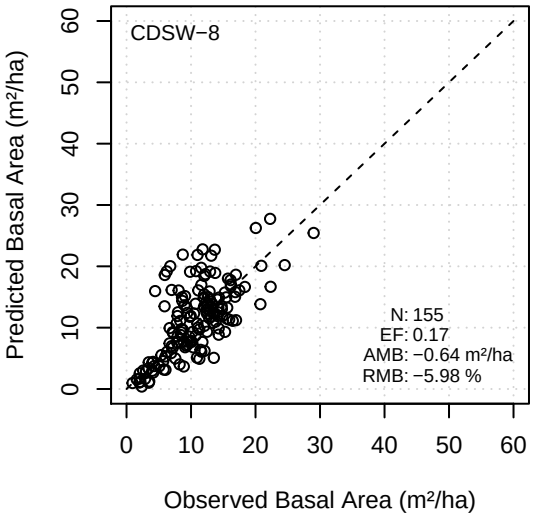

**Conifer Density − CDSW**



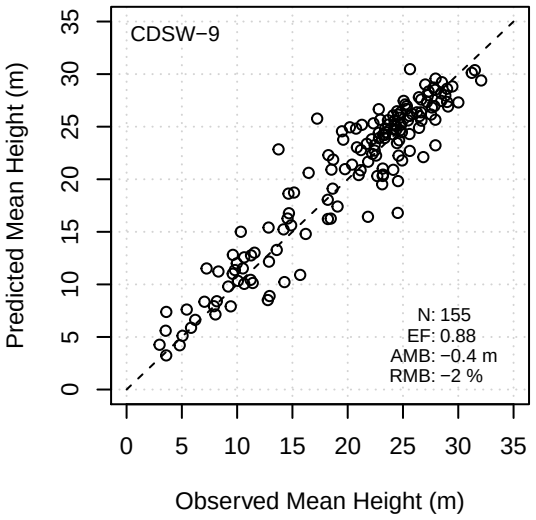
**Deciduous Volume − CDSW**



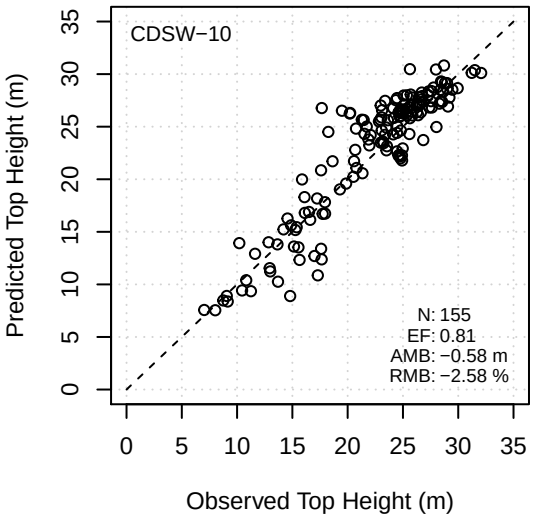

**Deciduous Basal Area − CDSW**



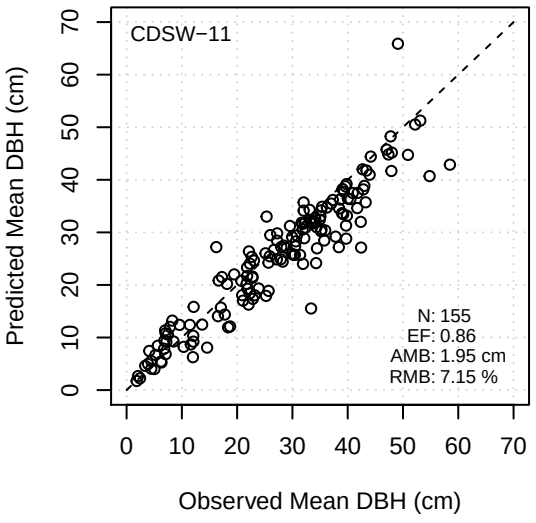

**Deciduous Mean Height − CDSW**



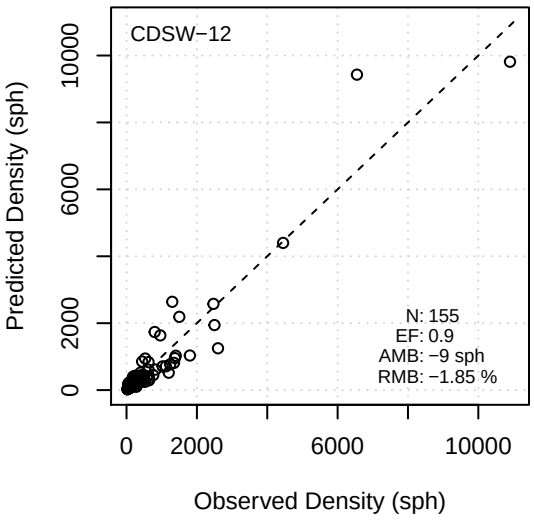

**Deciduous Top Height − CDSW**



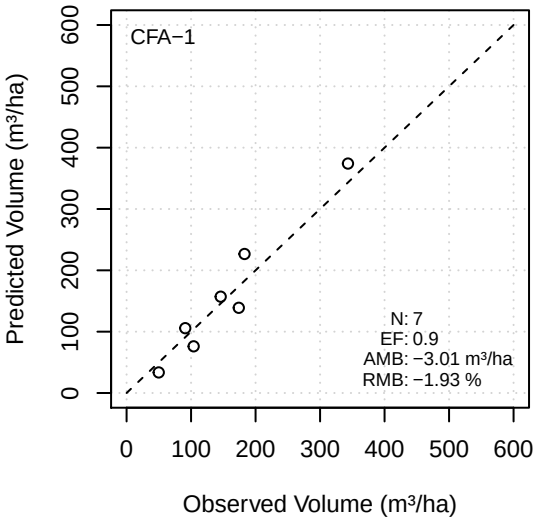

**Deciduous Mean DBH − CDSW**



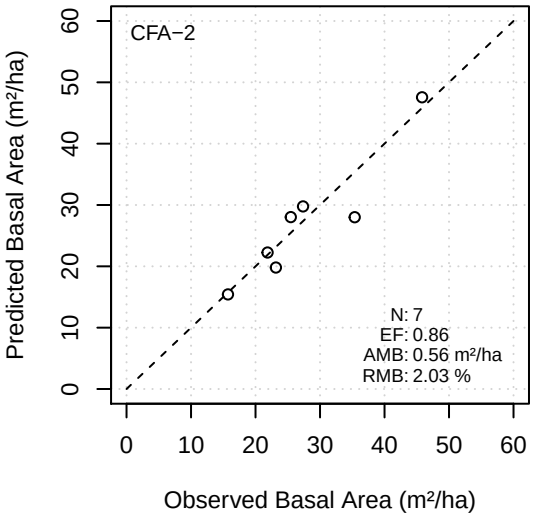

**Deciduous Density − CDSW**



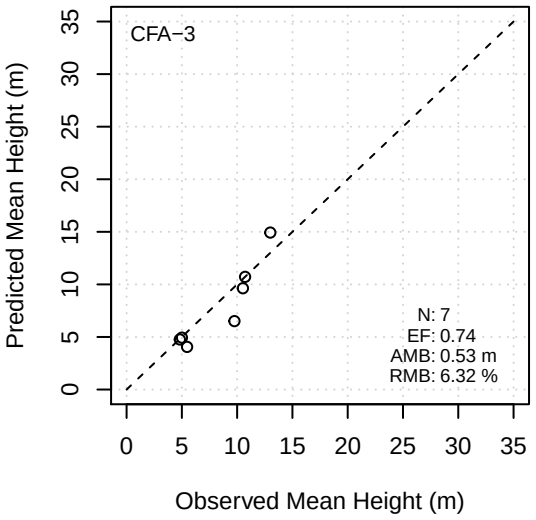
**Conifer Volume − CFA**



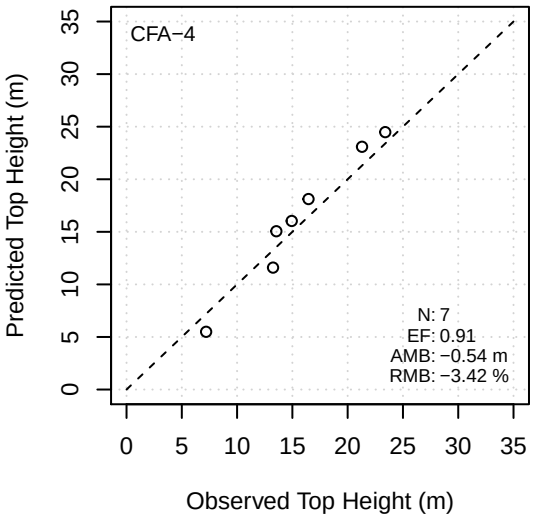

**Conifer Basal Area − CFA**



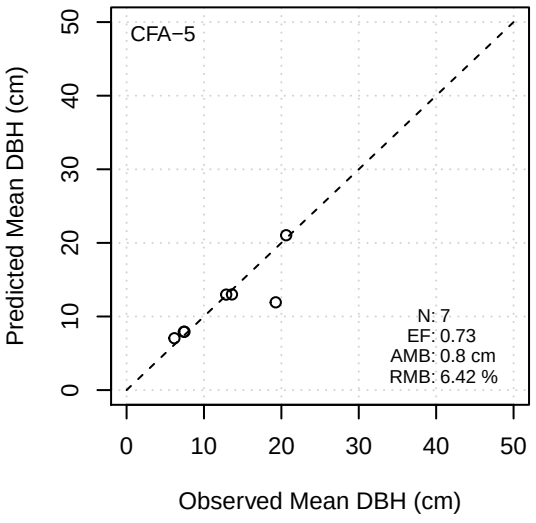

**Conifer Mean Height − CFA**



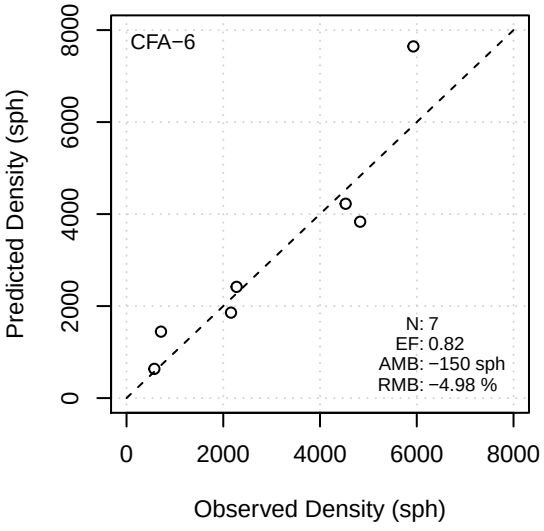

**Conifer Top Height − CFA**



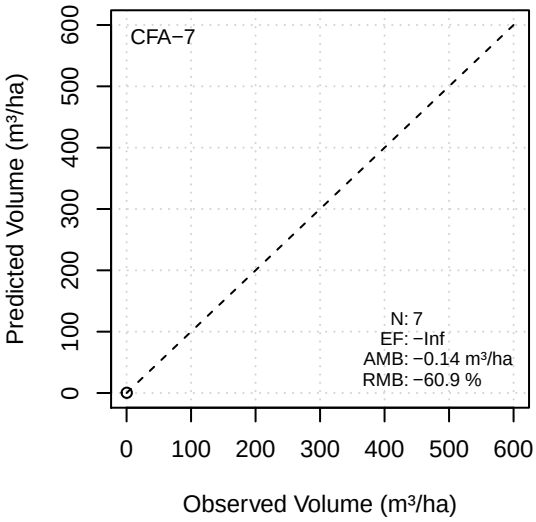

**Conifer Mean DBH − CFA**



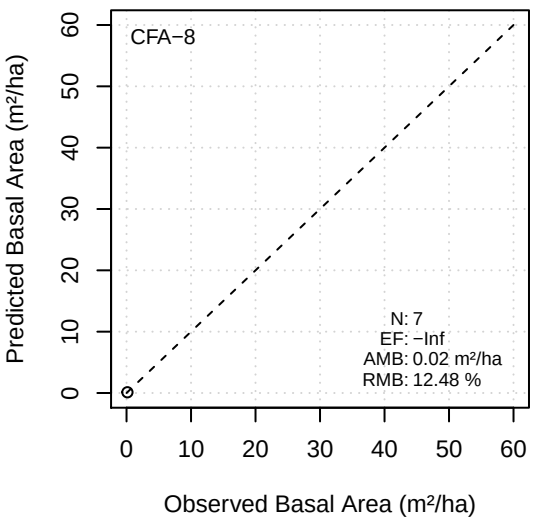

**Conifer Density − CFA**



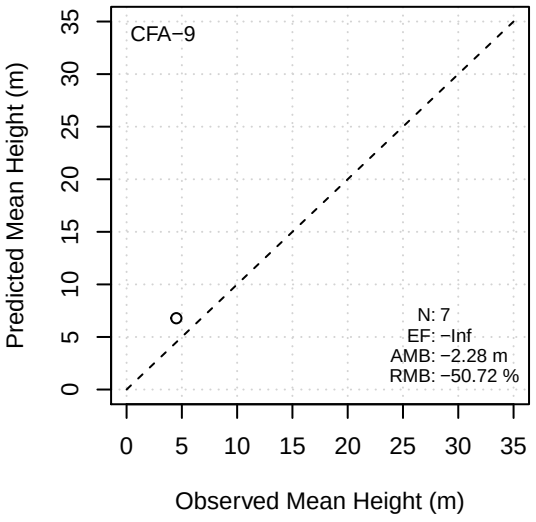
**Deciduous Volume − CFA**



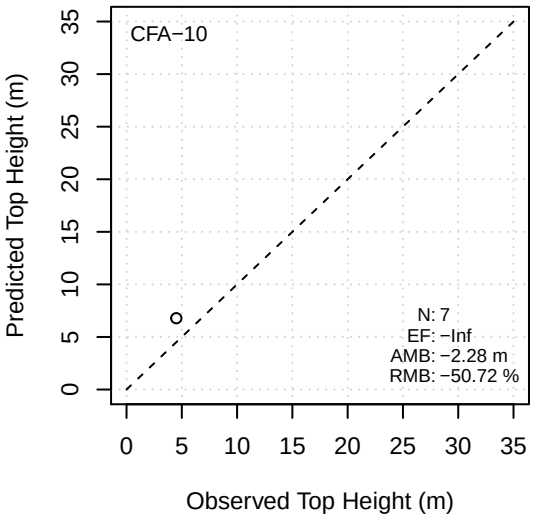

**Deciduous Basal Area − CFA**



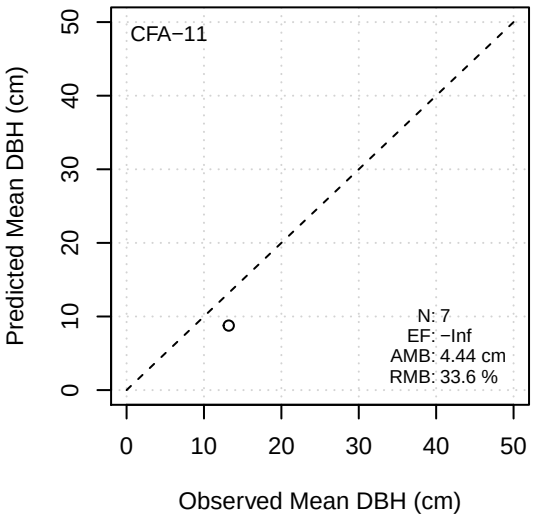

**Deciduous Mean Height − CFA**



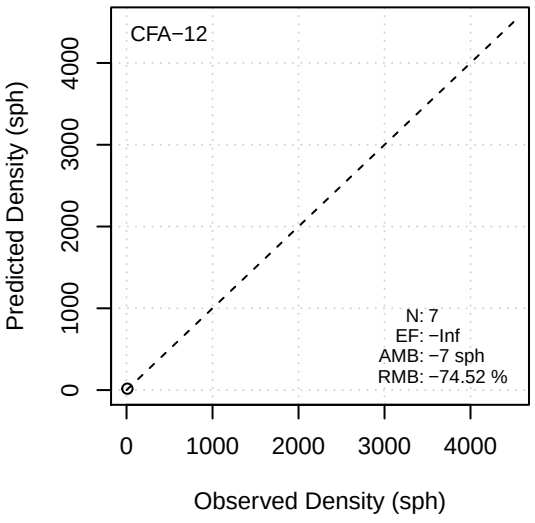

**Deciduous Top Height − CFA**



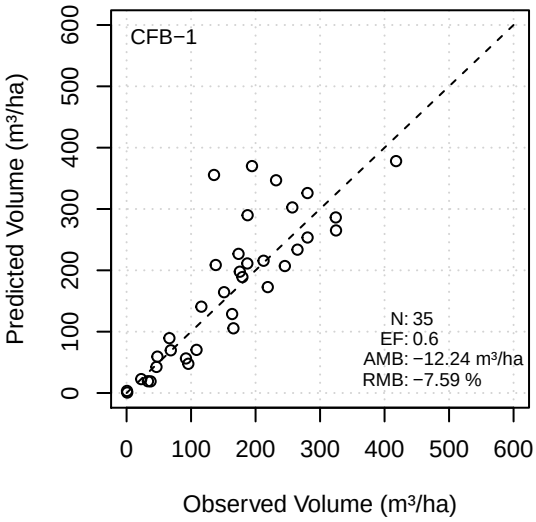

**Deciduous Mean DBH − CFA**



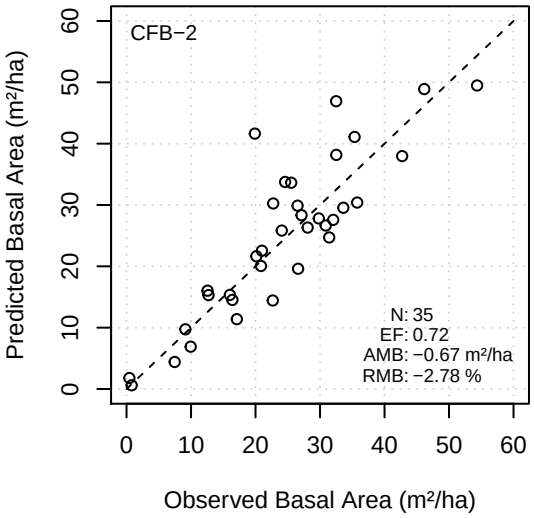

**Deciduous Density − CFA**



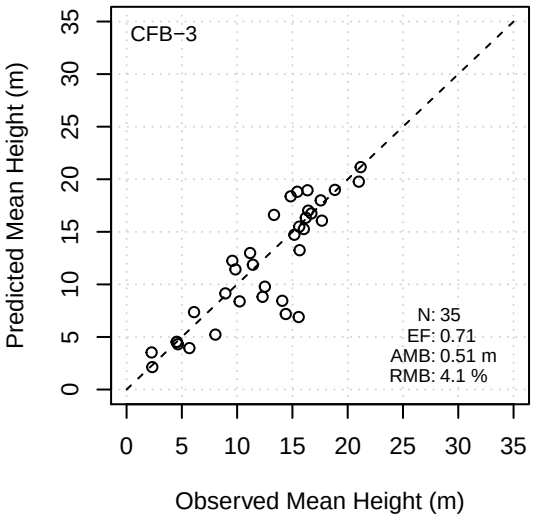
**Conifer Volume − CFB**



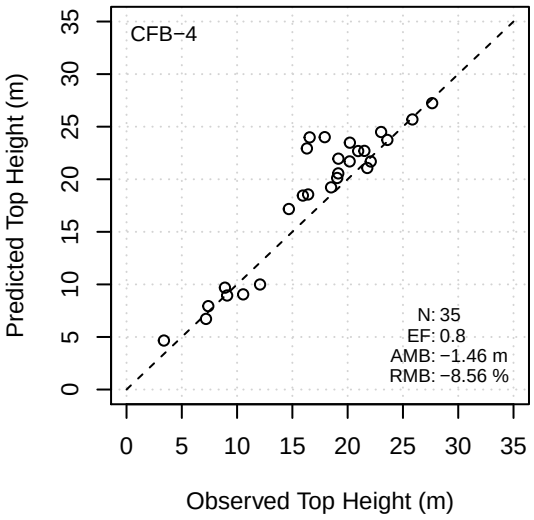

**Conifer Basal Area − CFB**



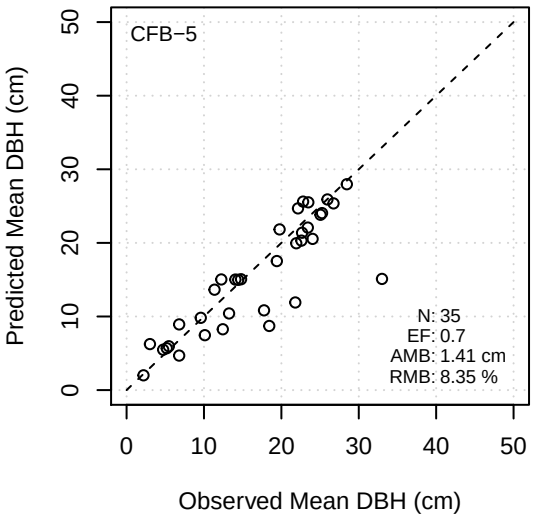

**Conifer Mean Height − CFB**



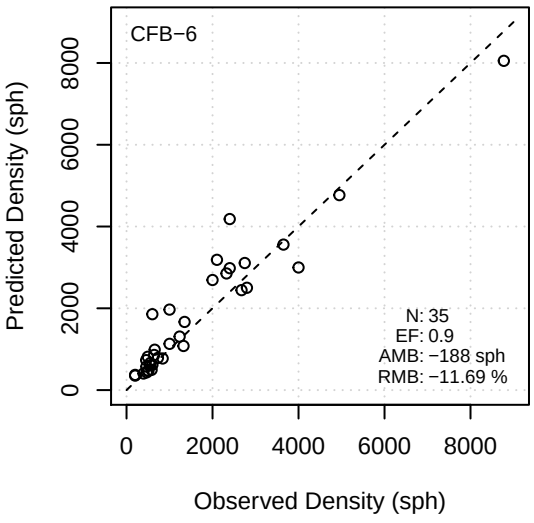

**Conifer Top Height − CFB**



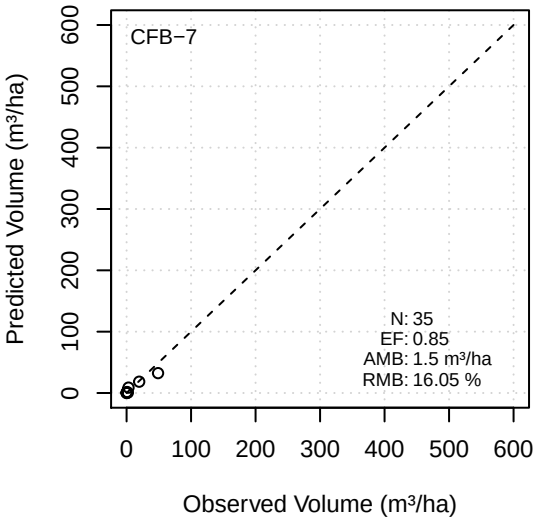

**Conifer Mean DBH − CFB**



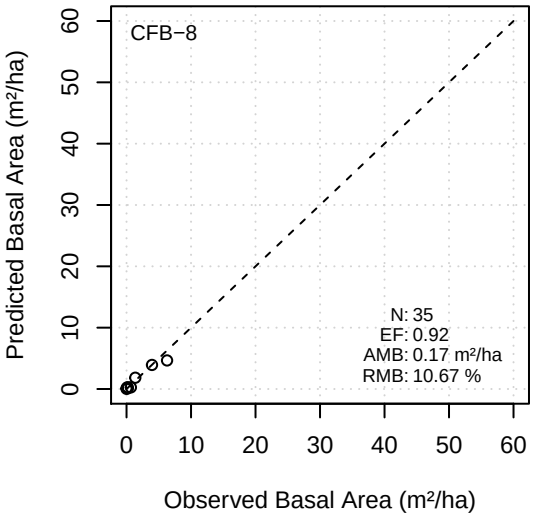

**Conifer Density − CFB**



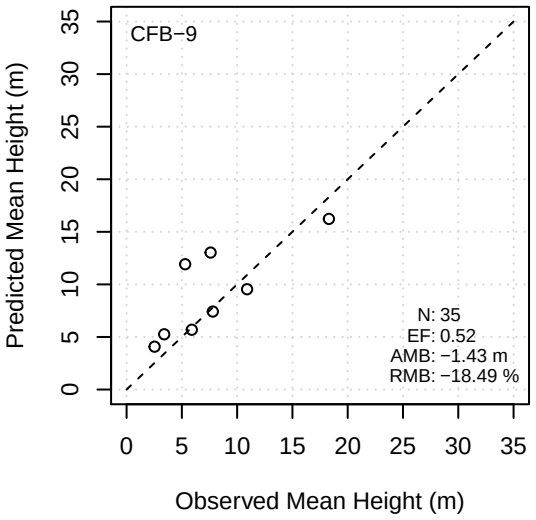
**Deciduous Volume − CFB**



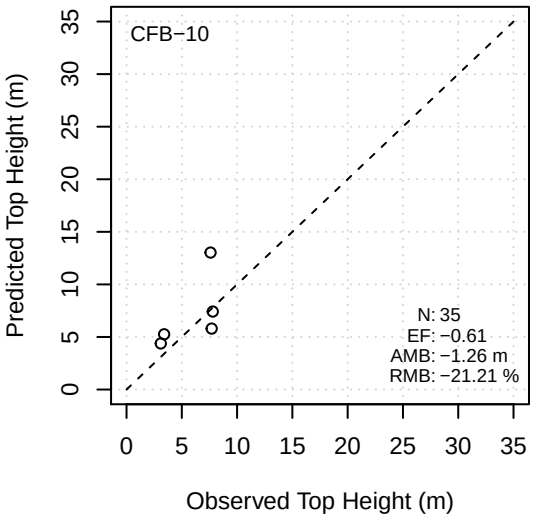

**Deciduous Basal Area − CFB**



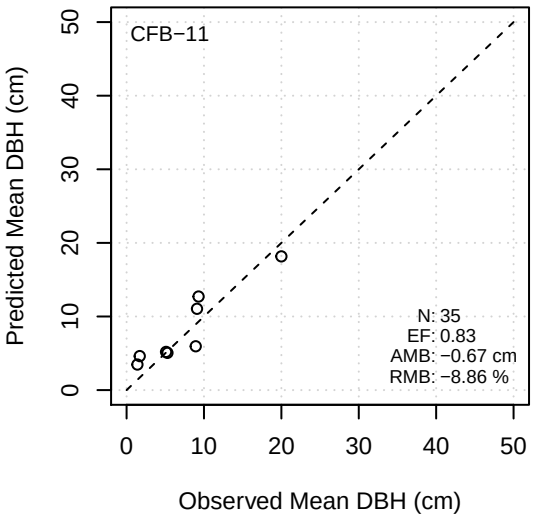

**Deciduous Mean Height − CFB**



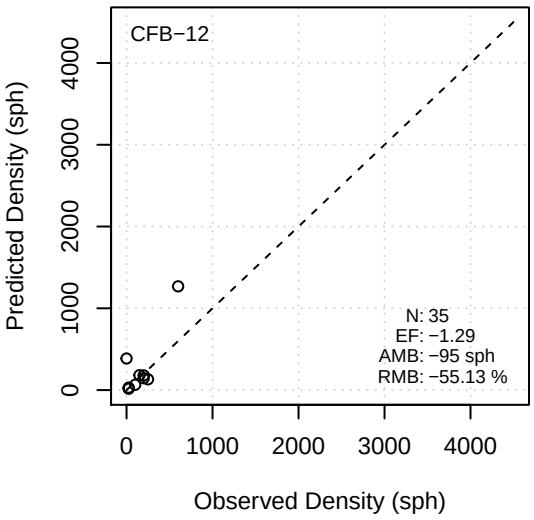

**Deciduous Top Height − CFB**



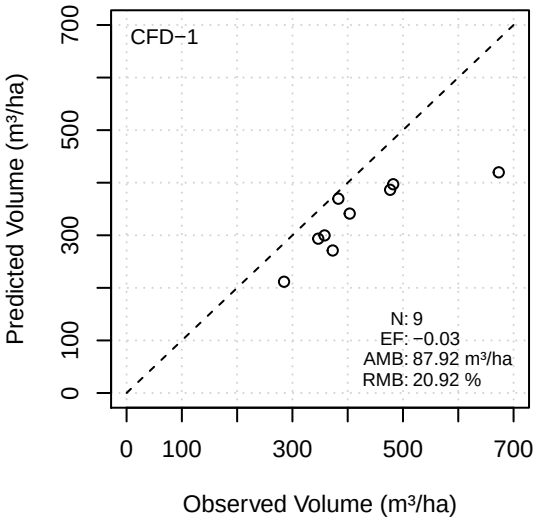

**Deciduous Mean DBH − CFB**



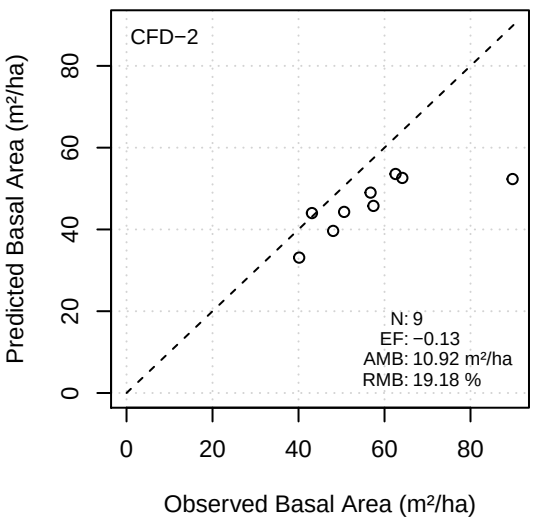

**Deciduous Density − CFB**



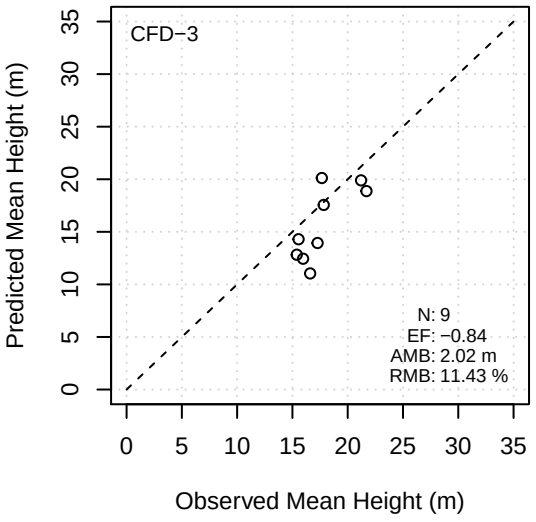
**Conifer Volume − CFD**



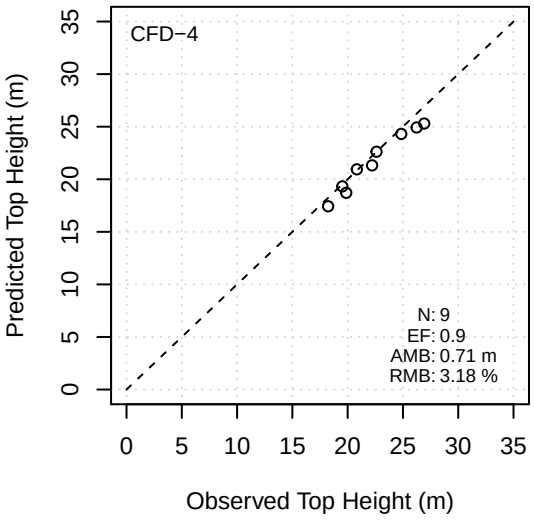

**Conifer Basal Area − CFD**



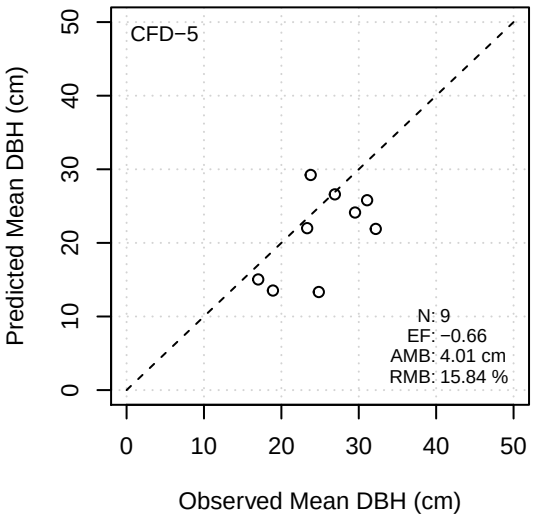

**Conifer Mean Height − CFD**



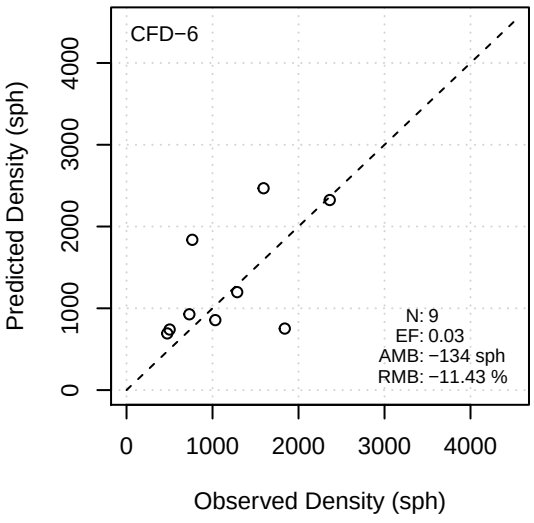

**Conifer Top Height − CFD**



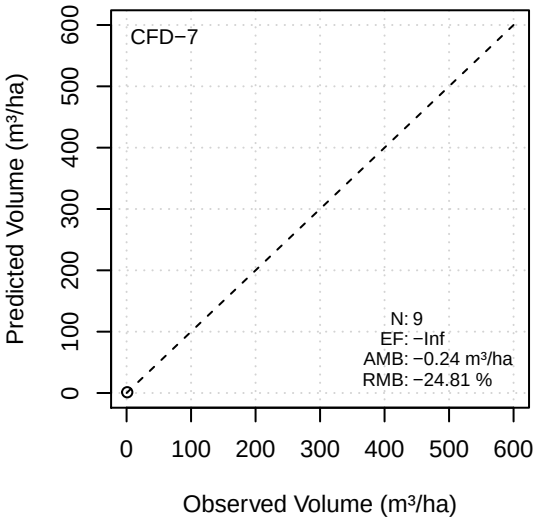

**Conifer Mean DBH − CFD**



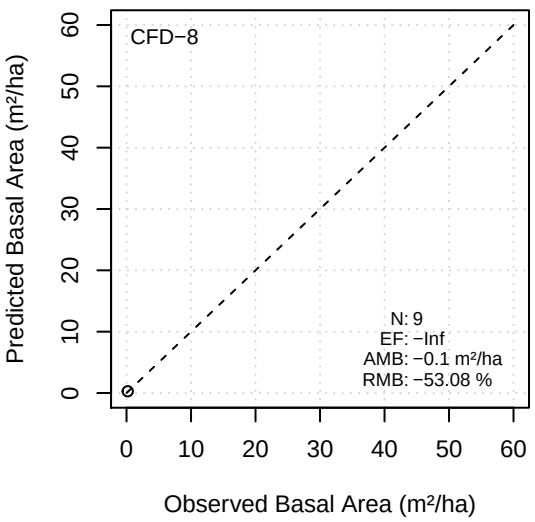

**Conifer Density − CFD**



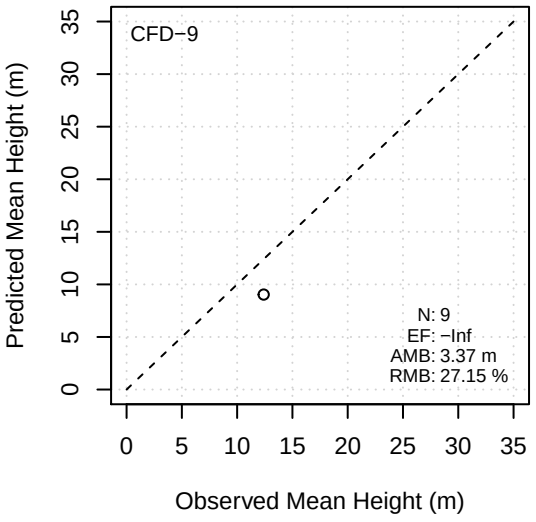
**Deciduous Volume − CFD**



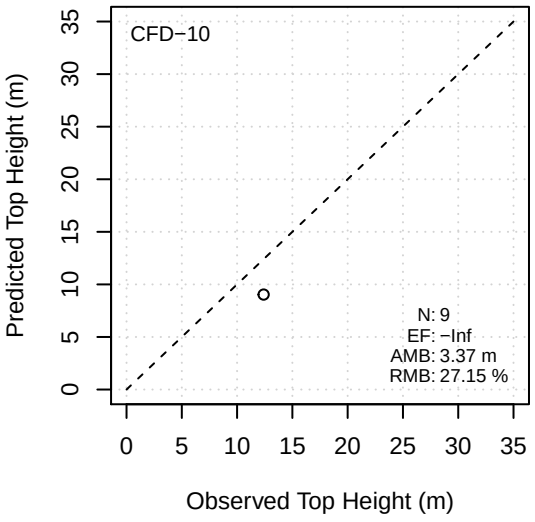

**Deciduous Basal Area − CFD**



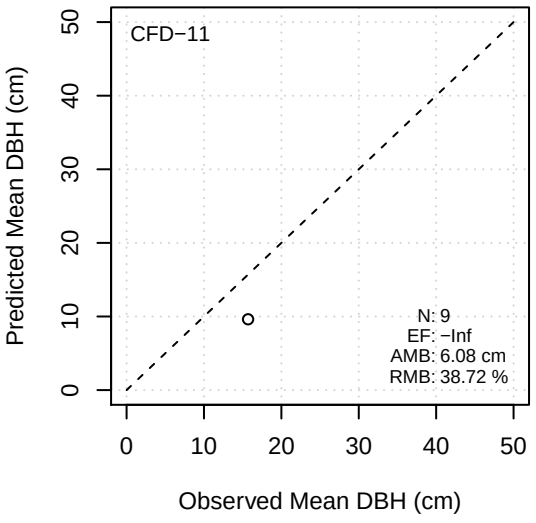

**Deciduous Mean Height − CFD**



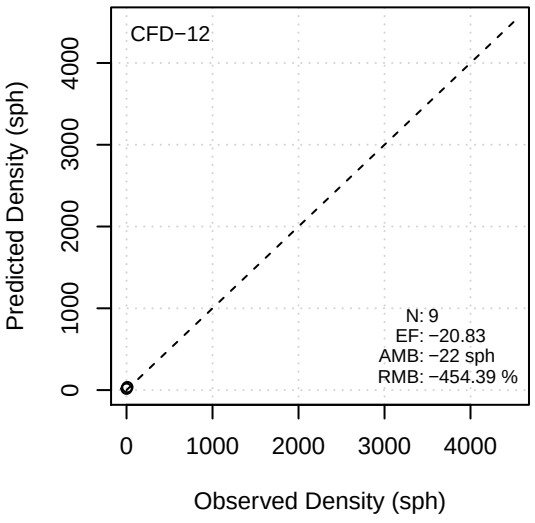

**Deciduous Top Height − CFD**



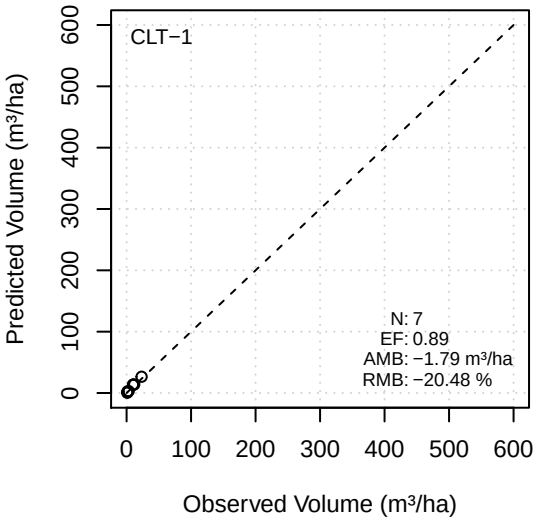

**Deciduous Mean DBH − CFD**



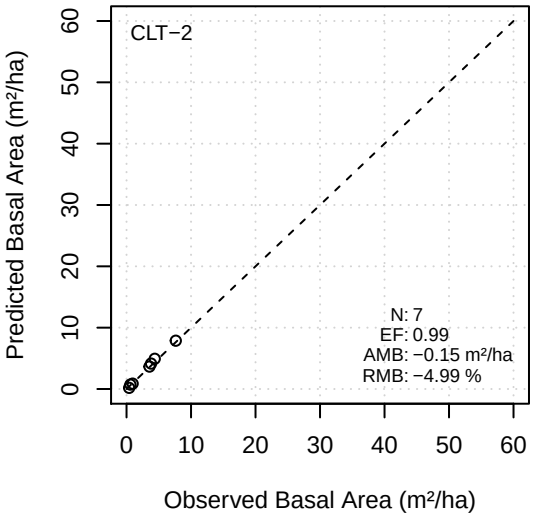

**Deciduous Density − CFD**



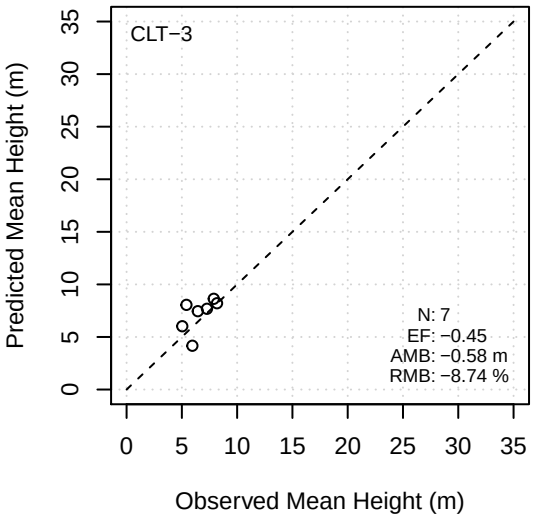
**Conifer Volume − CLT**



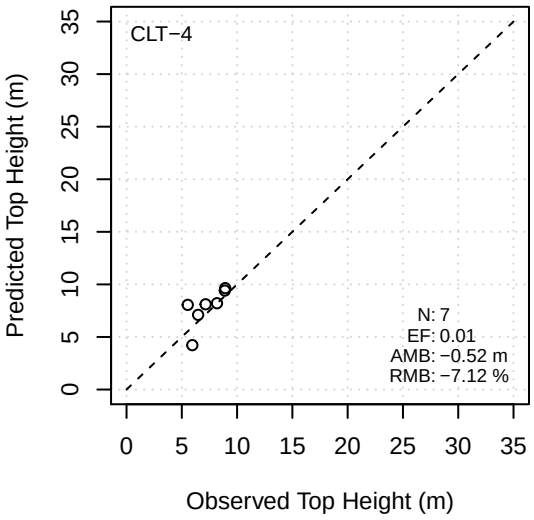

**Conifer Basal Area − CLT**



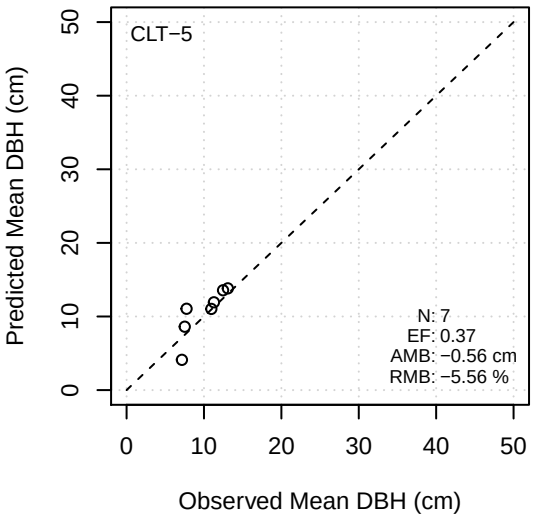

**Conifer Mean Height − CLT**



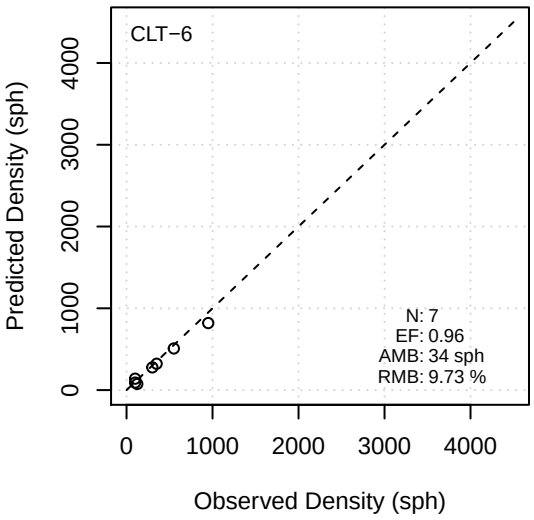

**Conifer Top Height − CLT**



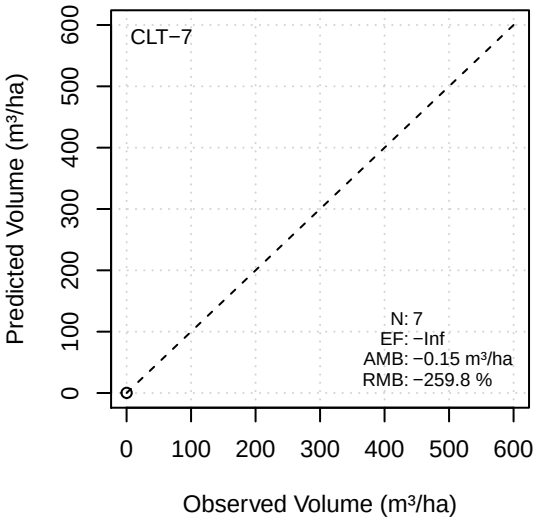

**Conifer Mean DBH − CLT**



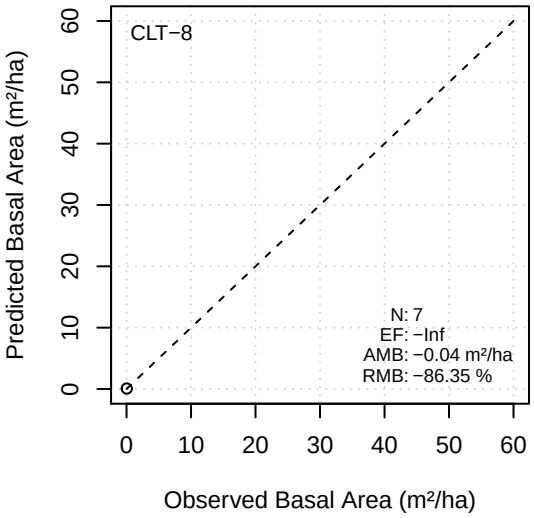

**Conifer Density − CLT**



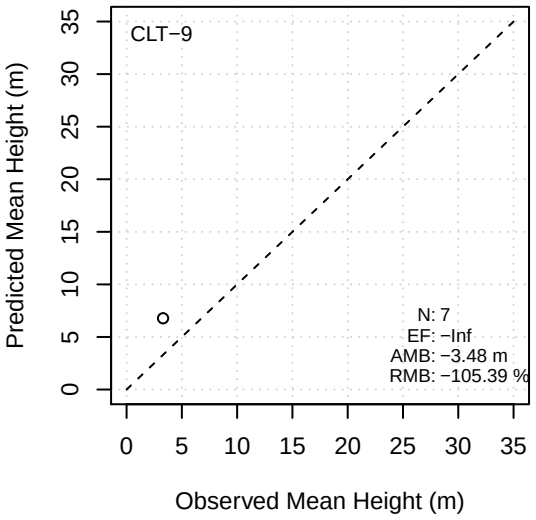
**Deciduous Volume − CLT**



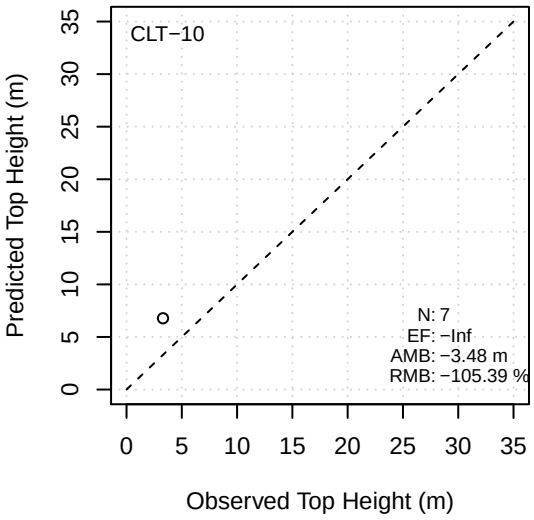

**Deciduous Basal Area − CLT**



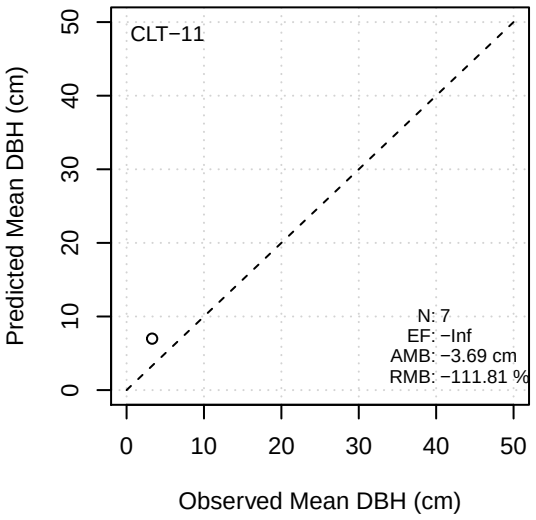

**Deciduous Mean Height − CLT**



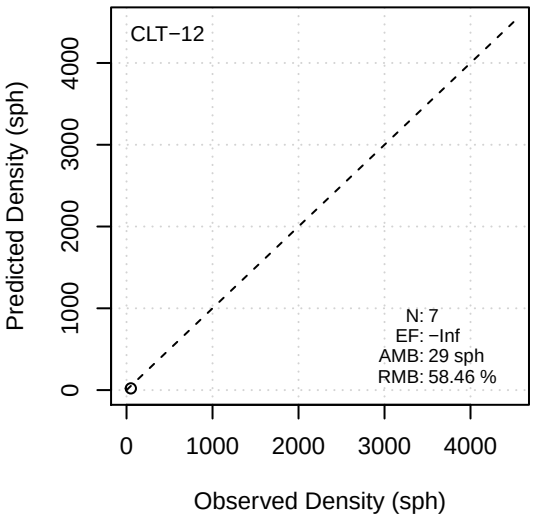

**Deciduous Top Height − CLT**



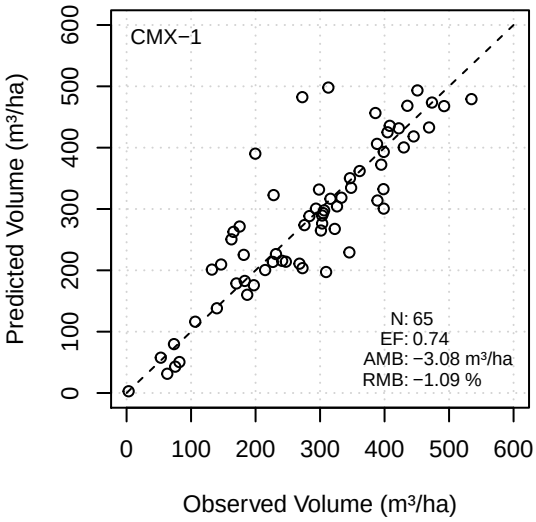

**Deciduous Mean DBH − CLT**



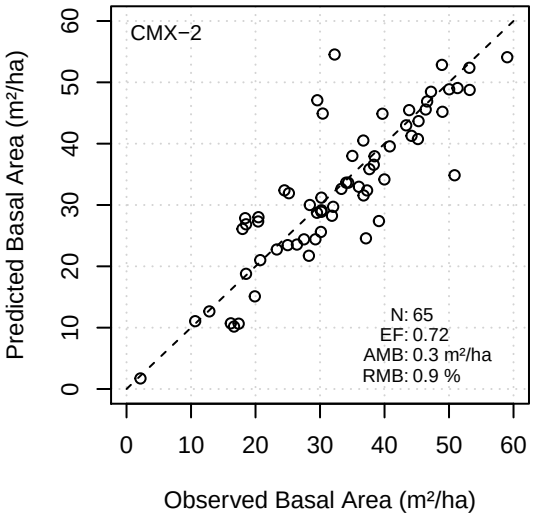

**Deciduous Density − CLT**



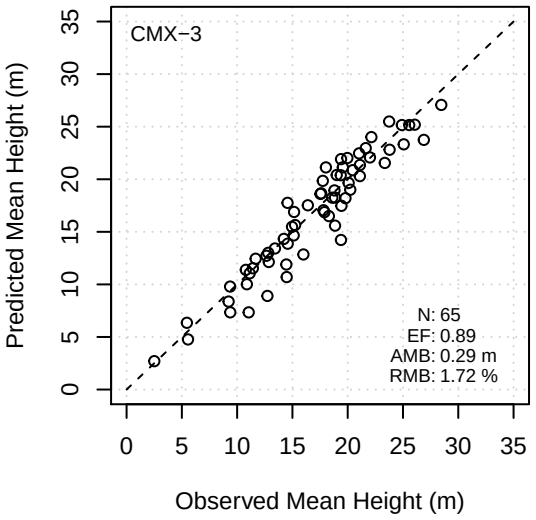
**Conifer Volume − CMX**



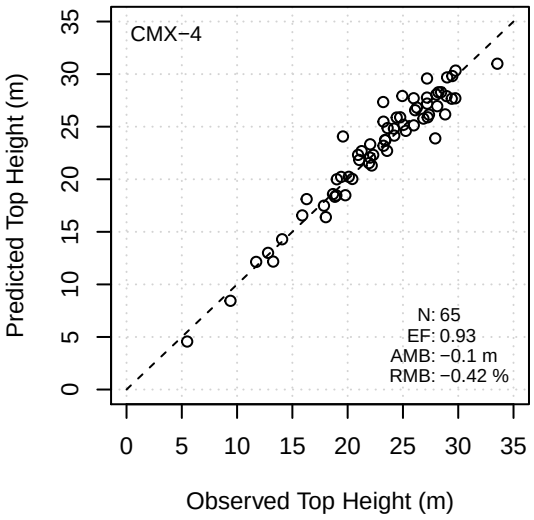

**Conifer Basal Area − CMX**



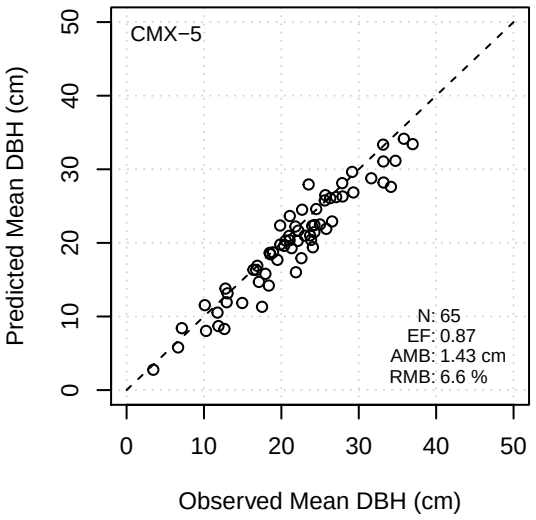

**Conifer Mean Height − CMX**



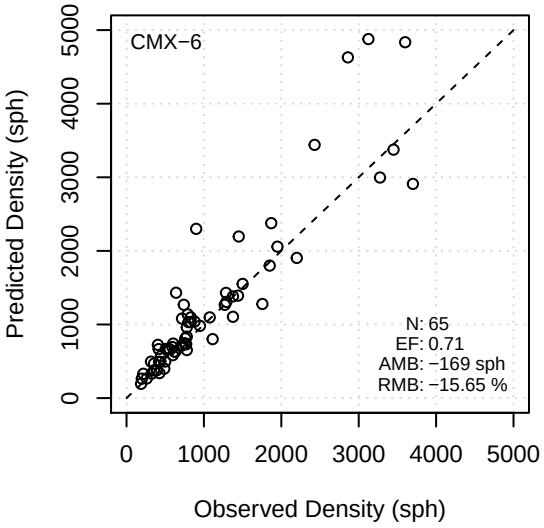

**Conifer Top Height − CMX**



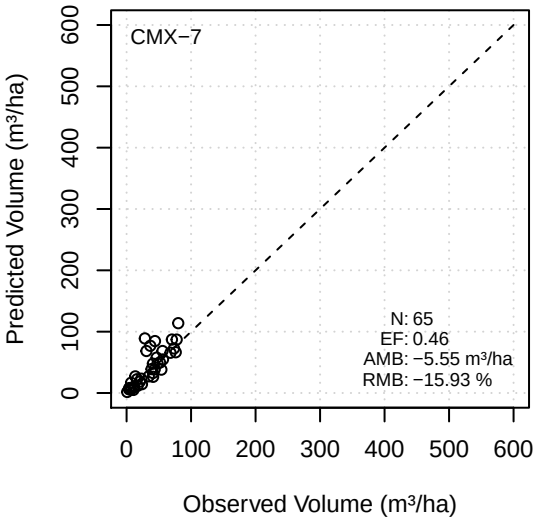

**Conifer Mean DBH − CMX**



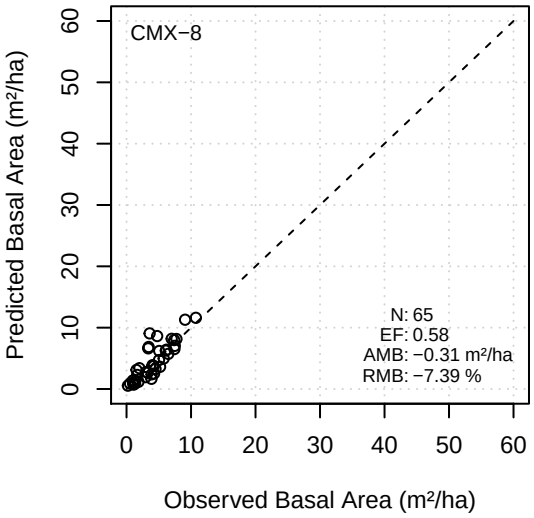

**Conifer Density − CMX**



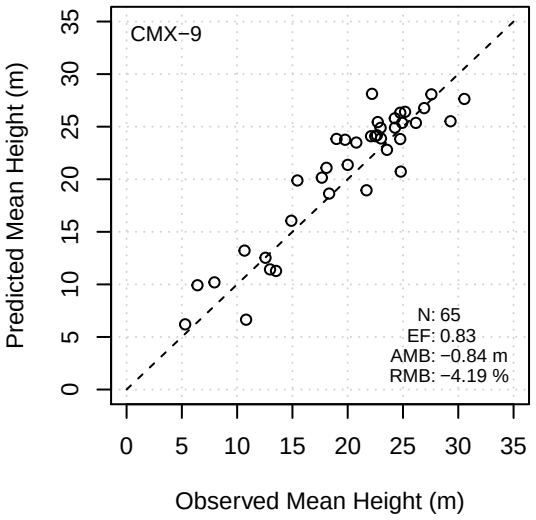
**Deciduous Volume − CMX**



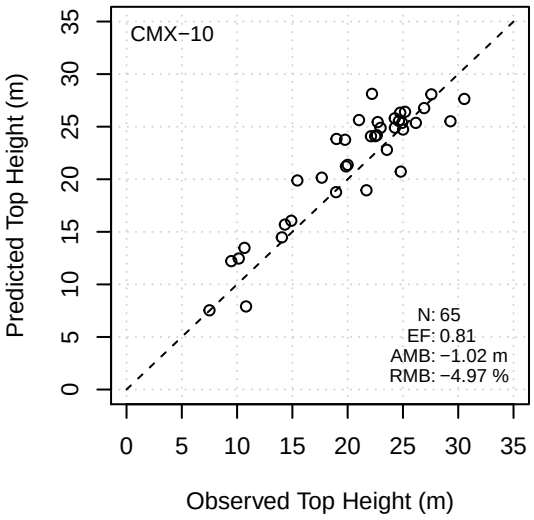

**Deciduous Basal Area − CMX**



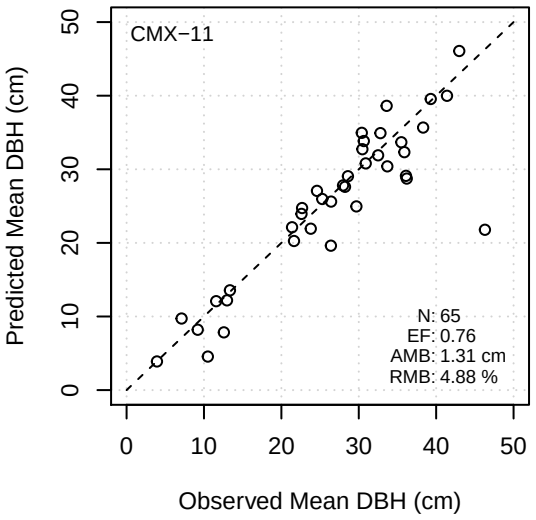

**Deciduous Mean Height − CMX**



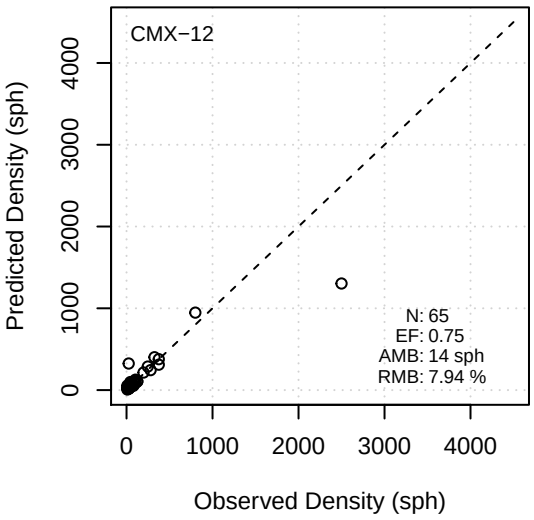

**Deciduous Top Height − CMX**



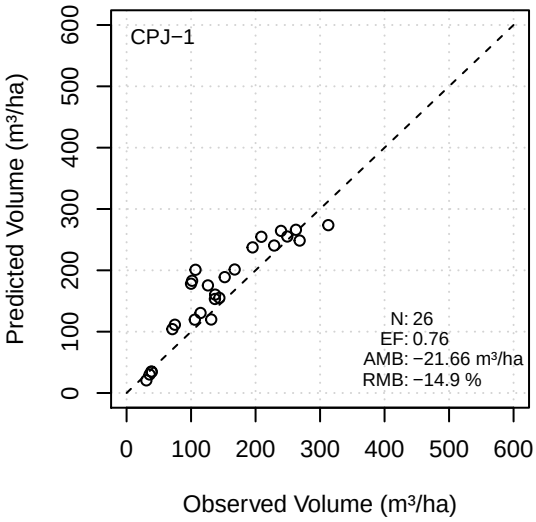

**Deciduous Mean DBH − CMX**



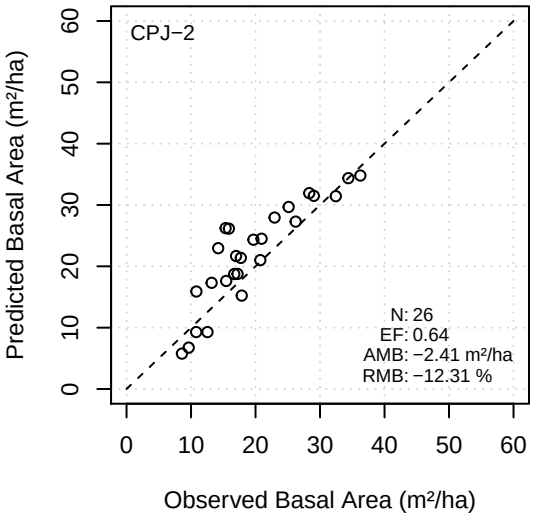

**Deciduous Density − CMX**



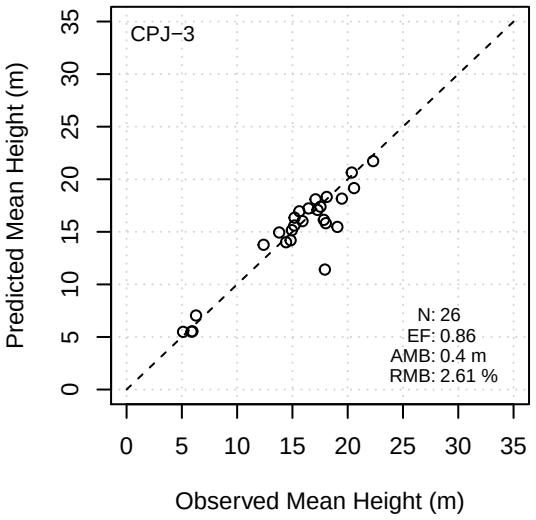
**Conifer Volume − CPJ**



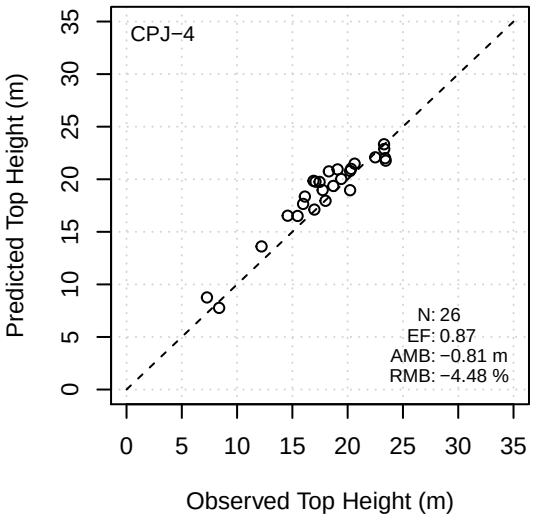

**Conifer Basal Area − CPJ**



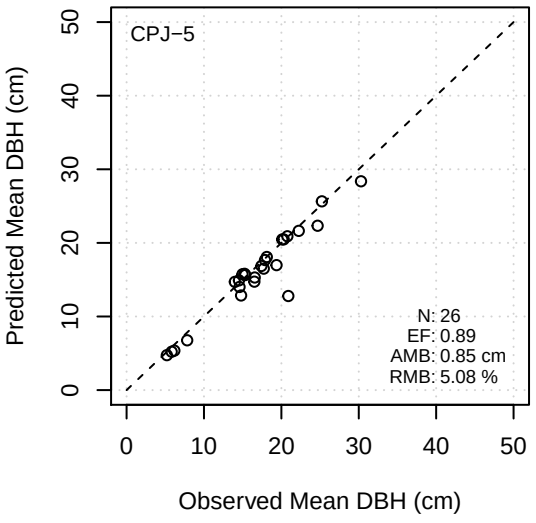

**Conifer Mean Height − CPJ**



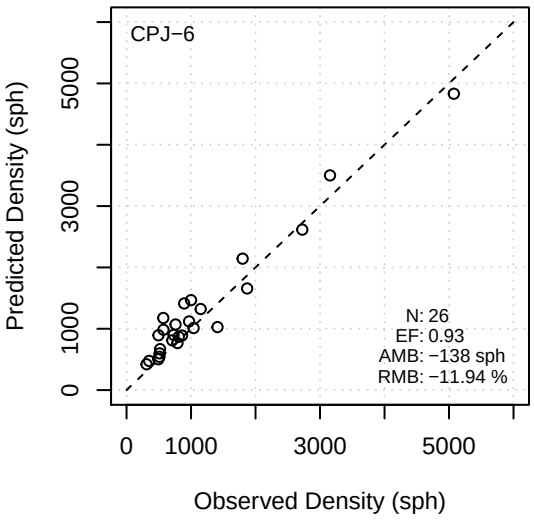

**Conifer Top Height − CPJ**



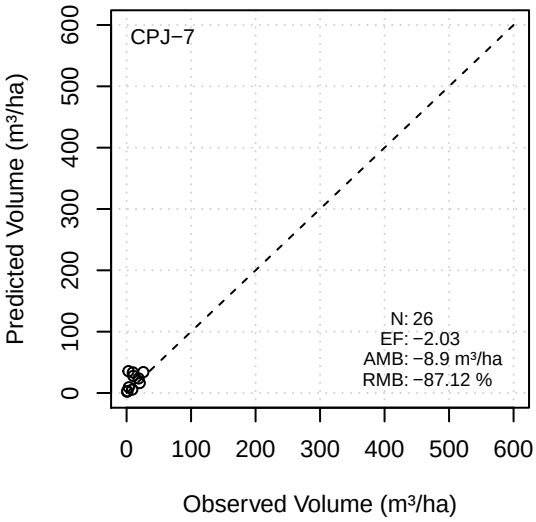

**Conifer Mean DBH − CPJ**



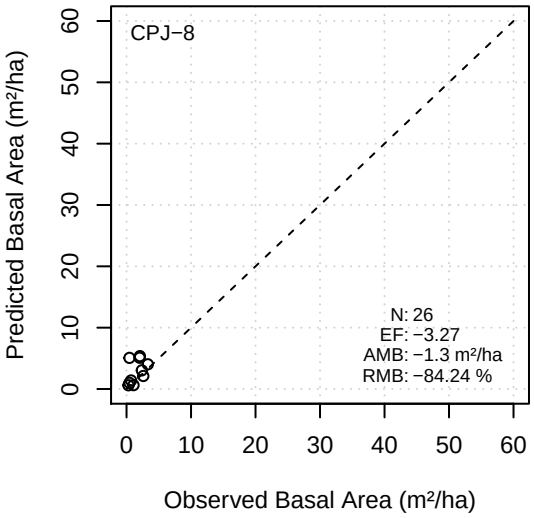

**Conifer Density − CPJ**



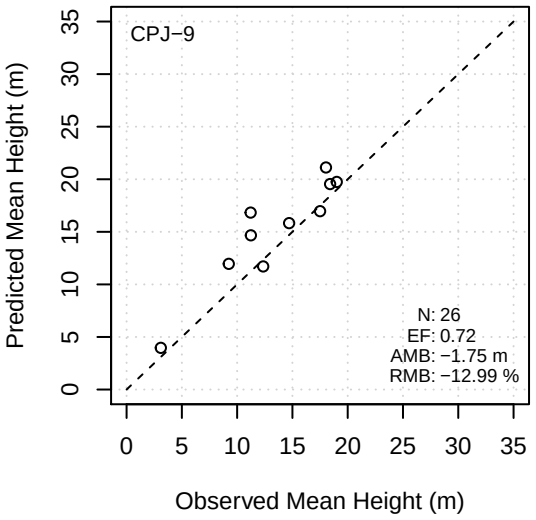
**Deciduous Volume − CPJ**



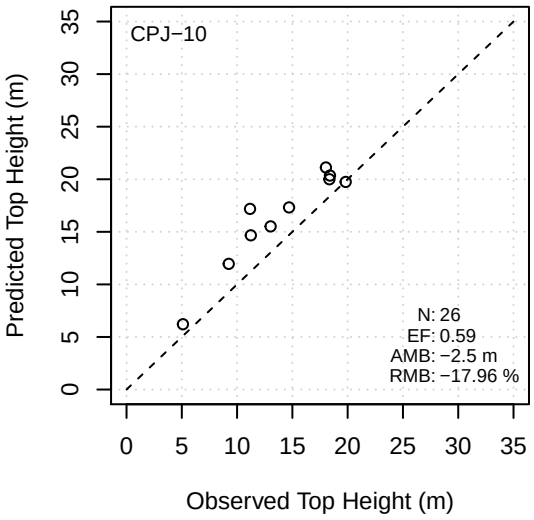

**Deciduous Basal Area − CPJ**



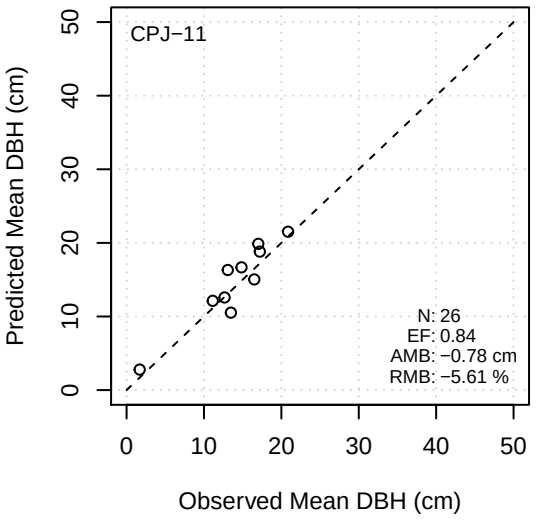

**Deciduous Mean Height − CPJ**



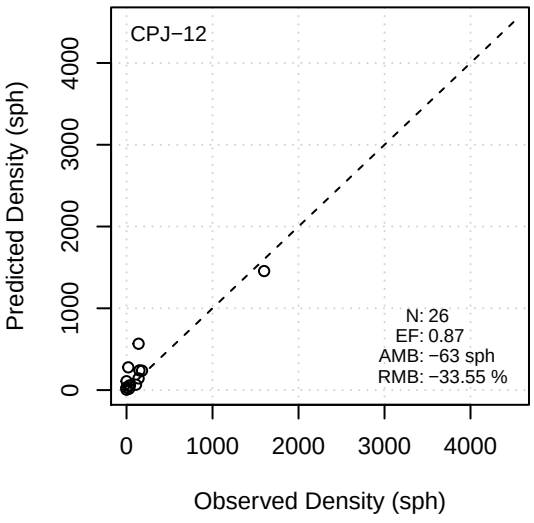

**Deciduous Top Height − CPJ**



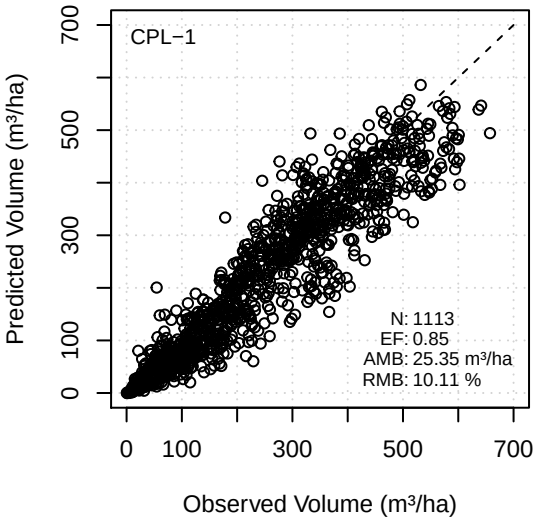

**Deciduous Mean DBH − CPJ**



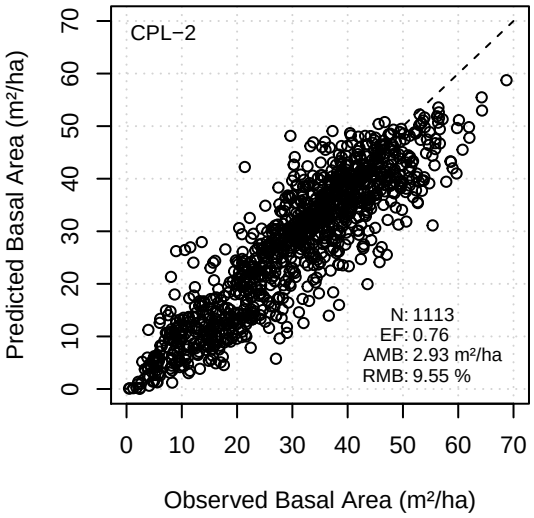

**Deciduous Density − CPJ**



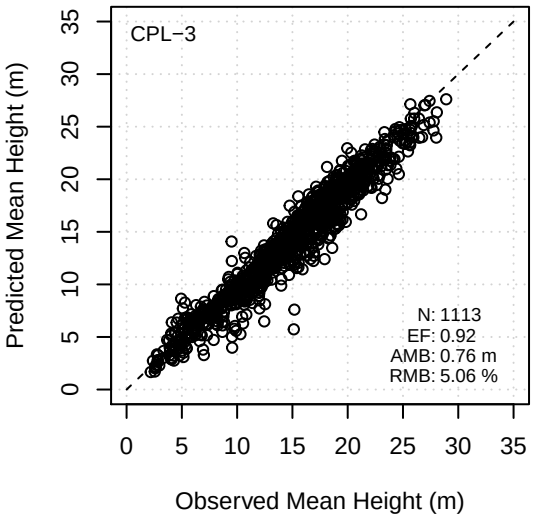
**Conifer Volume − CPL**



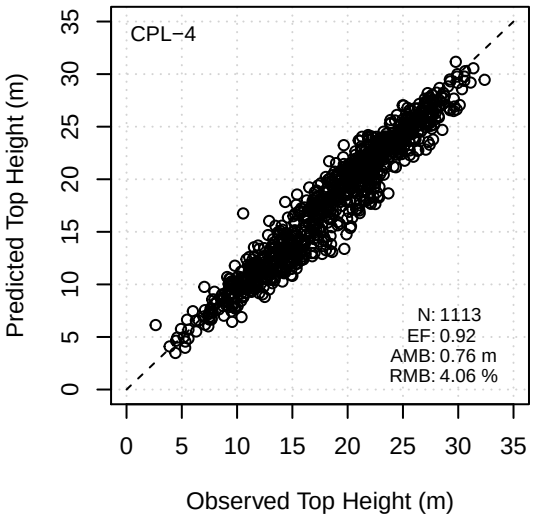

**Conifer Basal Area − CPL**



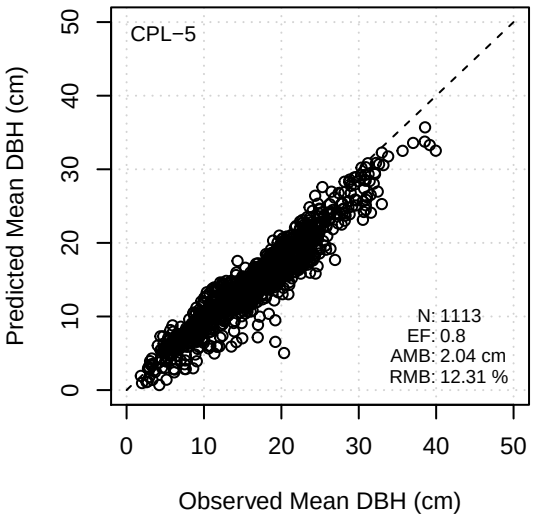

**Conifer Mean Height − CPL**



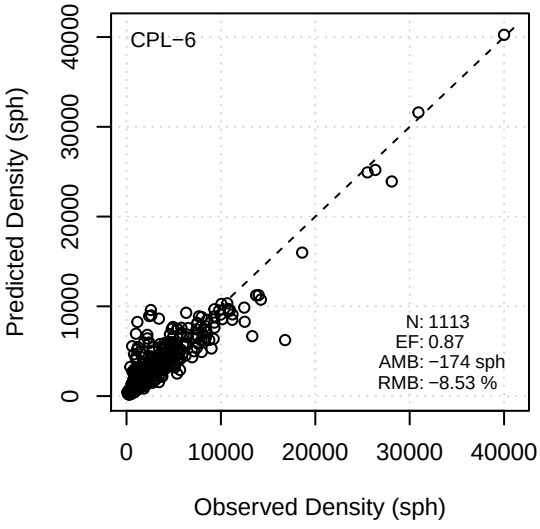

**Conifer Top Height − CPL**



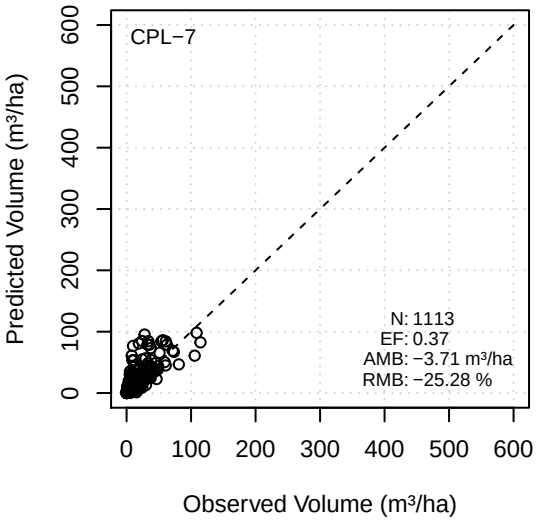

**Conifer Mean DBH − CPL**



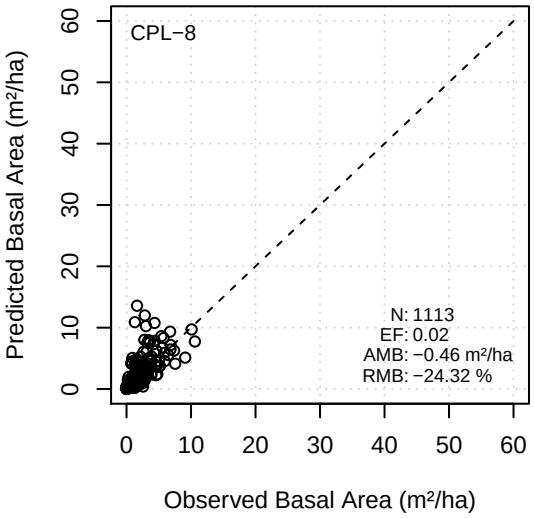

**Conifer Density − CPL**



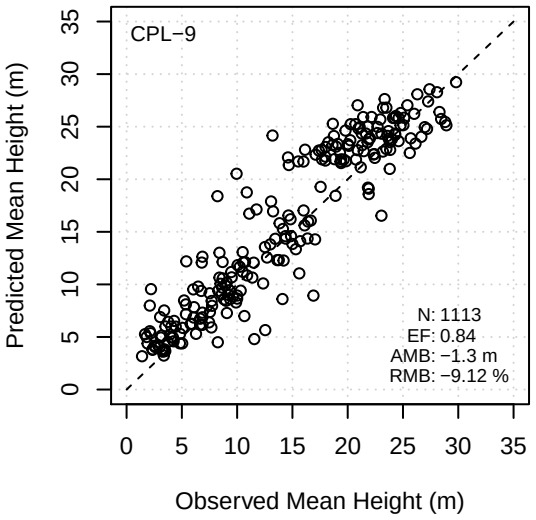
**Deciduous Volume − CPL**



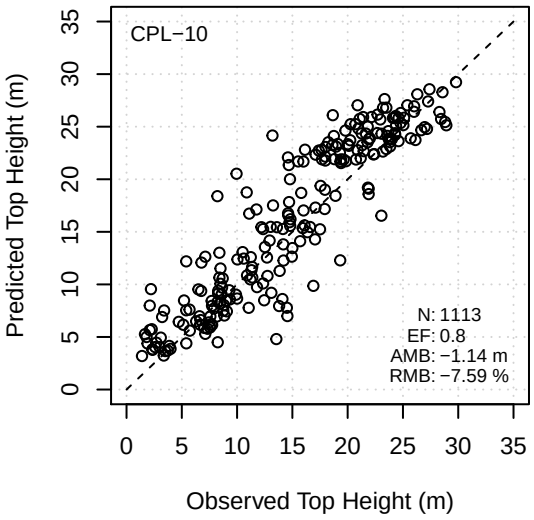

**Deciduous Basal Area − CPL**



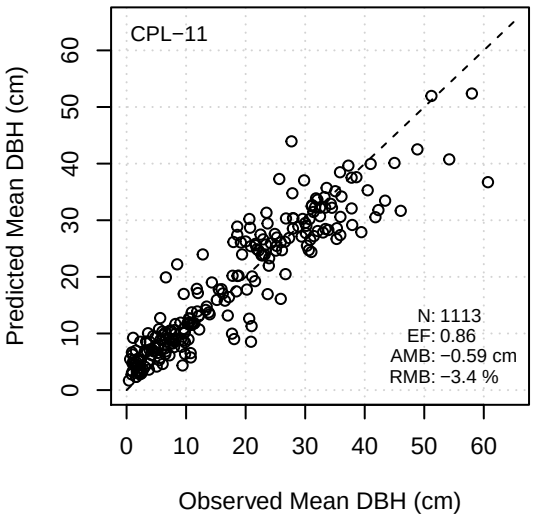

**Deciduous Mean Height − CPL**



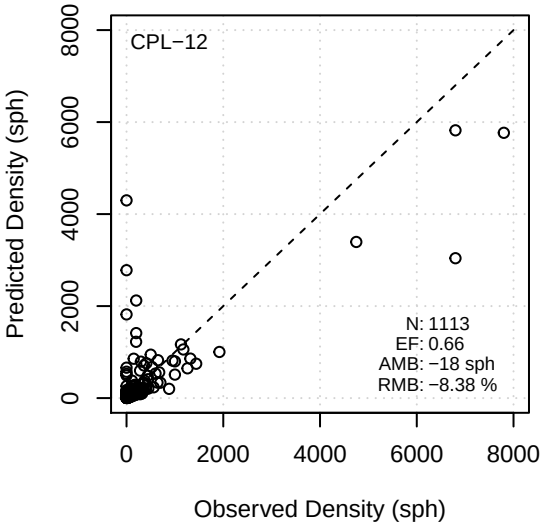

**Deciduous Top Height − CPL**



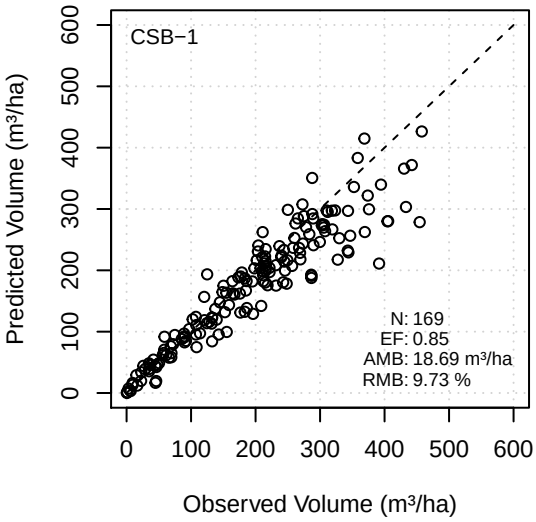

**Deciduous Mean DBH − CPL**



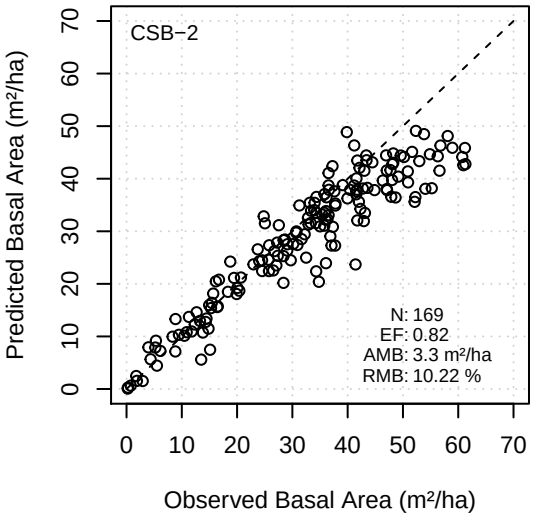

**Deciduous Density − CPL**



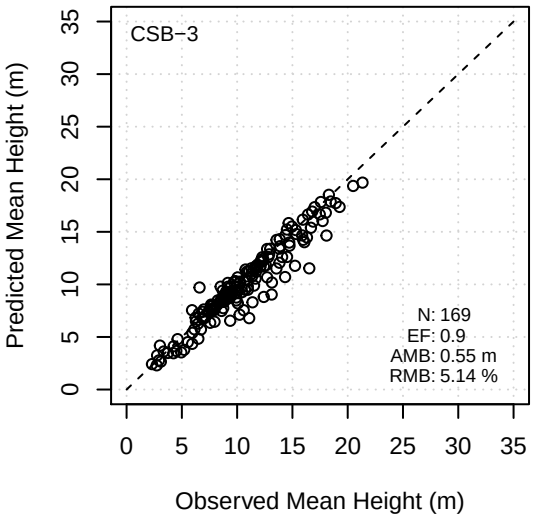
**Conifer Volume − CSB**



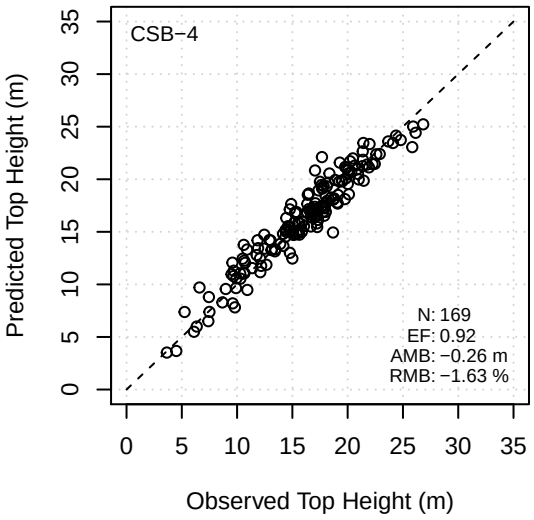

**Conifer Basal Area − CSB**



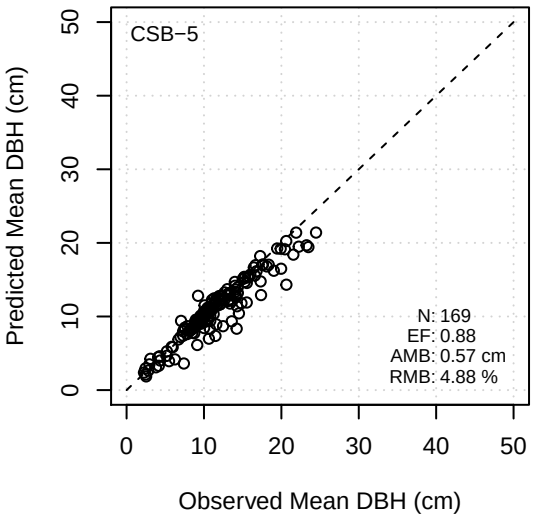

**Conifer Mean Height − CSB**



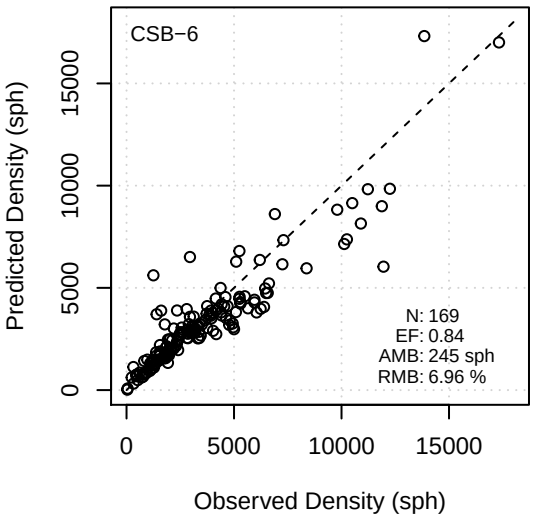

**Conifer Top Height − CSB**



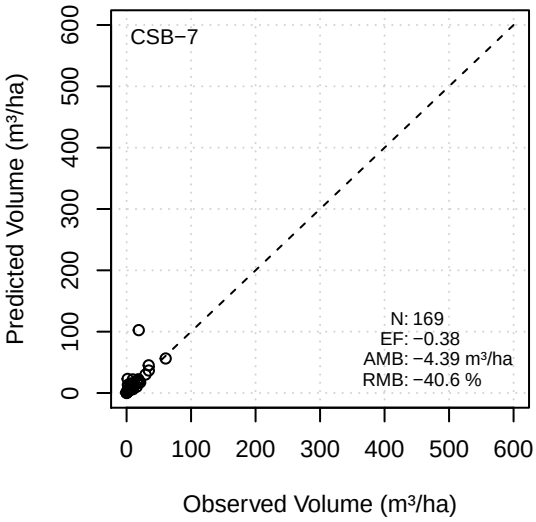

**Conifer Mean DBH − CSB**



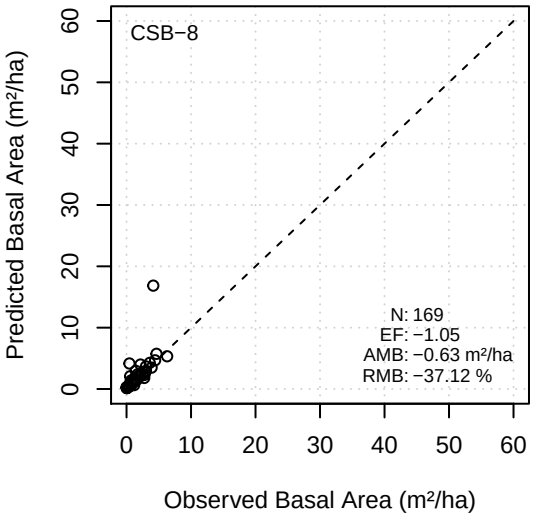

**Conifer Density − CSB**



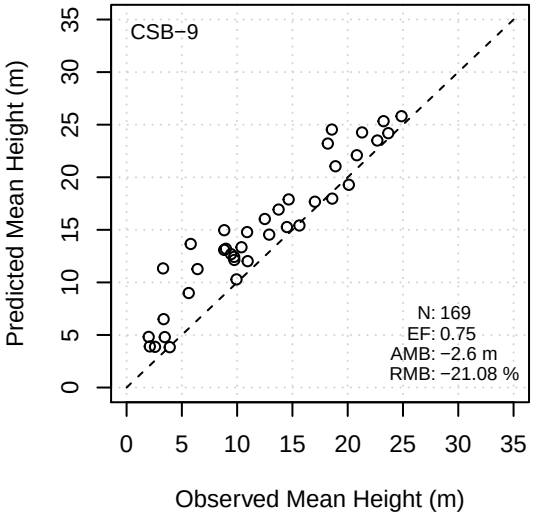
**Deciduous Volume − CSB**



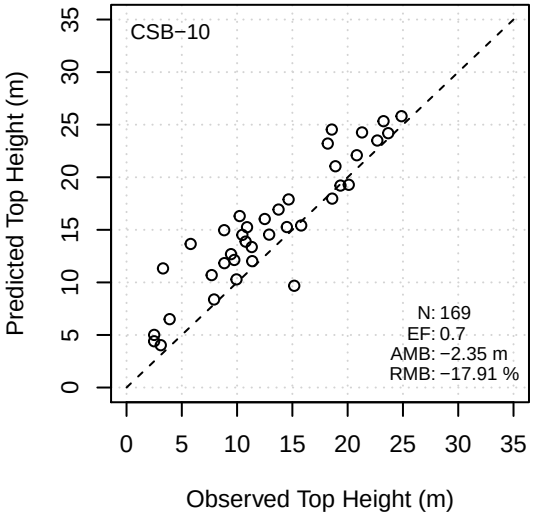

**Deciduous Basal Area − CSB**



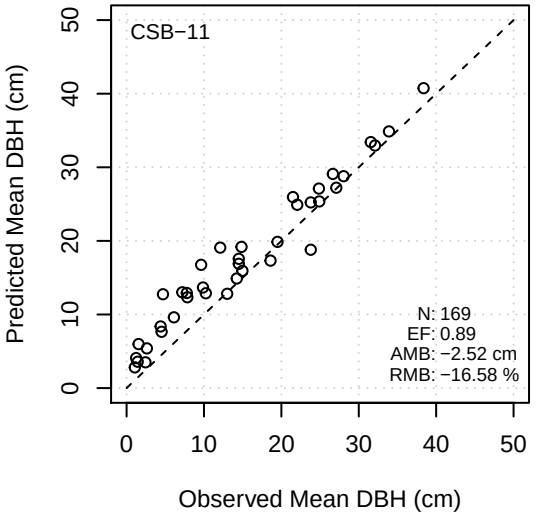

**Deciduous Mean Height − CSB**



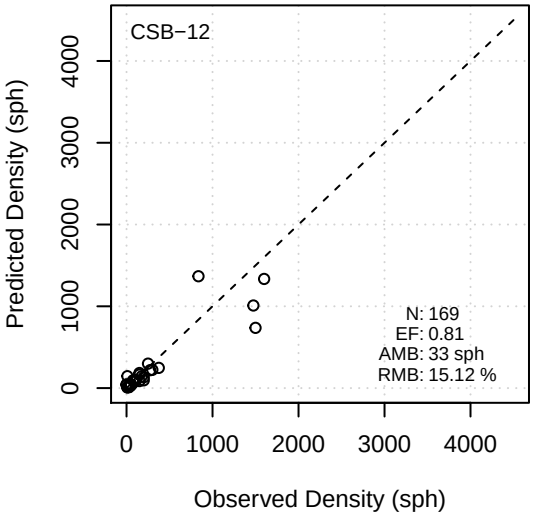

**Deciduous Top Height − CSB**



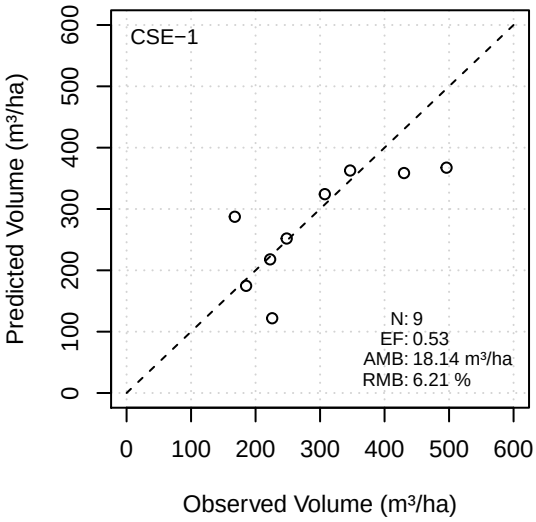

**Deciduous Mean DBH − CSB**



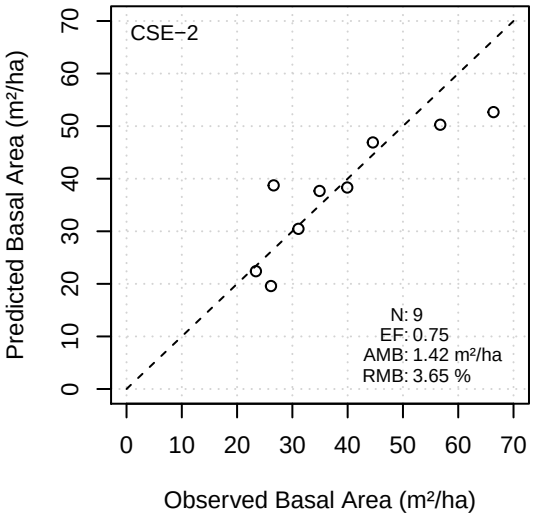

**Deciduous Density − CSB**



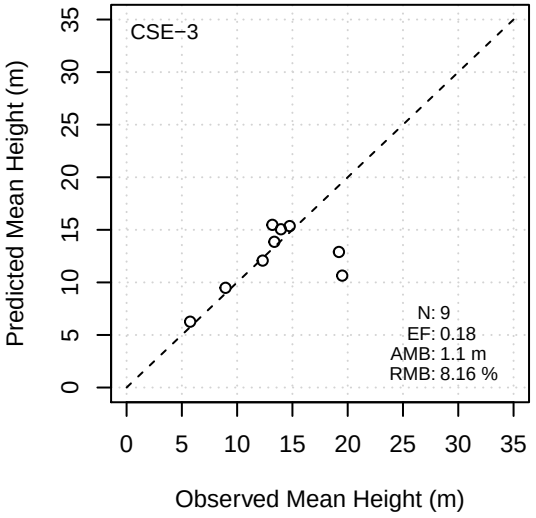
**Conifer Volume − CSE**



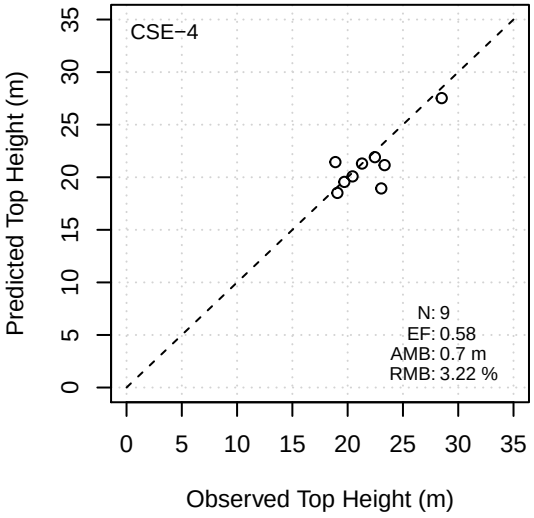

**Conifer Basal Area − CSE**



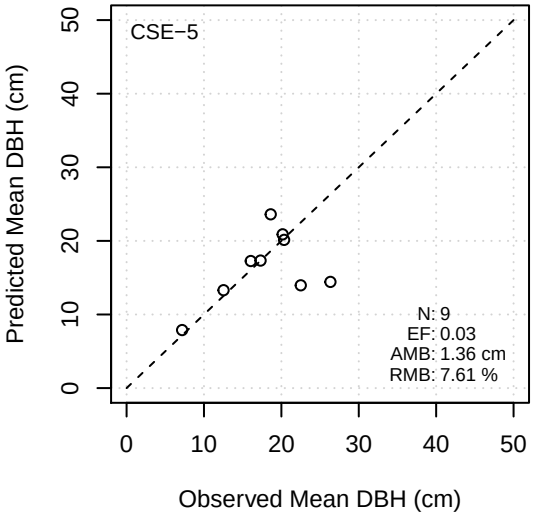

**Conifer Mean Height − CSE**



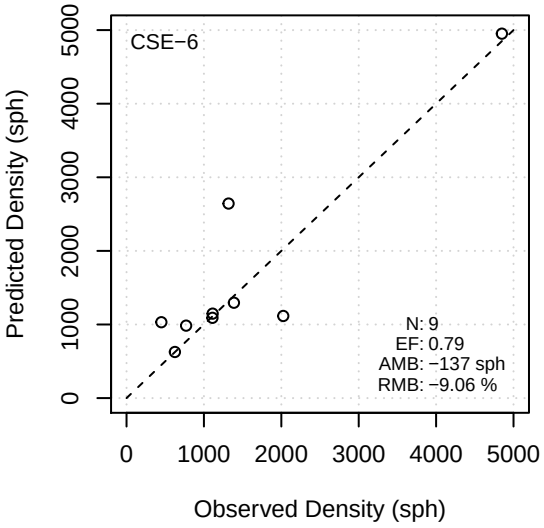

**Conifer Top Height − CSE**



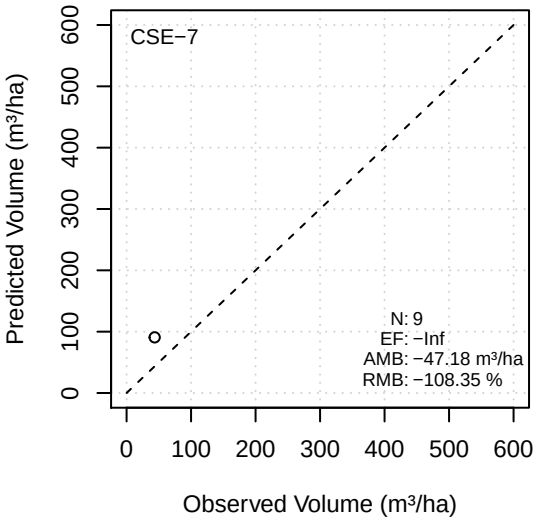

**Conifer Mean DBH − CSE**



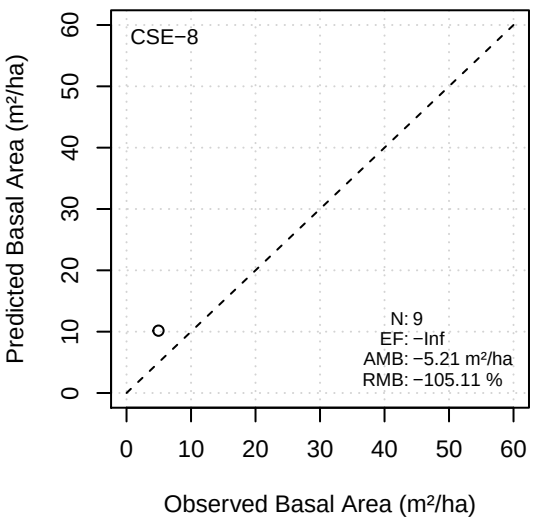

**Conifer Density − CSE**



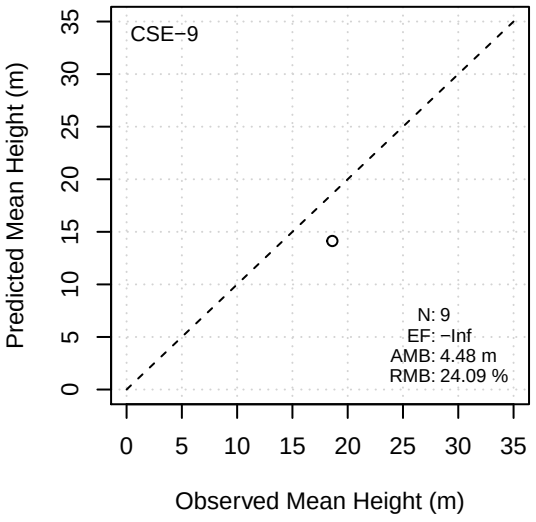
**Deciduous Volume − CSE**



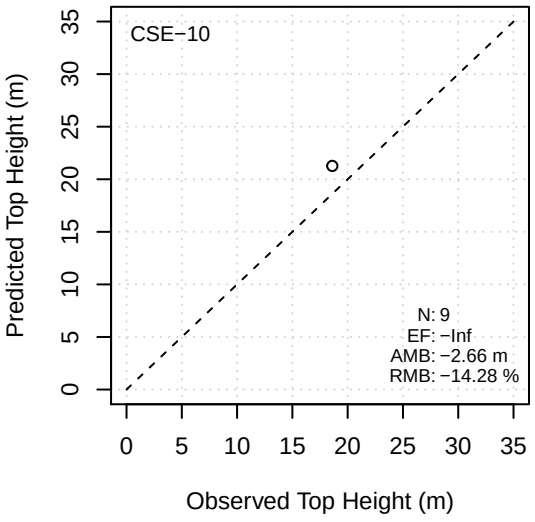

**Deciduous Basal Area − CSE**



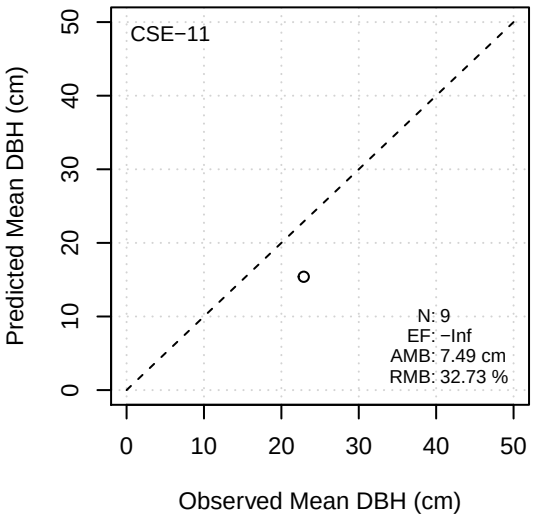

**Deciduous Mean Height − CSE**



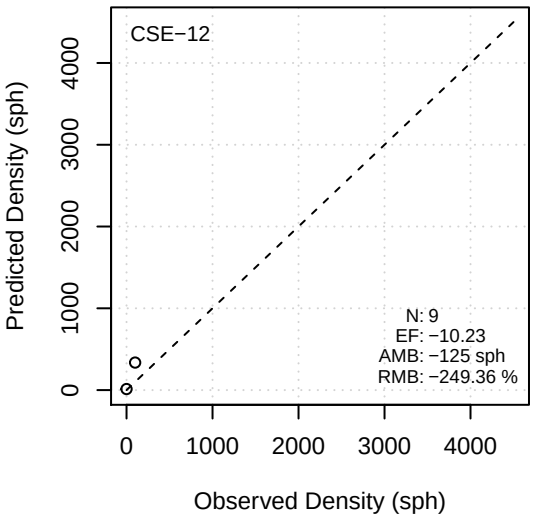

**Deciduous Top Height − CSE**



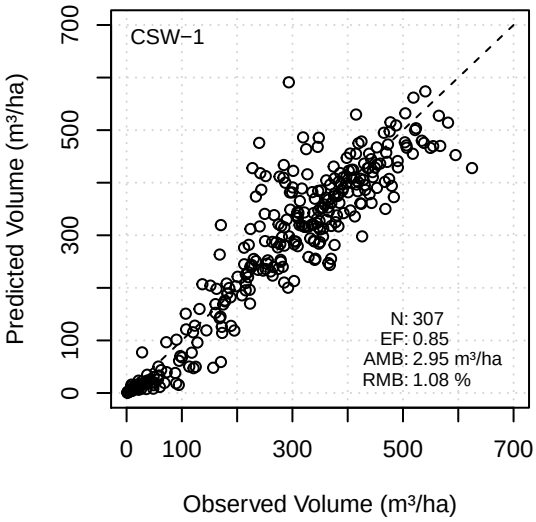

**Deciduous Mean DBH − CSE**



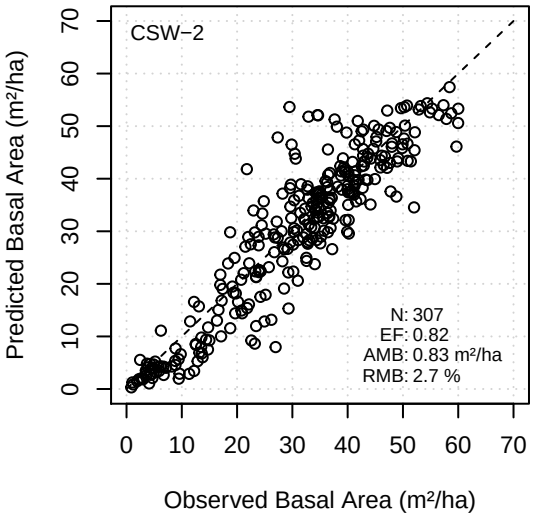

**Deciduous Density − CSE**



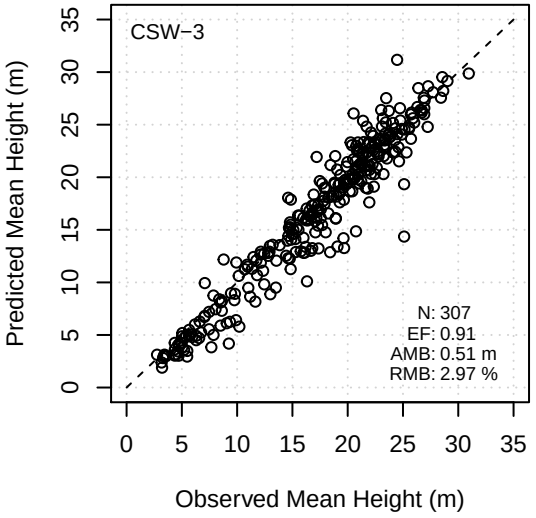
**Conifer Volume − CSW**



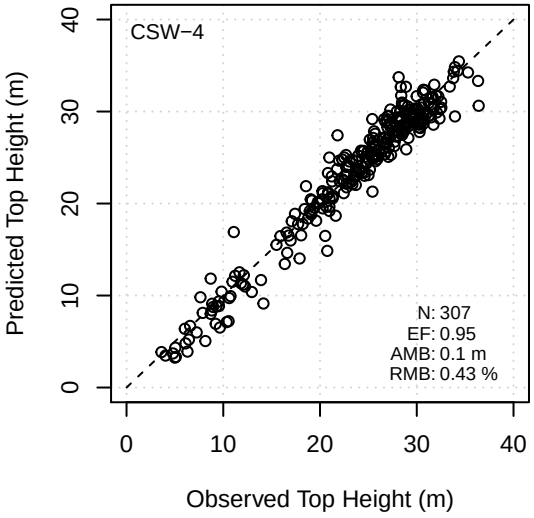

**Conifer Basal Area − CSW**



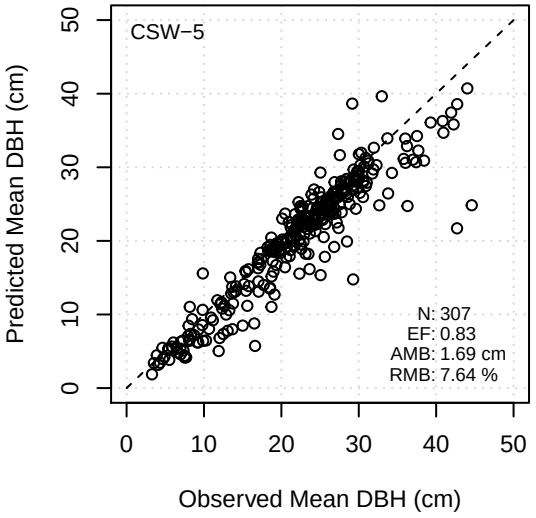

**Conifer Mean Height − CSW**



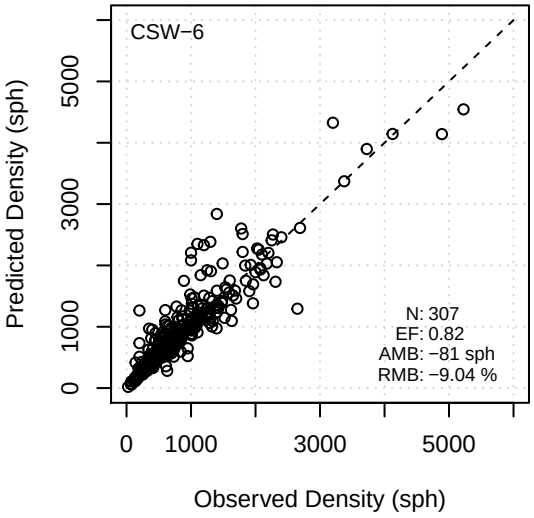

**Conifer Top Height − CSW**



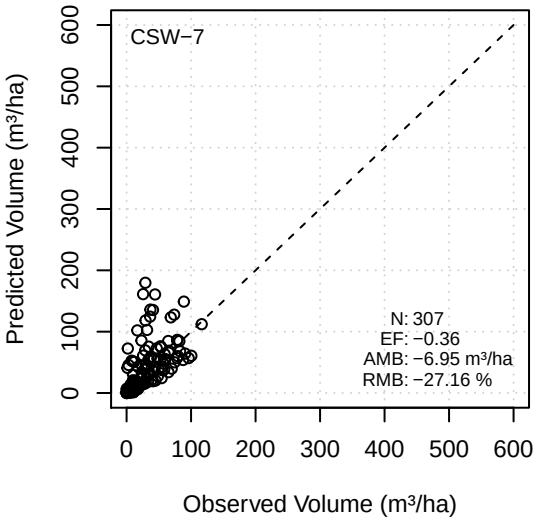

**Conifer Mean DBH − CSW**



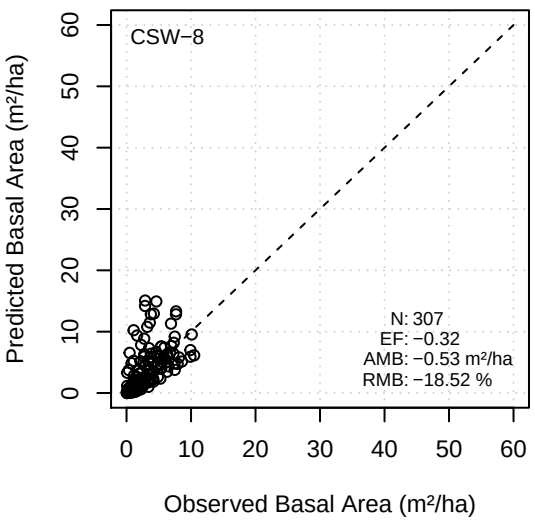

**Conifer Density − CSW**



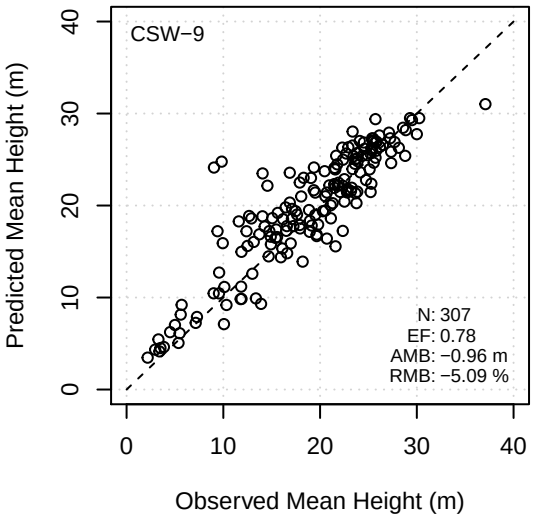
**Deciduous Volume − CSW**



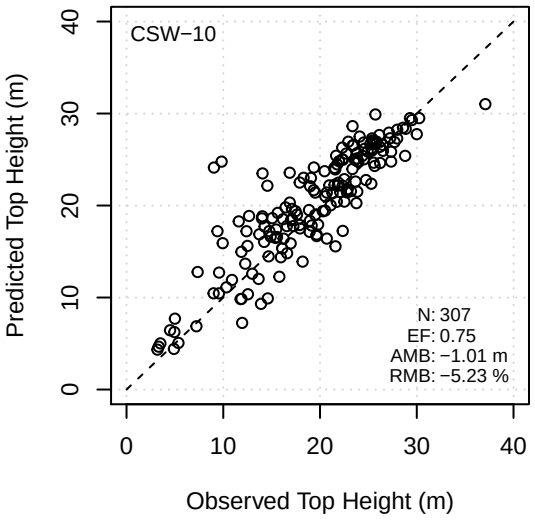

**Deciduous Basal Area − CSW**



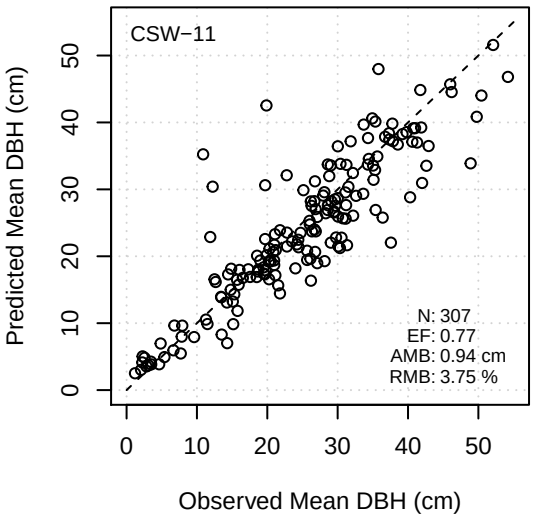

**Deciduous Mean Height − CSW**



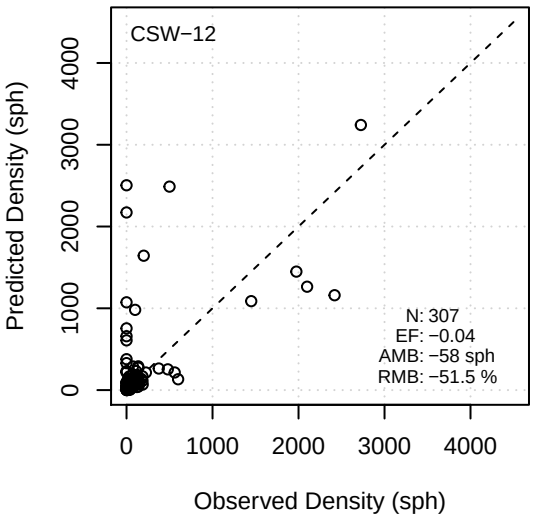

**Deciduous Top Height − CSW**



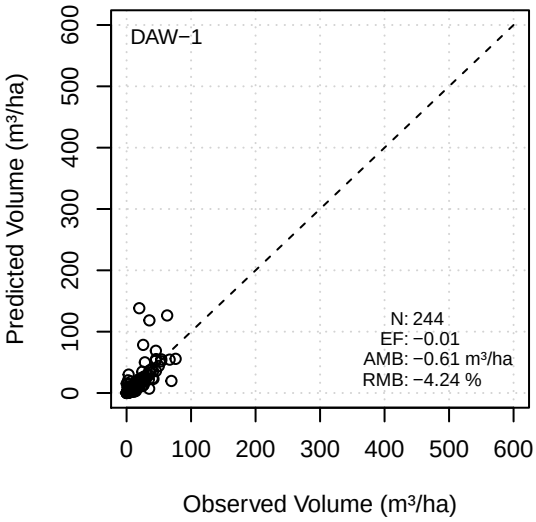

**Deciduous Mean DBH − CSW**



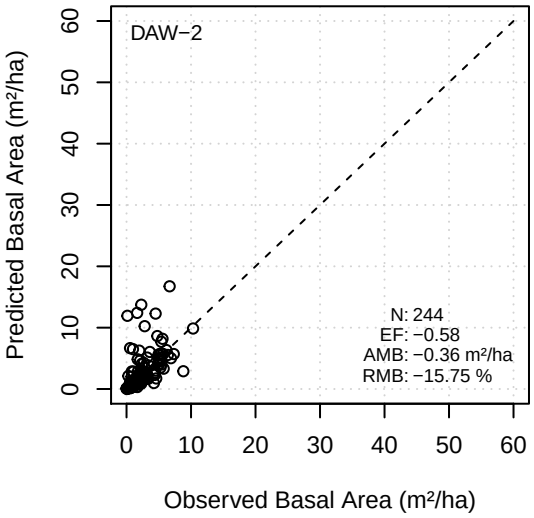

**Deciduous Density − CSW**



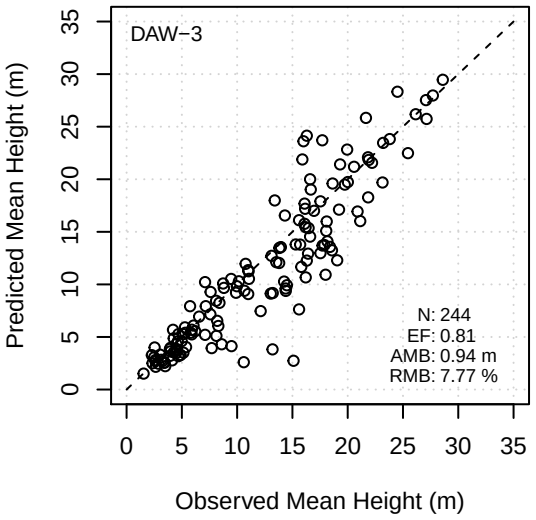
**Conifer Volume − DAW**



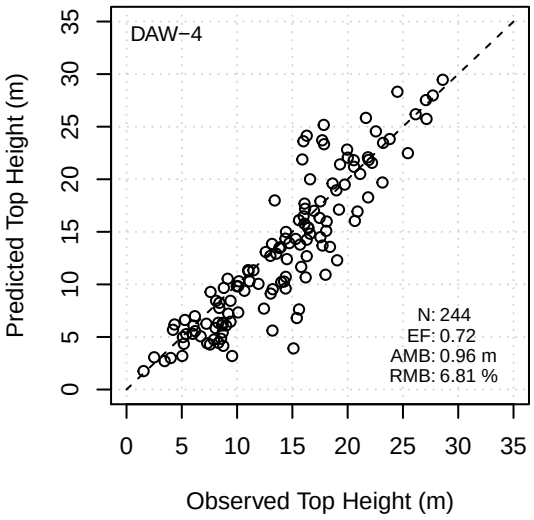

**Conifer Basal Area − DAW**



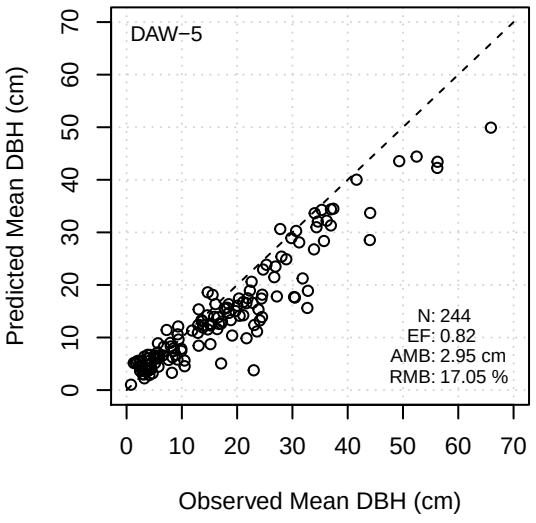

**Conifer Mean Height − DAW**



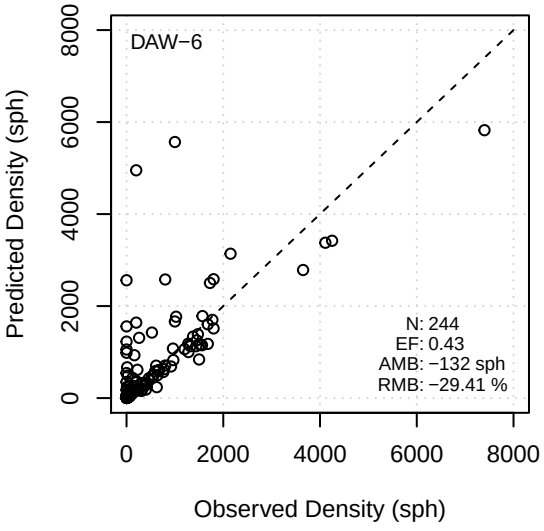

**Conifer Top Height − DAW**



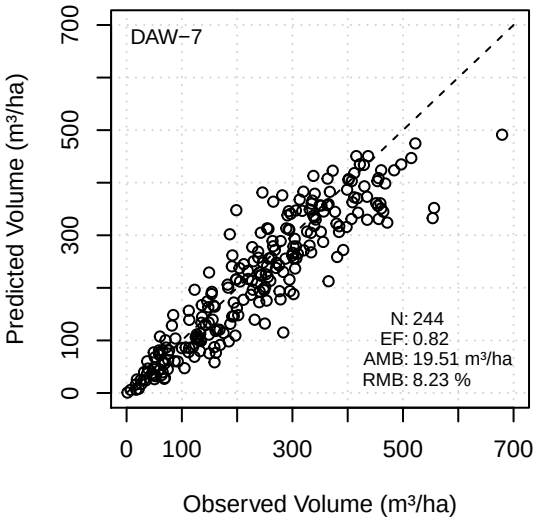

**Conifer Mean DBH − DAW**



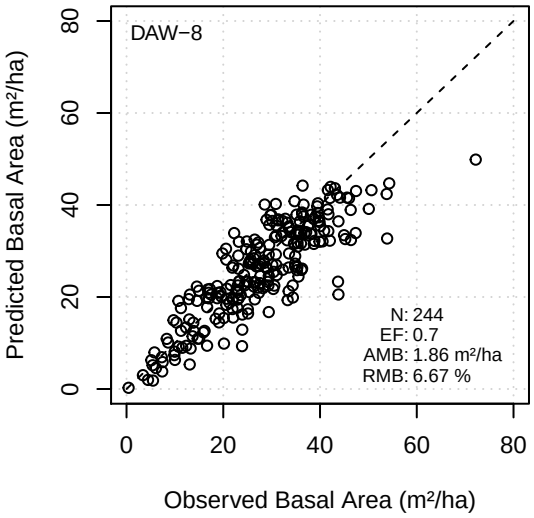

**Conifer Density − DAW**



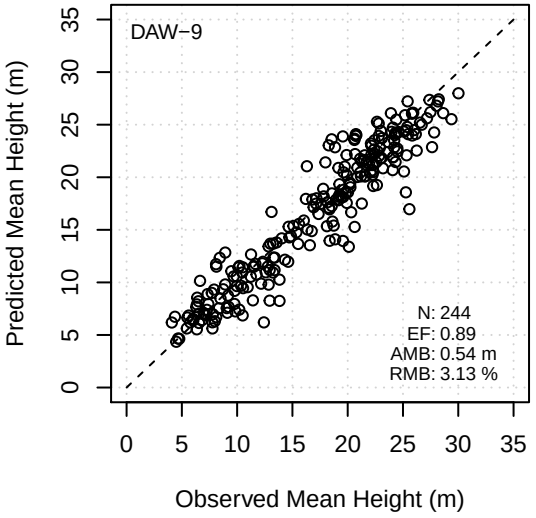
**Deciduous Volume − DAW**



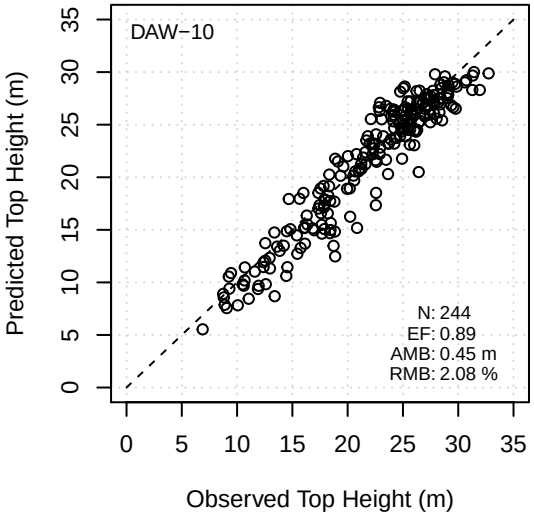

**Deciduous Basal Area − DAW**



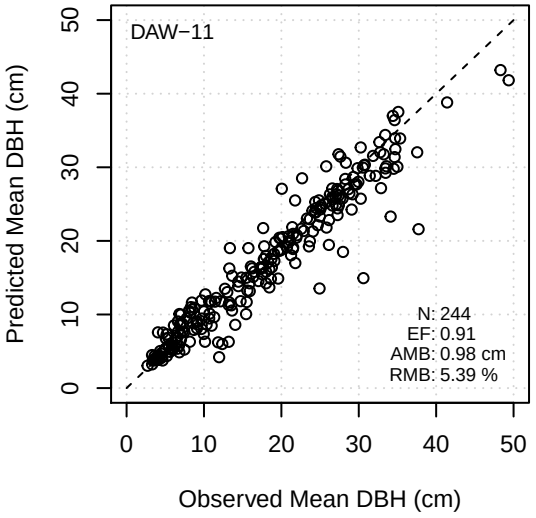

**Deciduous Mean Height − DAW**



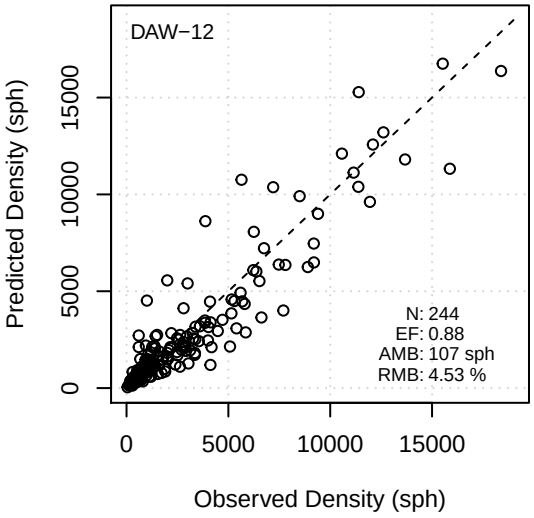

**Deciduous Top Height − DAW**



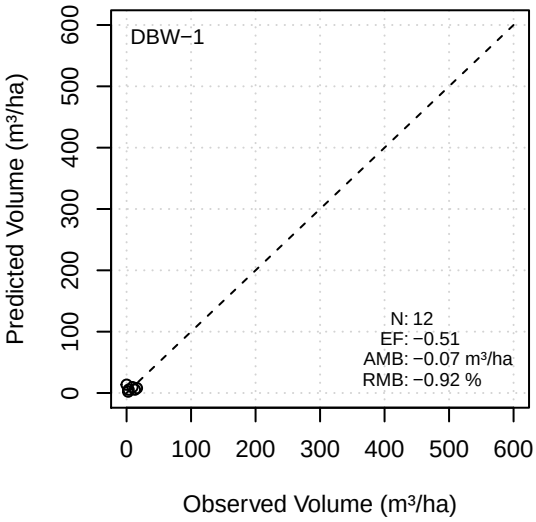

**Deciduous Mean DBH − DAW**



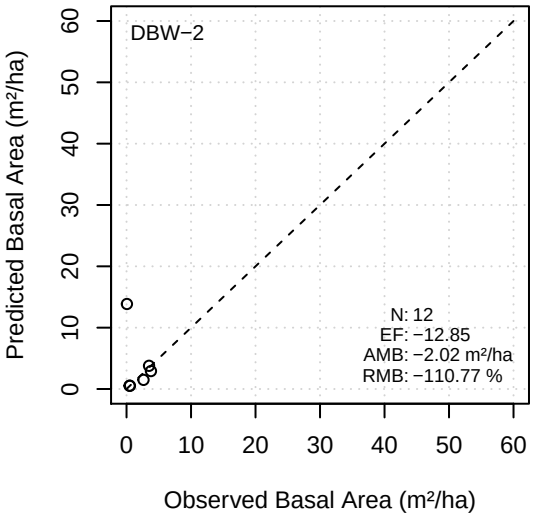

**Deciduous Density − DAW**



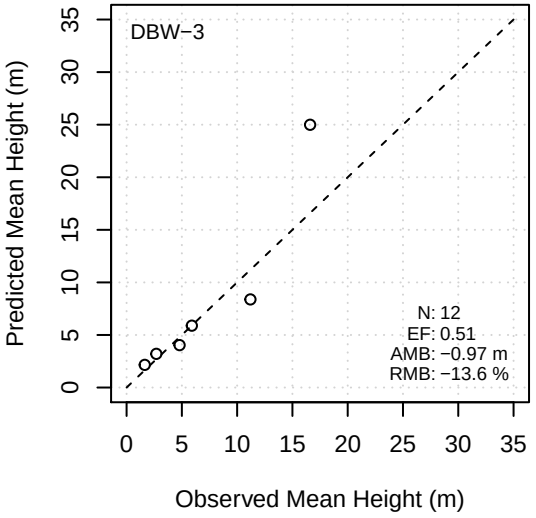
**Conifer Volume − DBW**



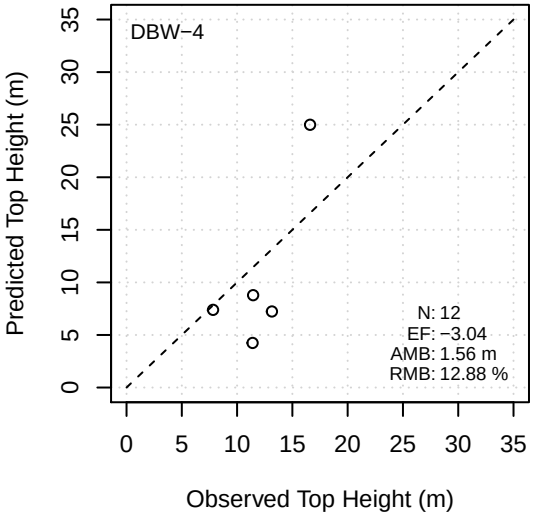

**Conifer Basal Area − DBW**



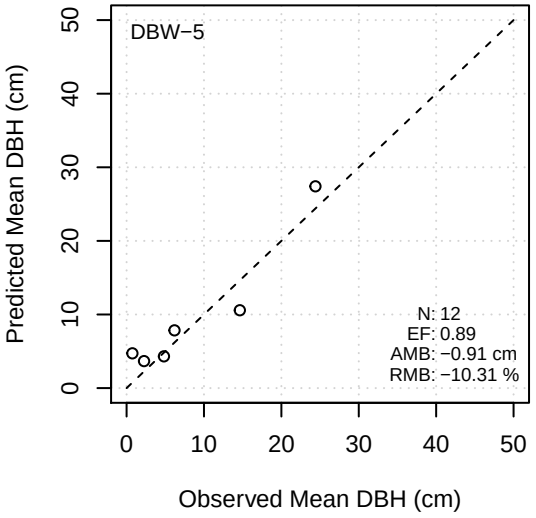

**Conifer Mean Height − DBW**



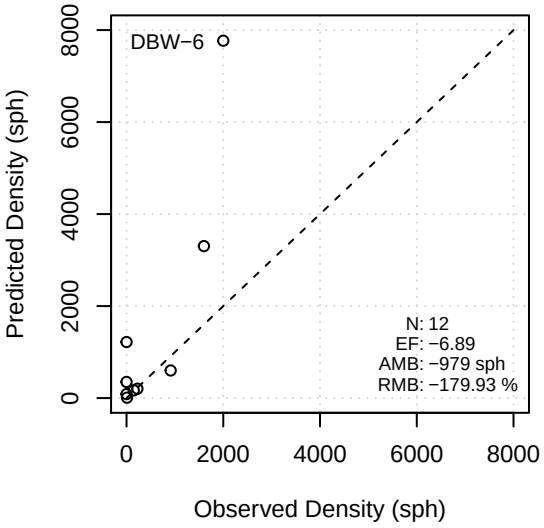

**Conifer Top Height − DBW**



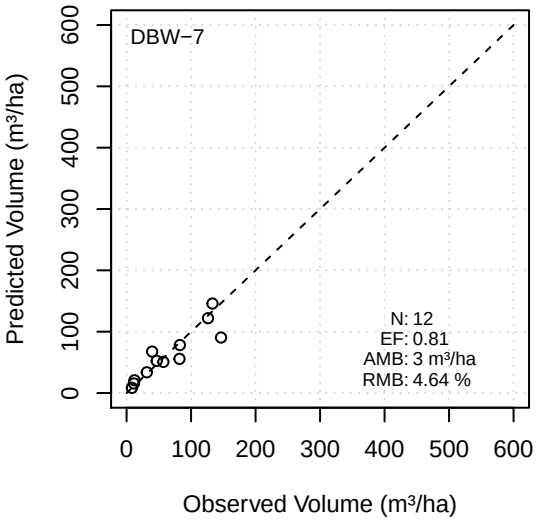

**Conifer Mean DBH − DBW**



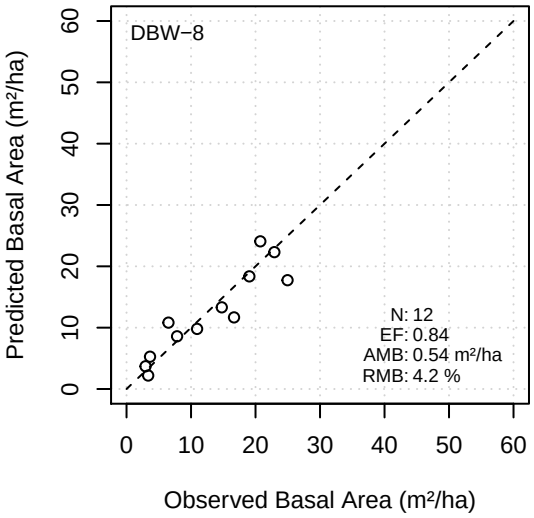

**Conifer Density − DBW**



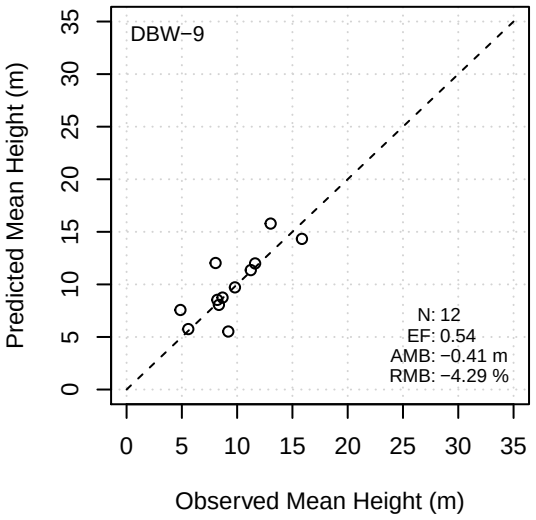
**Deciduous Volume − DBW**



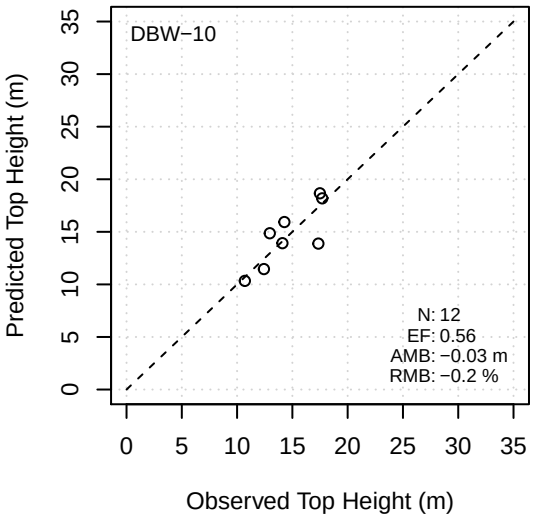

**Deciduous Basal Area − DBW**



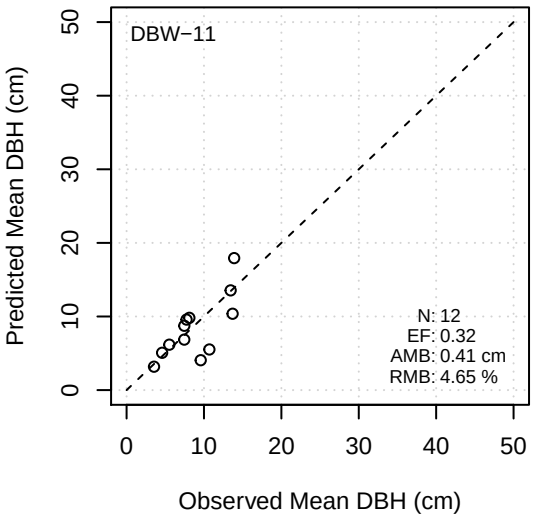

**Deciduous Mean Height − DBW**



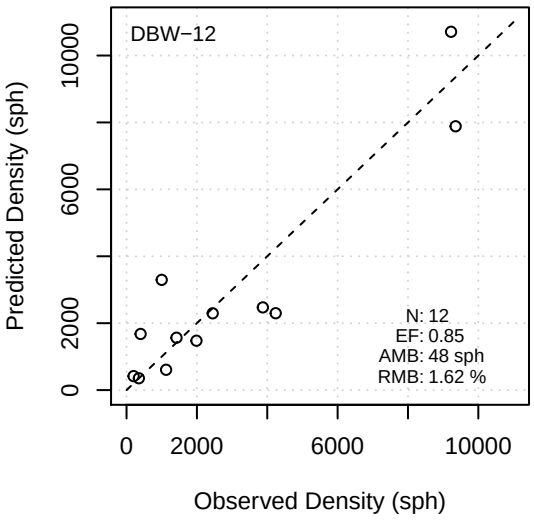

**Deciduous Top Height − DBW**



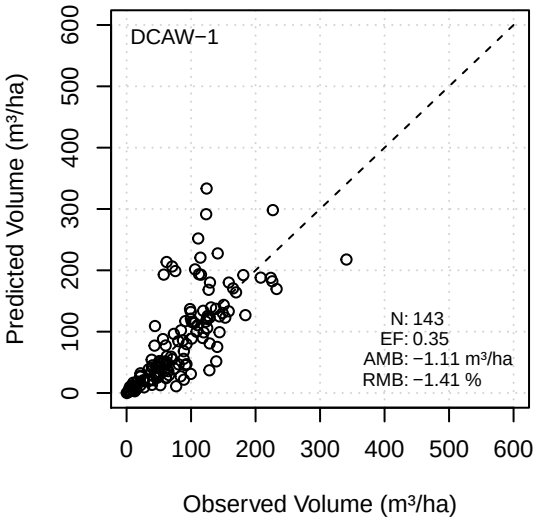

**Deciduous Mean DBH − DBW**



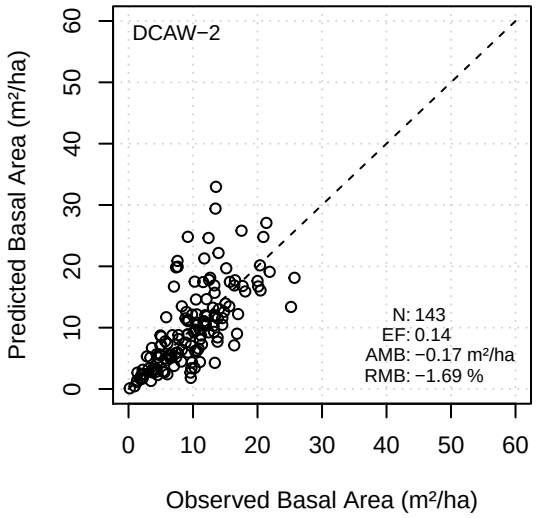

**Deciduous Density − DBW**



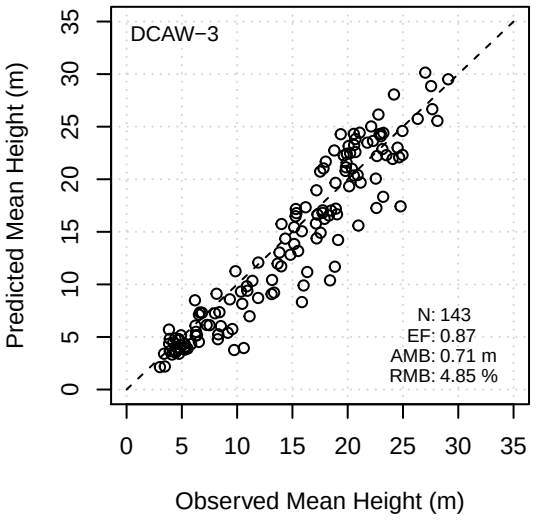
**Conifer Volume − DCAW**



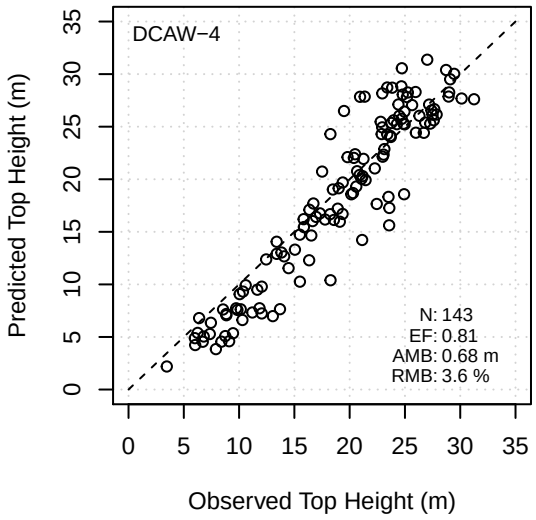

**Conifer Basal Area − DCAW**



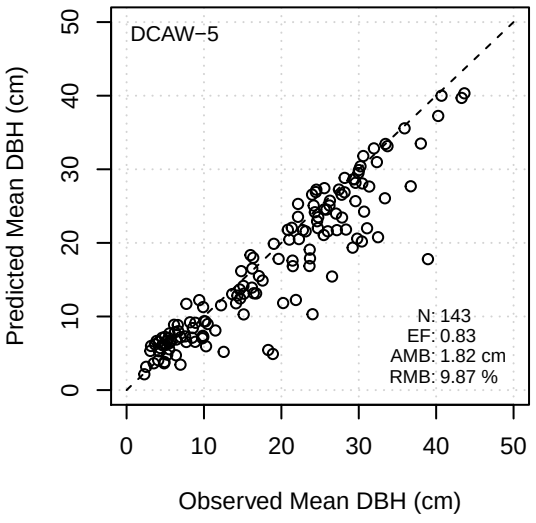

**Conifer Mean Height − DCAW**



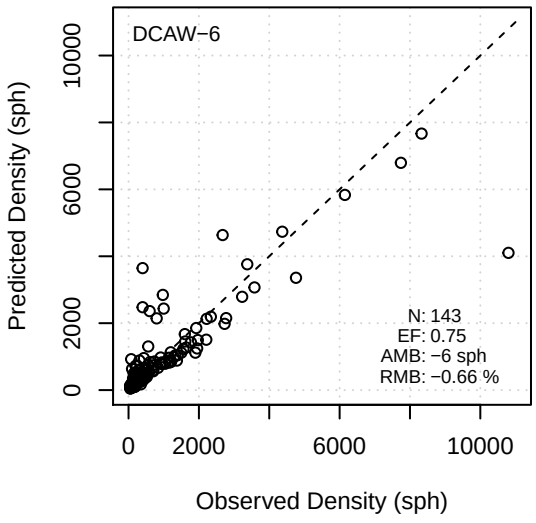

**Conifer Top Height − DCAW**



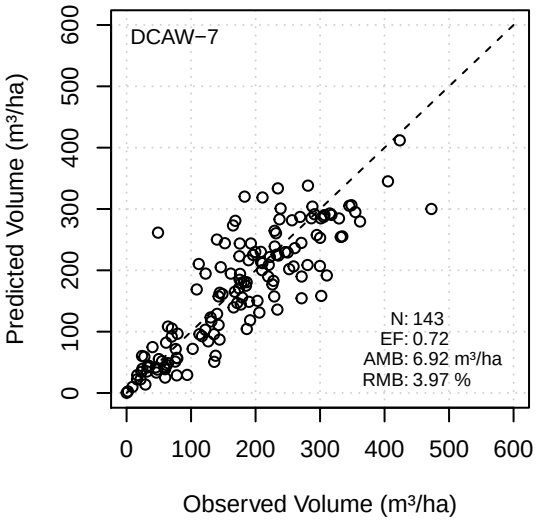

**Conifer Mean DBH − DCAW**



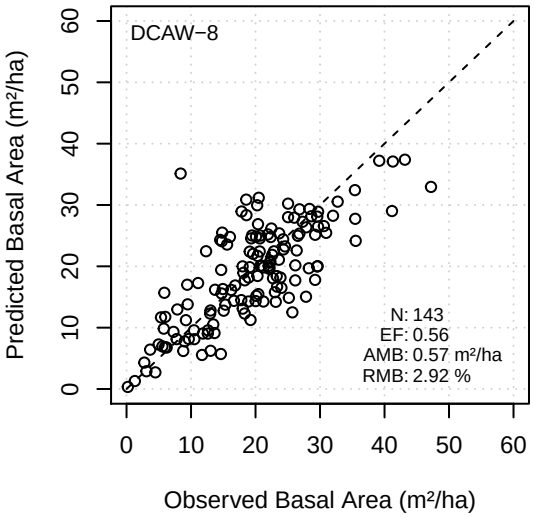

**Conifer Density − DCAW**



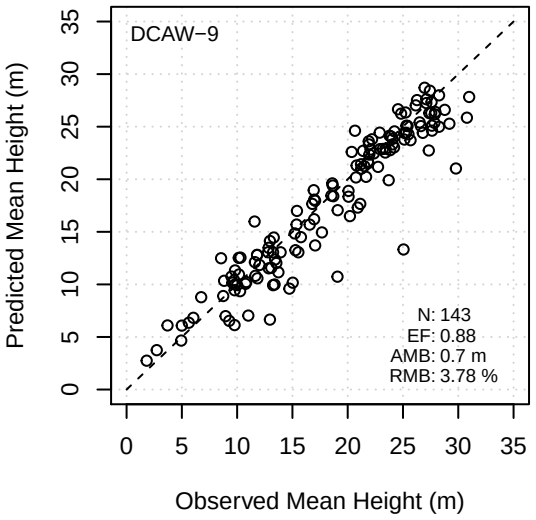
**Deciduous Volume − DCAW**



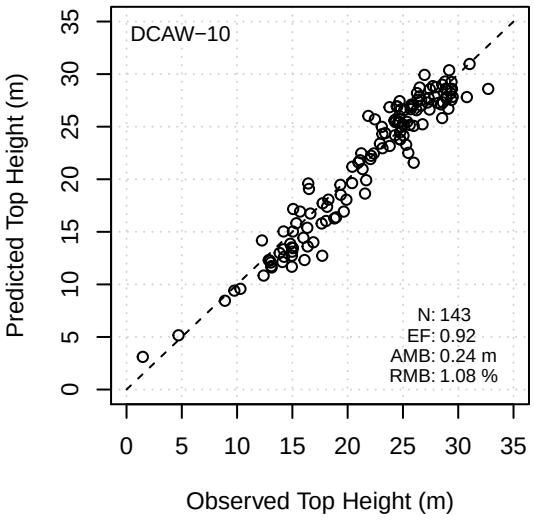

**Deciduous Basal Area − DCAW**



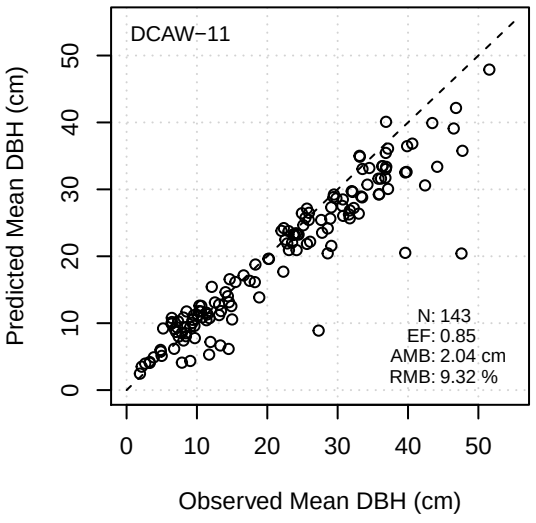

**Deciduous Mean Height − DCAW**



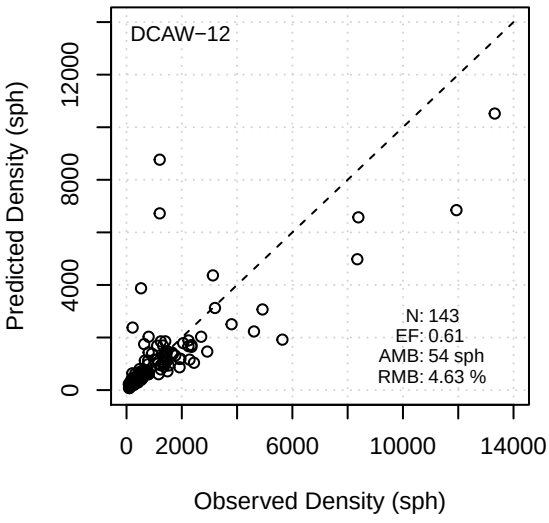

**Deciduous Top Height − DCAW**



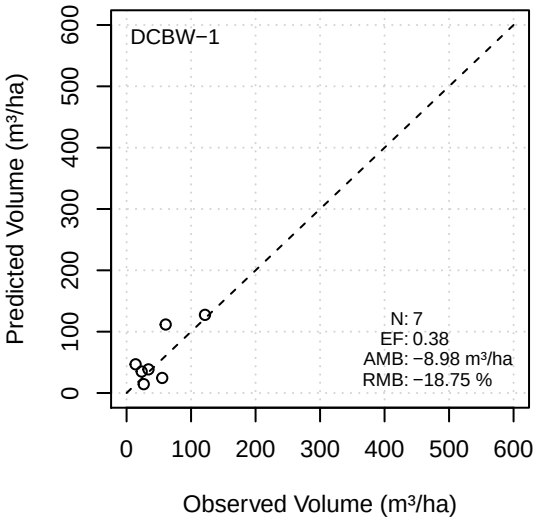

**Deciduous Mean DBH − DCAW**



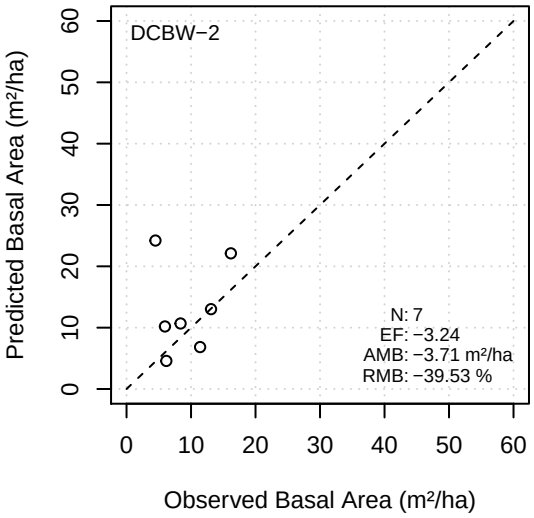

**Deciduous Density − DCAW**



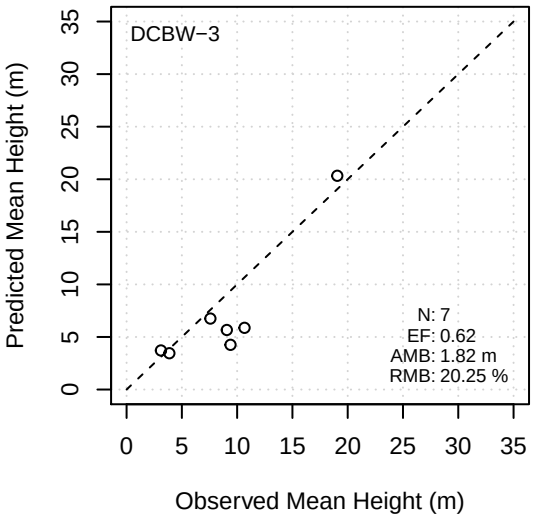
**Conifer Volume − DCBW**



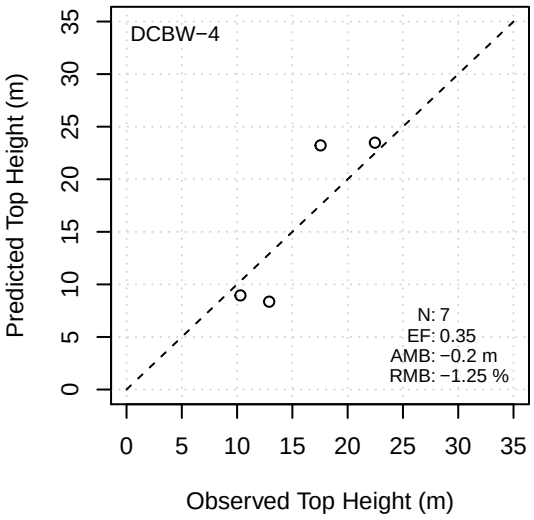

**Conifer Basal Area − DCBW**



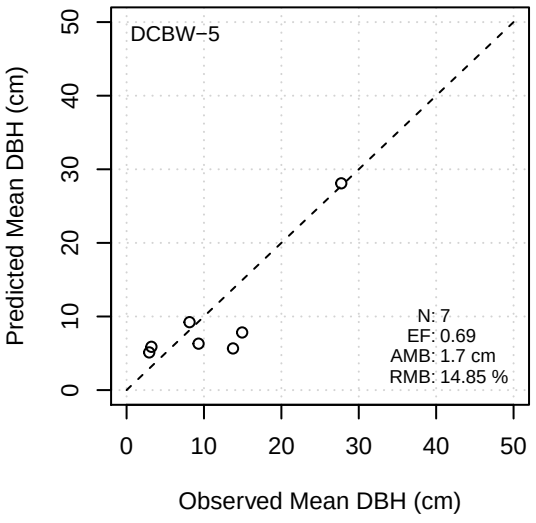

**Conifer Mean Height − DCBW**



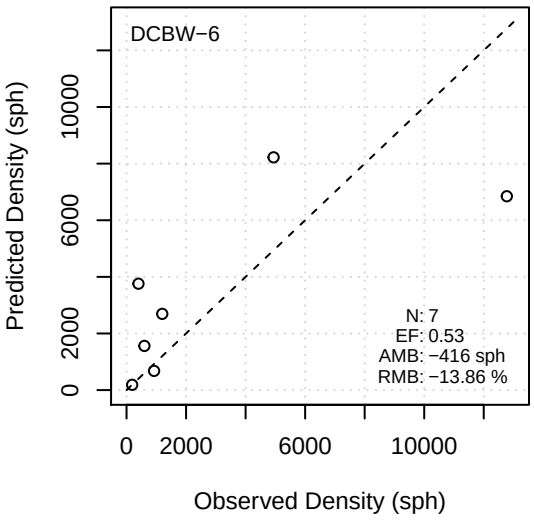

**Conifer Top Height − DCBW**



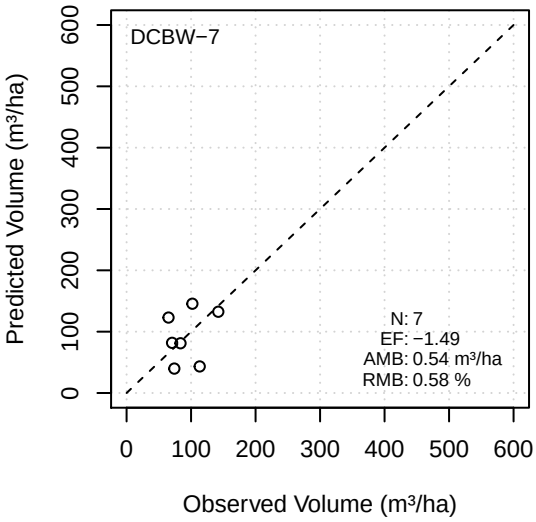

**Conifer Mean DBH − DCBW**



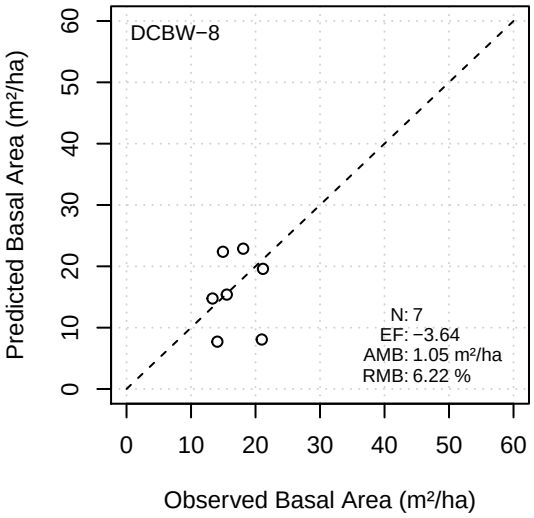

**Conifer Density − DCBW**



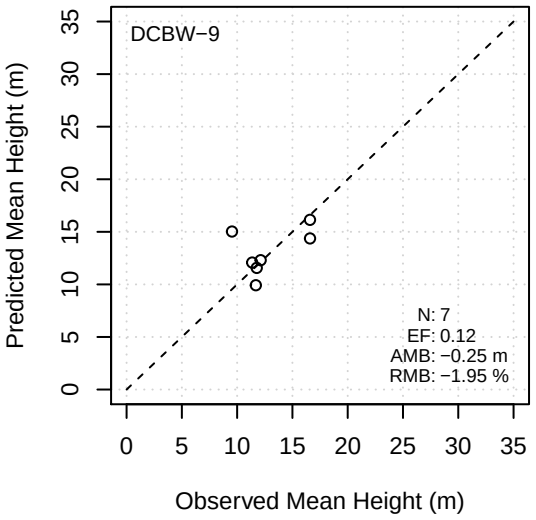
**Deciduous Volume − DCBW**



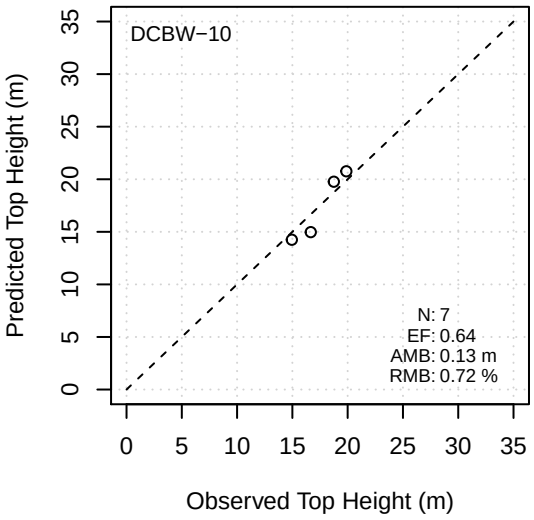

**Deciduous Basal Area − DCBW**



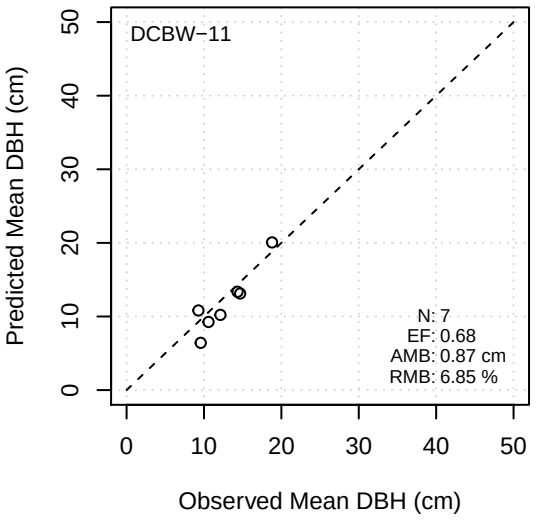

**Deciduous Mean Height − DCBW**



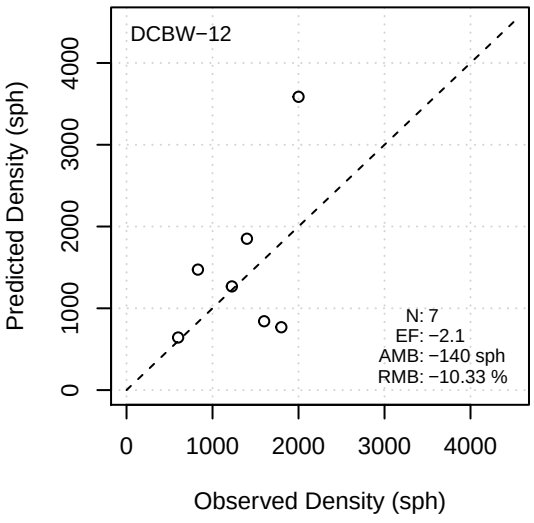

**Deciduous Top Height − DCBW**



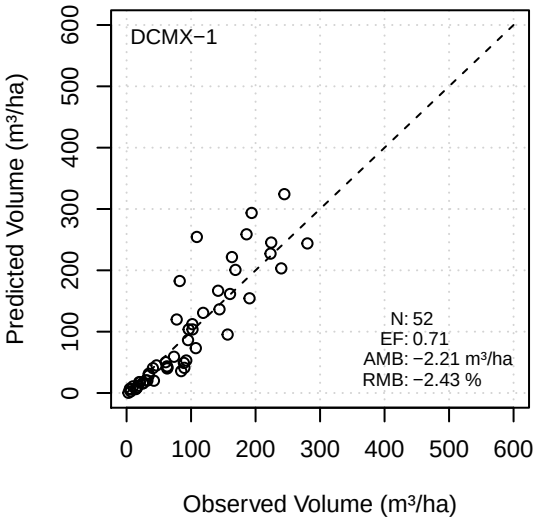

**Deciduous Mean DBH − DCBW**



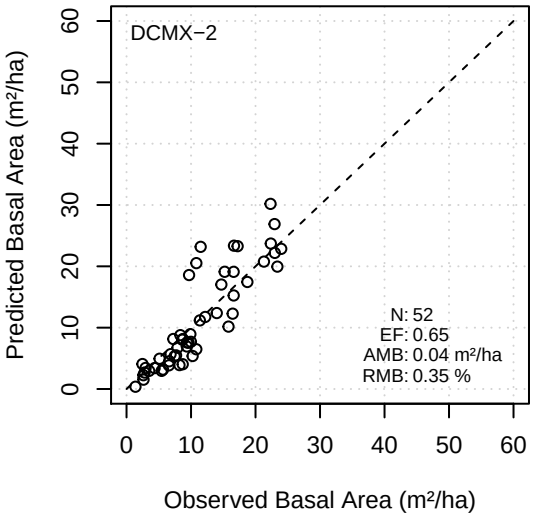

**Deciduous Density − DCBW**



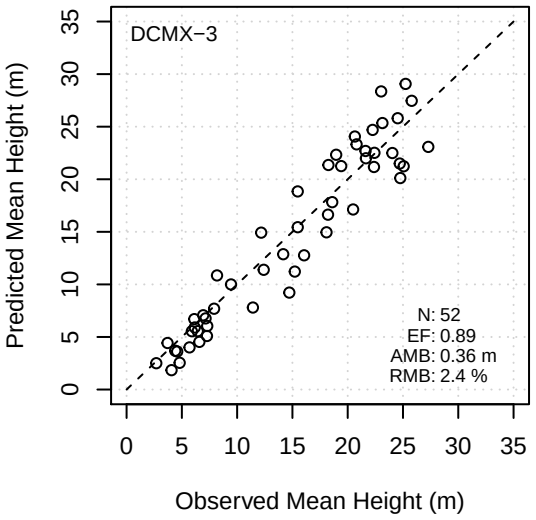
**Conifer Volume − DCMX**



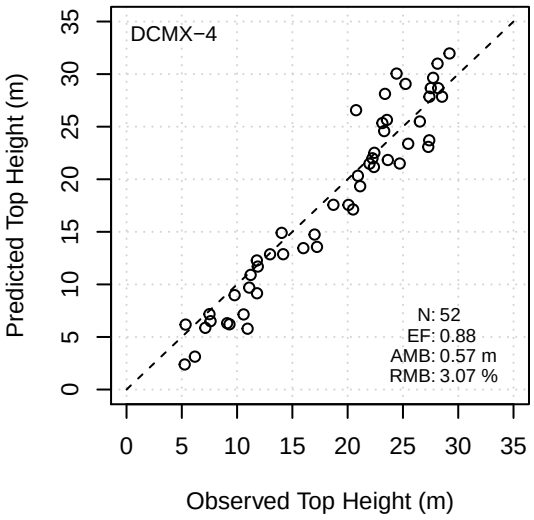

**Conifer Basal Area − DCMX**



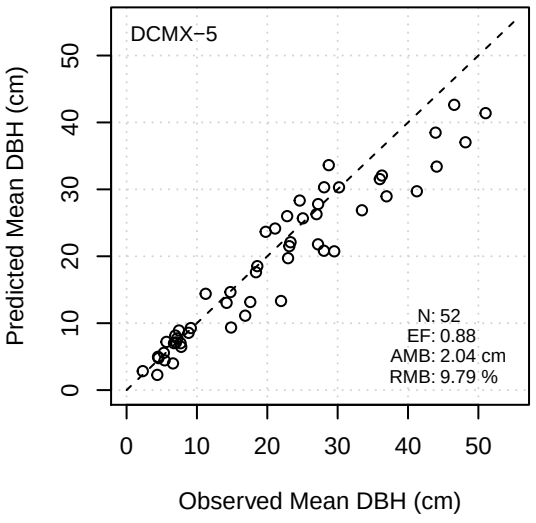

**Conifer Mean Height − DCMX**



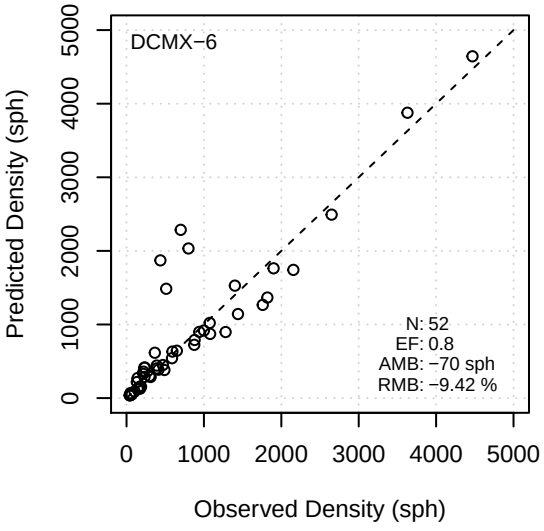

**Conifer Top Height − DCMX**



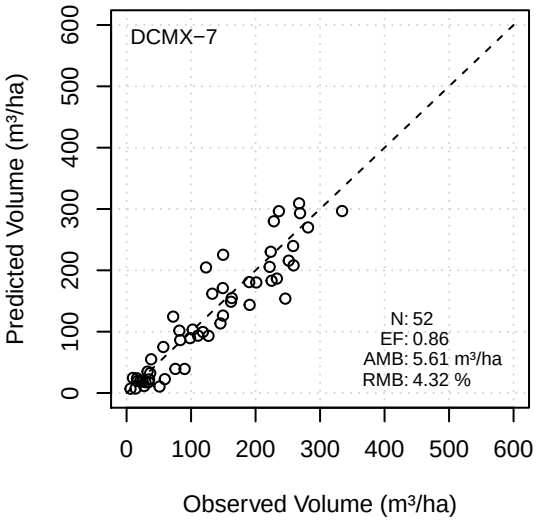

**Conifer Mean DBH − DCMX**



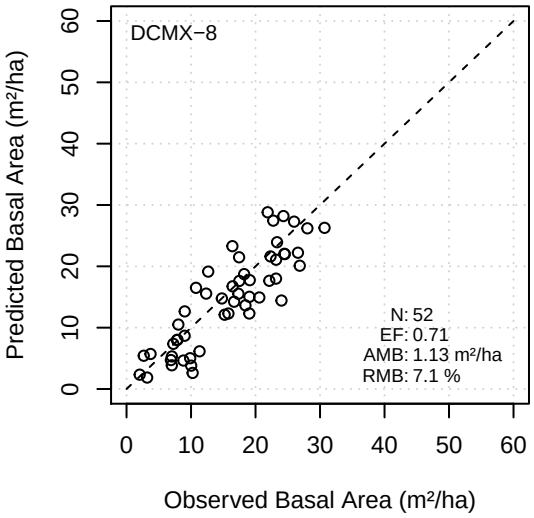

**Conifer Density − DCMX**



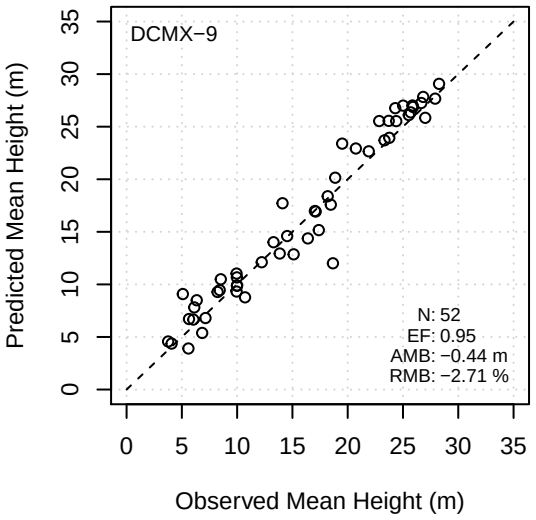
**Deciduous Volume − DCMX**



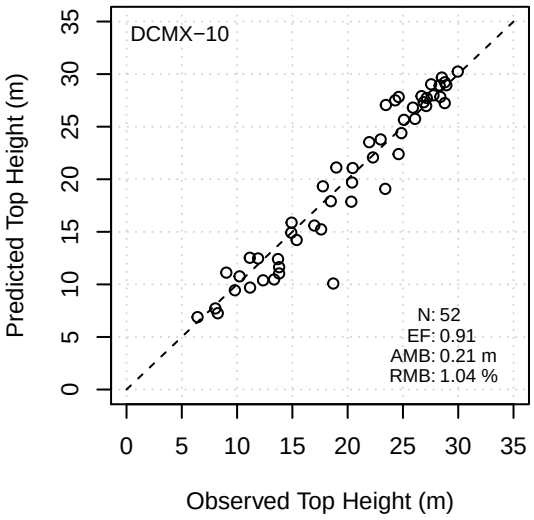

**Deciduous Basal Area − DCMX**



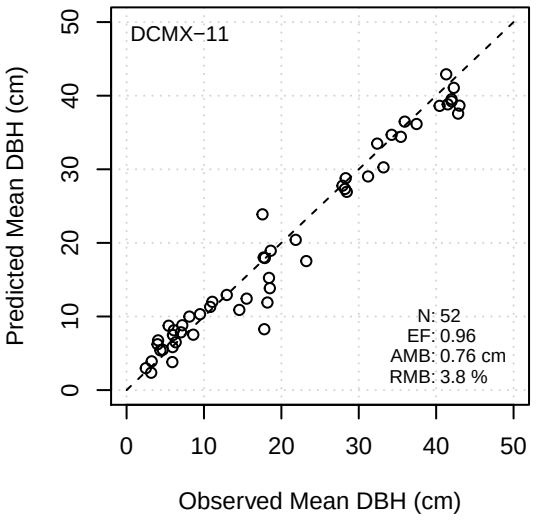

**Deciduous Mean Height − DCMX**



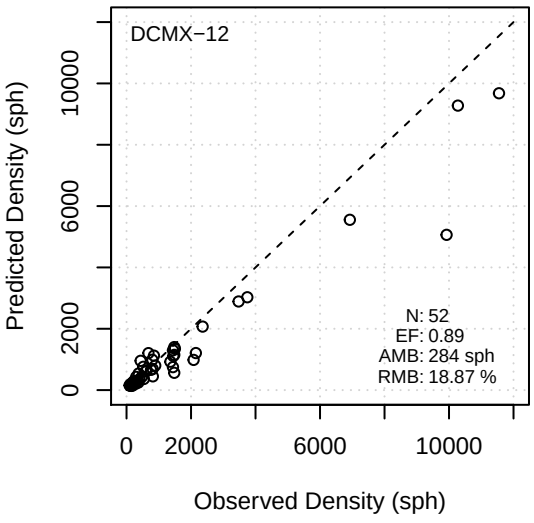

**Deciduous Top Height − DCMX**



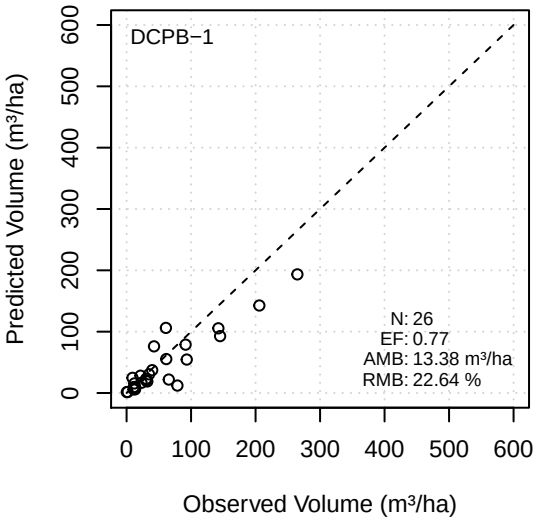

**Deciduous Mean DBH − DCMX**



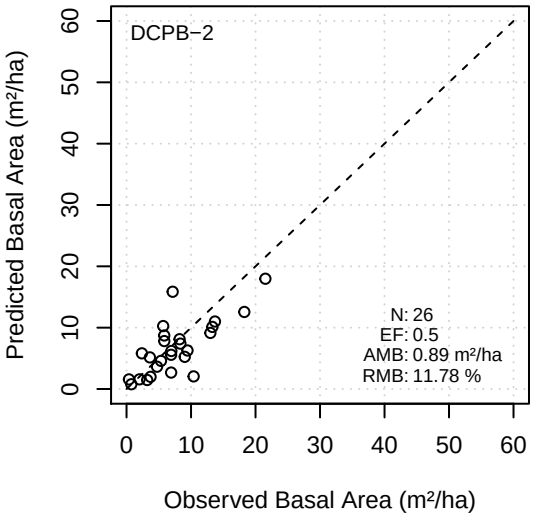

**Deciduous Density − DCMX**



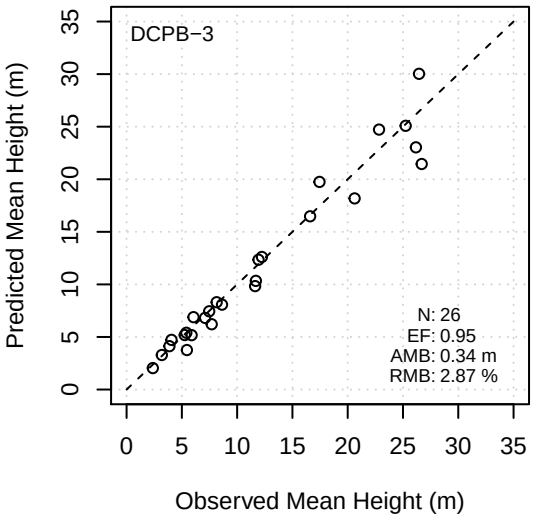
**Conifer Volume − DCPB**



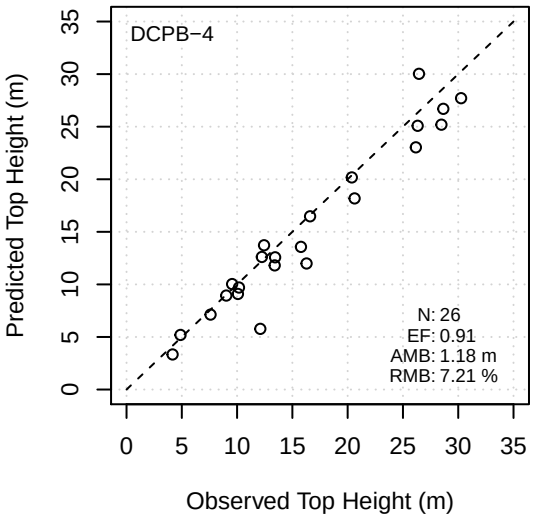

**Conifer Basal Area − DCPB**



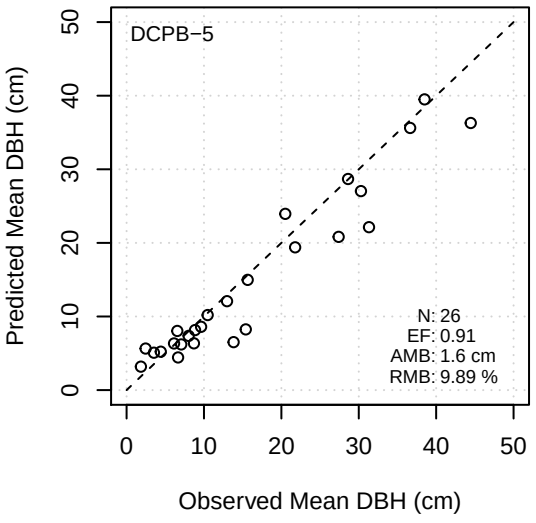

**Conifer Mean Height − DCPB**



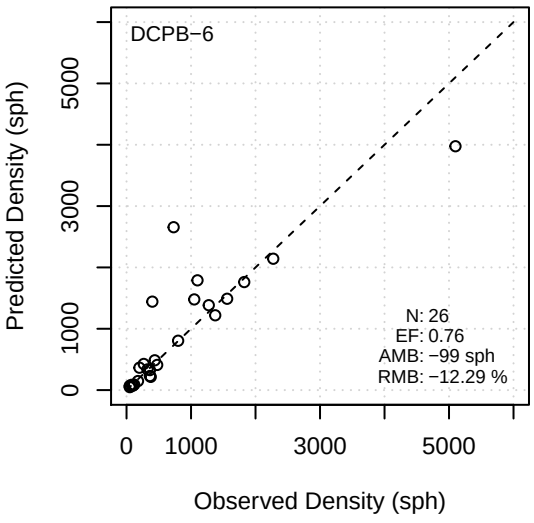

**Conifer Top Height − DCPB**



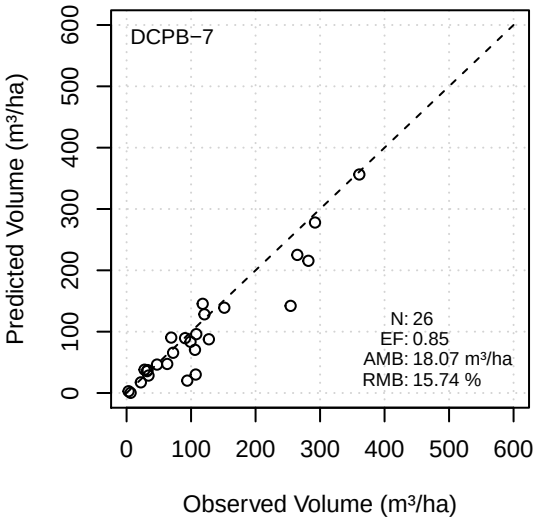

**Conifer Mean DBH − DCPB**



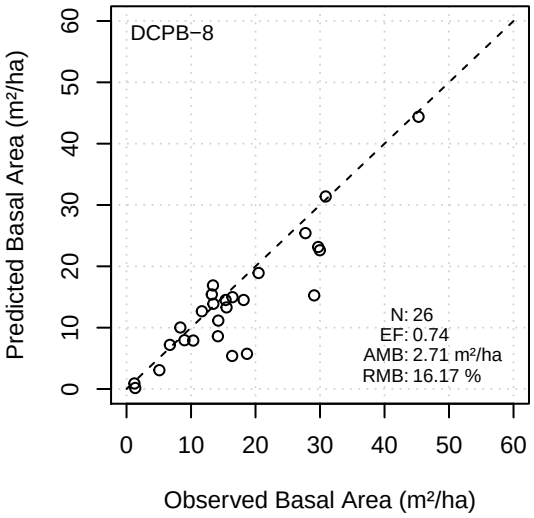

**Conifer Density − DCPB**



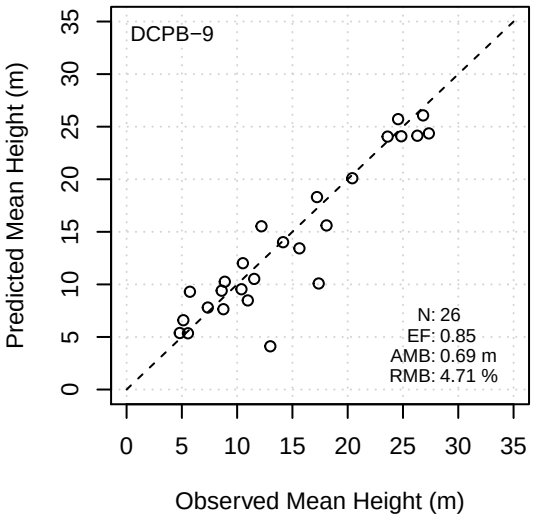
**Deciduous Volume − DCPB**



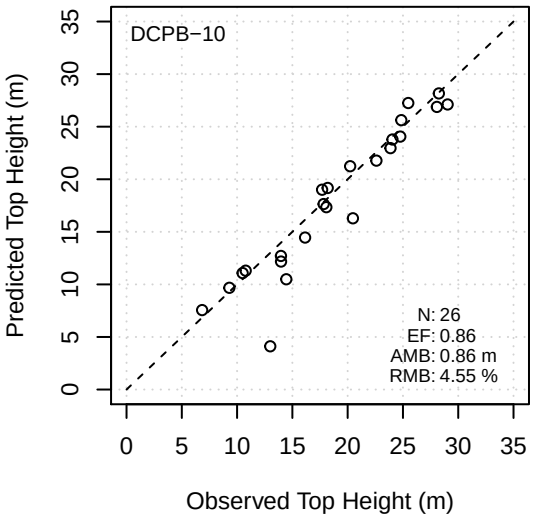

**Deciduous Basal Area − DCPB**



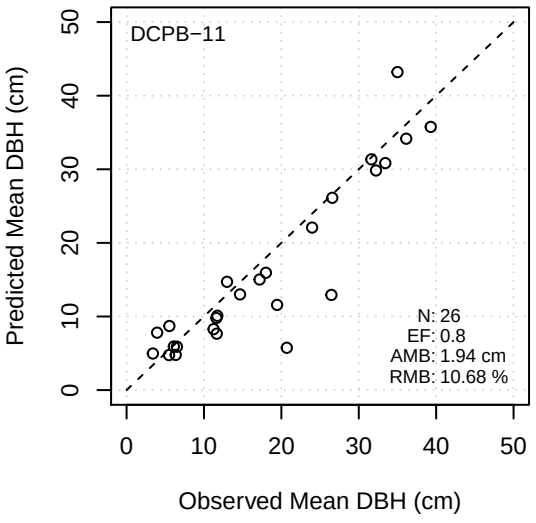

**Deciduous Mean Height − DCPB**



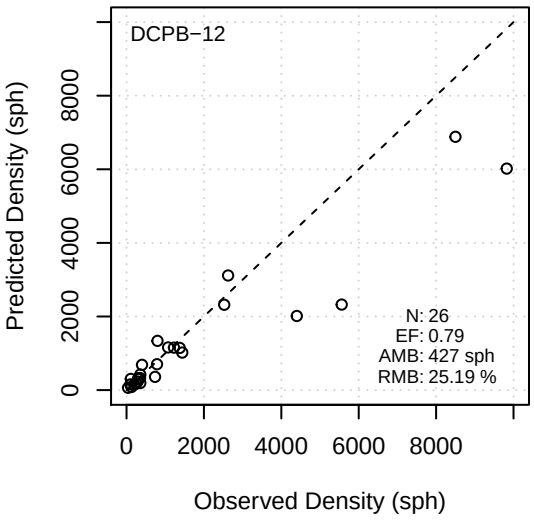

**Deciduous Top Height − DCPB**



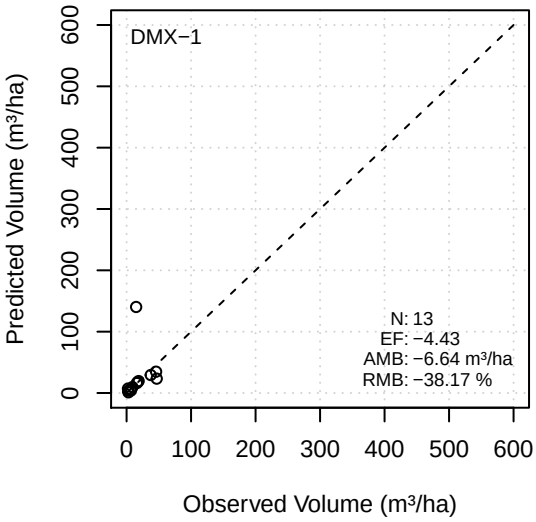

**Deciduous Mean DBH − DCPB**



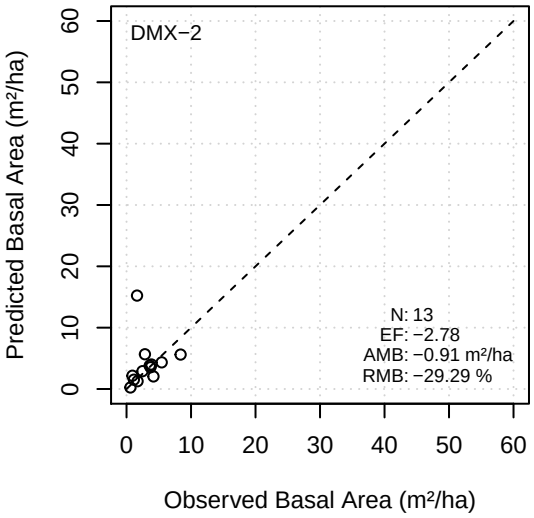

**Deciduous Density − DCPB**



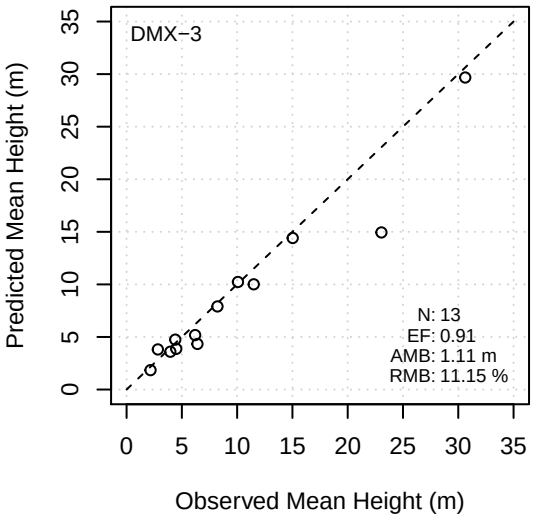
**Conifer Volume − DMX**



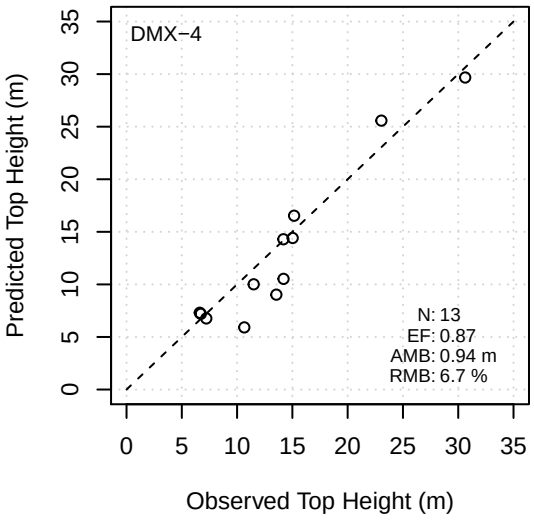

**Conifer Basal Area − DMX**



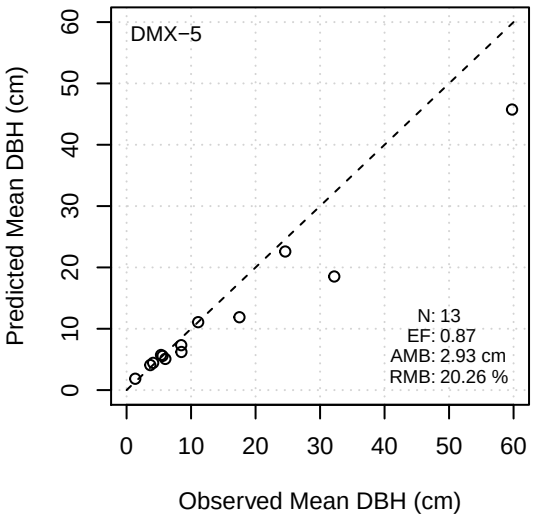

**Conifer Mean Height − DMX**



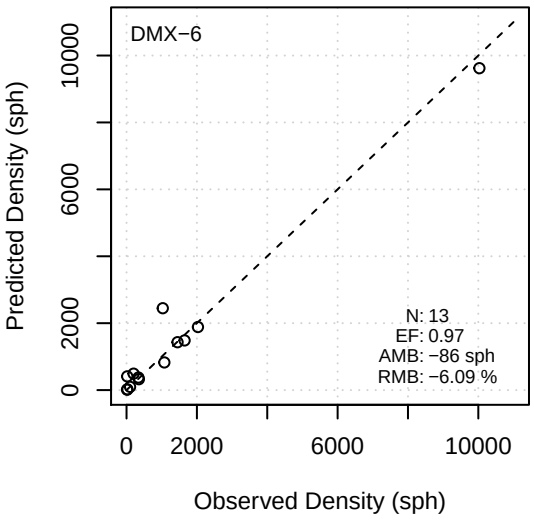

**Conifer Top Height − DMX**



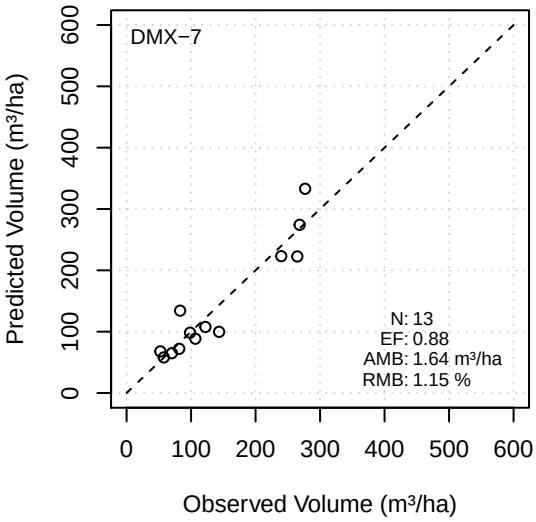

**Conifer Mean DBH − DMX**



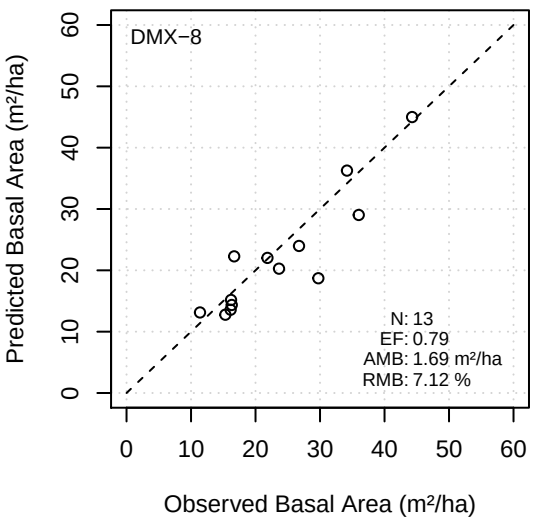

**Conifer Density − DMX**



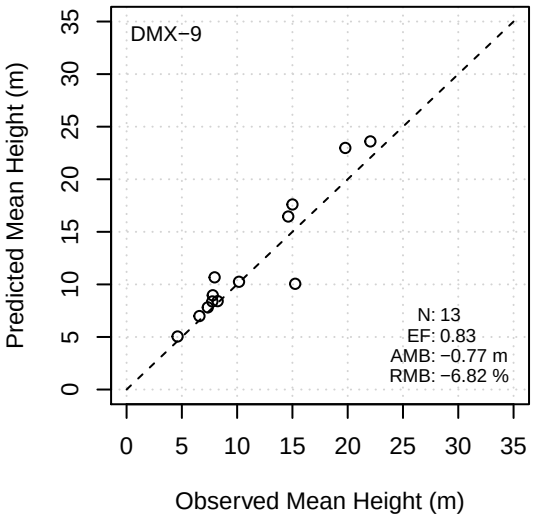
**Deciduous Volume − DMX**



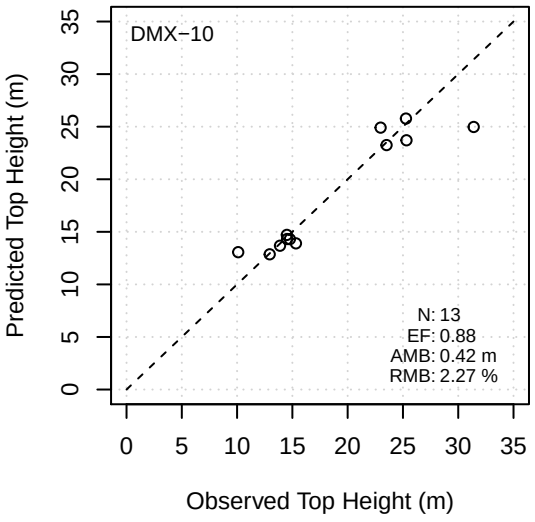

**Deciduous Basal Area − DMX**



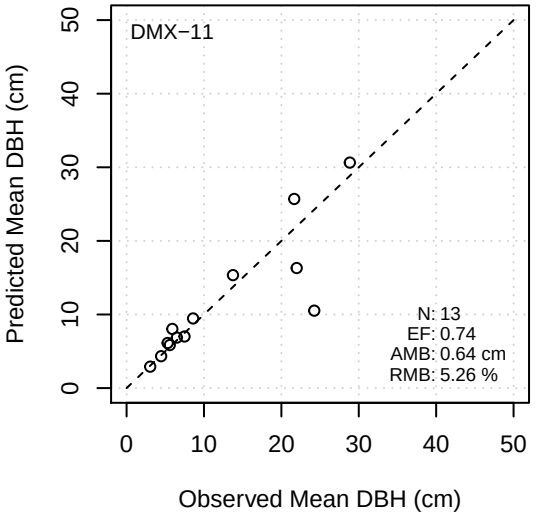

**Deciduous Mean Height − DMX**



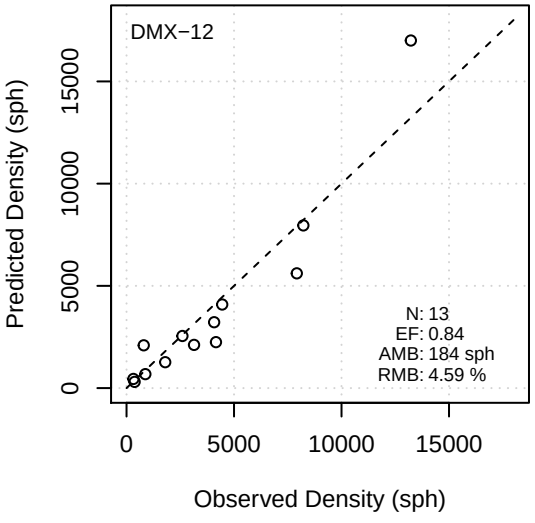

**Deciduous Top Height − DMX**



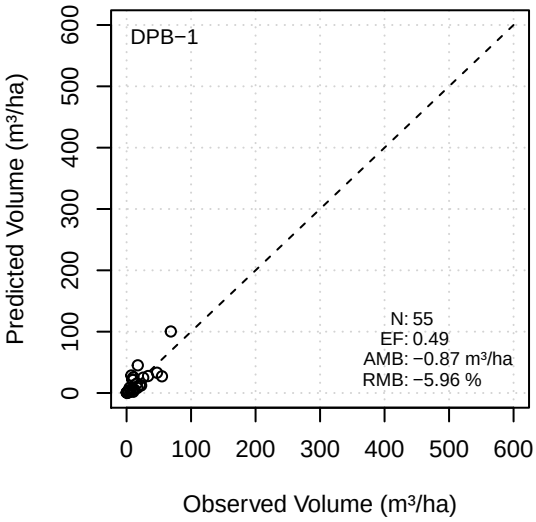

**Deciduous Mean DBH − DMX**



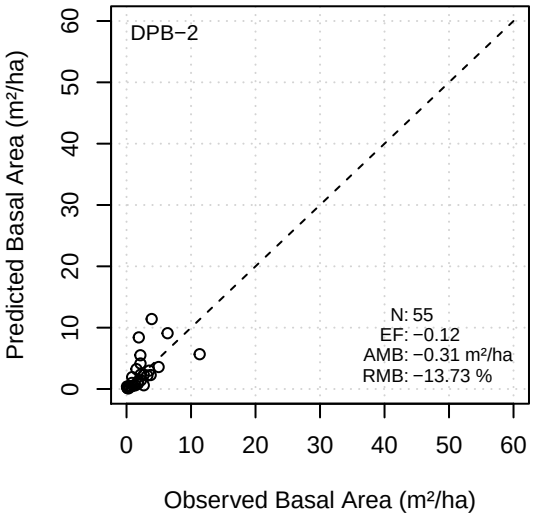

**Deciduous Density − DMX**



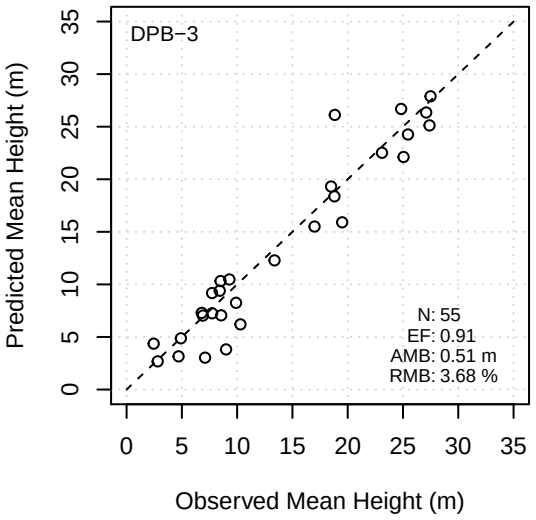
**Conifer Volume − DPB**



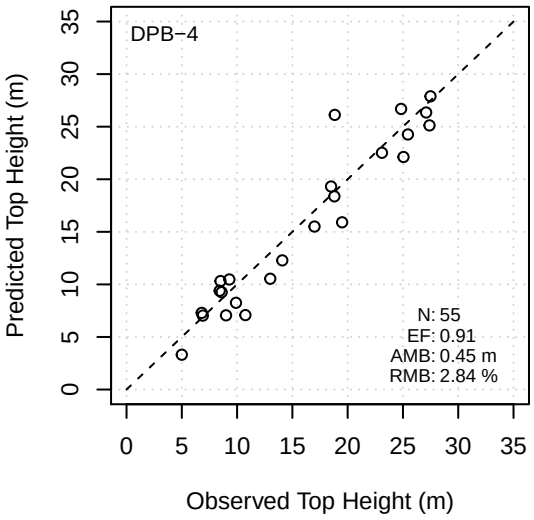

**Conifer Basal Area − DPB**



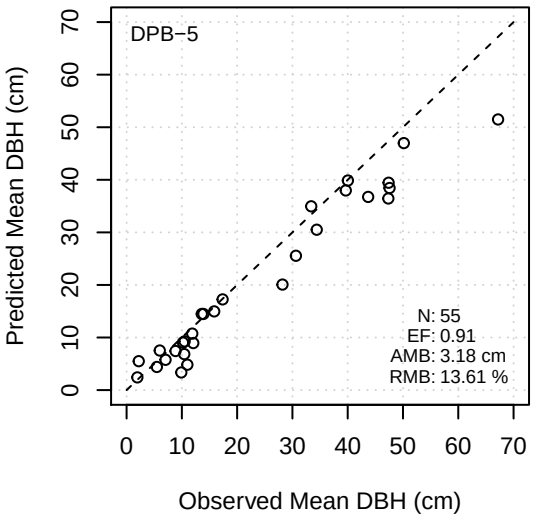

**Conifer Mean Height − DPB**



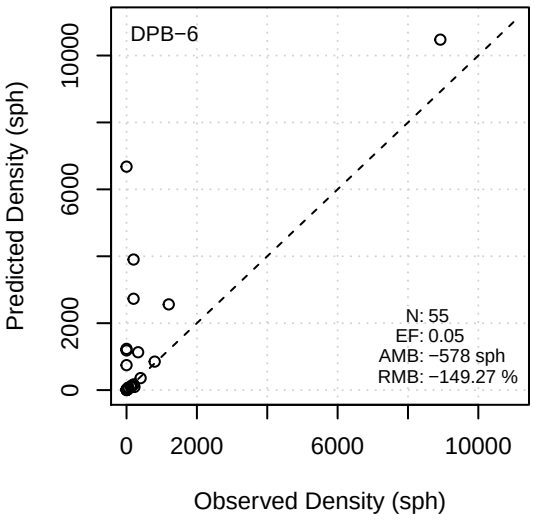

**Conifer Top Height − DPB**



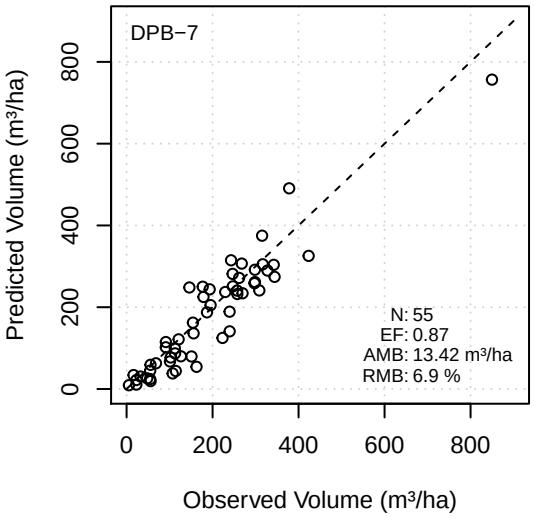

**Conifer Mean DBH − DPB**



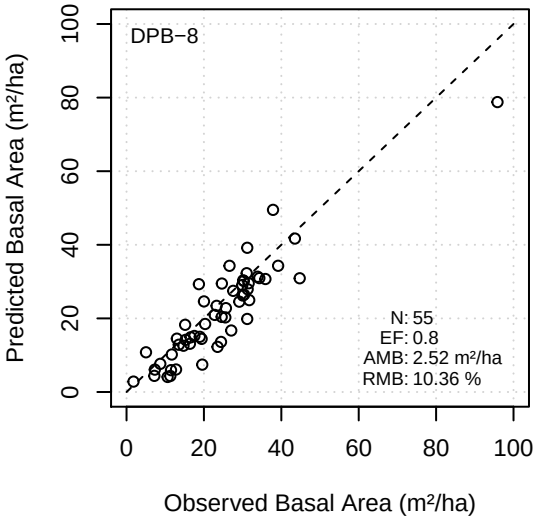

**Conifer Density − DPB**



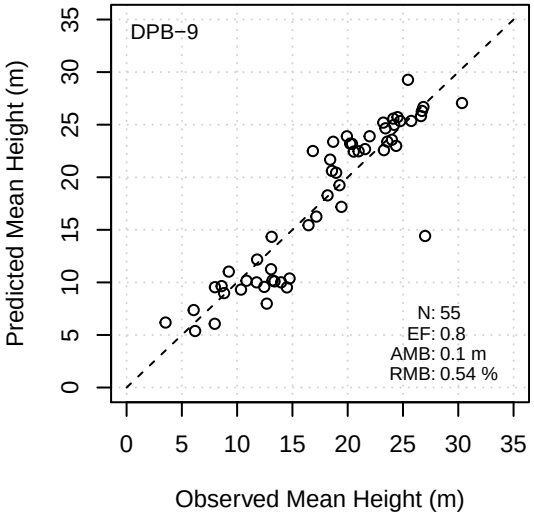
**Deciduous Volume − DPB**



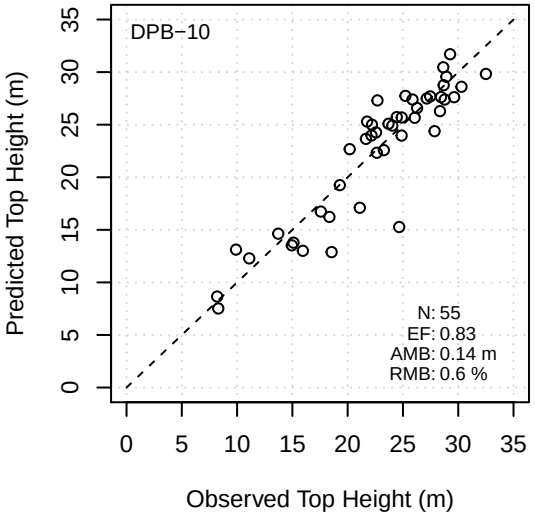

**Deciduous Basal Area − DPB**



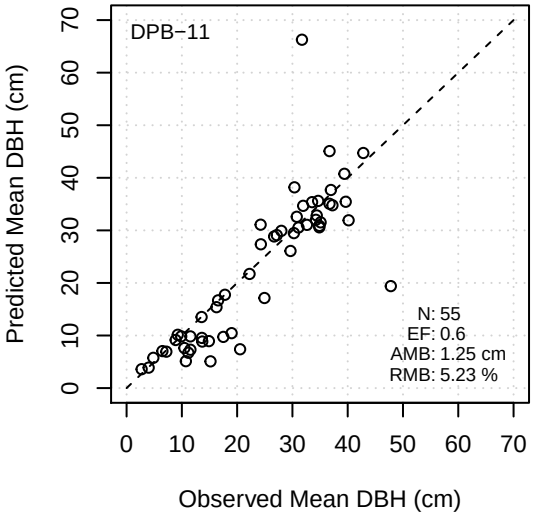

**Deciduous Mean Height − DPB**



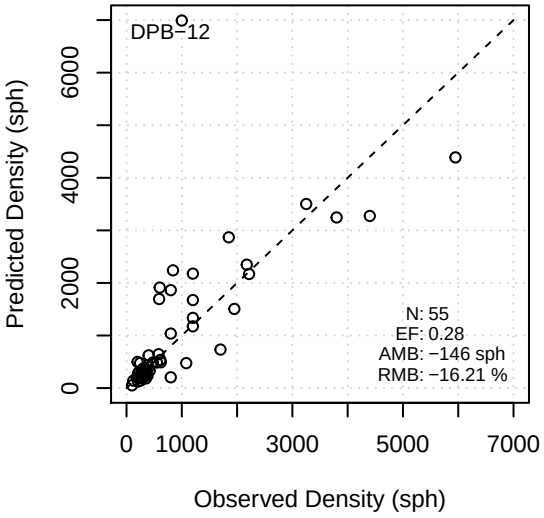

**Deciduous Top Height − DPB**




**Deciduous Mean DBH − DPB**




**Deciduous Density − DPB**



**Appendix B.** Plots of residuals (difference between actual and predicted) for conifer and deciduous volume against 12 variables: Initial conifer and deciduous density, initial conifer and deciduous volume, predicted conifer and deciduous volume, initial conifer and deciduous DBH, initial stand age, projection length, CMI, and site index for MGM's primary species groups (AW, PJ, PL, SB, SW). Results are presented for: 1) the full dataset (ALL, pages 1-4), 2) broad cover group (pages 5-20), and 3) species (pages 21-44).

Broad Cover Groups:

C – Conifer

CD – Conifer Dominated Mixedwood

D - Deciduous

DC – Deciduous Dominated Mixedwood

Species:

AW – trembling aspen (*Populus tremuloides* Michx.)

BW – white birch (*Betula papyrifera* Marsh.)

FA – alpine fir (*Abies lasiocarpa* (Hook.) Nutt.)

FB – balsam fir (*Abies balsamea* (L.) Mill.)

FD – Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)

LT – tamarack (*Larix laricina* (Du Roi) K. Koch)

MX – tree mixture without a clear dominant species

PB – balsam poplar (*Populus balsamifera* L.)

PJ – jack pine (*Pinus banksiana* Lamb.)

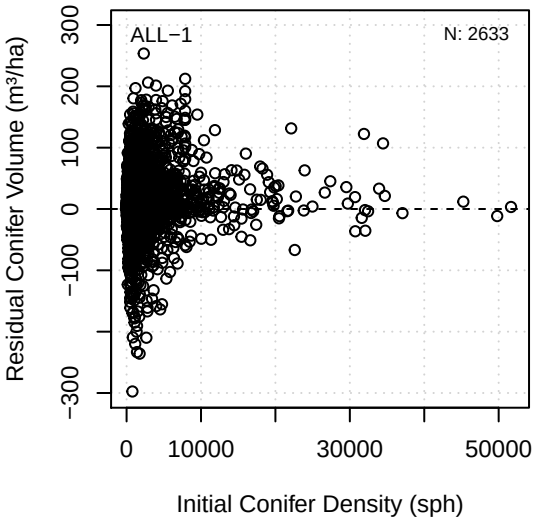
PL – lodgepole pine (*Pinus contorta* Loudon)

SB – black spruce (*Picea mariana* (Mill.) BSP.)

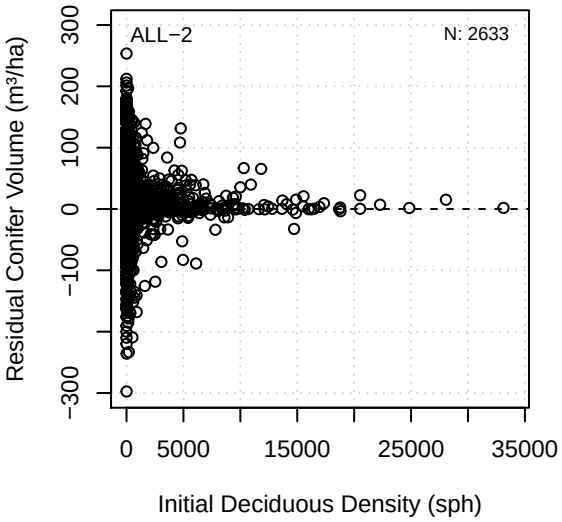
SE – Engelmann spruce (*Picea engelmannii* Parry ex Engelm.)

SW – white spruce (*Picea glauca* (Moench) Voss)

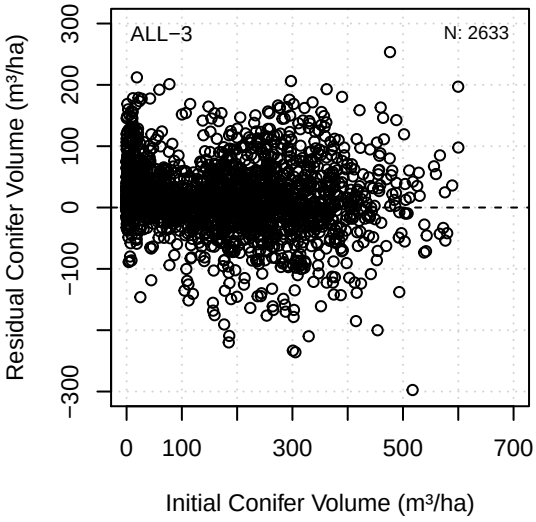
**ConResVol − Initial Conifer Density − ALL**



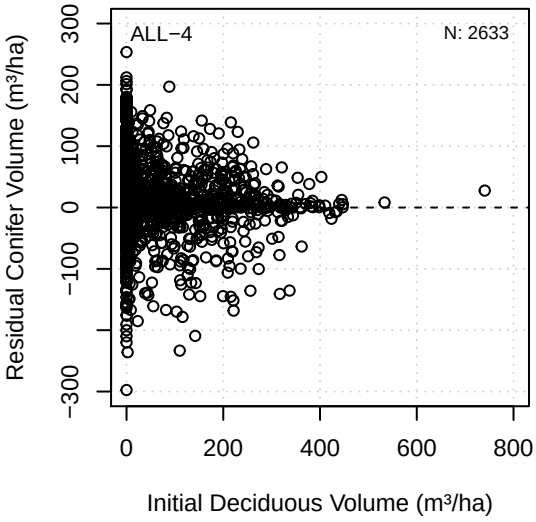

**ConResVol − Initial Deciduous Density − ALL**



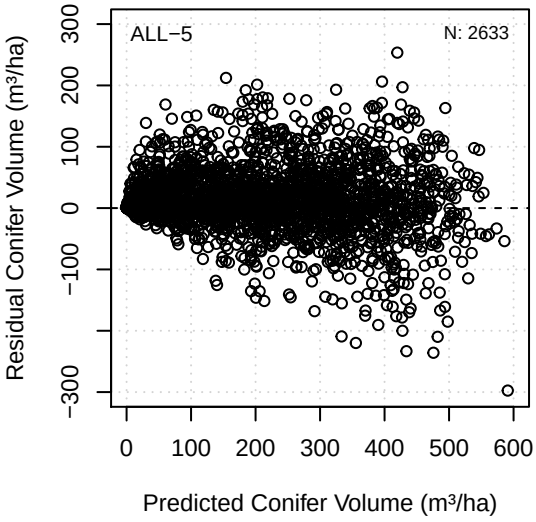

**ConResVol − Initial Conifer Volume − ALL**



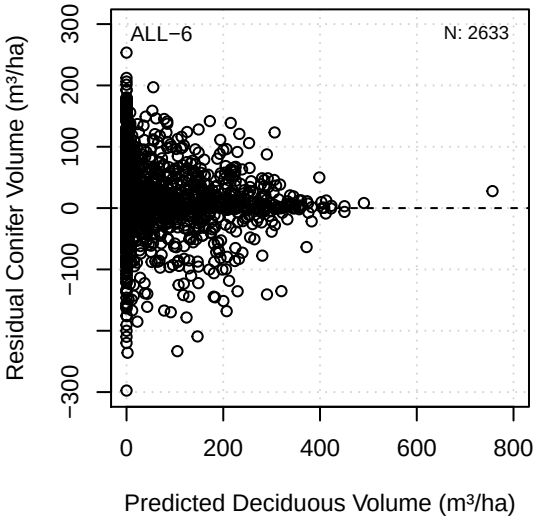

**ConResVol − Initial Deciduous Volume − ALL**



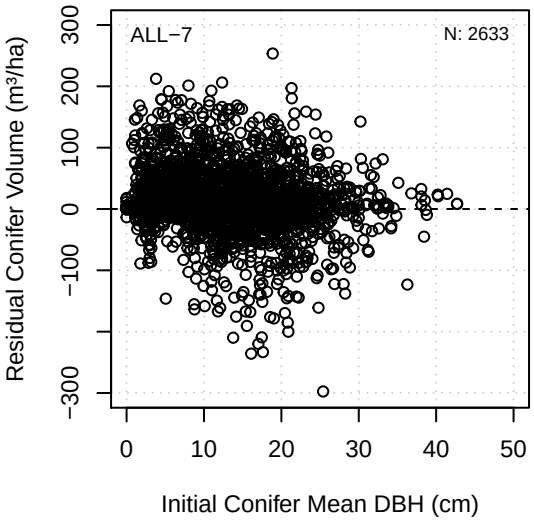

**ConResVol − Predicted Conifer Volume − ALL**



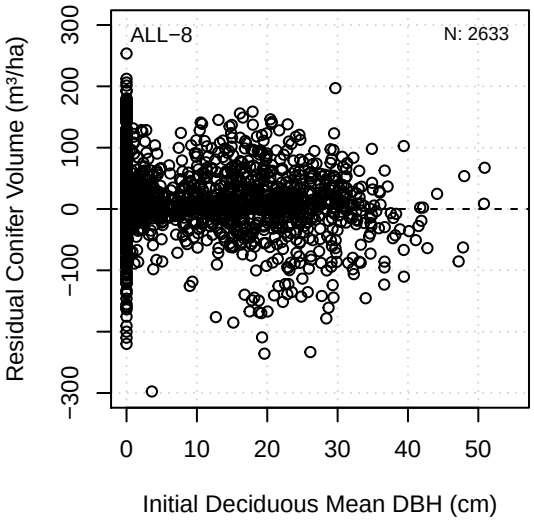

**ConResVol − Predicted Deciduous Volume − ALL**



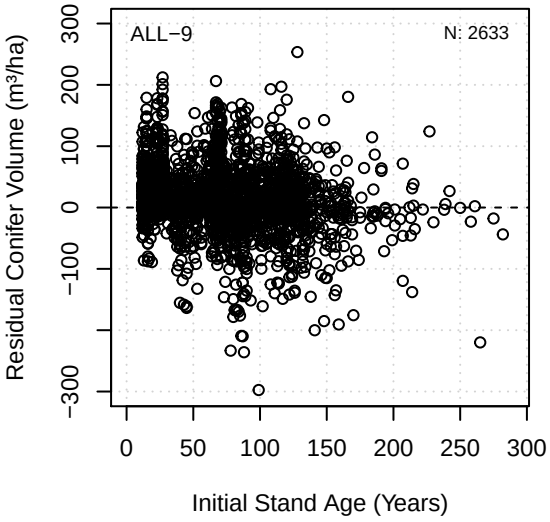
**ConResVol − Initial Conifer Mean DBH − ALL**



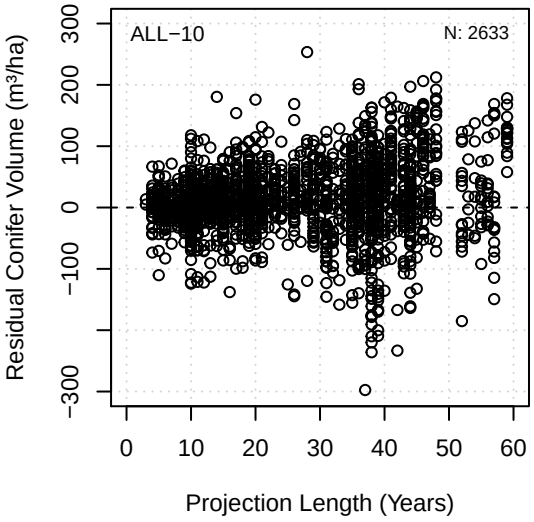

**ConResVol − Initial Deciduous Mean DBH − ALL**



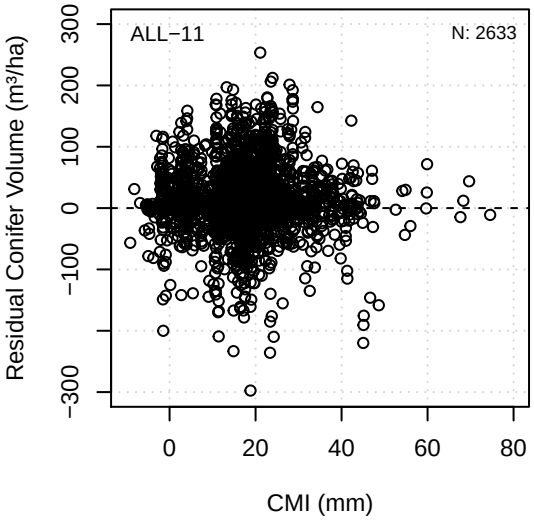

**ConResVol − Initial Stand Age − ALL**



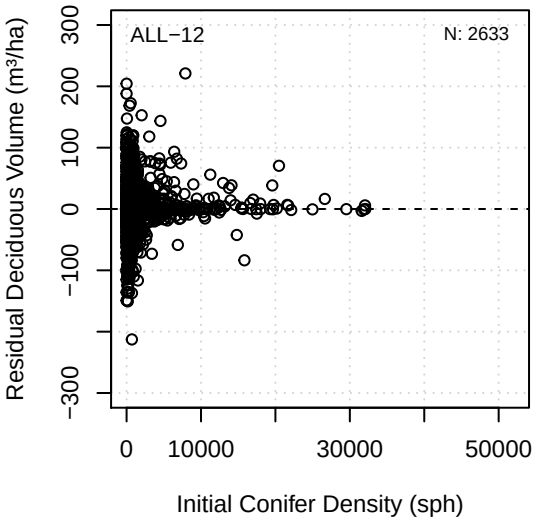

**ConResVol − Projection Length − ALL**



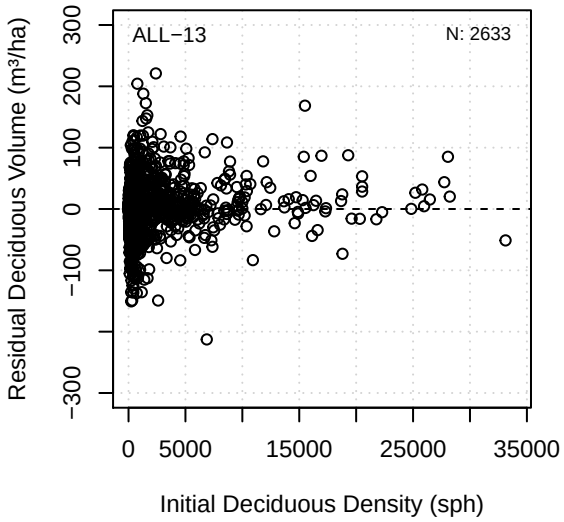

**ConResVol − CMI − ALL**



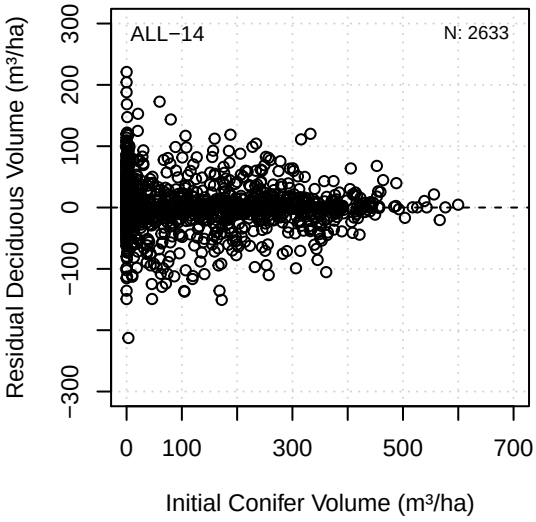
**DecResVol − Initial Conifer Density − ALL**



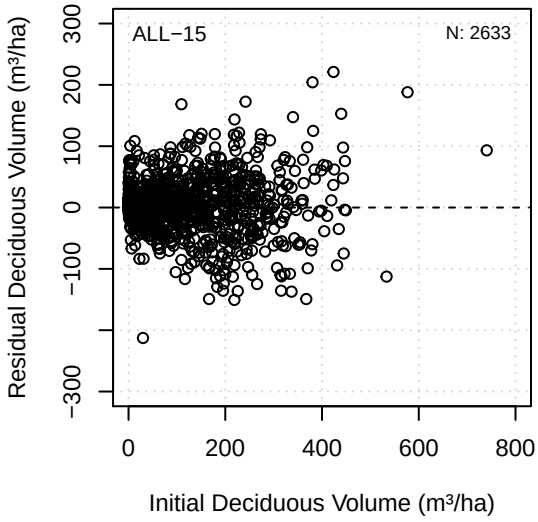

**DecResVol − Initial Deciduous Density − ALL**



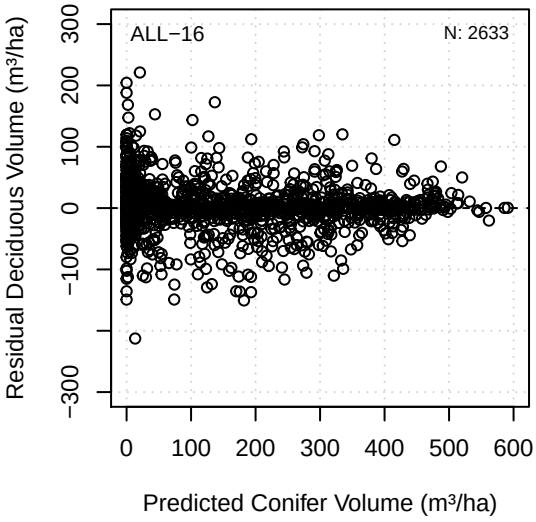

**DecResVol − Initial Conifer Volume − ALL**



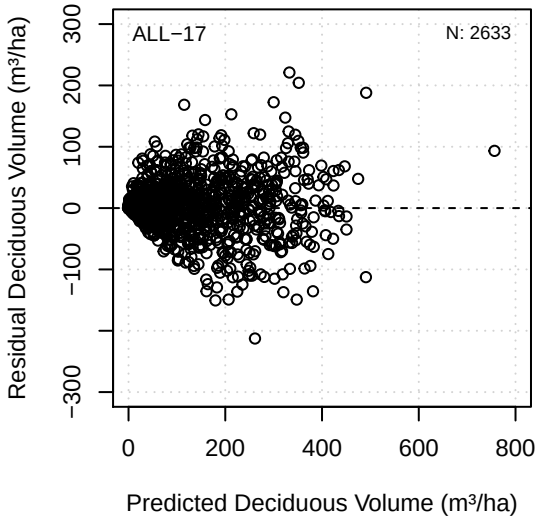

**DecResVol − Initial Deciduous Volume − ALL**



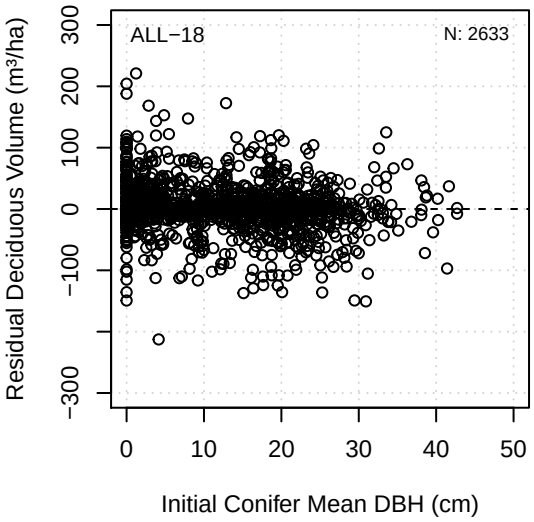

**DecResVol − Predicted Conifer Volume − ALL**



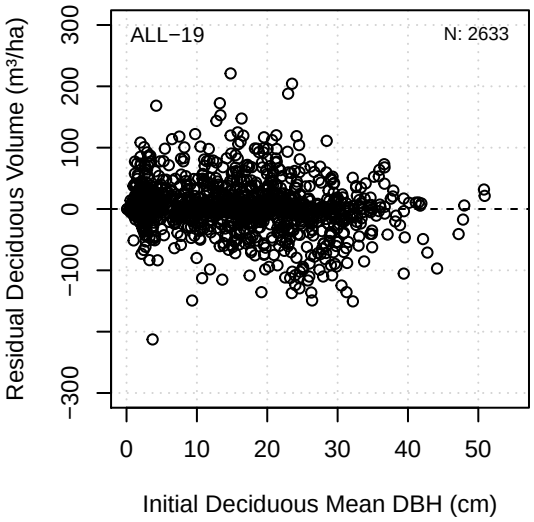

**DecResVol − Predicted Deciduous Volume − ALL**



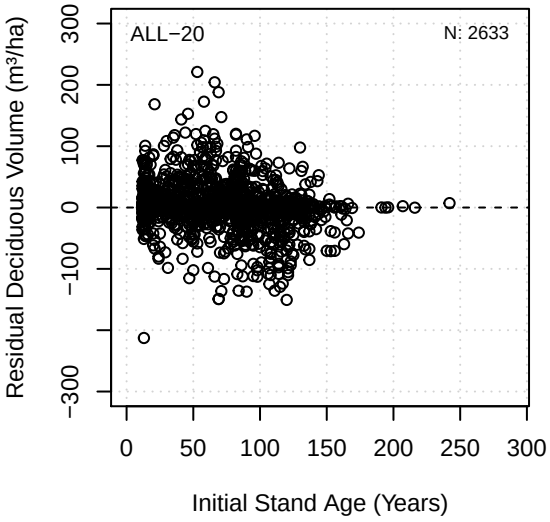
**DecResVol − Initial Conifer Mean DBH − ALL**



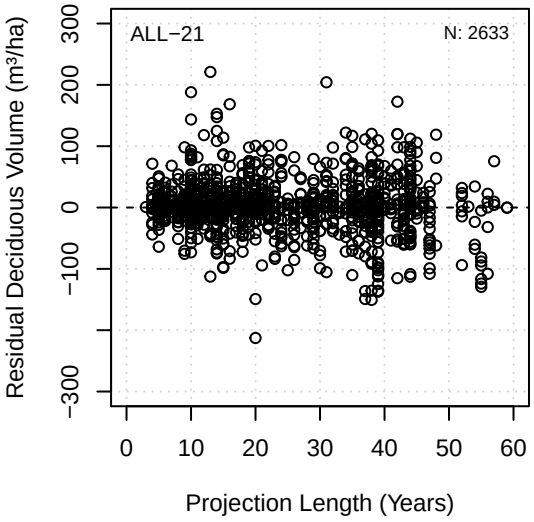

**DecResVol − Initial Deciduous Mean DBH − ALL**



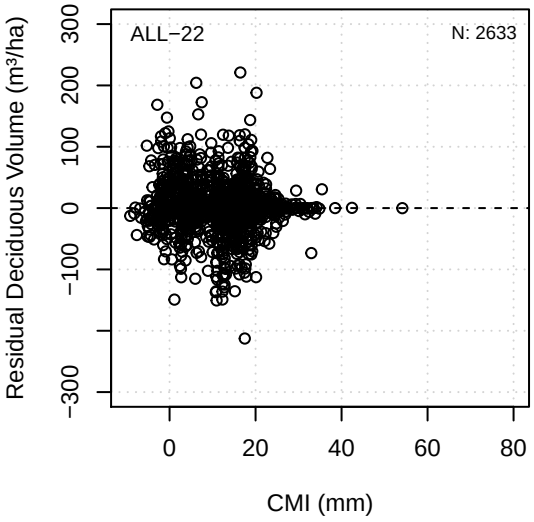

**DecResVol − Initial Stand Age − ALL**



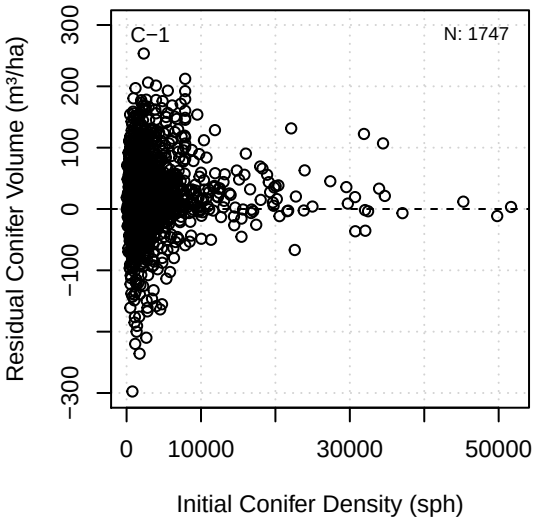

**DecResVol − Projection Length − ALL**



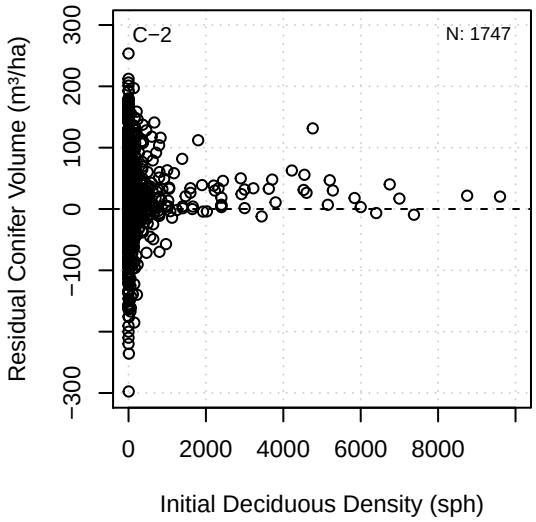

**DecResVol − CMI − ALL**



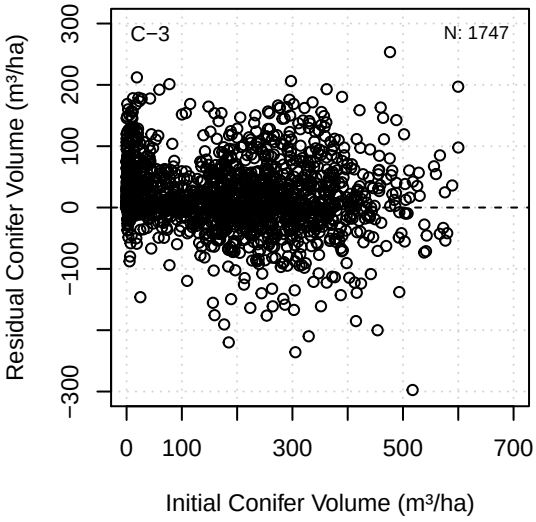
**ConResVol − Initial Conifer Density − C**



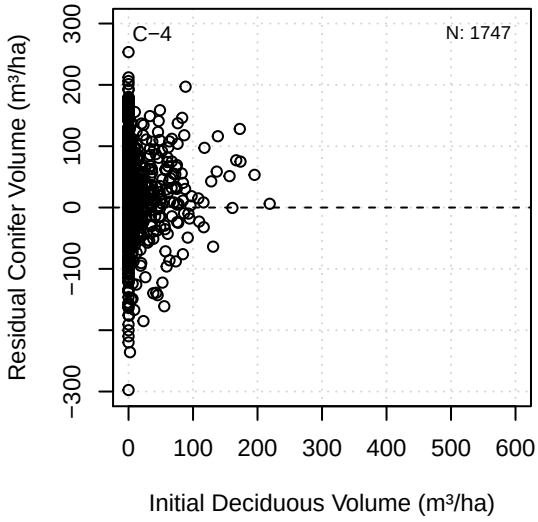

**ConResVol − Initial Deciduous Density − C**



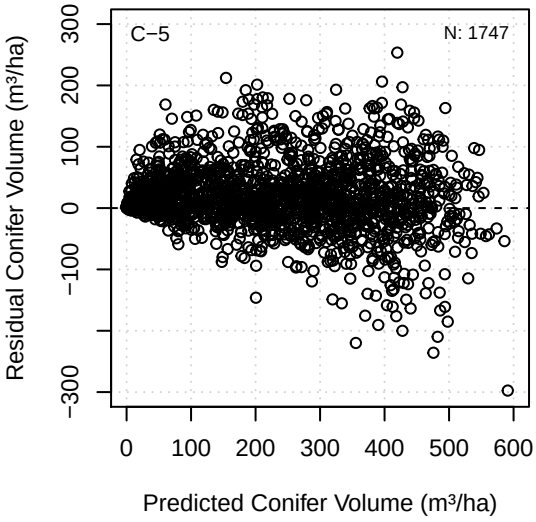

**ConResVol − Initial Conifer Volume − C**



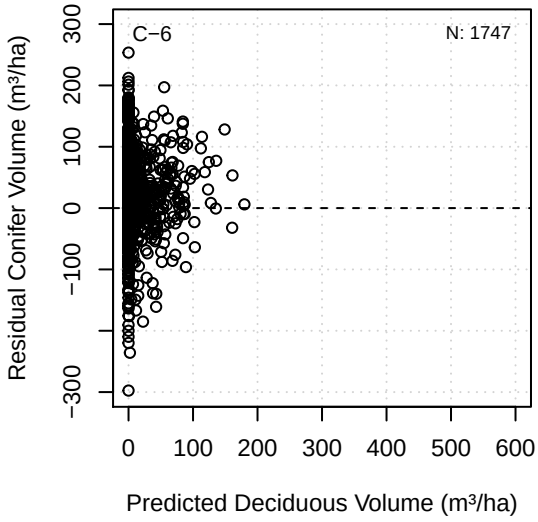

**ConResVol − Initial Deciduous Volume − C**



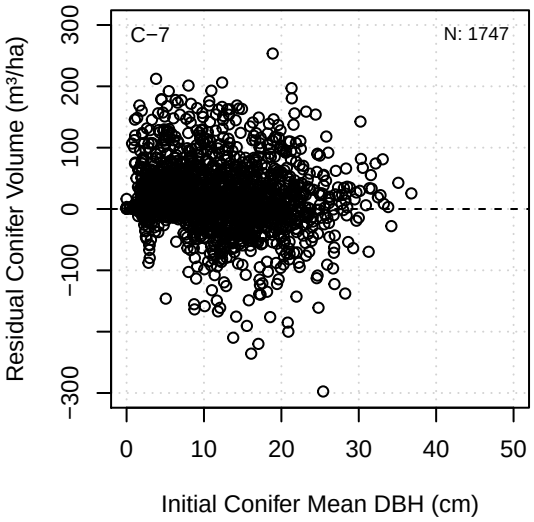

**ConResVol − Predicted Conifer Volume − C**



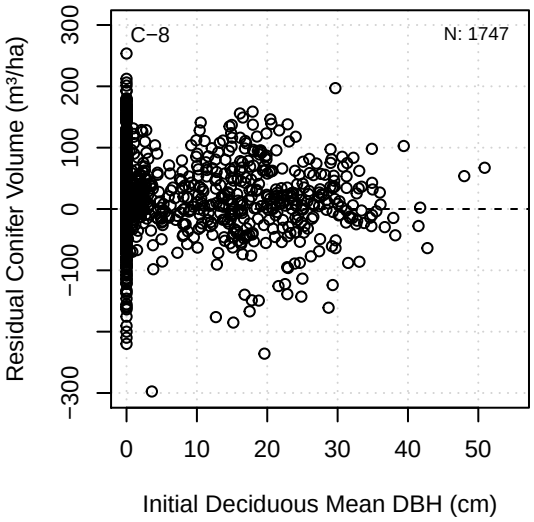

**ConResVol − Predicted Deciduous Volume − C**



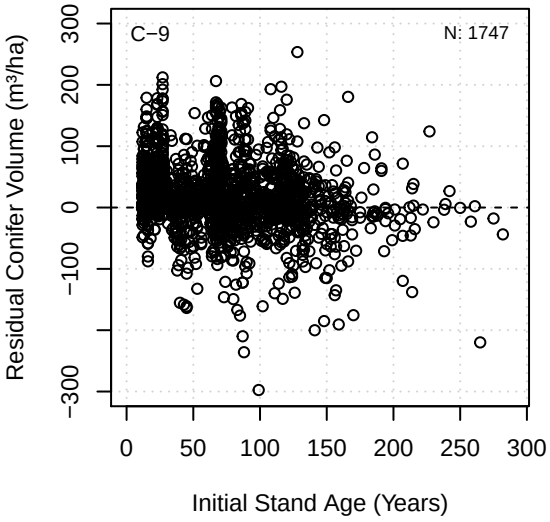
**ConResVol − Initial Conifer Mean DBH − C**



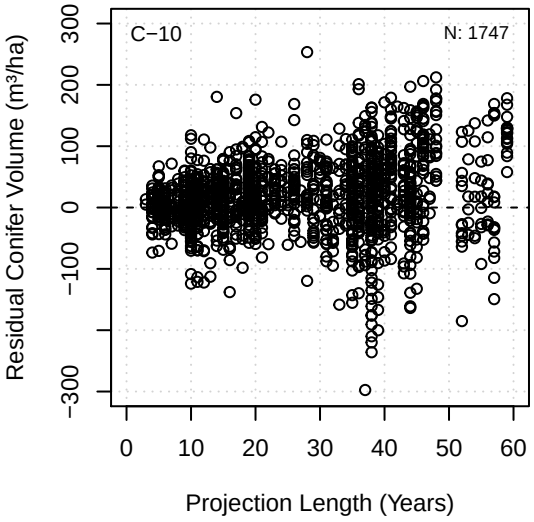

**ConResVol − Initial Deciduous Mean DBH − C**



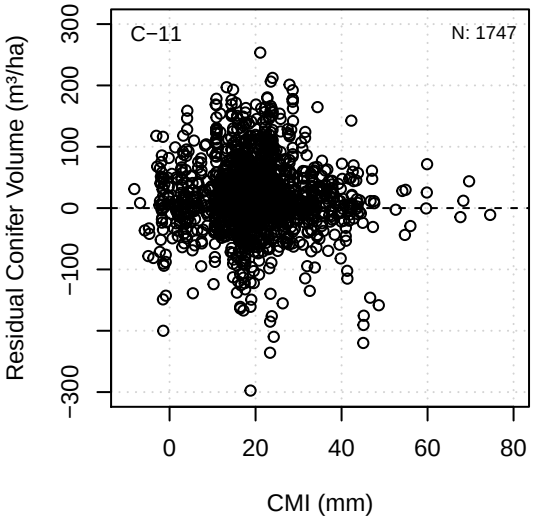

**ConResVol − Initial Stand Age − C**



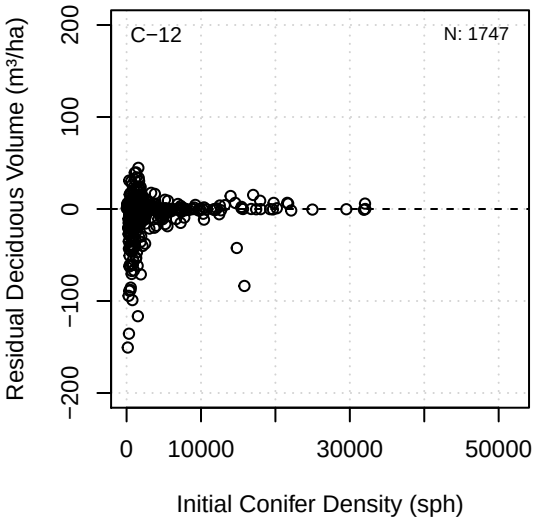

**ConResVol − Projection Length − C**



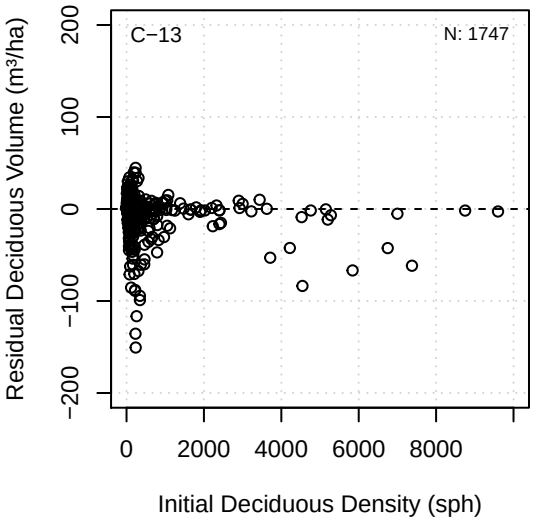

**ConResVol − CMI − C**



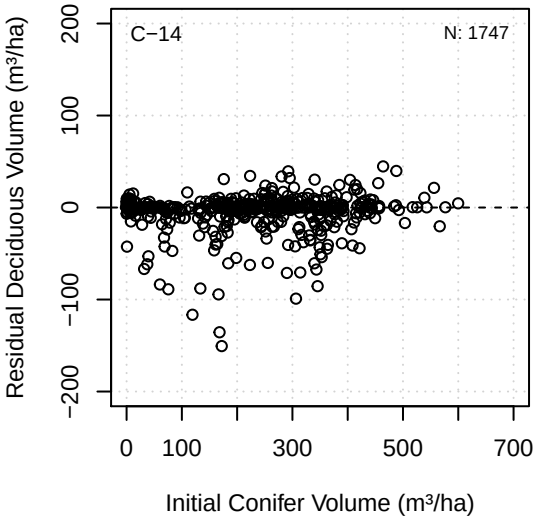
**DecResVol − Initial Conifer Density − C**



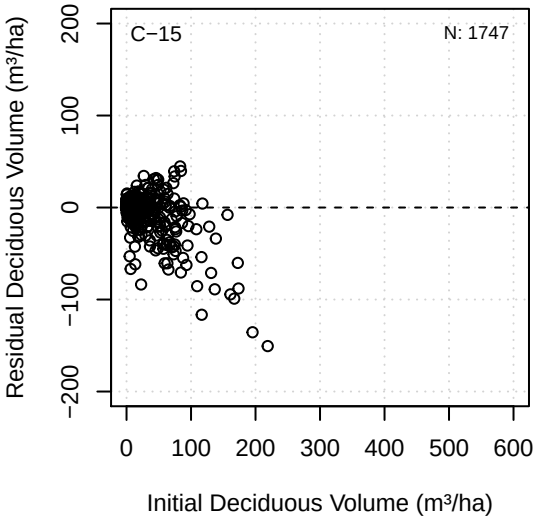

**DecResVol − Initial Deciduous Density − C**



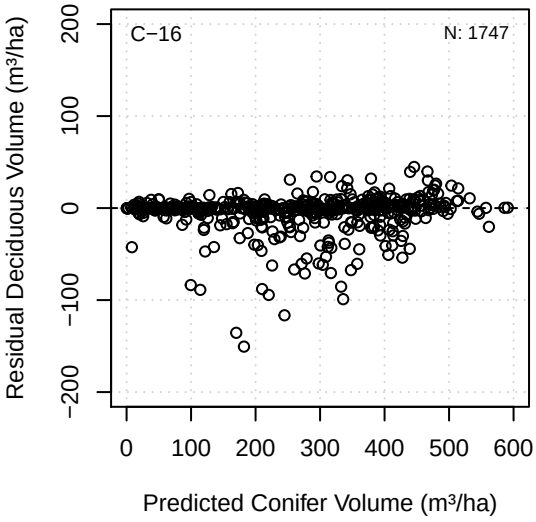

**DecResVol − Initial Conifer Volume − C**



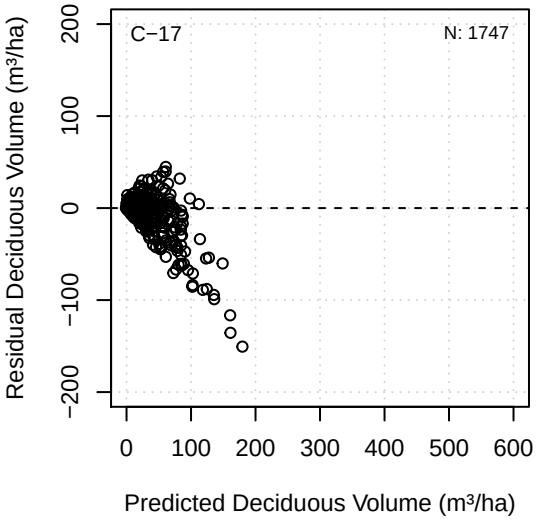

**DecResVol − Initial Deciduous Volume − C**



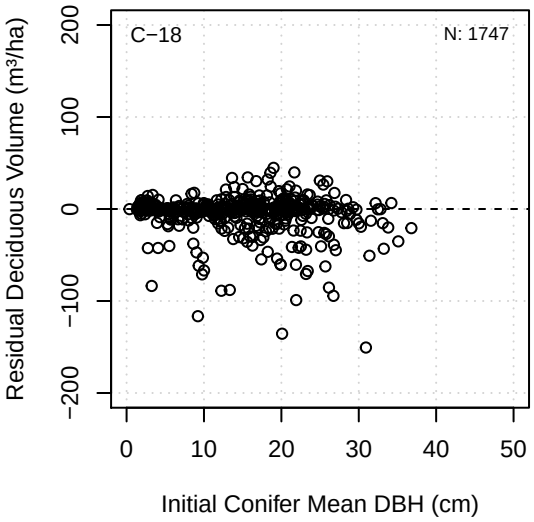

**DecResVol − Predicted Conifer Volume − C**



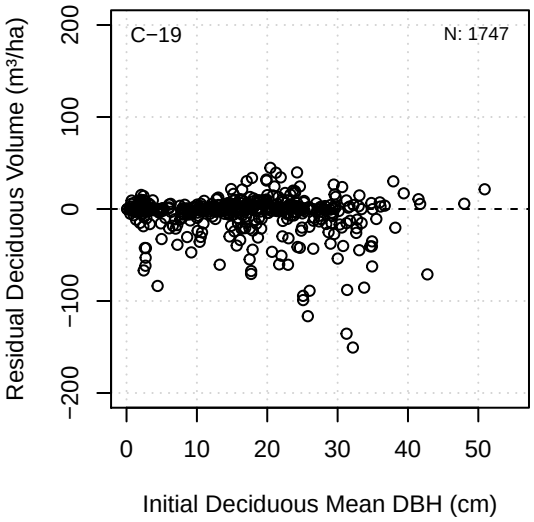

**DecResVol − Predicted Deciduous Volume − C**



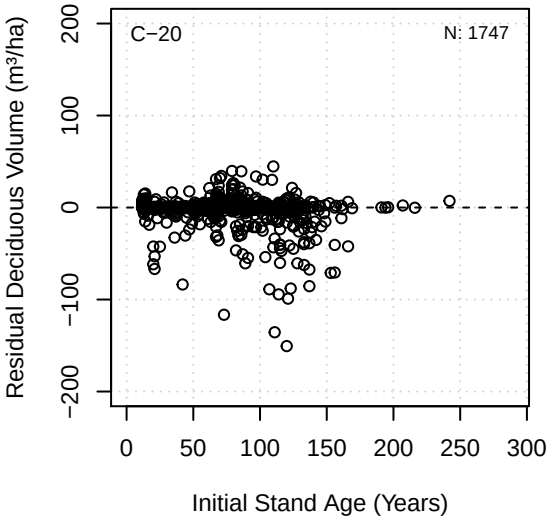
**DecResVol − Initial Conifer Mean DBH − C**



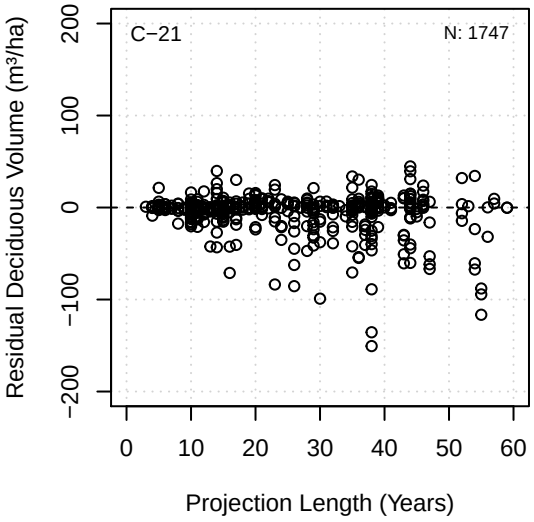

**DecResVol − Initial Deciduous Mean DBH − C**



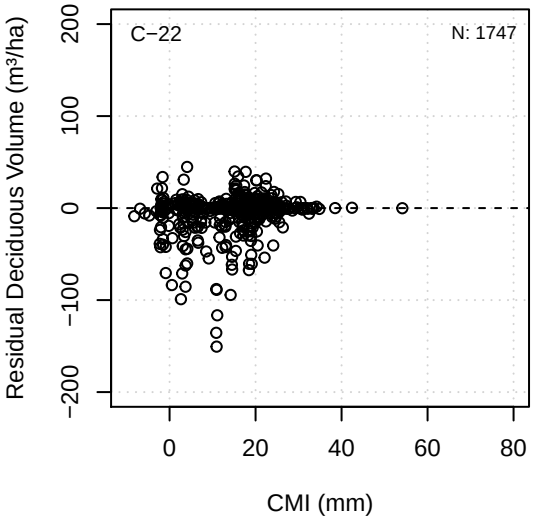

**DecResVol − Initial Stand Age − C**



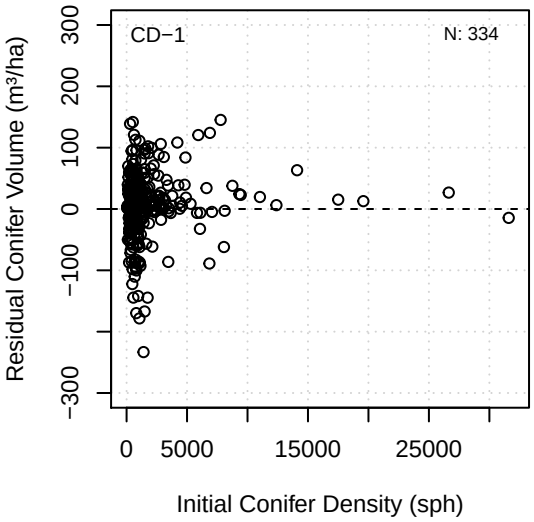

**DecResVol − Projection Length − C**



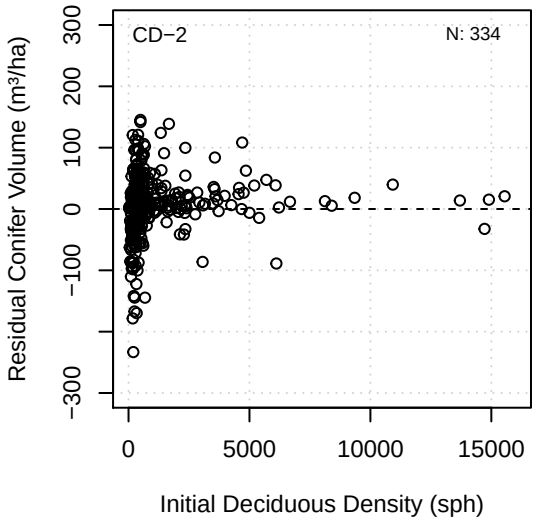

**DecResVol − CMI − C**



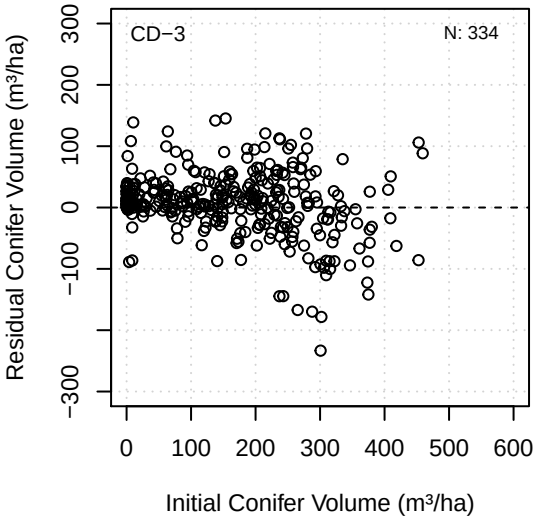
**ConResVol − Initial Conifer Density − CD**



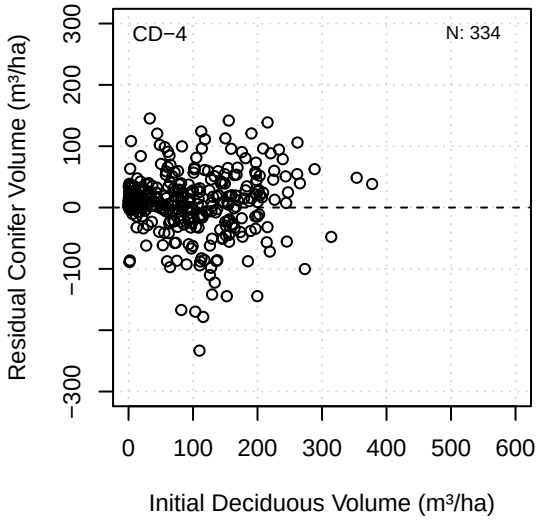

**ConResVol − Initial Deciduous Density − CD**



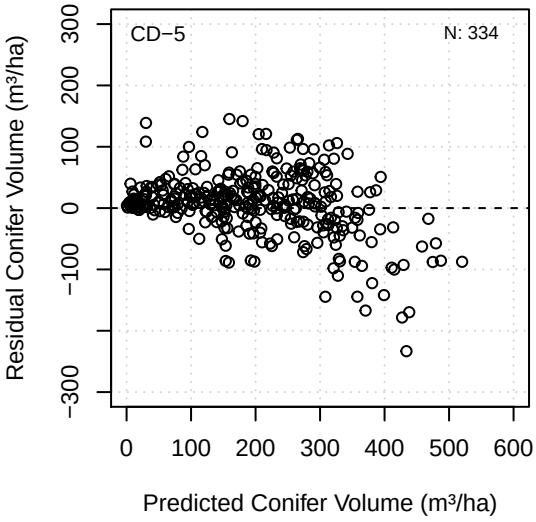

**ConResVol − Initial Conifer Volume − CD**



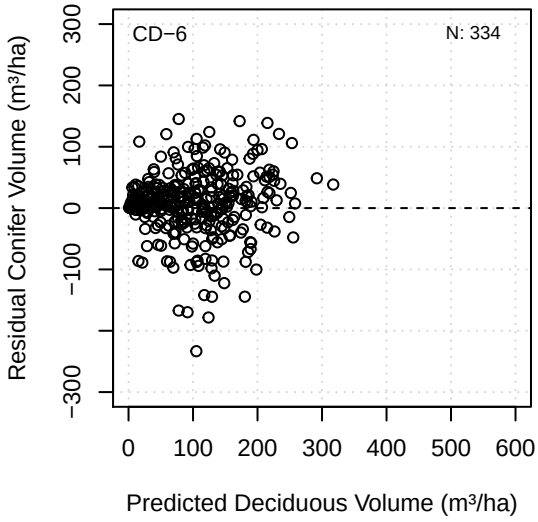

**ConResVol − Initial Deciduous Volume − CD**



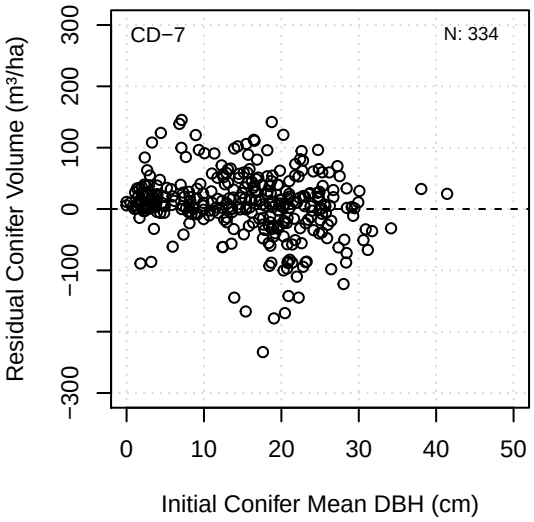

**ConResVol − Predicted Conifer Volume − CD**



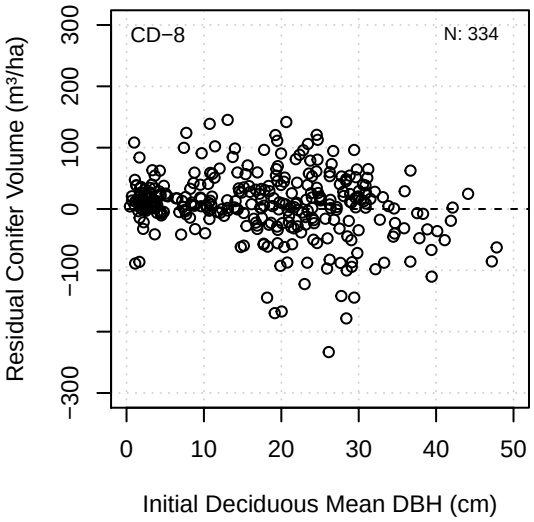

**ConResVol − Predicted Deciduous Volume − CD**



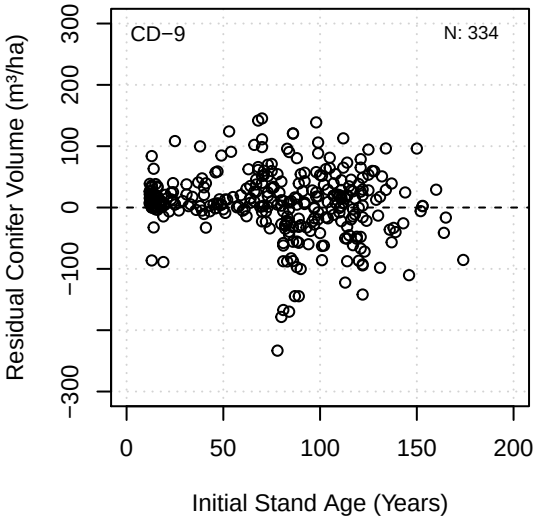
**ConResVol − Initial Conifer Mean DBH − CD**



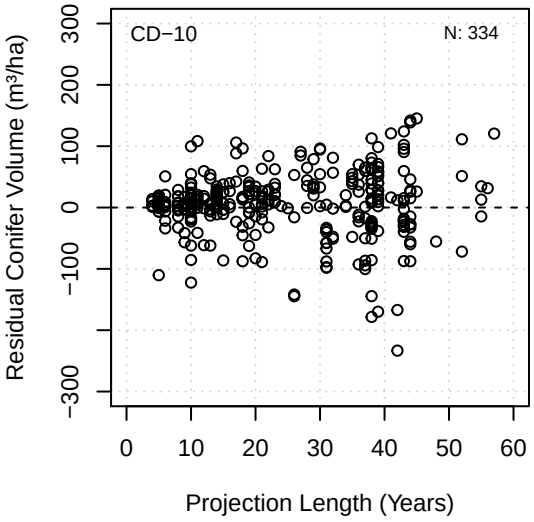

**ConResVol − Initial Deciduous Mean DBH − CD**



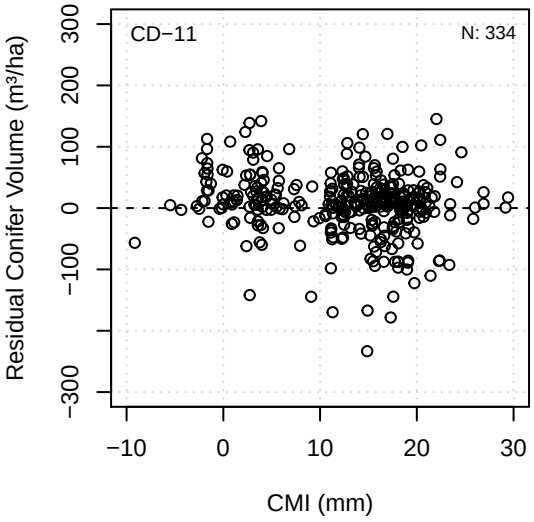

**ConResVol − Initial Stand Age − CD**



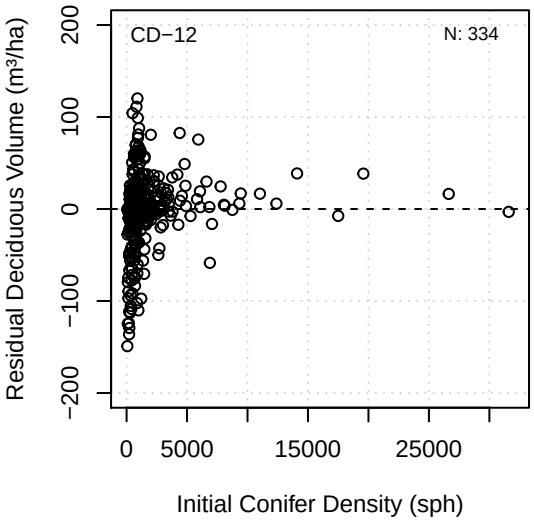

**ConResVol − Projection Length − CD**



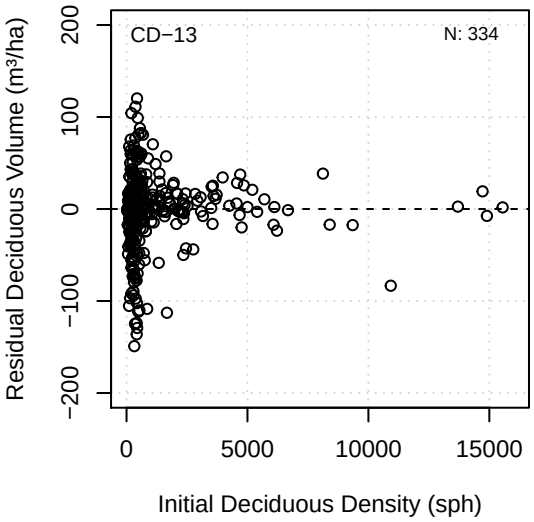

**ConResVol − CMI − CD**



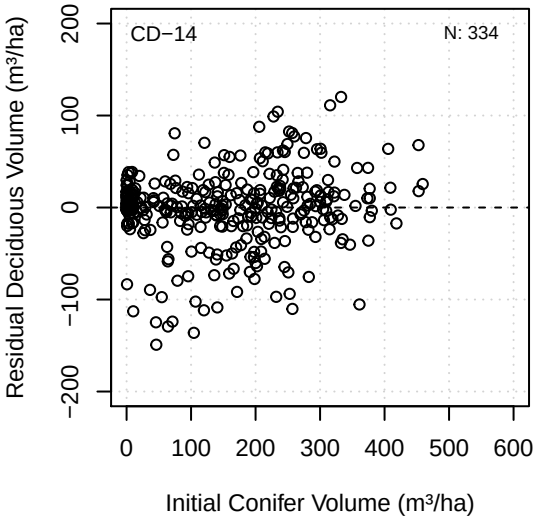
**DecResVol − Initial Conifer Density − CD**



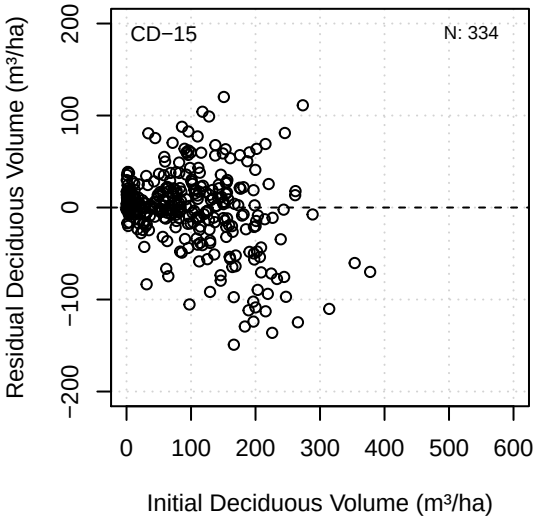

**DecResVol − Initial Deciduous Density − CD**



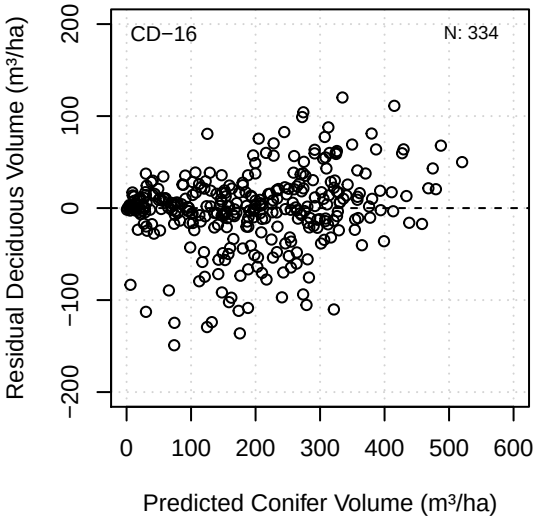

**DecResVol − Initial Conifer Volume − CD**



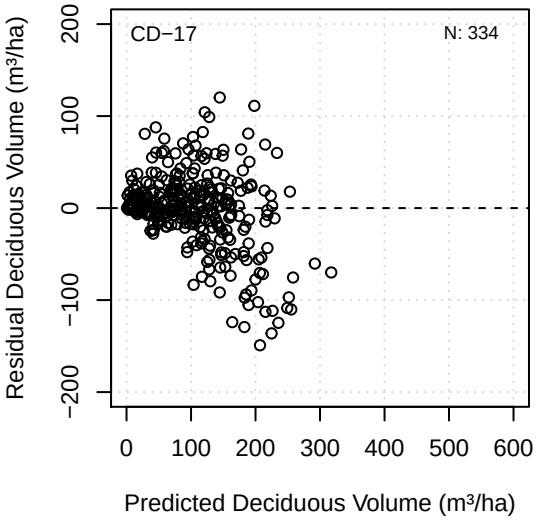

**DecResVol − Initial Deciduous Volume − CD**



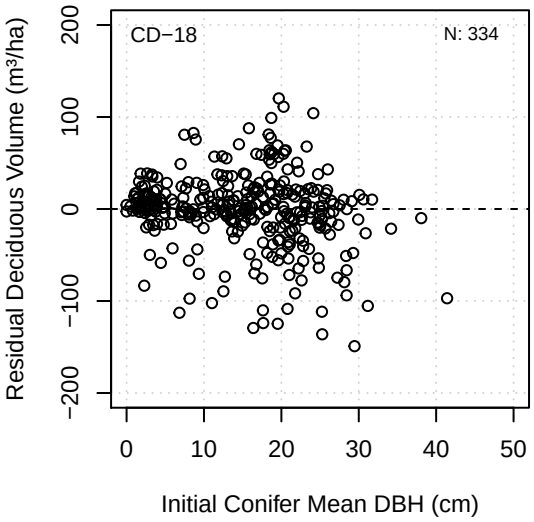

**DecResVol − Predicted Conifer Volume − CD**



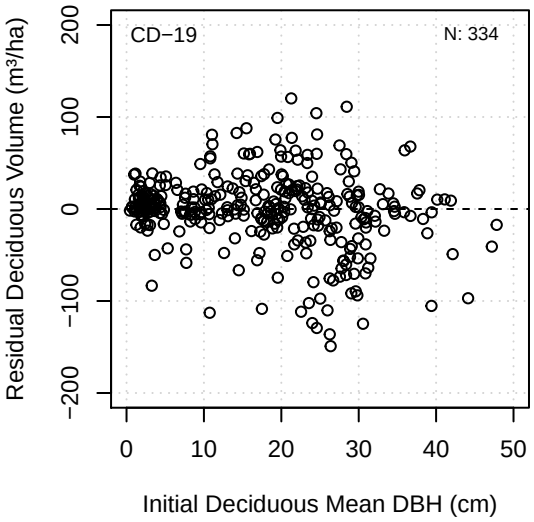

**DecResVol − Predicted Deciduous Volume − CD**



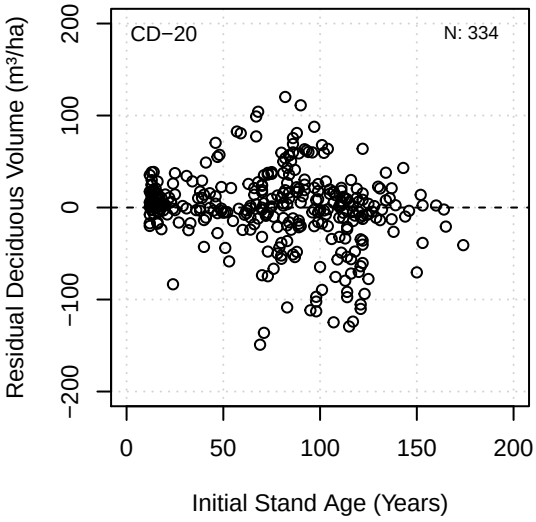
**DecResVol − Initial Conifer Mean DBH − CD**



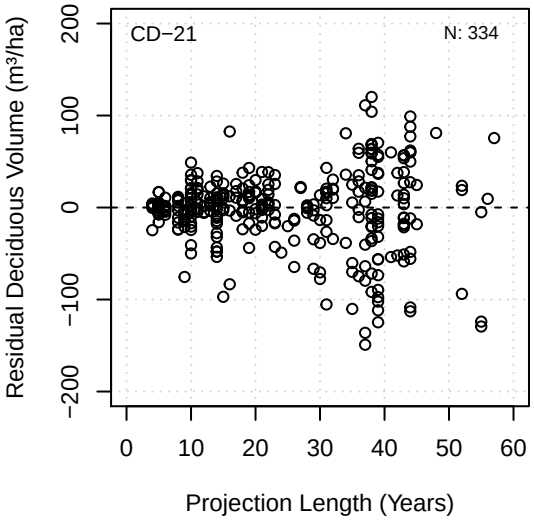

**DecResVol − Initial Deciduous Mean DBH − CD**



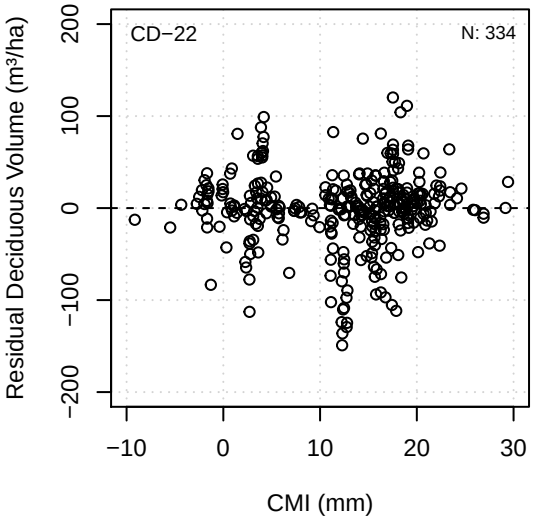

**DecResVol − Initial Stand Age − CD**



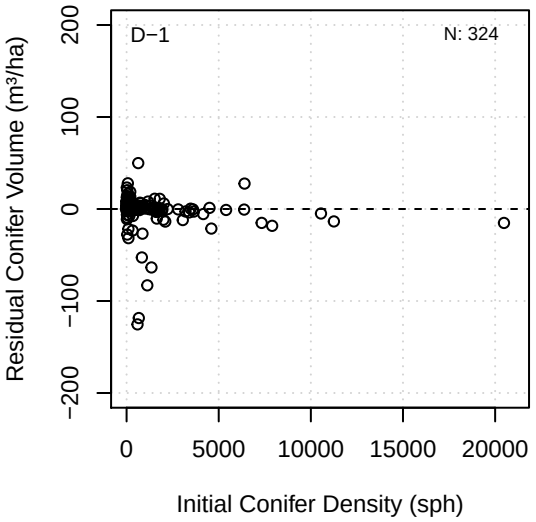

**DecResVol − Projection Length − CD**



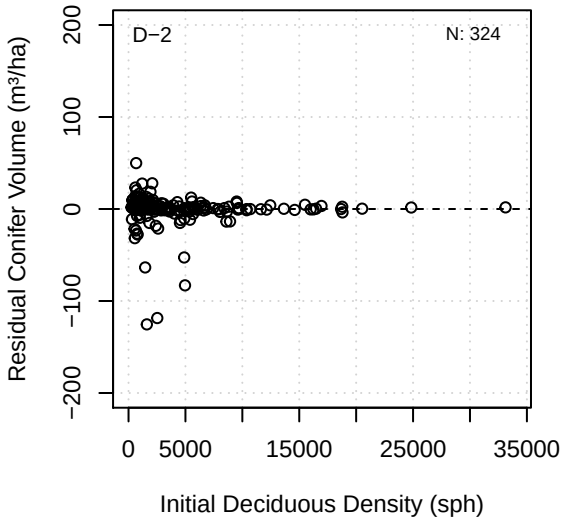

**DecResVol − CMI − CD**



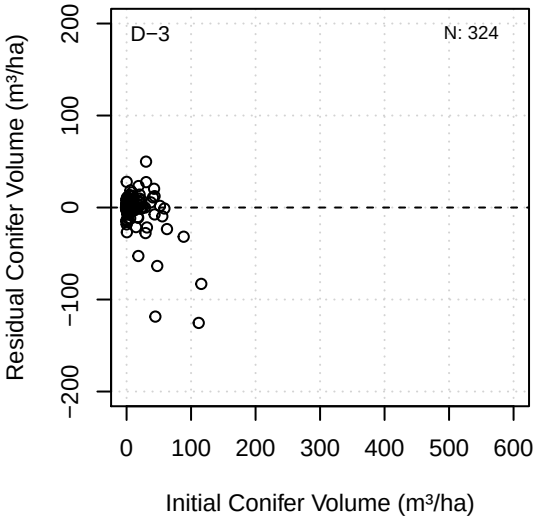
**ConResVol − Initial Conifer Density − D**



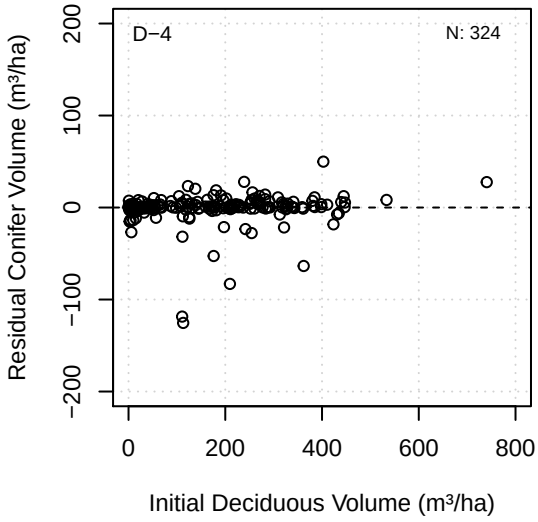

**ConResVol − Initial Deciduous Density − D**



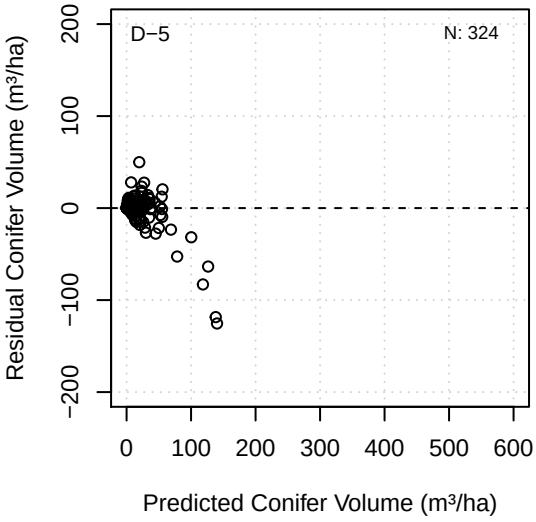

**ConResVol − Initial Conifer Volume − D**



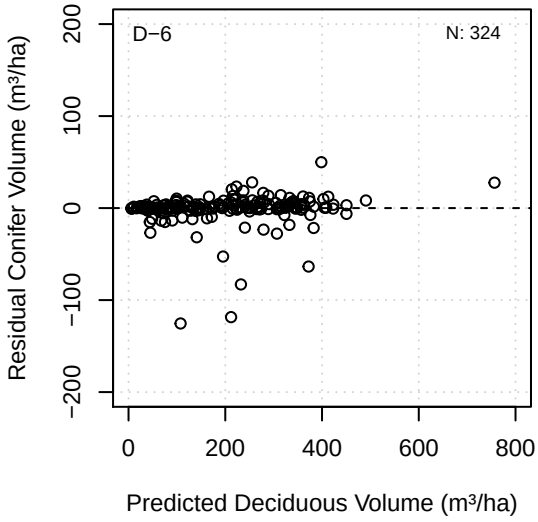

**ConResVol − Initial Deciduous Volume − D**



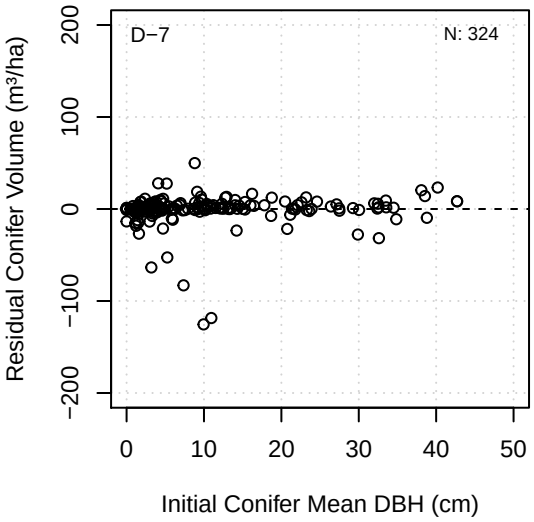

**ConResVol − Predicted Conifer Volume − D**



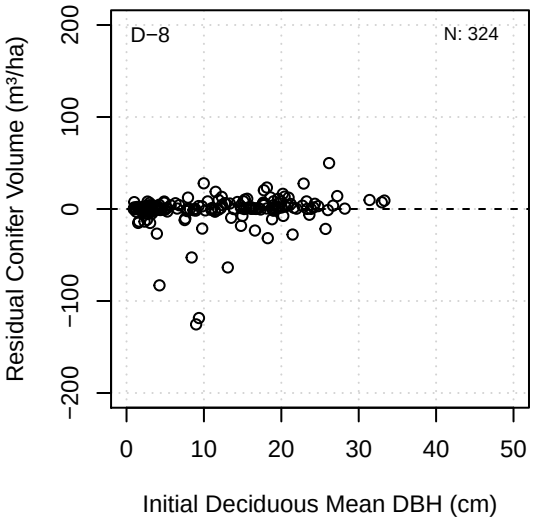

**ConResVol − Predicted Deciduous Volume − D**



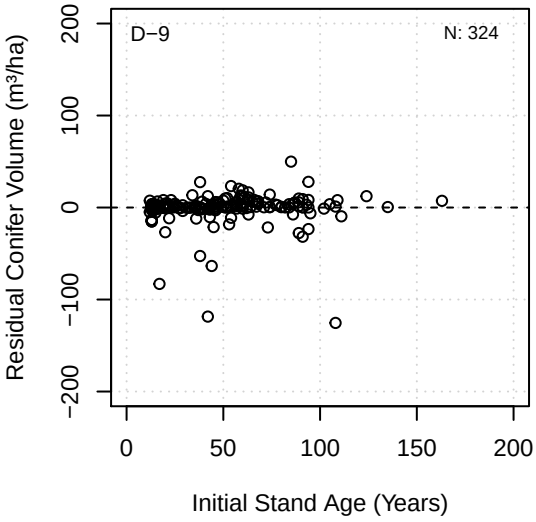
**ConResVol − Initial Conifer Mean DBH − D**



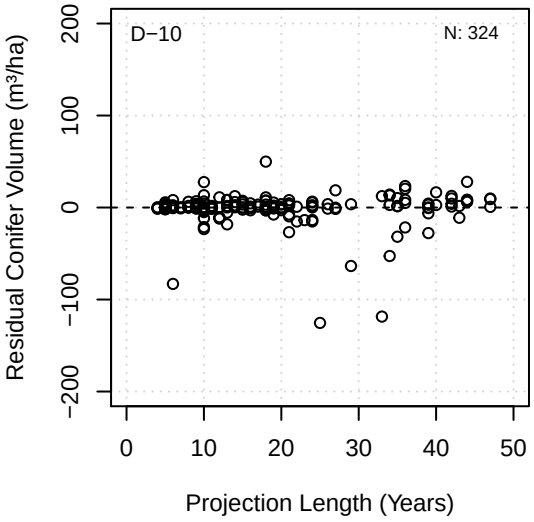

**ConResVol − Initial Deciduous Mean DBH − D**



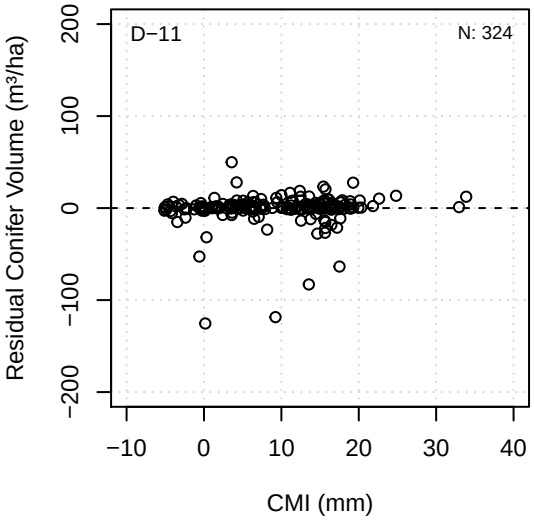

**ConResVol − Initial Stand Age − D**



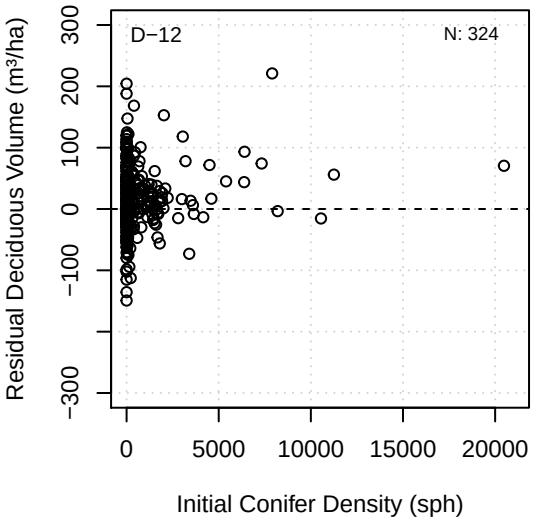

**ConResVol − Projection Length − D**



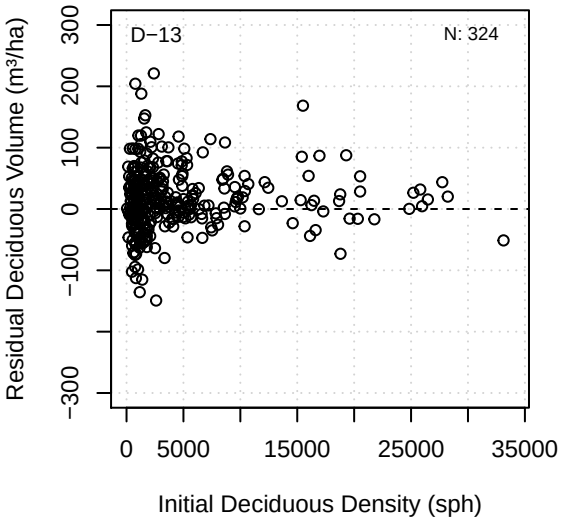

**ConResVol − CMI − D**



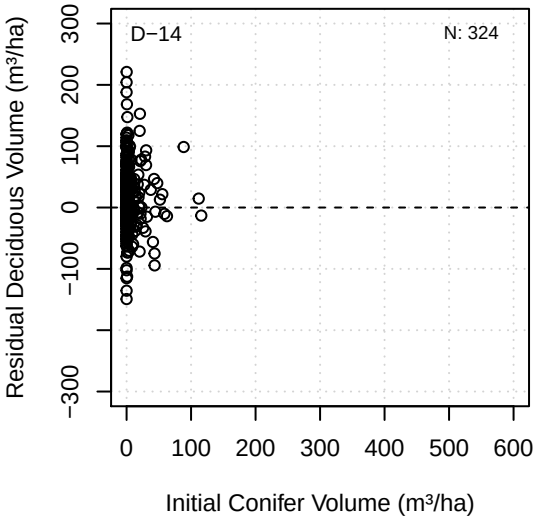
**DecResVol − Initial Conifer Density − D**



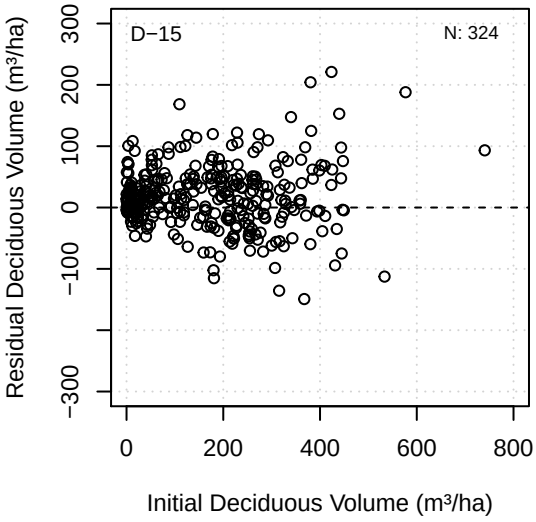

**DecResVol − Initial Deciduous Density − D**



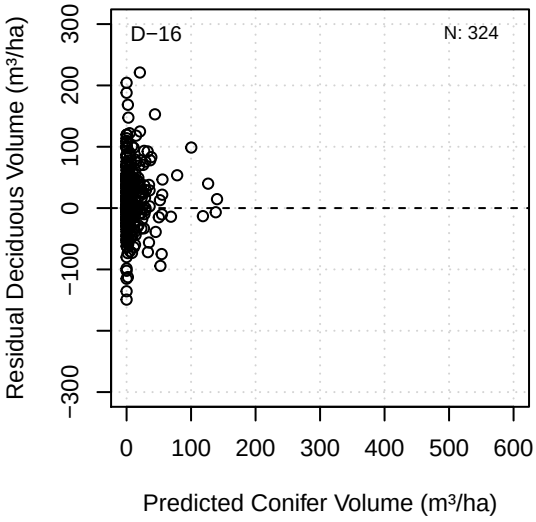

**DecResVol − Initial Conifer Volume − D**



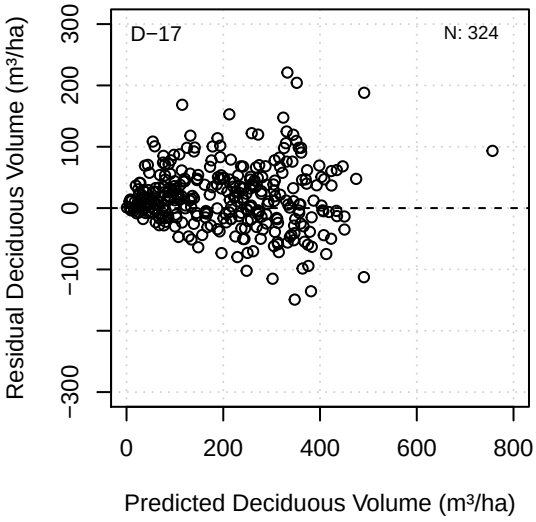

**DecResVol − Initial Deciduous Volume − D**



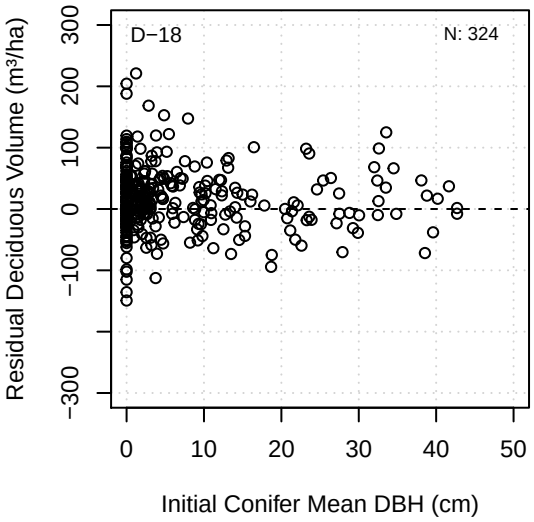

**DecResVol − Predicted Conifer Volume − D**



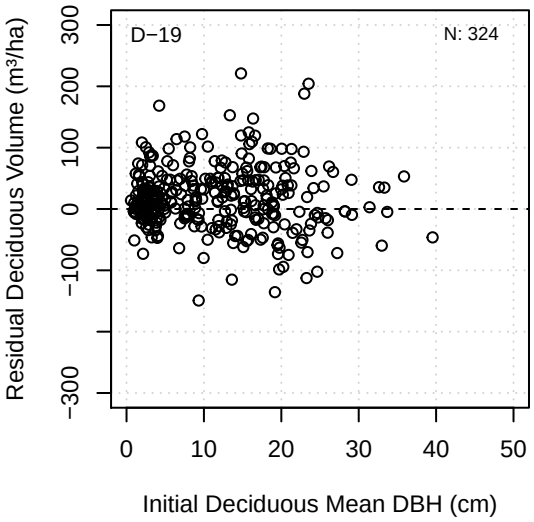

**DecResVol − Predicted Deciduous Volume − D**



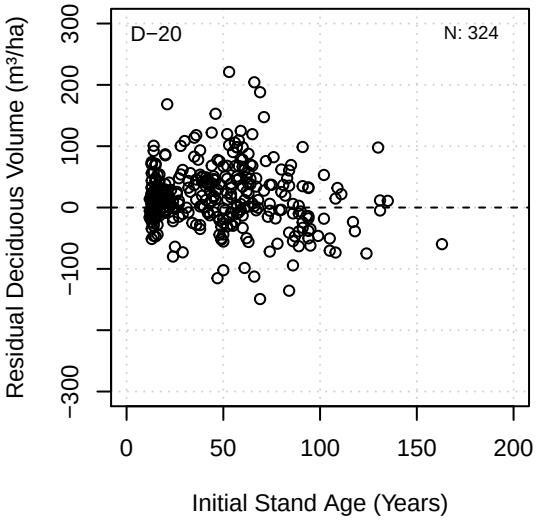
**DecResVol − Initial Conifer Mean DBH − D**



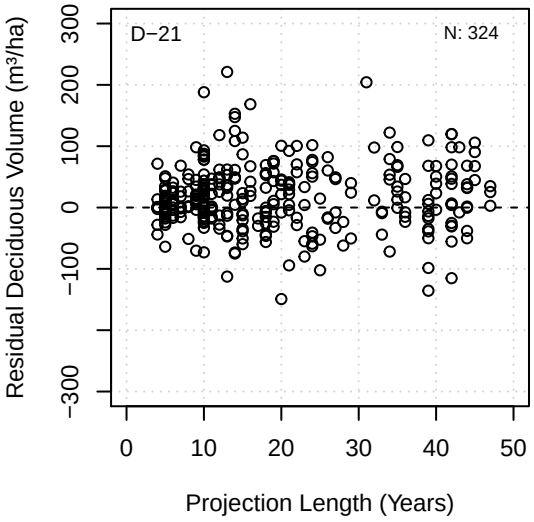

**DecResVol − Initial Deciduous Mean DBH − D**



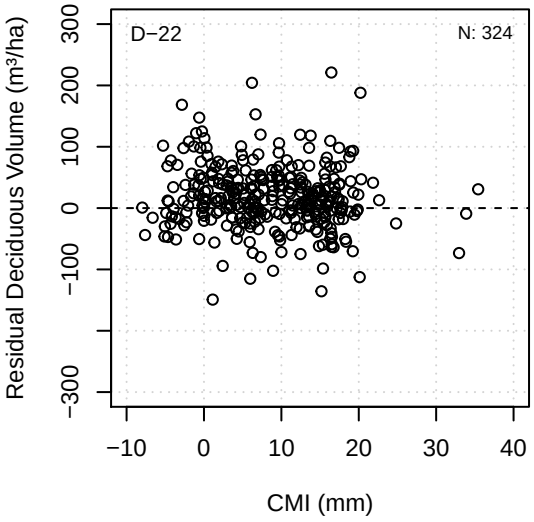

**DecResVol − Initial Stand Age − D**



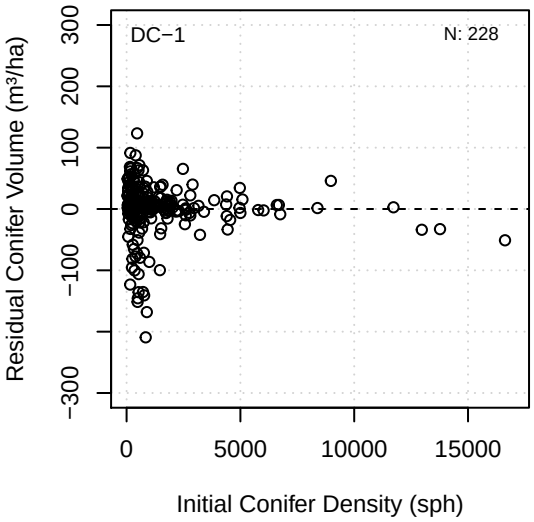

**DecResVol − Projection Length − D**



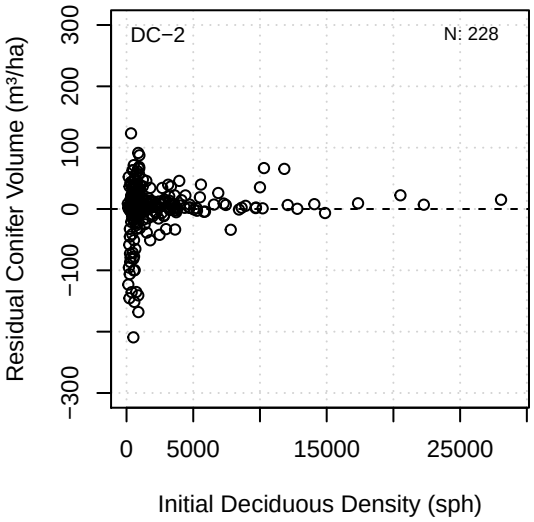

**DecResVol − CMI − D**



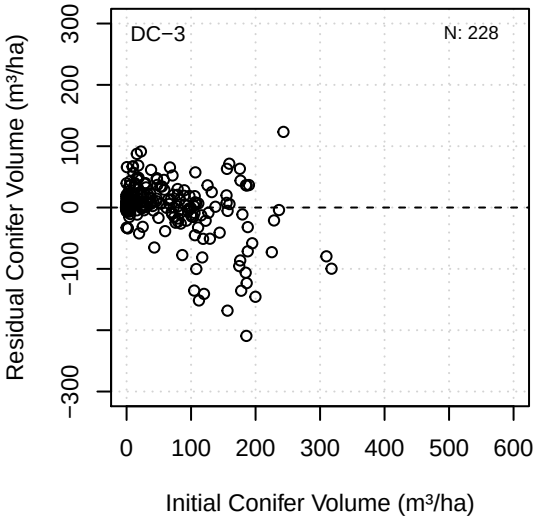
**ConResVol − Initial Conifer Density − DC**



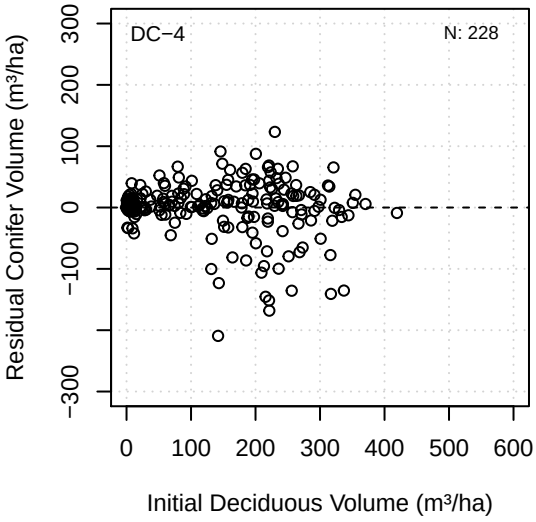

**ConResVol − Initial Deciduous Density − DC**



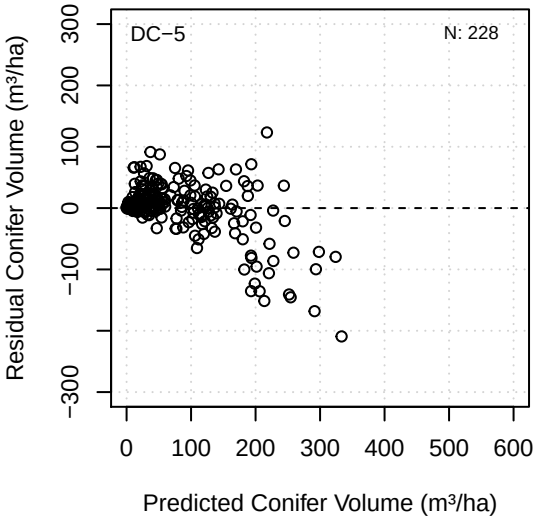

**ConResVol − Initial Conifer Volume − DC**



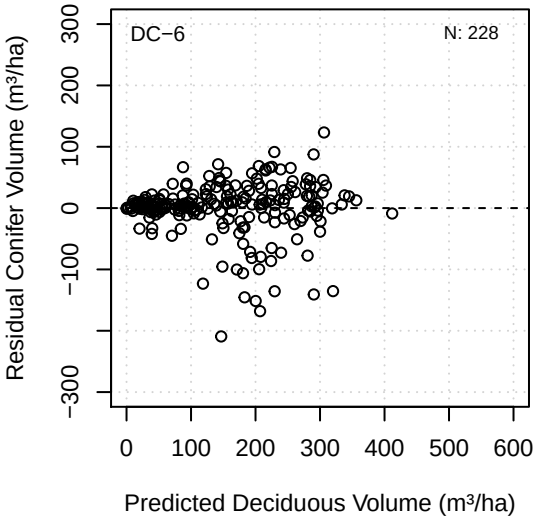

**ConResVol − Initial Deciduous Volume − DC**



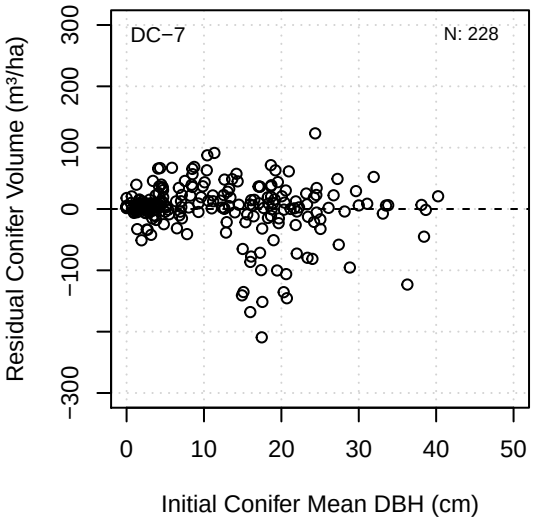

**ConResVol − Predicted Conifer Volume − DC**



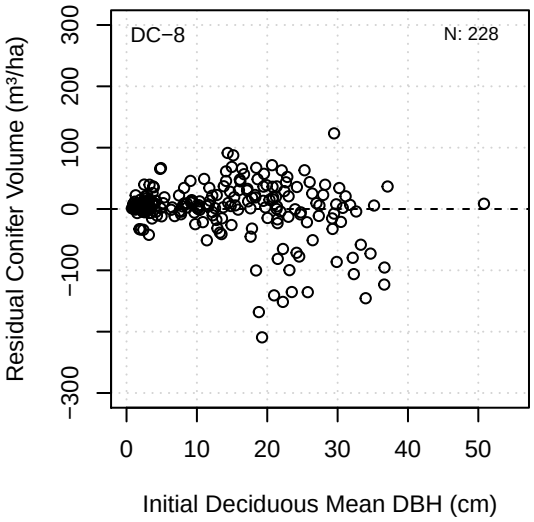

**ConResVol − Predicted Deciduous Volume − DC**



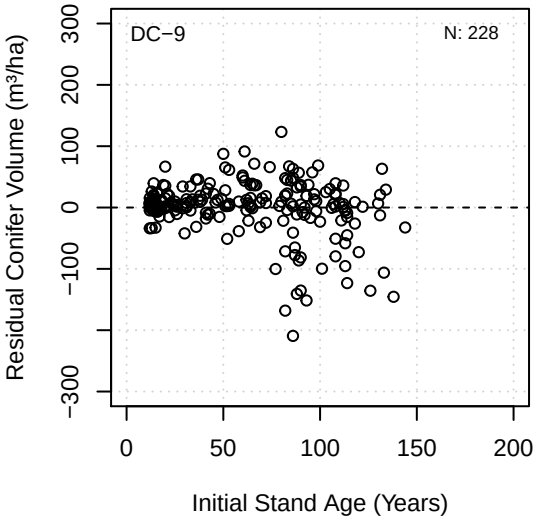
**ConResVol − Initial Conifer Mean DBH − DC**



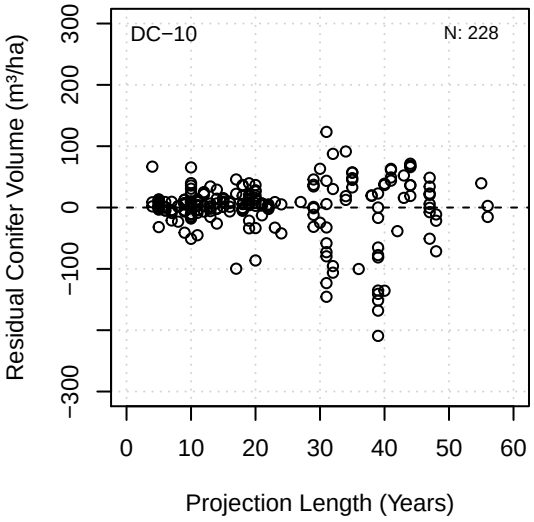

**ConResVol − Initial Deciduous Mean DBH − DC**



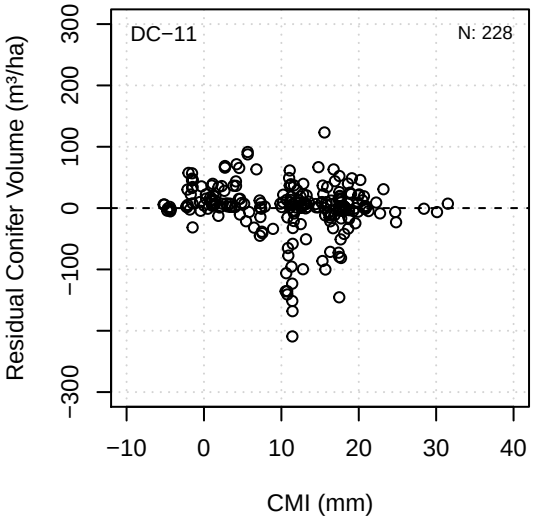

**ConResVol − Initial Stand Age − DC**



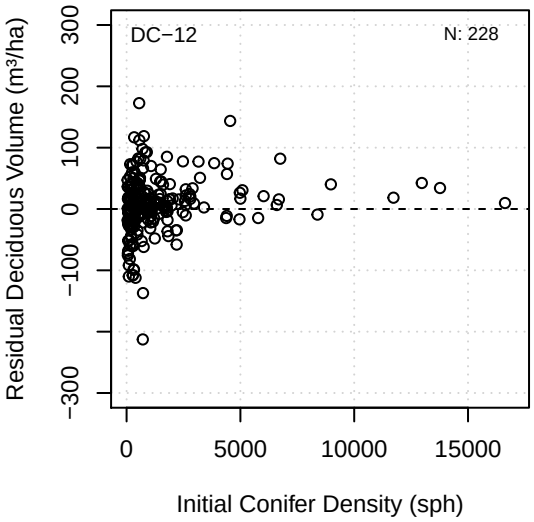

**ConResVol − Projection Length − DC**



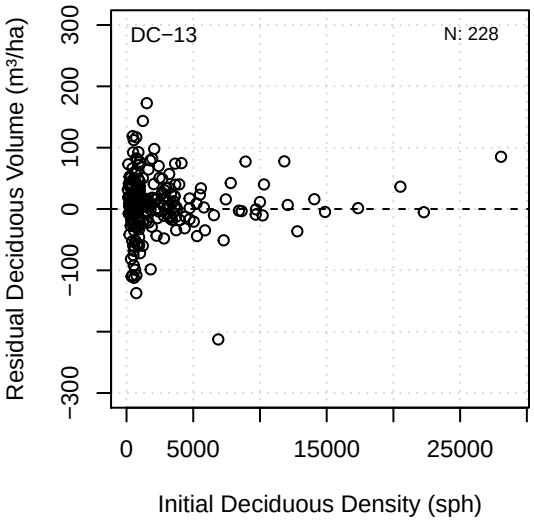

**ConResVol − CMI − DC**



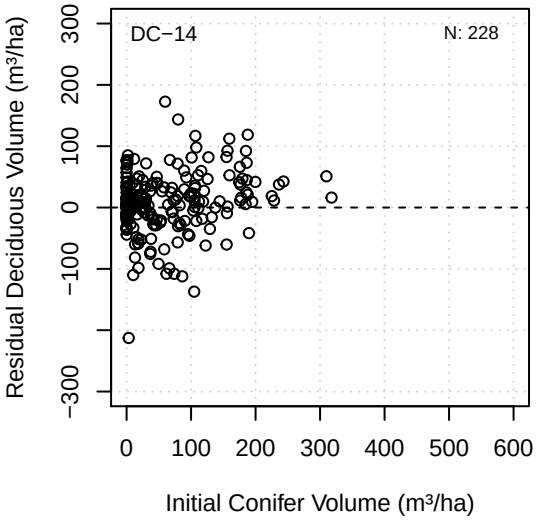
**DecResVol − Initial Conifer Density − DC**



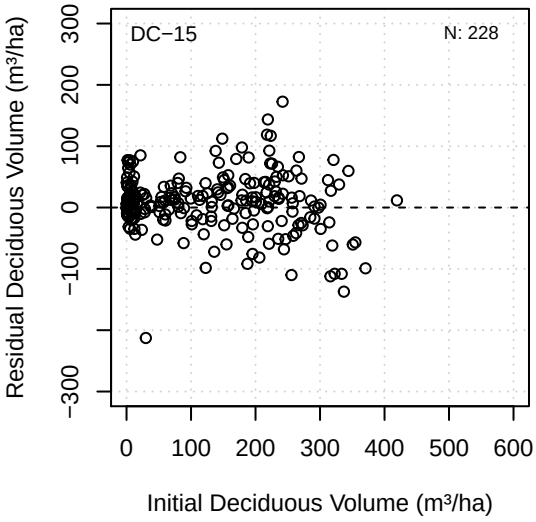

**DecResVol − Initial Deciduous Density − DC**



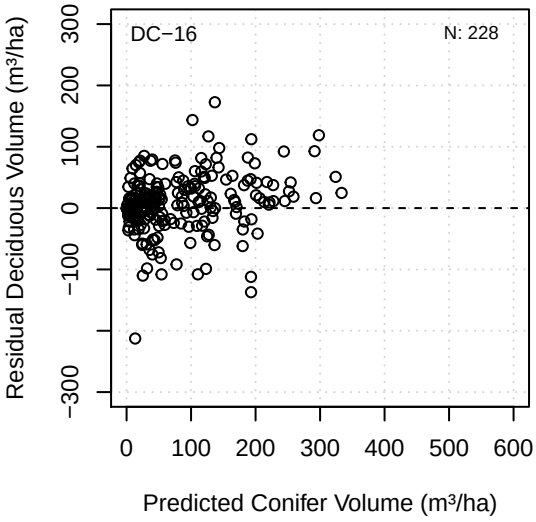

**DecResVol − Initial Conifer Volume − DC**



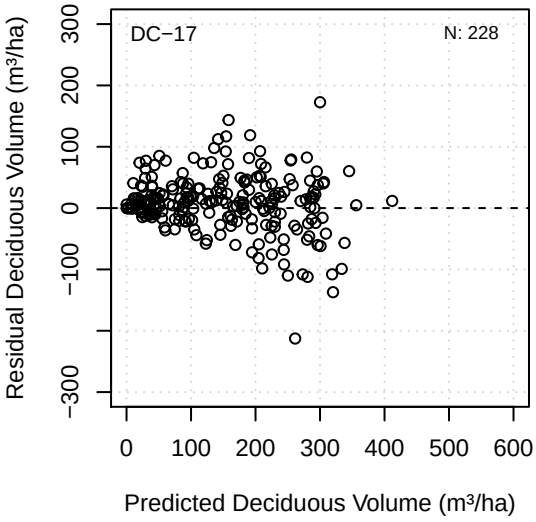

**DecResVol − Initial Deciduous Volume − DC**



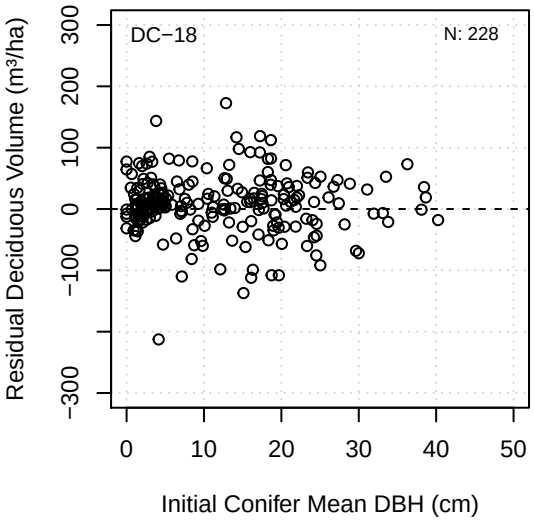

**DecResVol − Predicted Conifer Volume − DC**



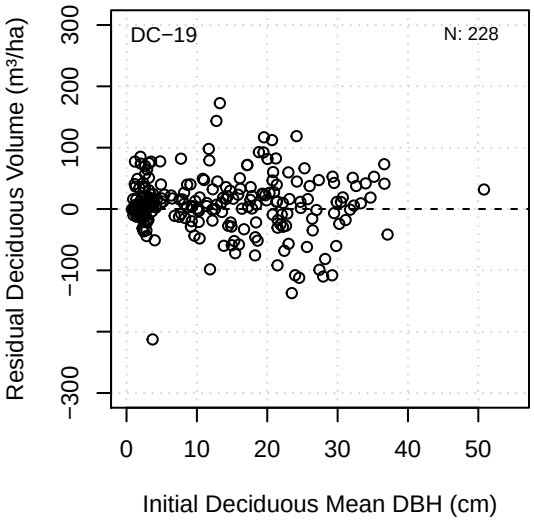

**DecResVol − Predicted Deciduous Volume − DC**



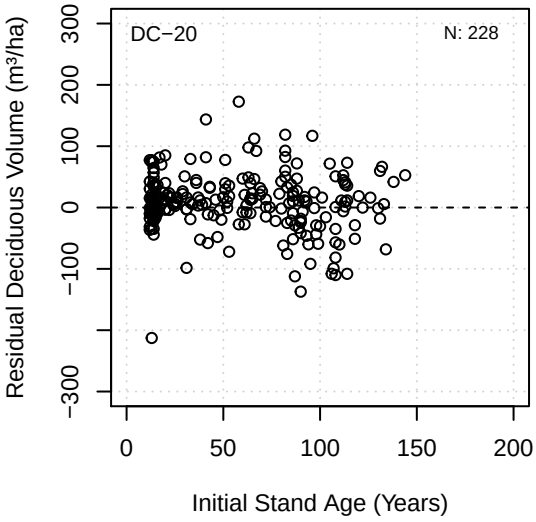
**DecResVol − Initial Conifer Mean DBH − DC**



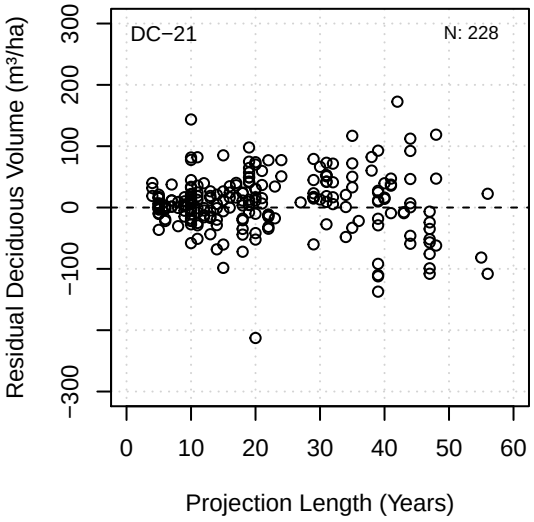

**DecResVol − Initial Deciduous Mean DBH − DC**



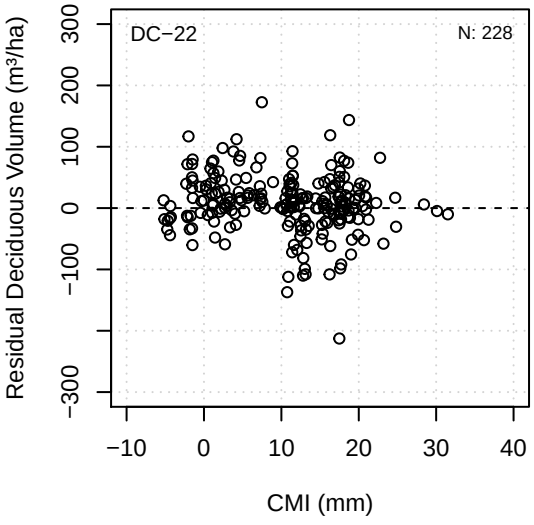

**DecResVol − Initial Stand Age − DC**



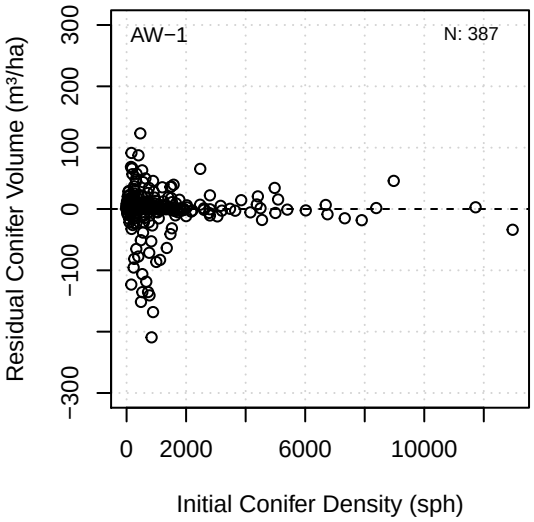

**DecResVol − Projection Length − DC**



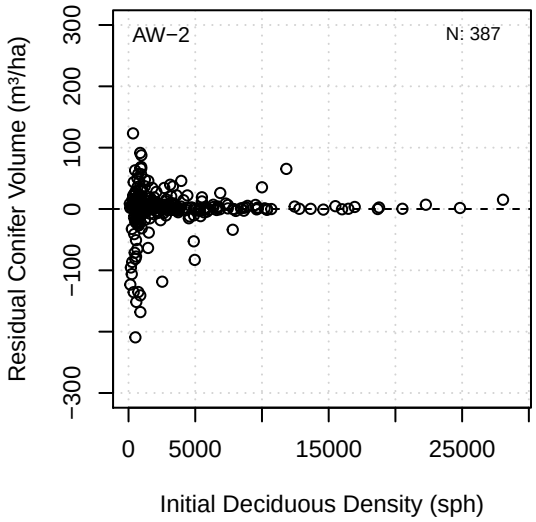

**DecResVol − CMI − DC**



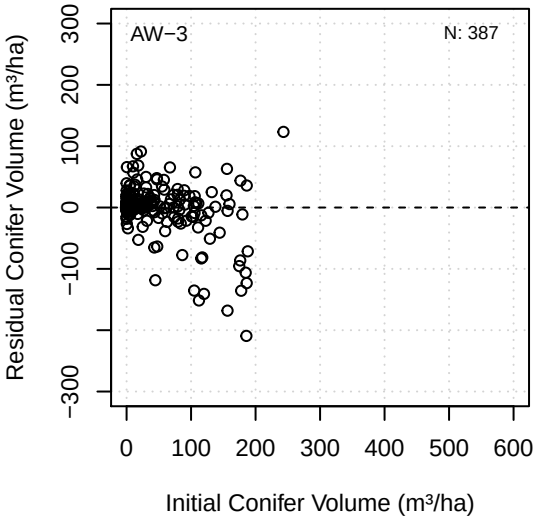
**ConResVol − Initial Conifer Density − AW**



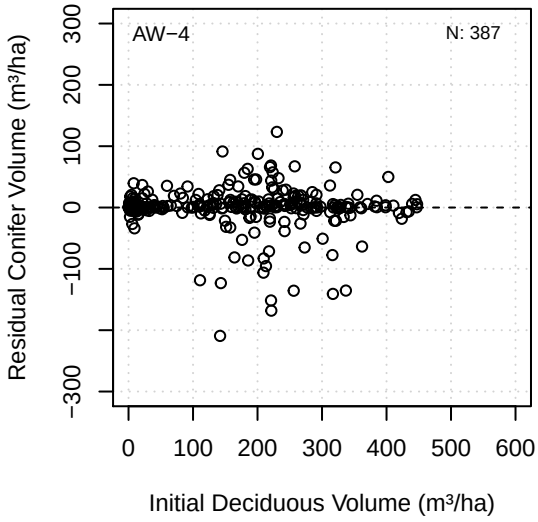

**ConResVol − Initial Deciduous Density − AW**



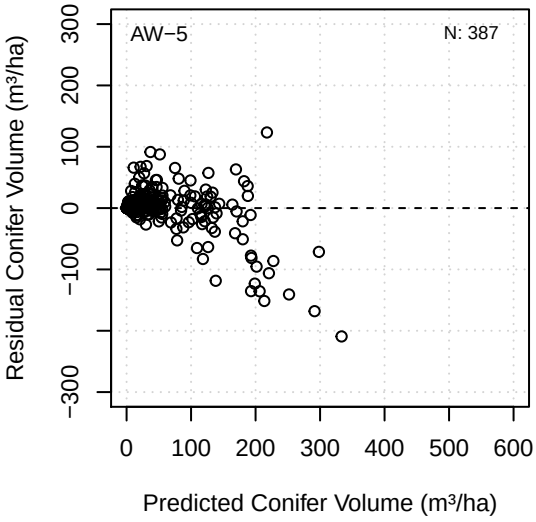

**ConResVol − Initial Conifer Volume − AW**



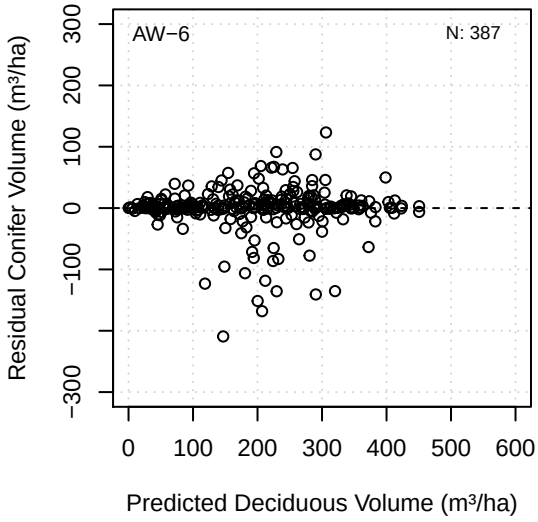

**ConResVol − Initial Deciduous Volume − AW**



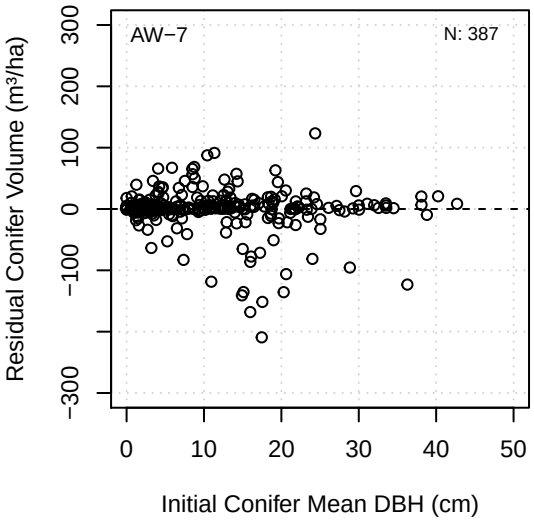

**ConResVol − Predicted Conifer Volume − AW**



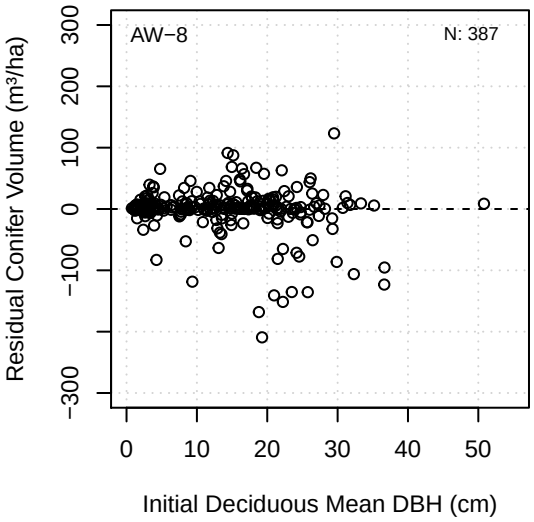

**ConResVol − Predicted Deciduous Volume − AW**



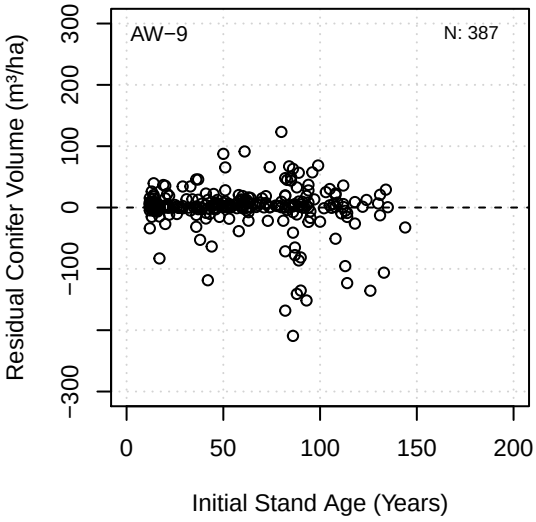
**ConResVol − Initial Conifer Mean DBH − AW**



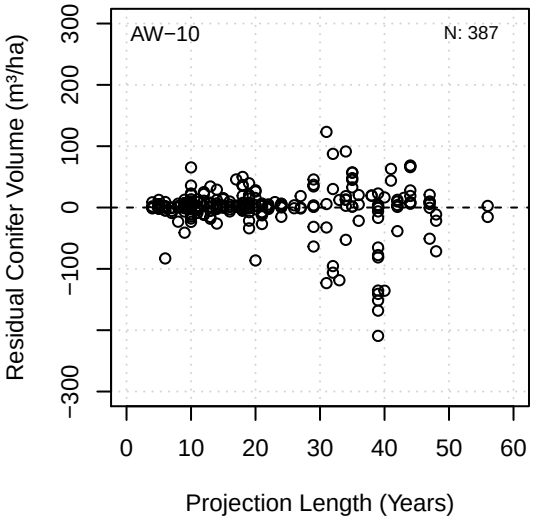

**ConResVol − Initial Deciduous Mean DBH − AW**



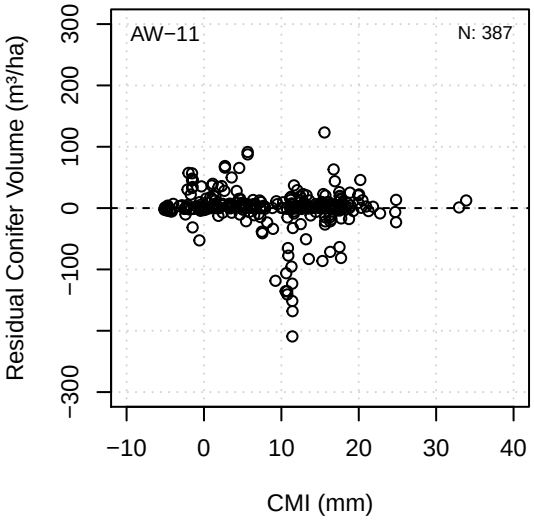

**ConResVol − Initial Stand Age − AW**



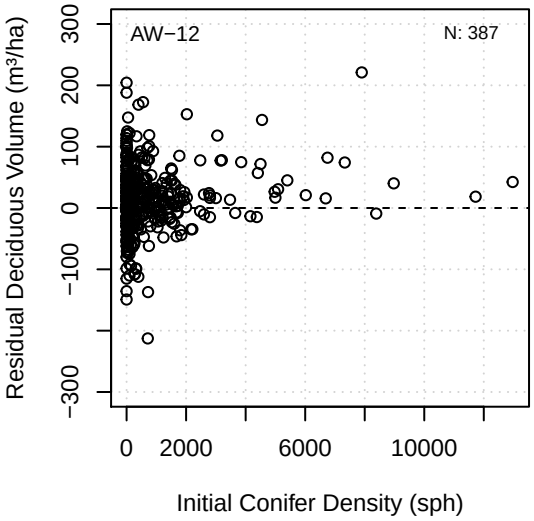

**ConResVol − Projection Length − AW**



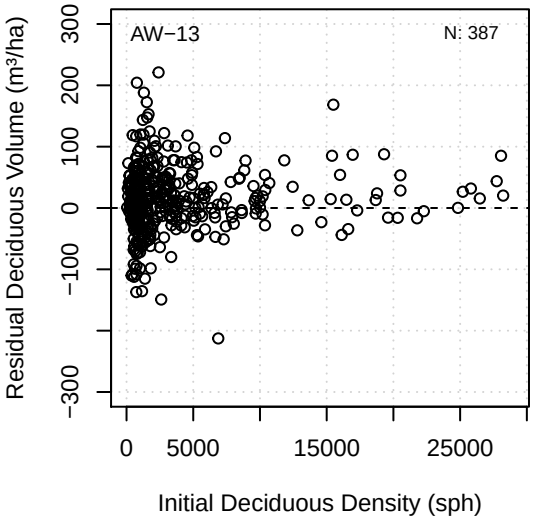

**ConResVol − CMI − AW**



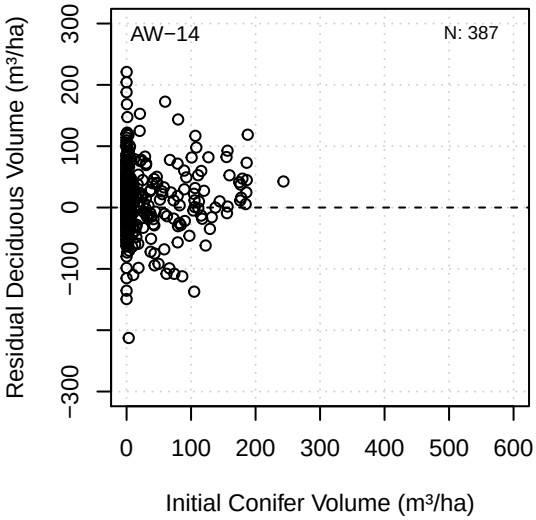
**DecResVol − Initial Conifer Density − AW**



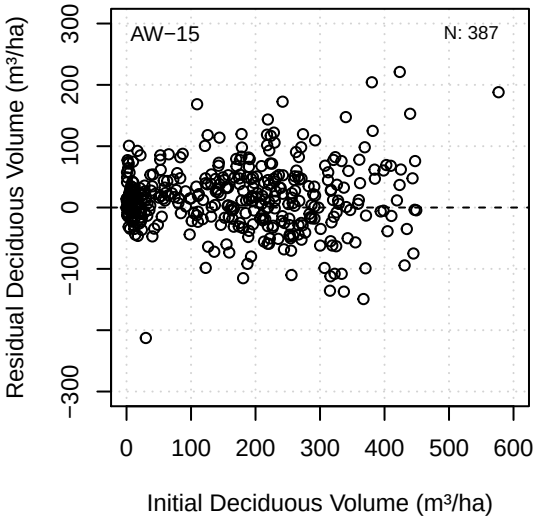

**DecResVol − Initial Deciduous Density − AW**



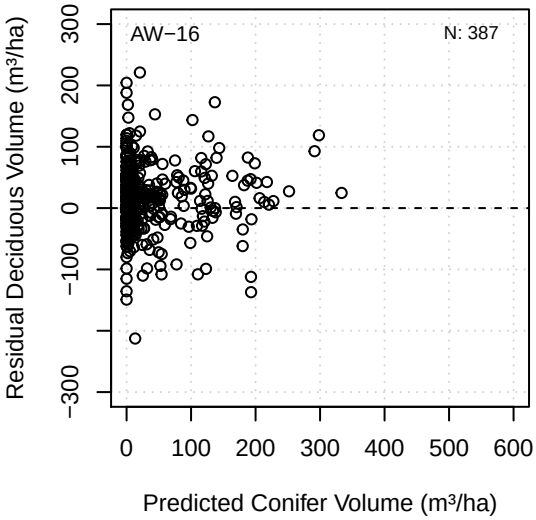

**DecResVol − Initial Conifer Volume − AW**



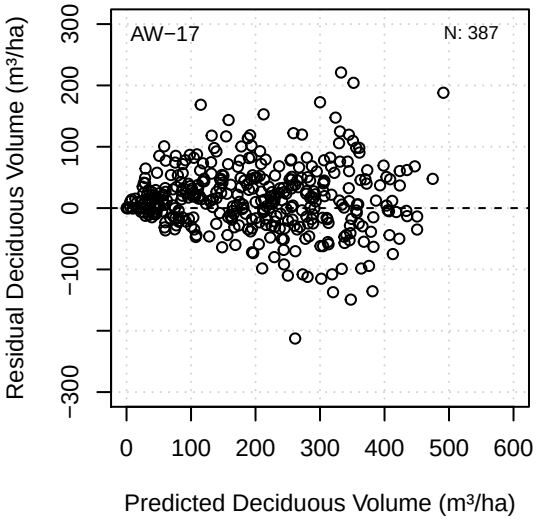

**DecResVol − Initial Deciduous Volume − AW**



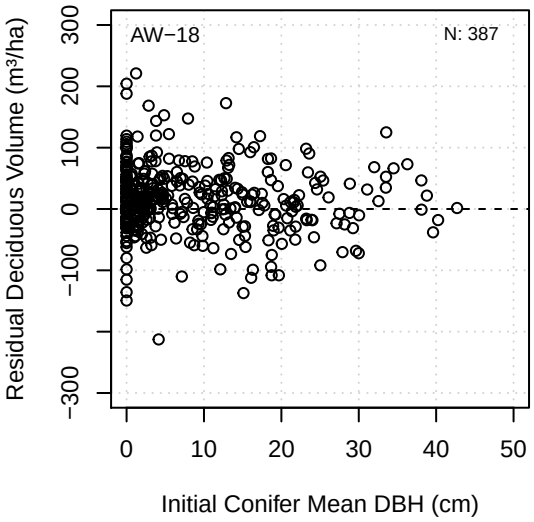

**DecResVol − Predicted Conifer Volume − AW**



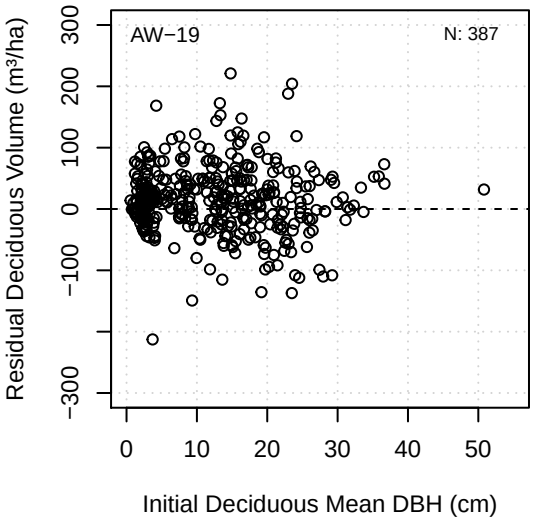

**DecResVol − Predicted Deciduous Volume − AW**



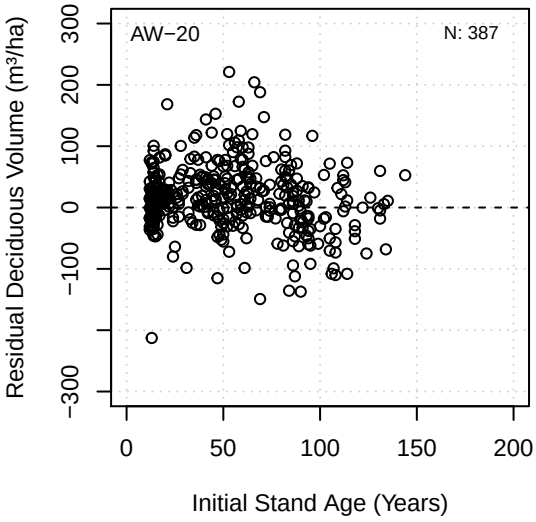
**DecResVol − Initial Conifer Mean DBH − AW**



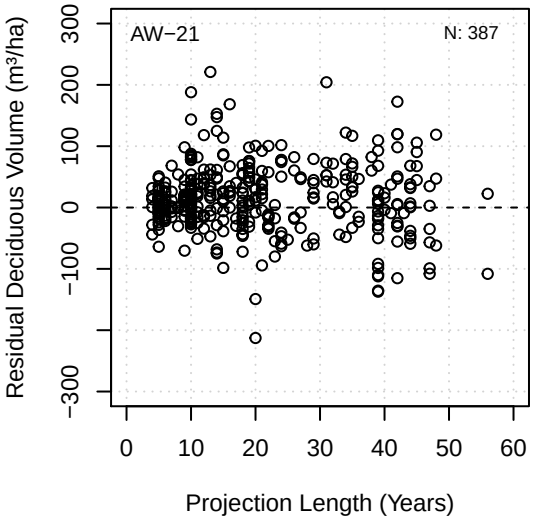

**DecResVol − Initial Deciduous Mean DBH − AW**



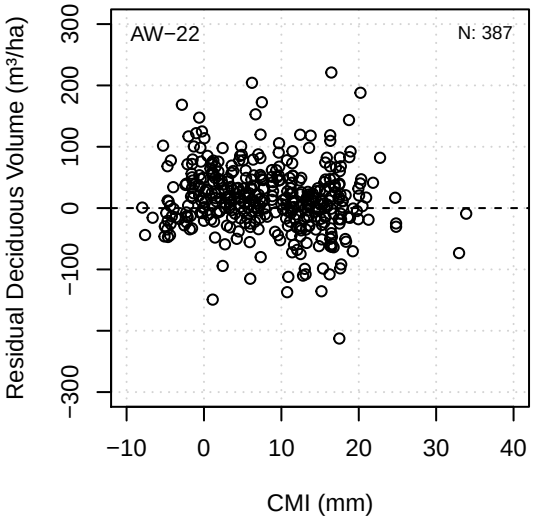

**DecResVol − Initial Stand Age − AW**



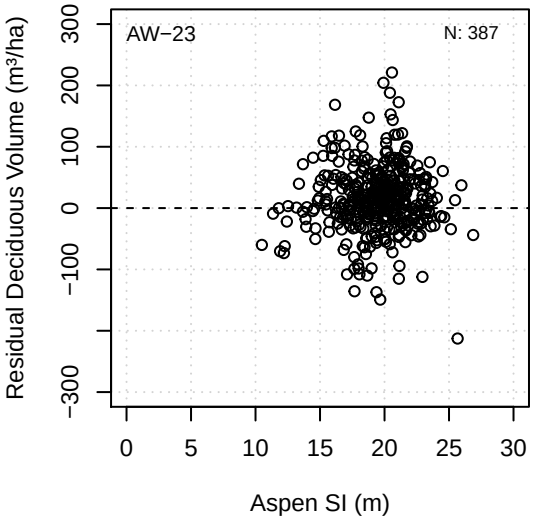

**DecResVol − Projection Length − AW**



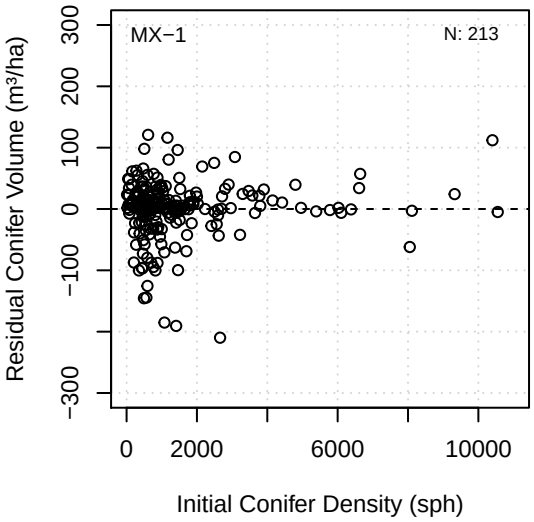

**DecResVol − CMI − AW**



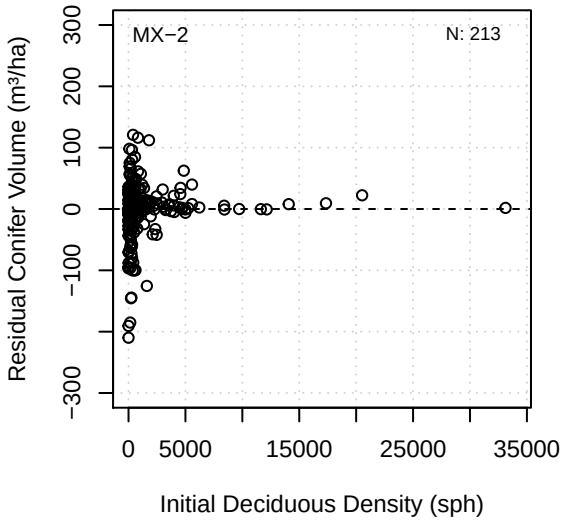

**DecResVol − Aspen SI − AW**



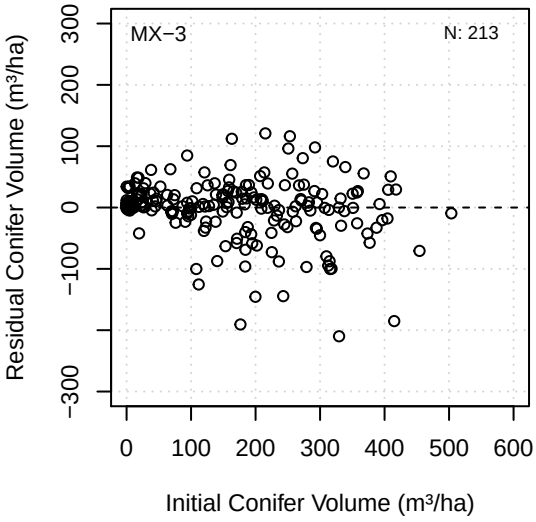
**ConResVol − Initial Conifer Density − MX**



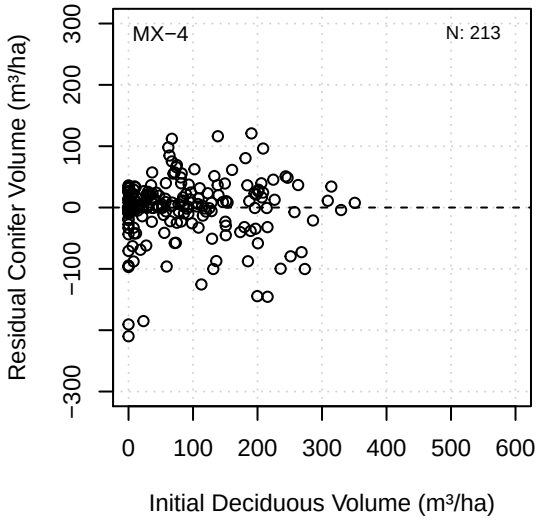

**ConResVol − Initial Deciduous Density − MX**



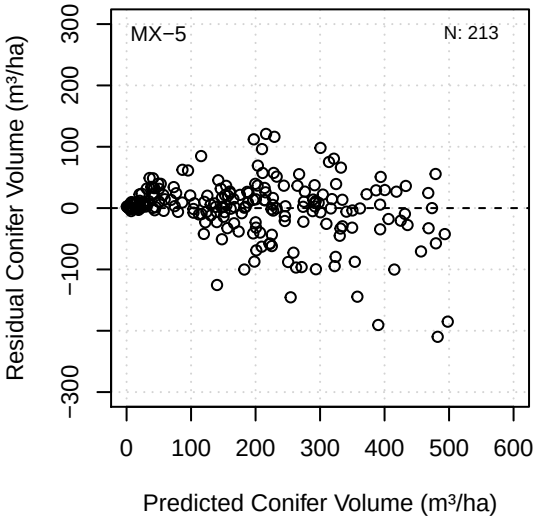

**ConResVol − Initial Conifer Volume − MX**



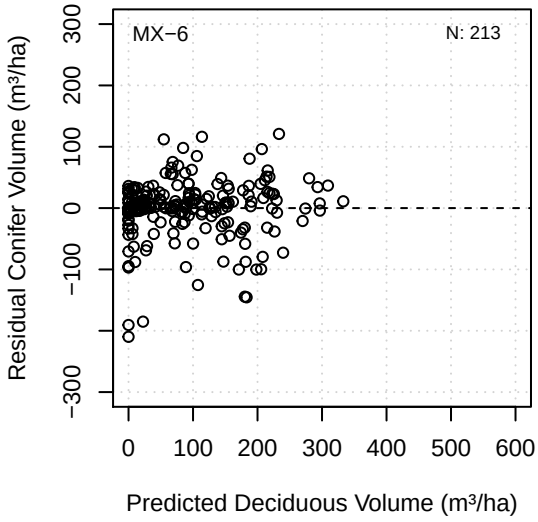

**ConResVol − Initial Deciduous Volume − MX**



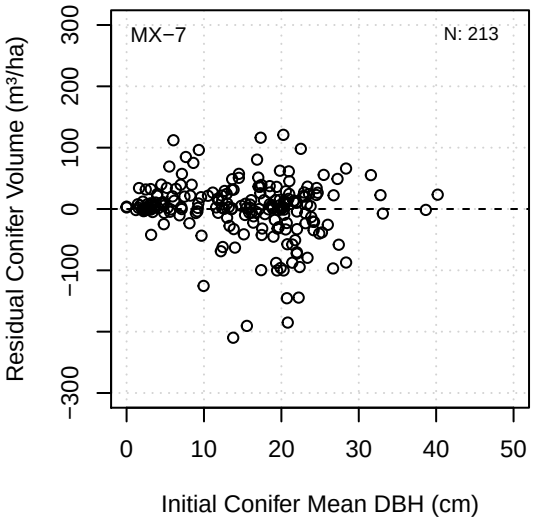

**ConResVol − Predicted Conifer Volume − MX**



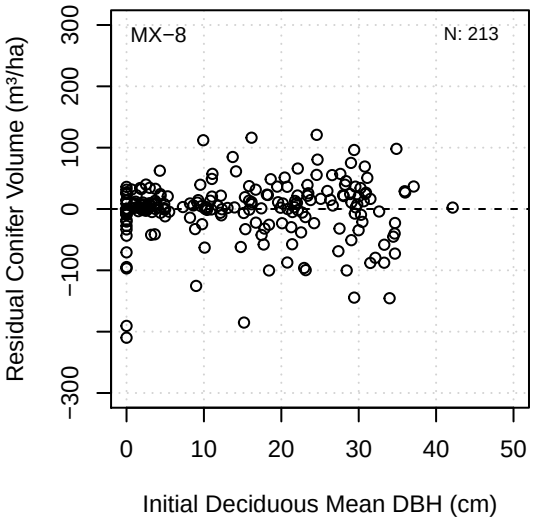

**ConResVol − Predicted Deciduous Volume − MX**



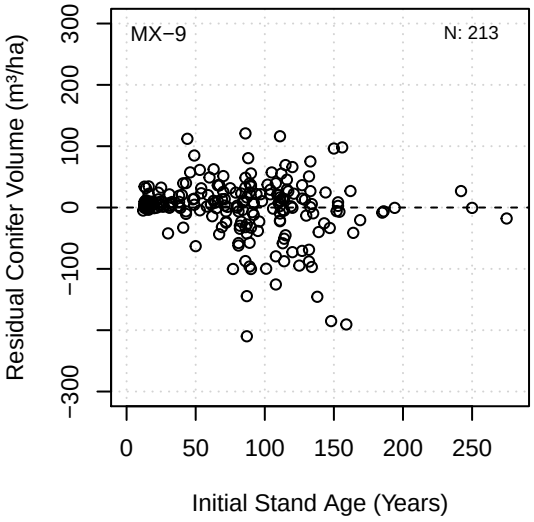
**ConResVol − Initial Conifer Mean DBH − MX**



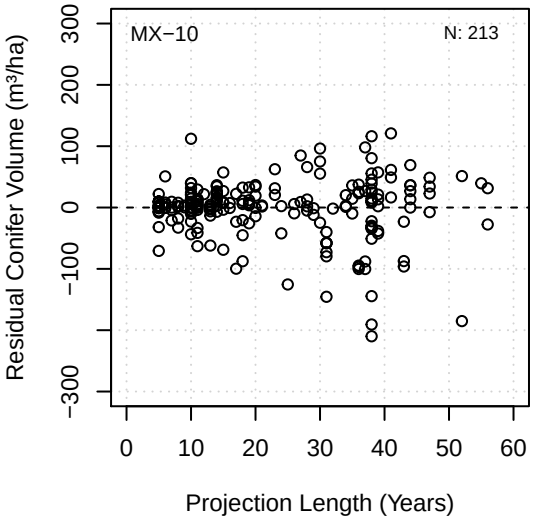

**ConResVol − Initial Deciduous Mean DBH − MX**



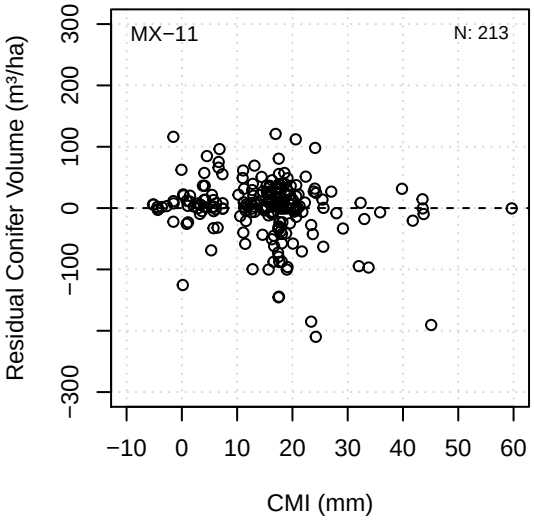

**ConResVol − Initial Stand Age − MX**



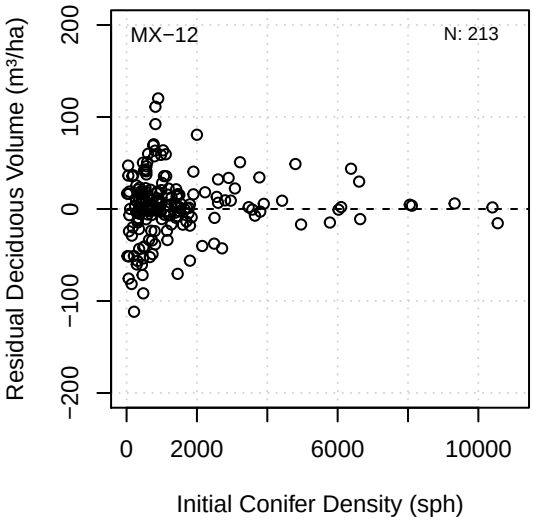

**ConResVol − Projection Length − MX**



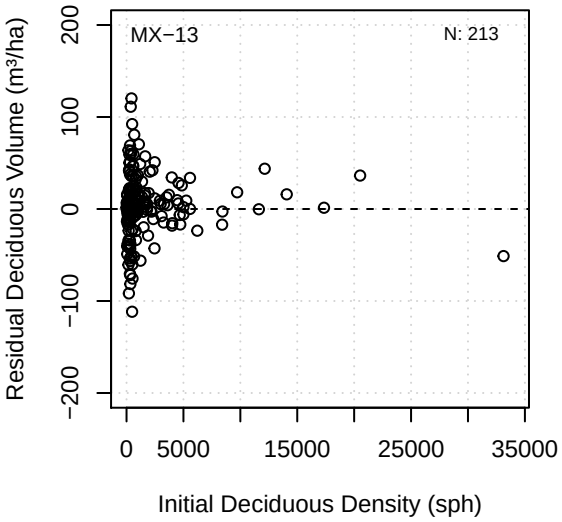

**ConResVol − CMI − MX**



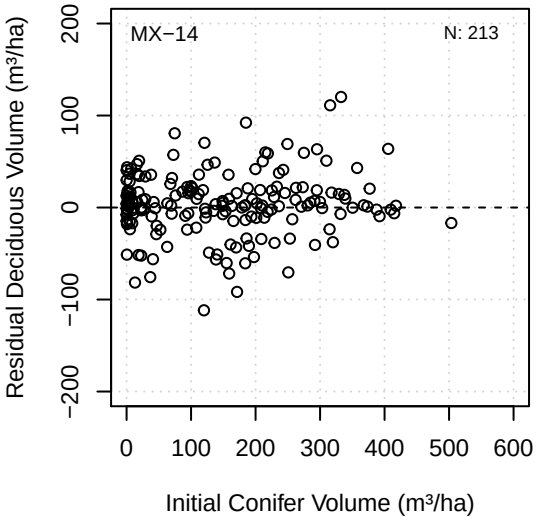
**DecResVol − Initial Conifer Density − MX**



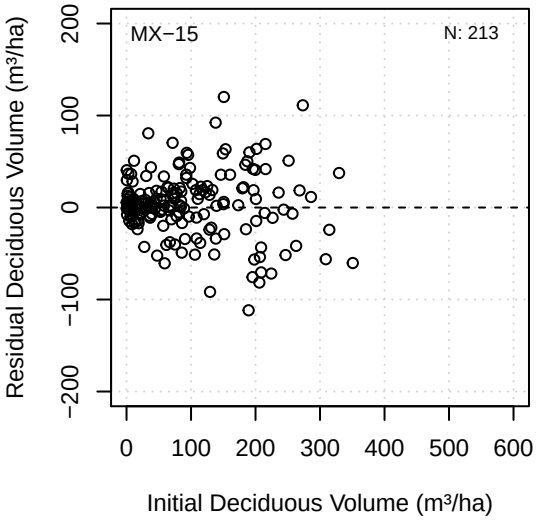

**DecResVol − Initial Deciduous Density − MX**



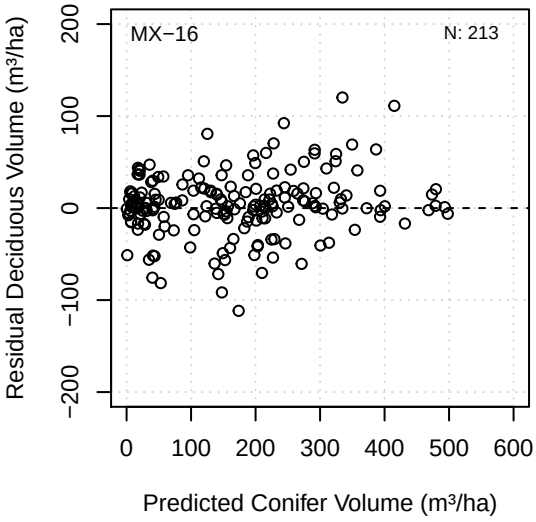

**DecResVol − Initial Conifer Volume − MX**



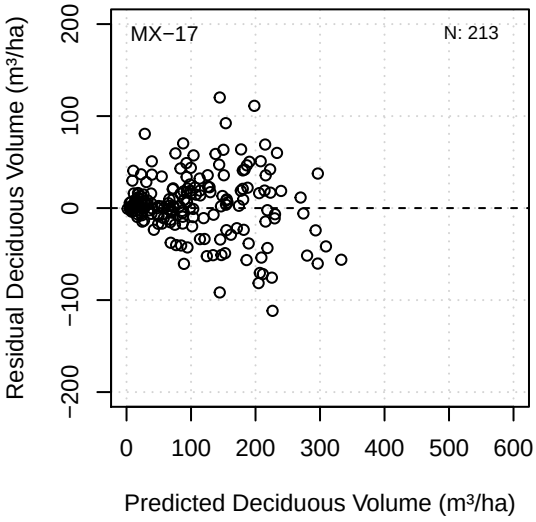

**DecResVol − Initial Deciduous Volume − MX**



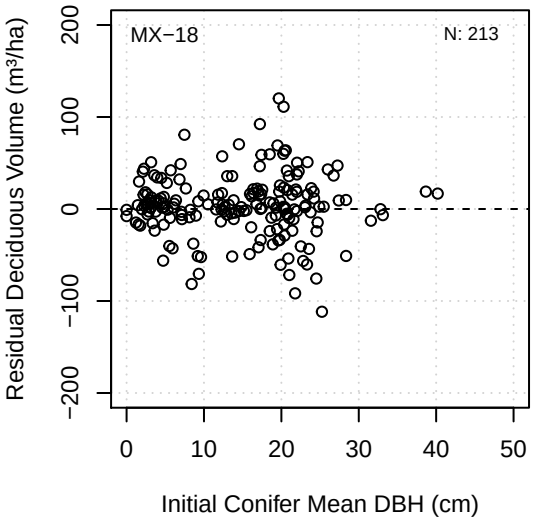

**DecResVol − Predicted Conifer Volume − MX**



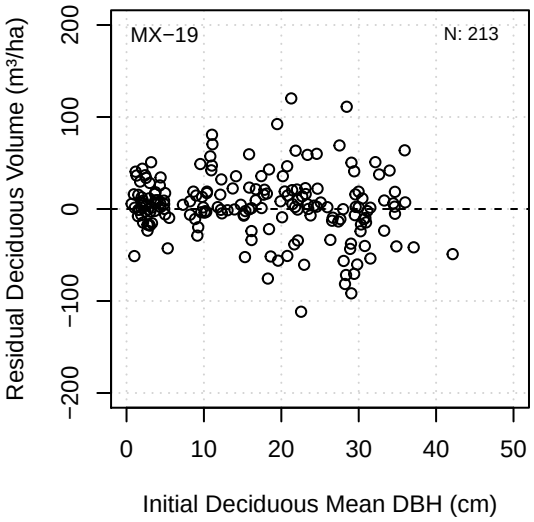

**DecResVol − Predicted Deciduous Volume − MX**



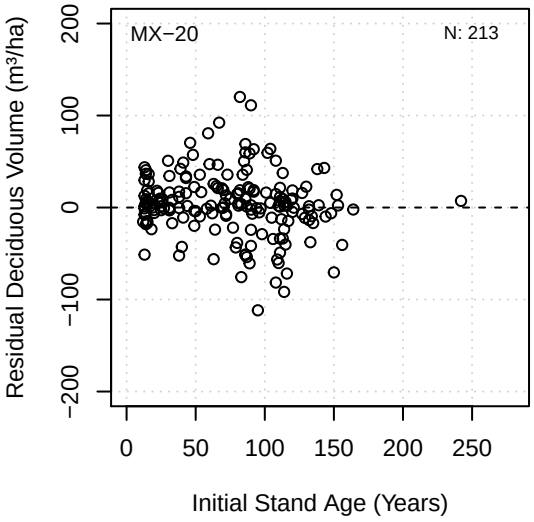
**DecResVol − Initial Conifer Mean DBH − MX**



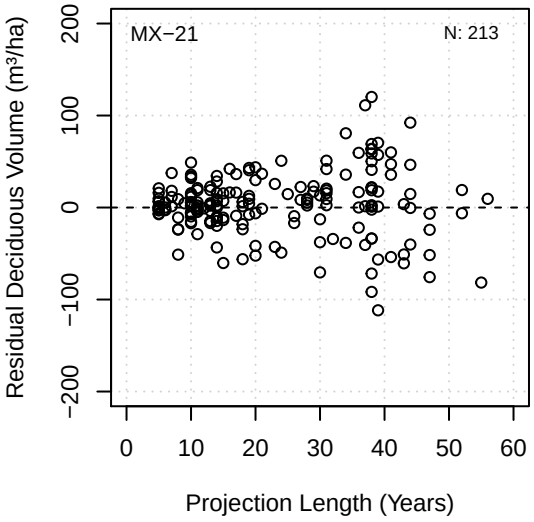

**DecResVol − Initial Deciduous Mean DBH − MX**



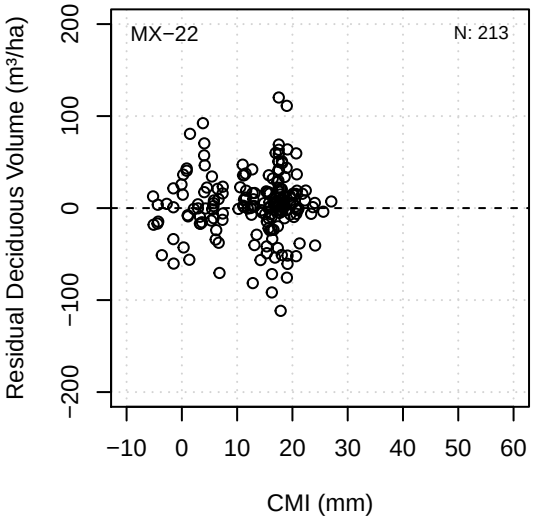

**DecResVol − Initial Stand Age − MX**



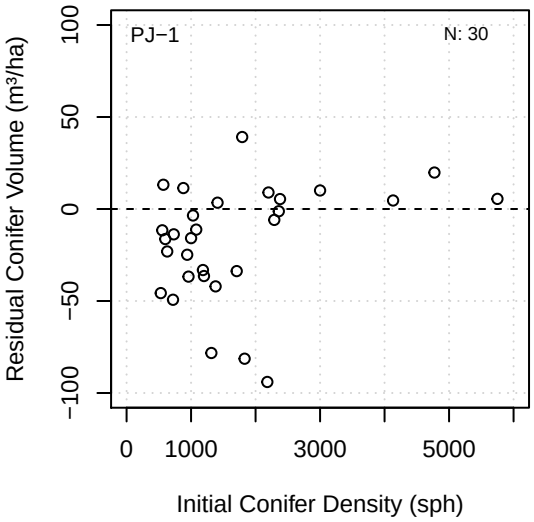

**DecResVol − Projection Length − MX**



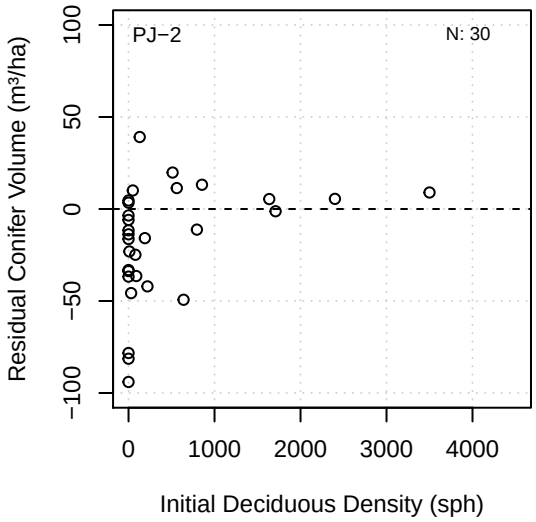

**DecResVol − CMI − MX**



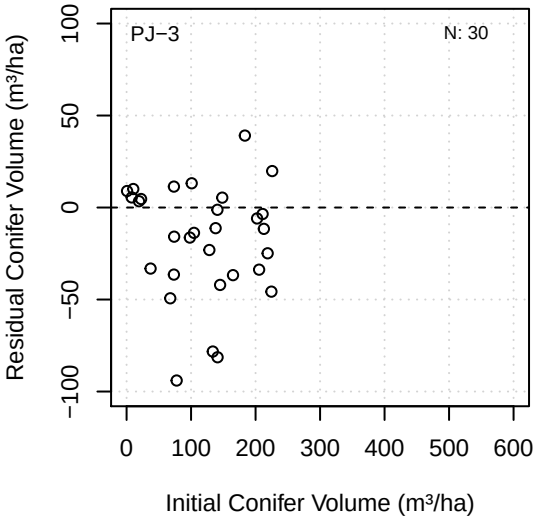
**ConResVol − Initial Conifer Density − PJ**



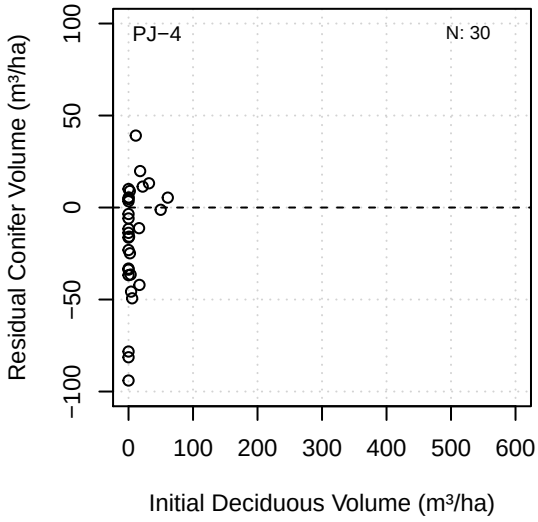

**ConResVol − Initial Deciduous Density − PJ**



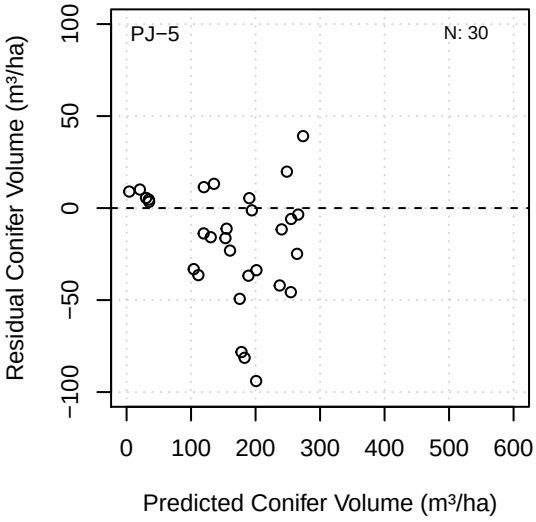

**ConResVol − Initial Conifer Volume − PJ**



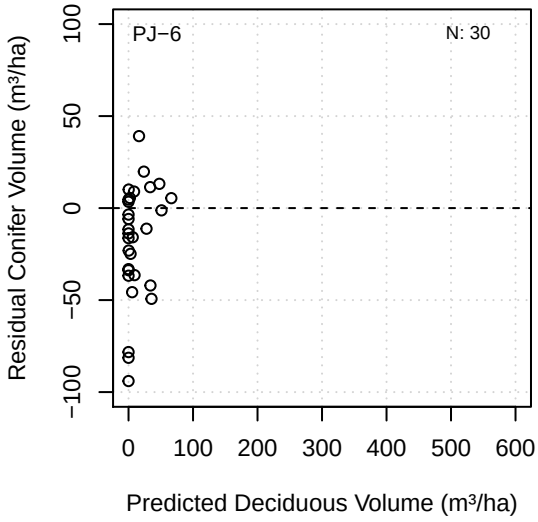

**ConResVol − Initial Deciduous Volume − PJ**



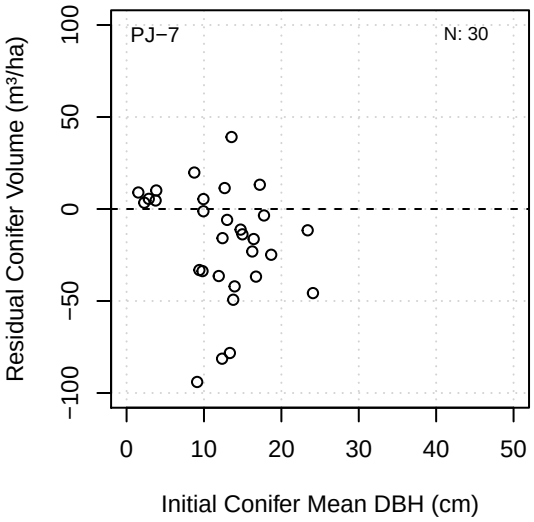

**ConResVol − Predicted Conifer Volume − PJ**



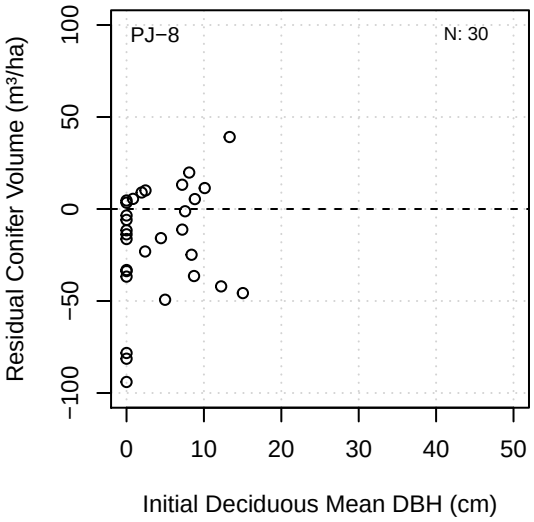

**ConResVol − Predicted Deciduous Volume − PJ**



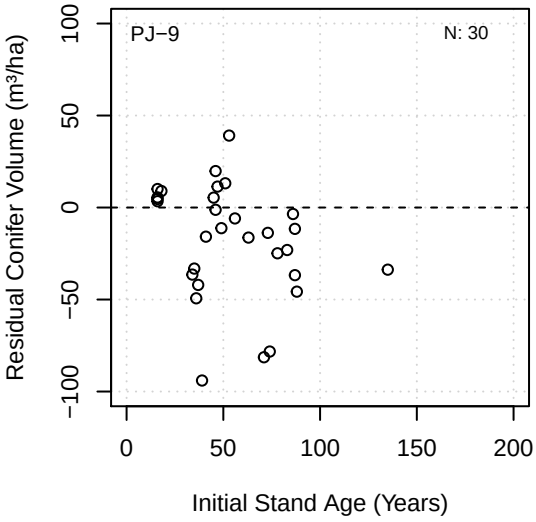
**ConResVol − Initial Conifer Mean DBH − PJ**



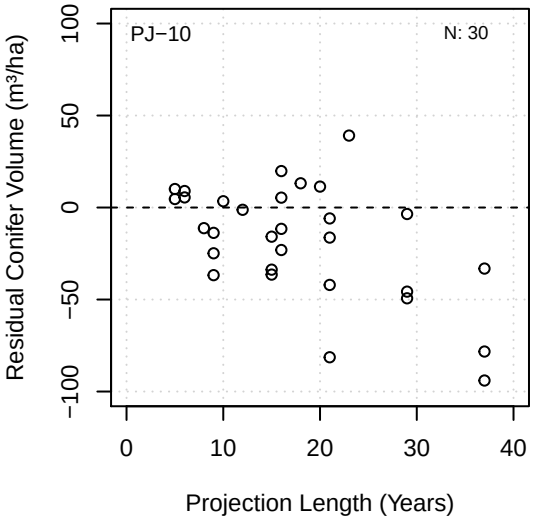

**ConResVol − Initial Deciduous Mean DBH − PJ**



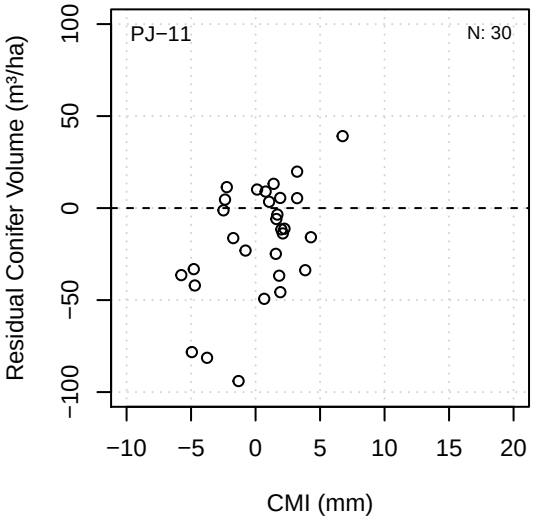

**ConResVol − Initial Stand Age − PJ**



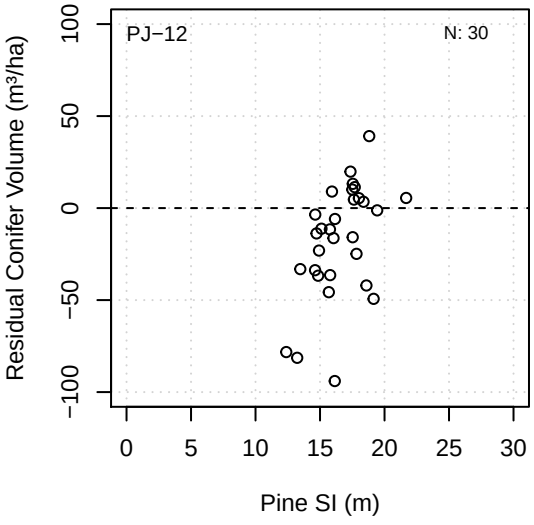

**ConResVol − Projection Length − PJ**



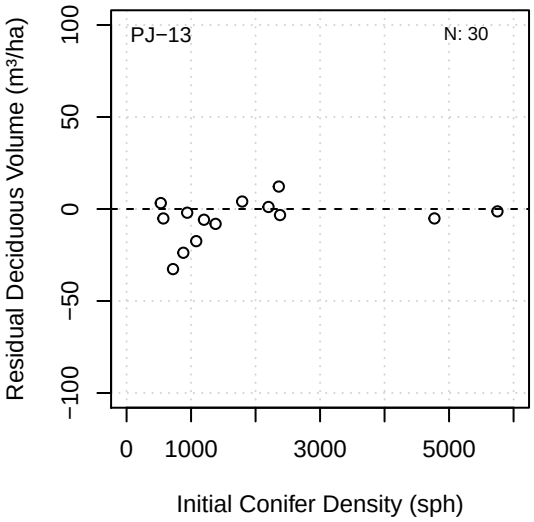

**ConResVol − CMI − PJ**



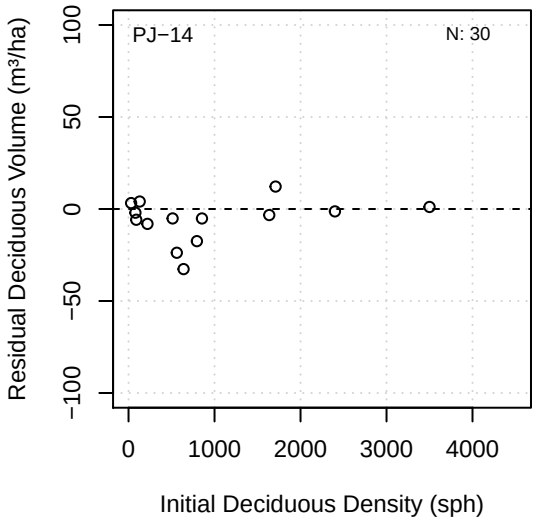

**ConResVol − Pine SI − PJ**



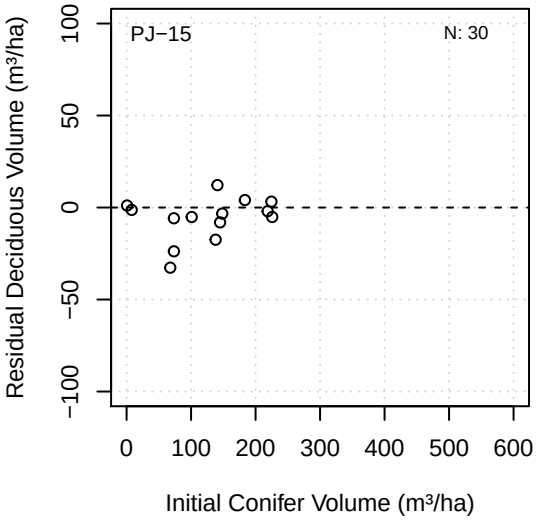
**DecResVol − Initial Conifer Density − PJ**



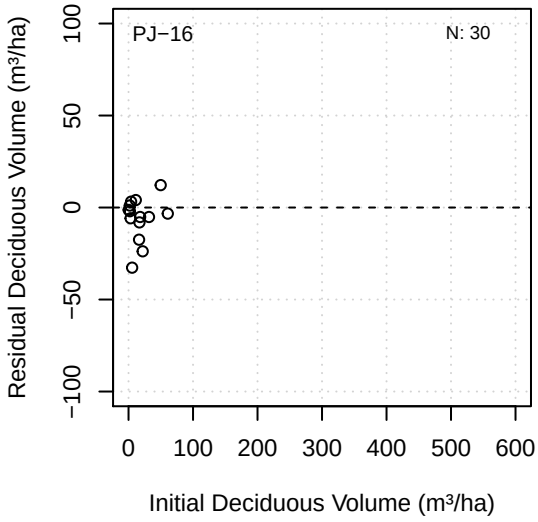

**DecResVol − Initial Deciduous Density − PJ**



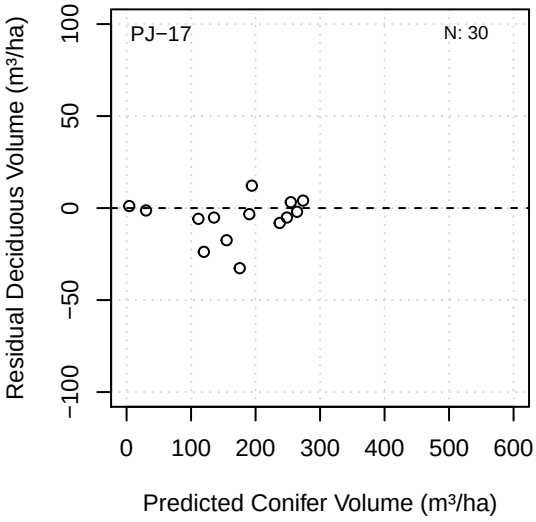

**DecResVol − Initial Conifer Volume − PJ**



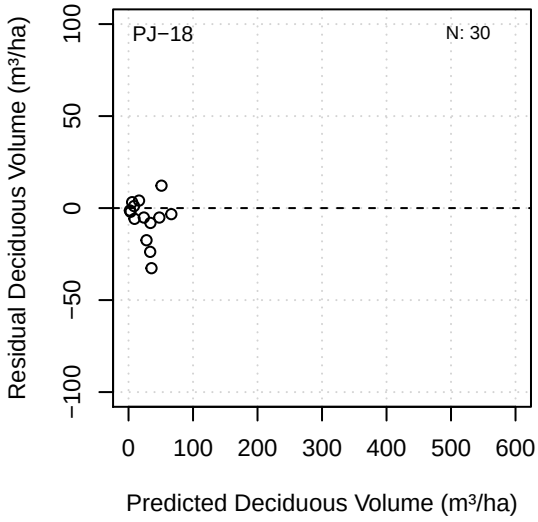

**DecResVol − Initial Deciduous Volume − PJ**



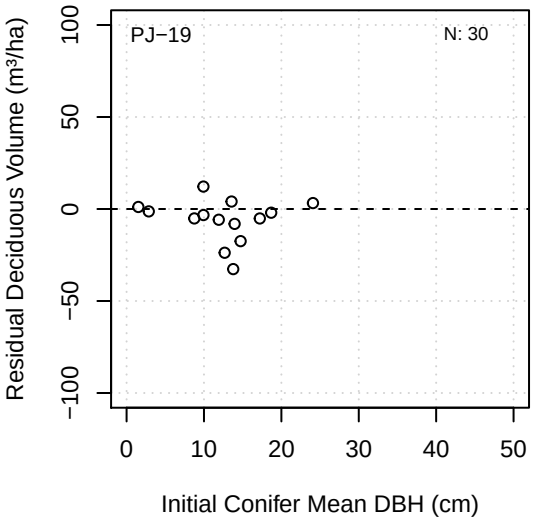

**DecResVol − Predicted Conifer Volume − PJ**



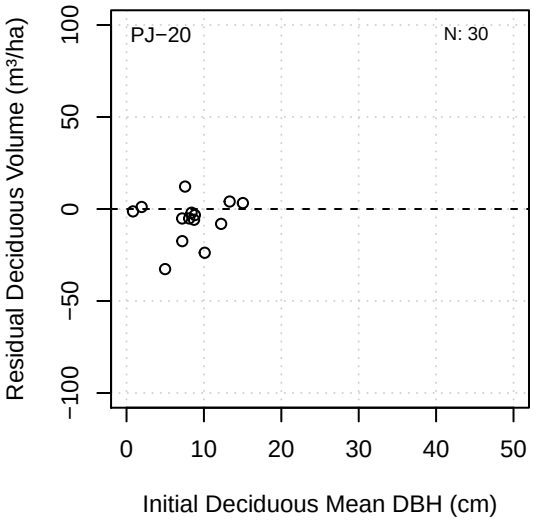

**DecResVol − Predicted Deciduous Volume − PJ**



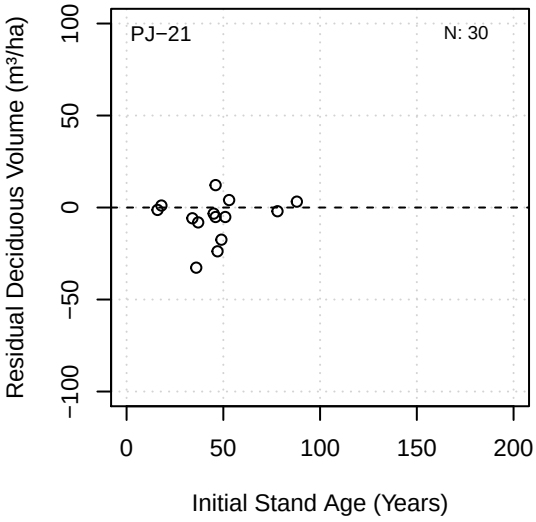
**DecResVol − Initial Conifer Mean DBH − PJ**



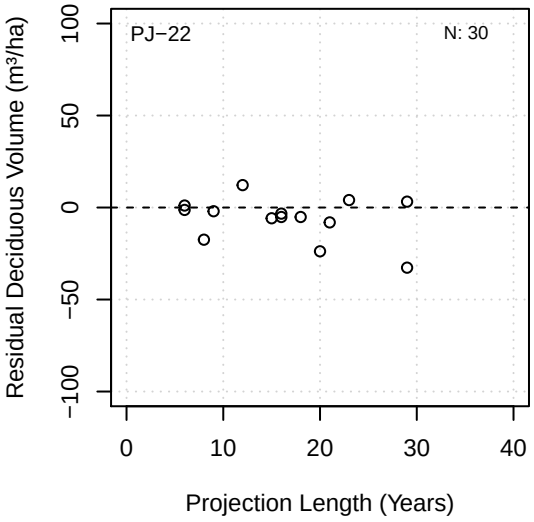

**DecResVol − Initial Deciduous Mean DBH − PJ**



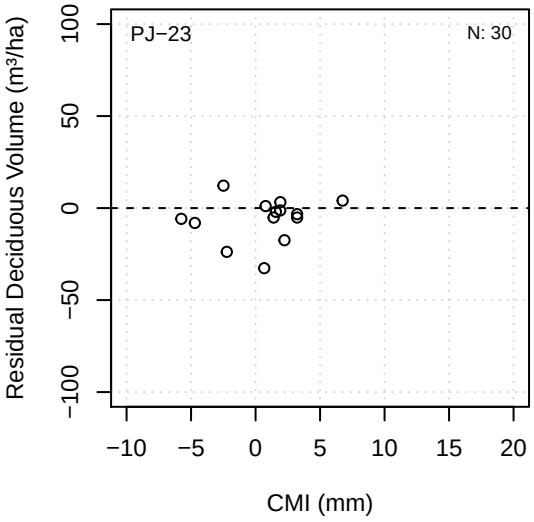

**DecResVol − Initial Stand Age − PJ**



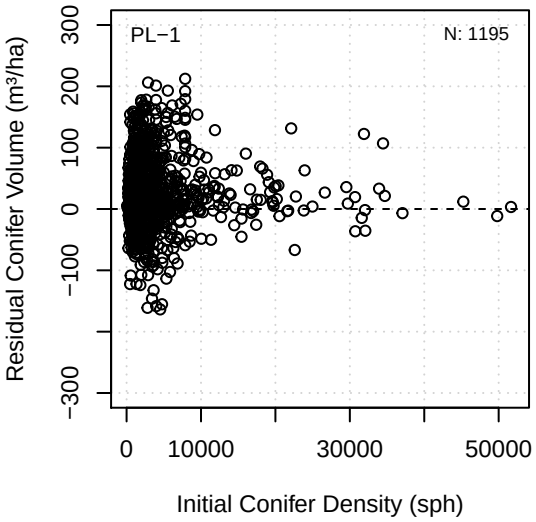

**DecResVol − Projection Length − PJ**



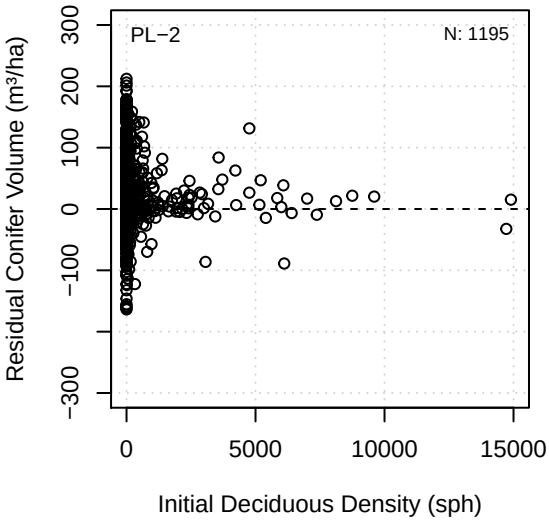

**DecResVol − CMI − PJ**



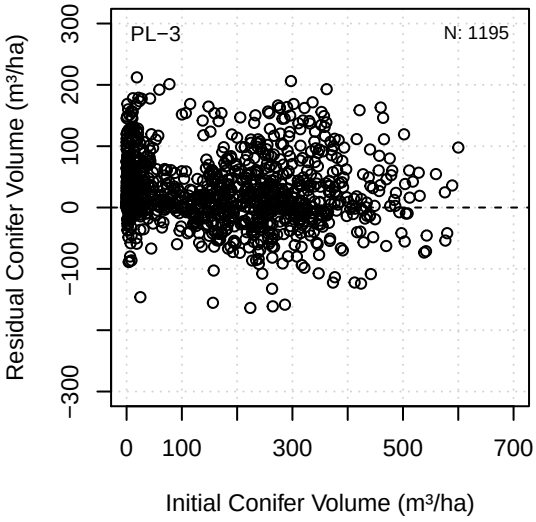
**ConResVol − Initial Conifer Density − PL**



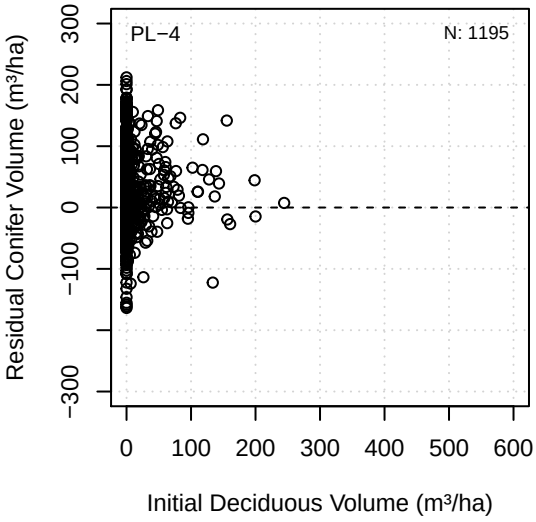

**ConResVol − Initial Deciduous Density − PL**



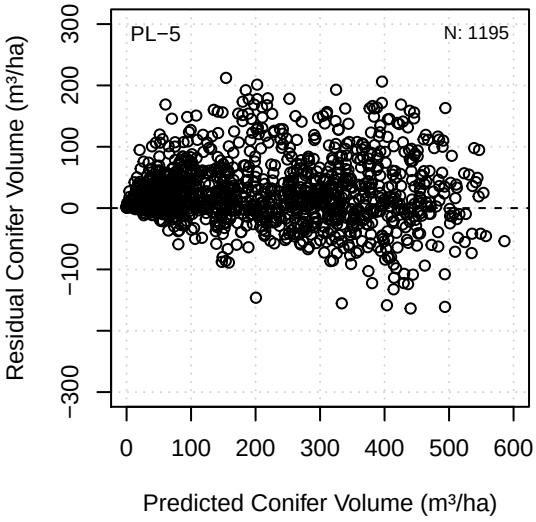

**ConResVol − Initial Conifer Volume − PL**



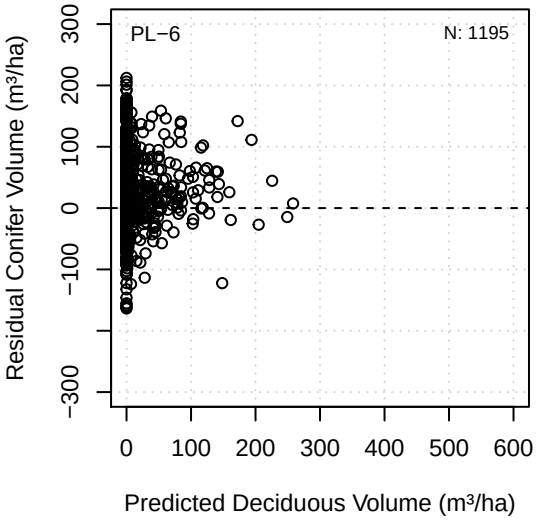

**ConResVol − Initial Deciduous Volume − PL**



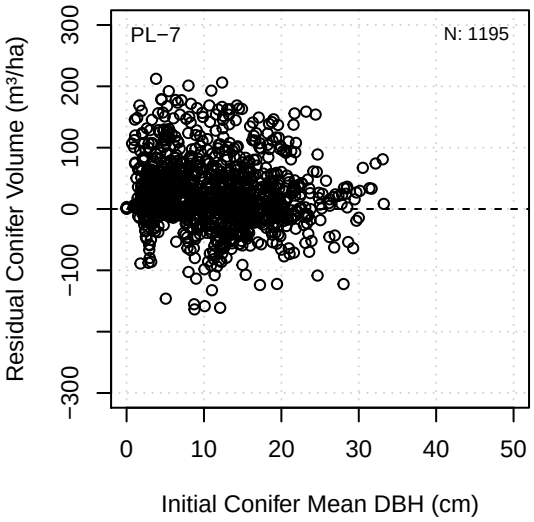

**ConResVol − Predicted Conifer Volume − PL**



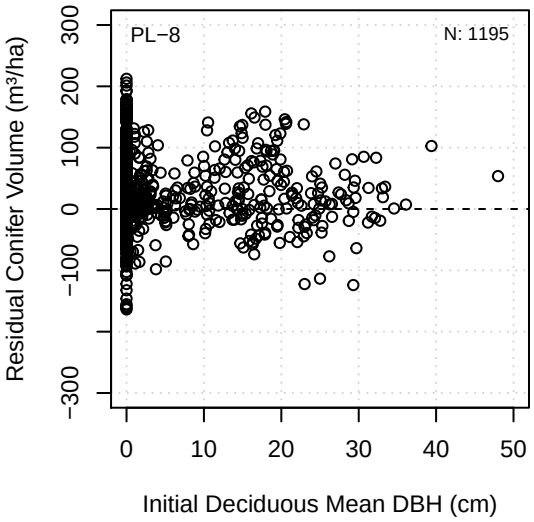

**ConResVol − Predicted Deciduous Volume − PL**



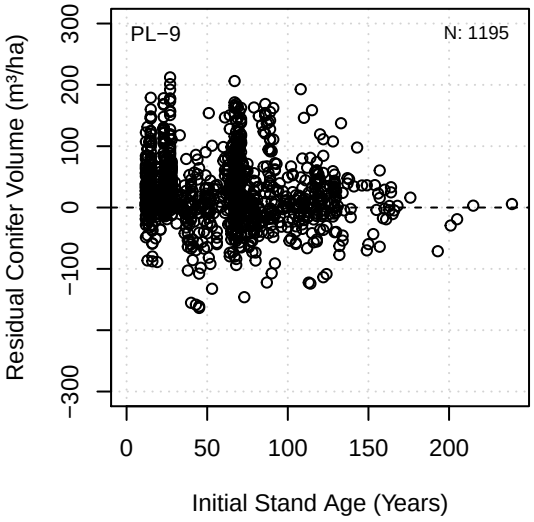
**ConResVol − Initial Conifer Mean DBH − PL**



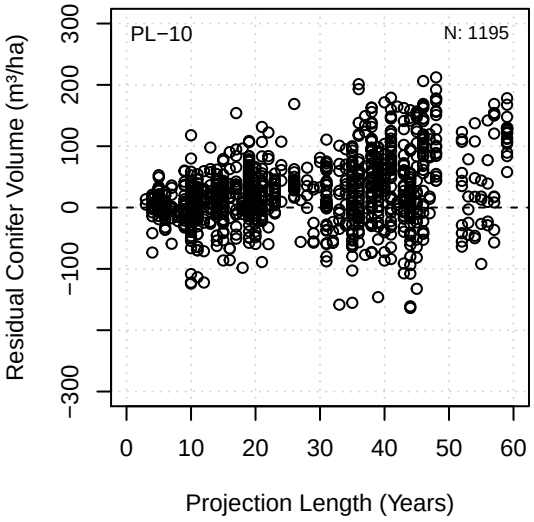

**ConResVol − Initial Deciduous Mean DBH − PL**



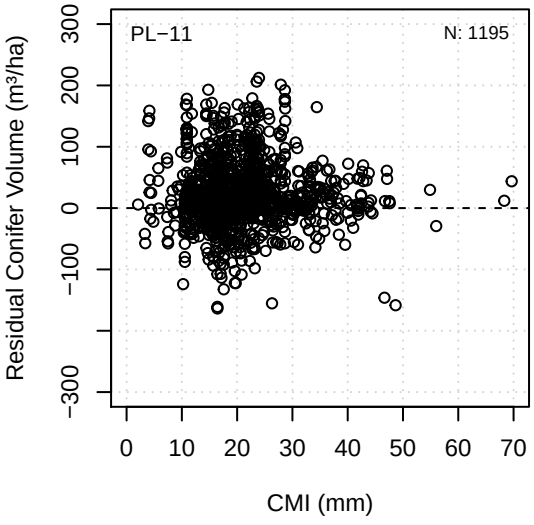

**ConResVol − Initial Stand Age − PL**



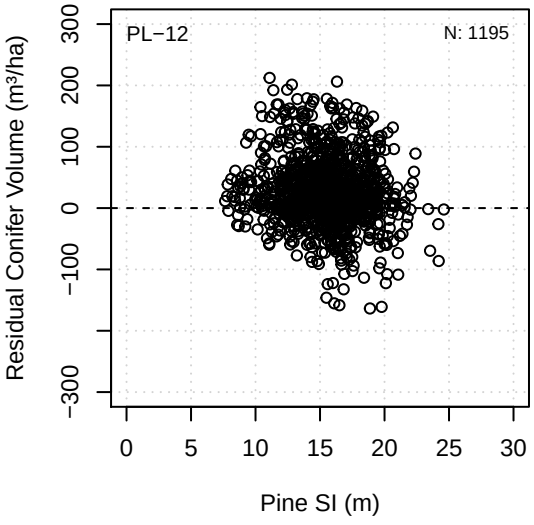

**ConResVol − Projection Length − PL**



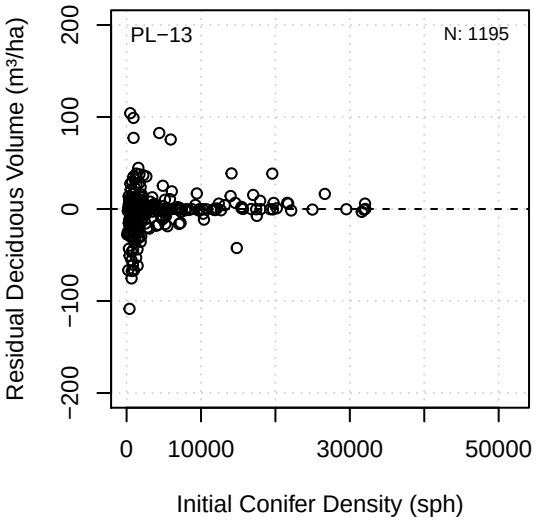

**ConResVol − CMI − PL**



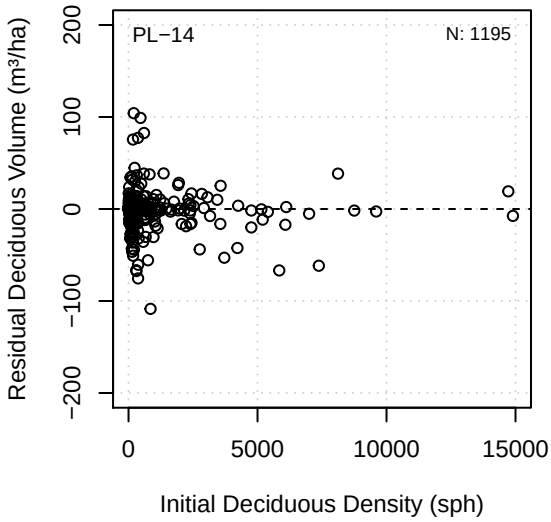

**ConResVol − Pine SI − PL**



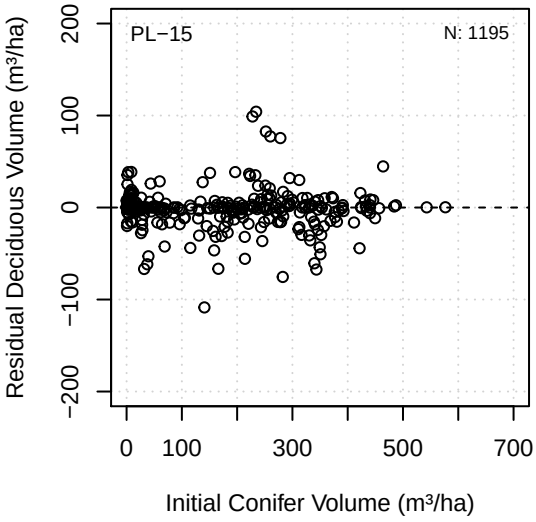
**DecResVol − Initial Conifer Density − PL**



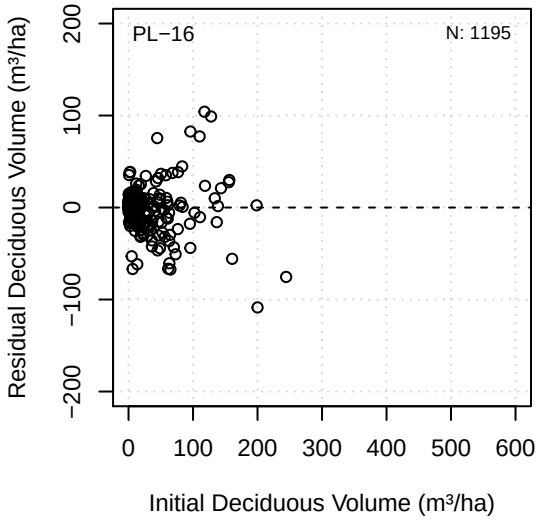

**DecResVol − Initial Deciduous Density − PL**



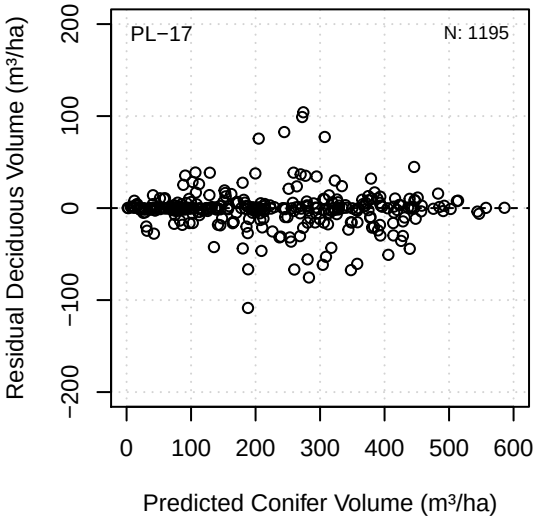

**DecResVol − Initial Conifer Volume − PL**



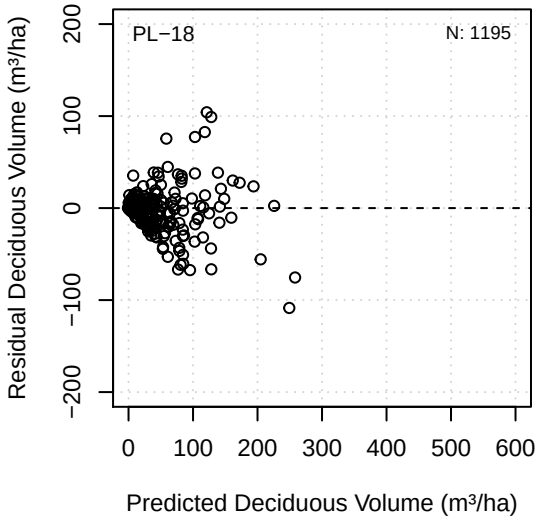

**DecResVol − Initial Deciduous Volume − PL**



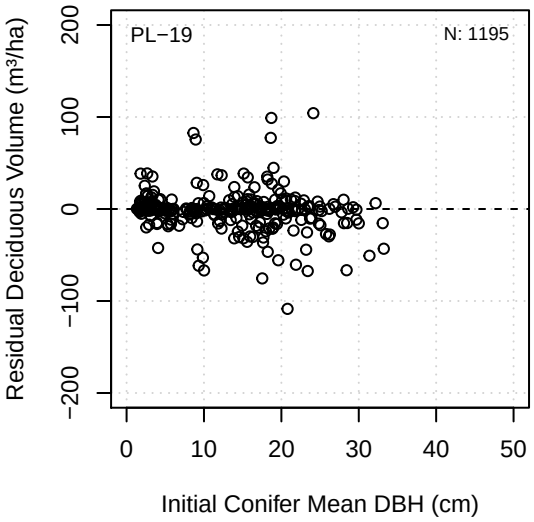

**DecResVol − Predicted Conifer Volume − PL**



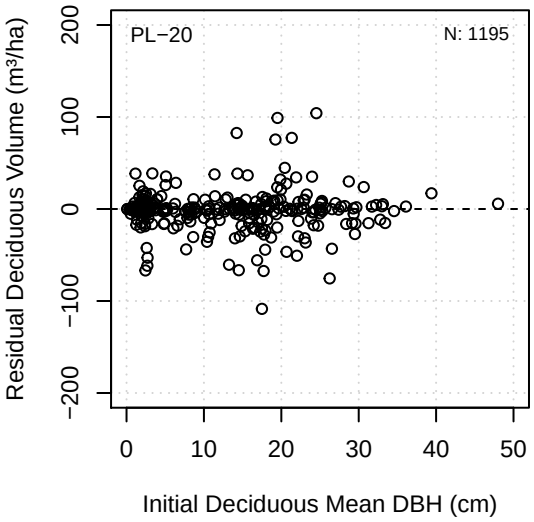

**DecResVol − Predicted Deciduous Volume − PL**



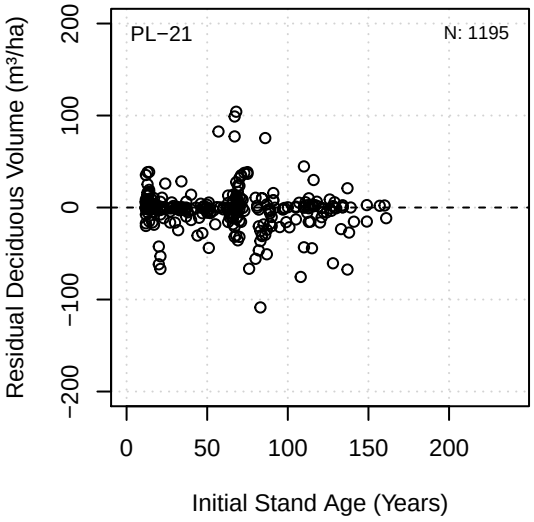
**DecResVol − Initial Conifer Mean DBH − PL**



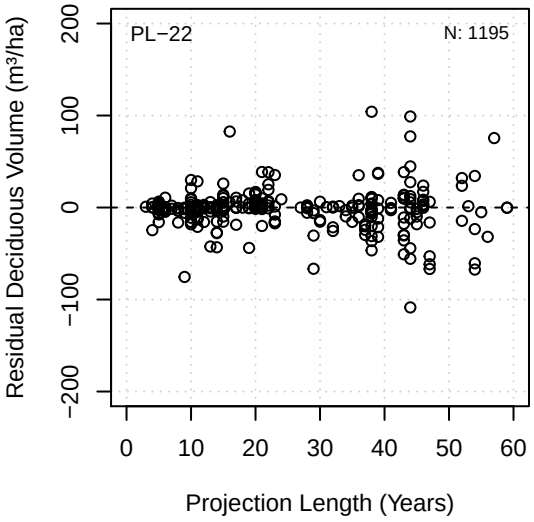

**DecResVol − Initial Deciduous Mean DBH − PL**



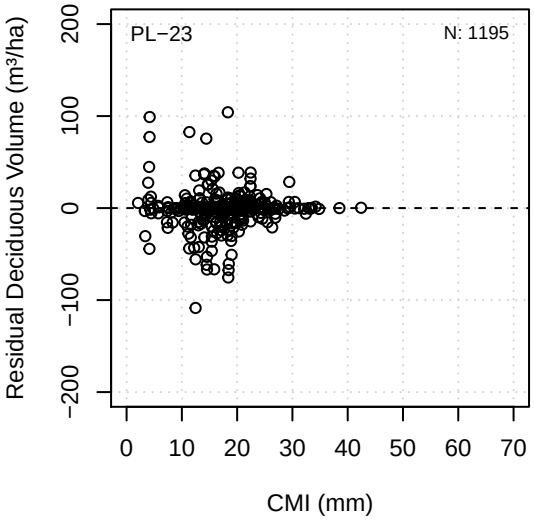

**DecResVol − Initial Stand Age − PL**



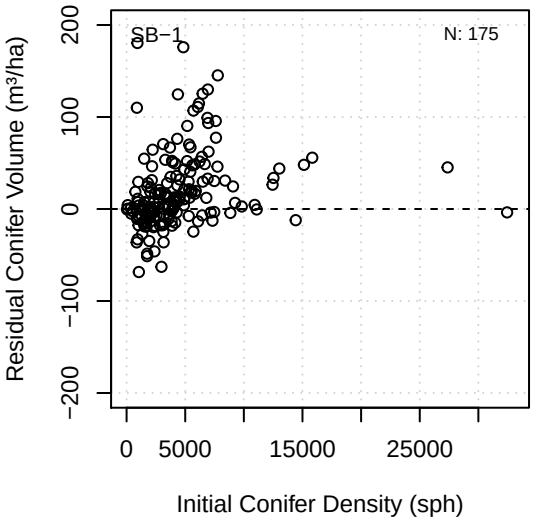

**DecResVol − Projection Length − PL**



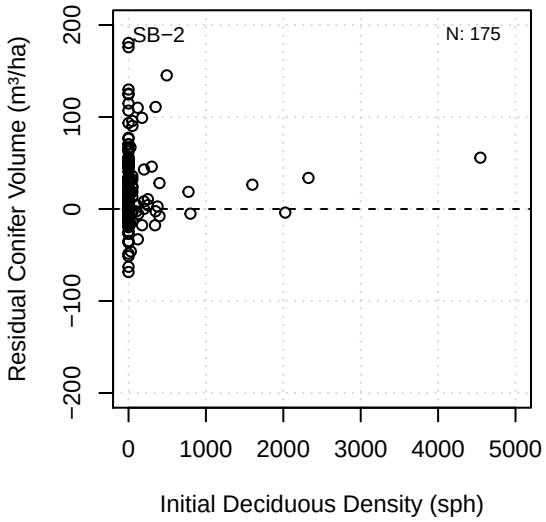

**DecResVol − CMI − PL**



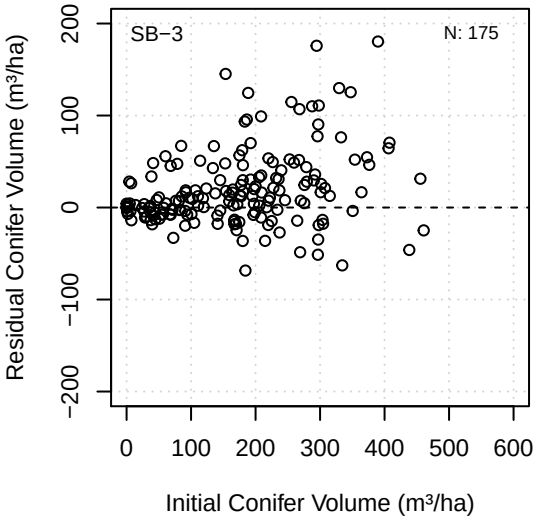
**ConResVol − Initial Conifer Density − SB**



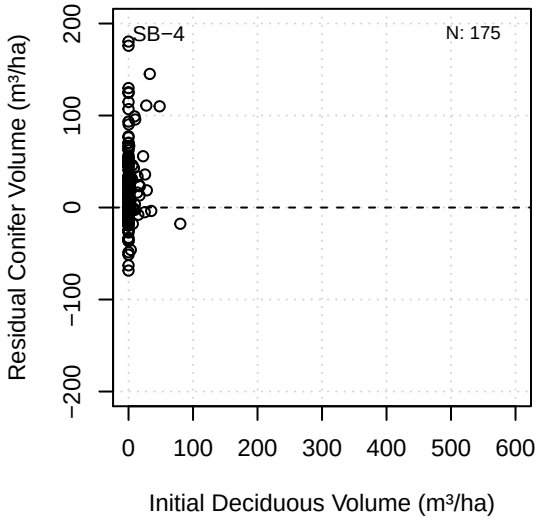

**ConResVol − Initial Deciduous Density − SB**



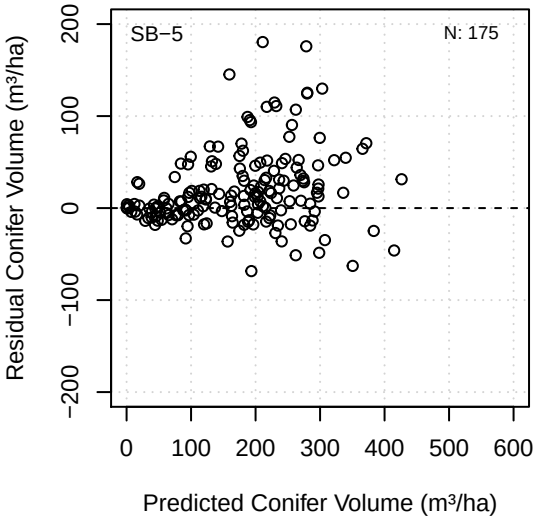

**ConResVol − Initial Conifer Volume − SB**



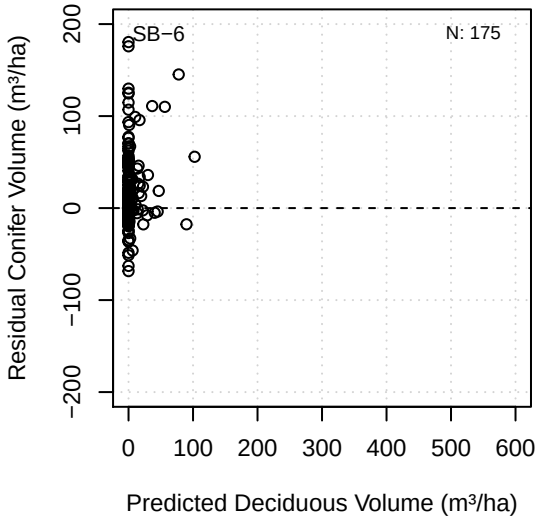

**ConResVol − Initial Deciduous Volume − SB**



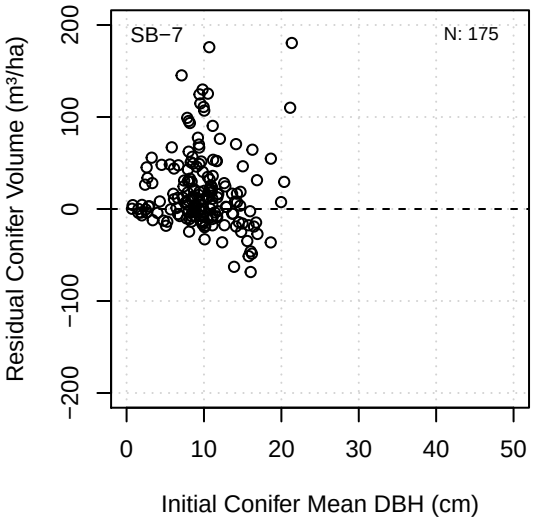

**ConResVol − Predicted Conifer Volume − SB**



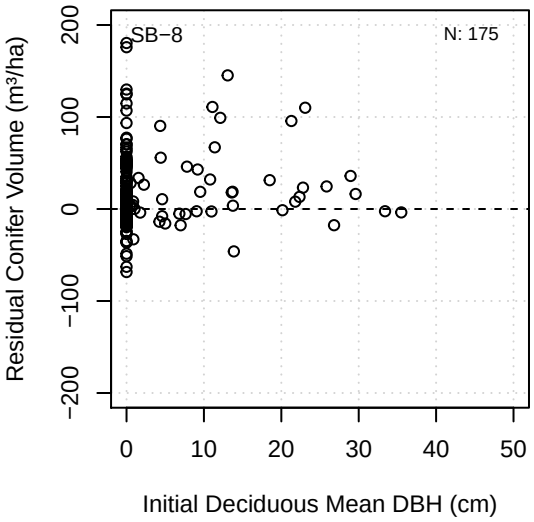

**ConResVol − Predicted Deciduous Volume − SB**



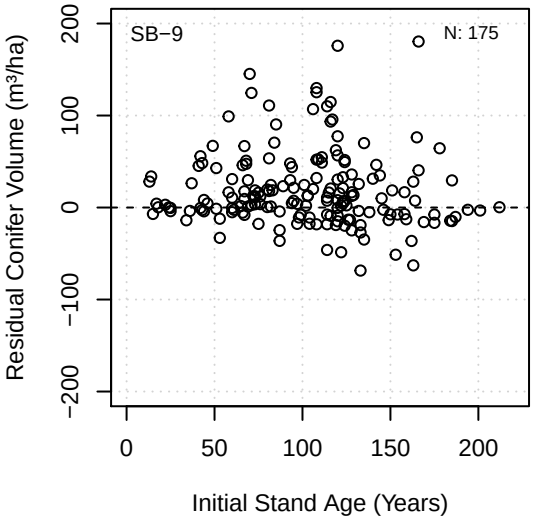
**ConResVol − Initial Conifer Mean DBH − SB**



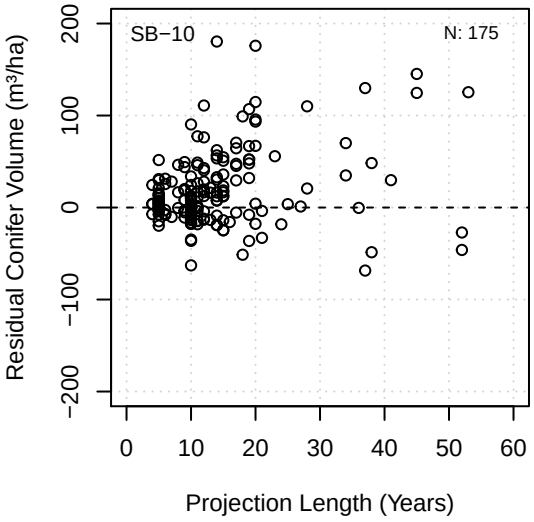

**ConResVol − Initial Deciduous Mean DBH − SB**



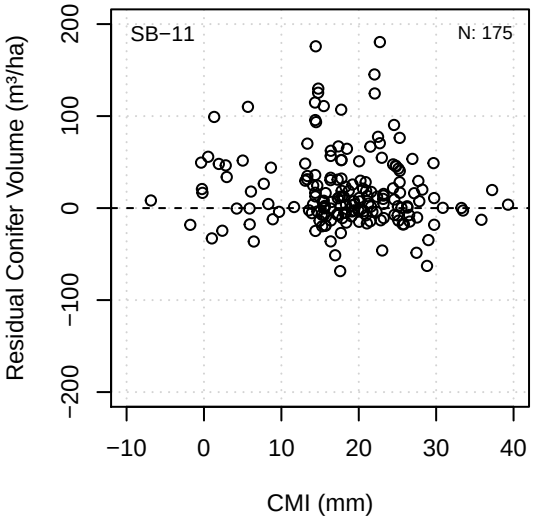

**ConResVol − Initial Stand Age − SB**



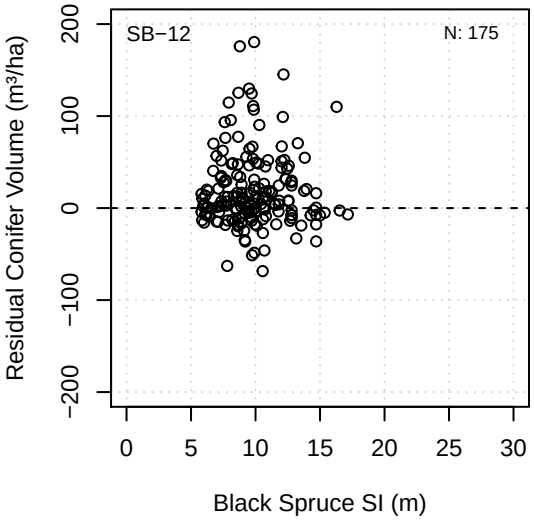

**ConResVol − Projection Length − SB**



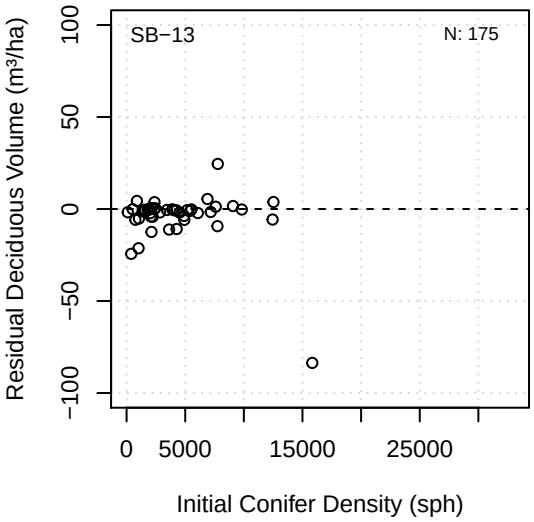

**ConResVol − CMI − SB**



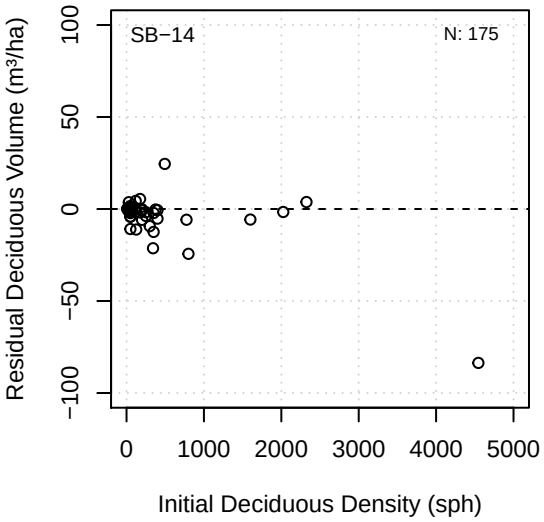

**ConResVol − Black Spruce SI − SB**



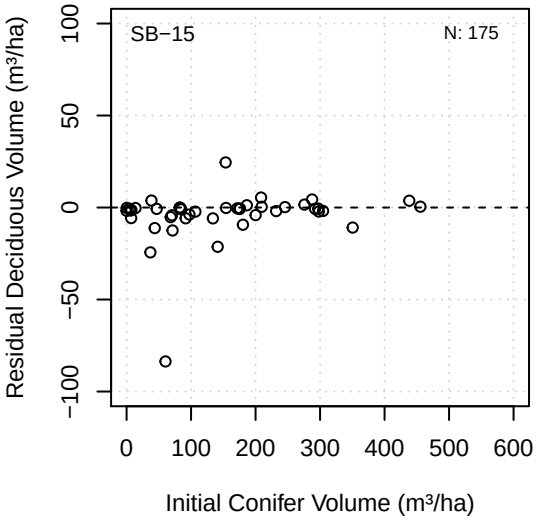
**DecResVol − Initial Conifer Density − SB**



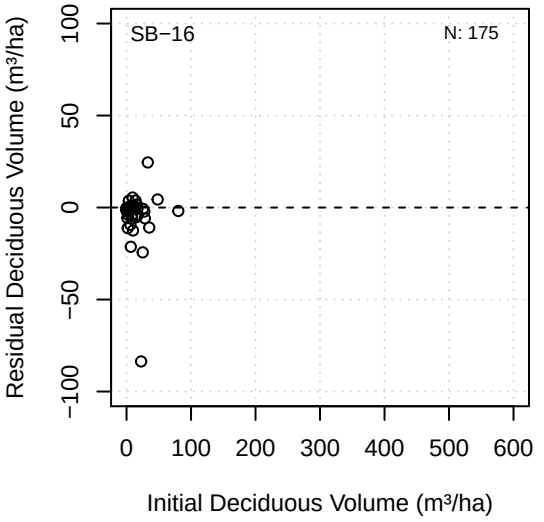

**DecResVol − Initial Deciduous Density − SB**



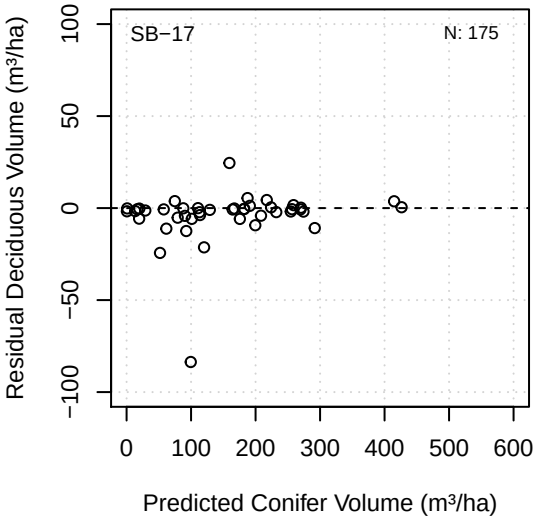

**DecResVol − Initial Conifer Volume − SB**



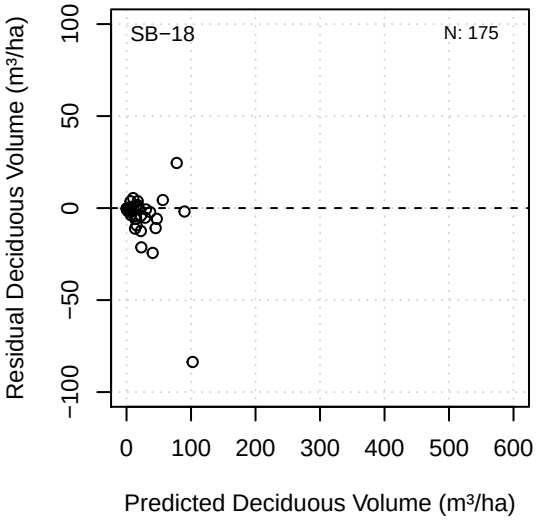

**DecResVol − Initial Deciduous Volume − SB**



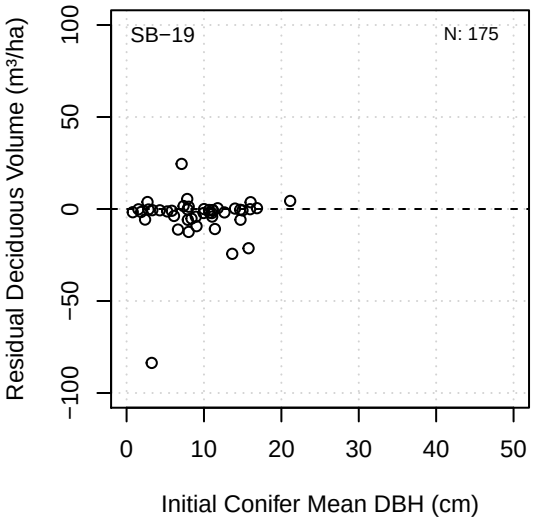

**DecResVol − Predicted Conifer Volume − SB**



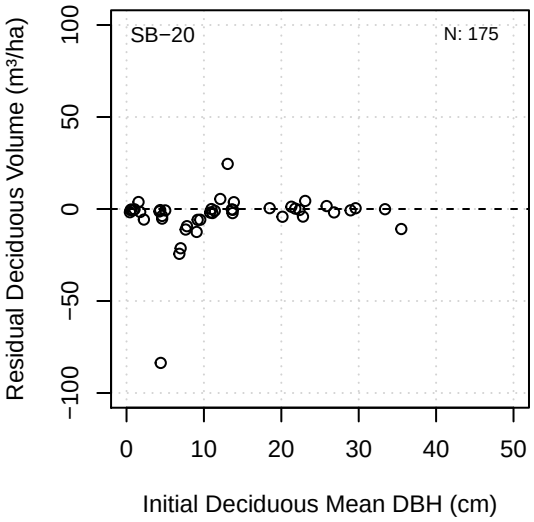

**DecResVol − Predicted Deciduous Volume − SB**



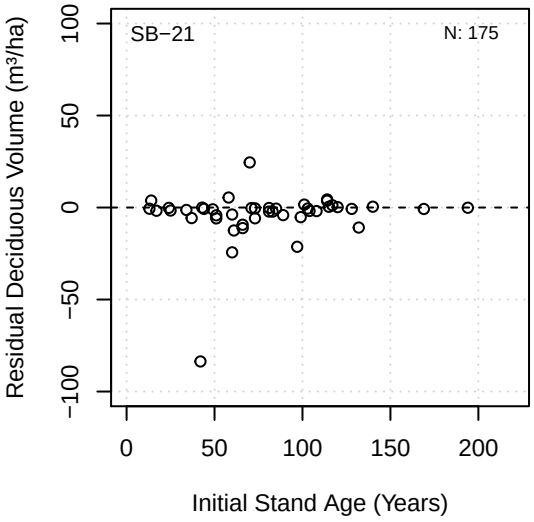
**DecResVol − Initial Conifer Mean DBH − SB**



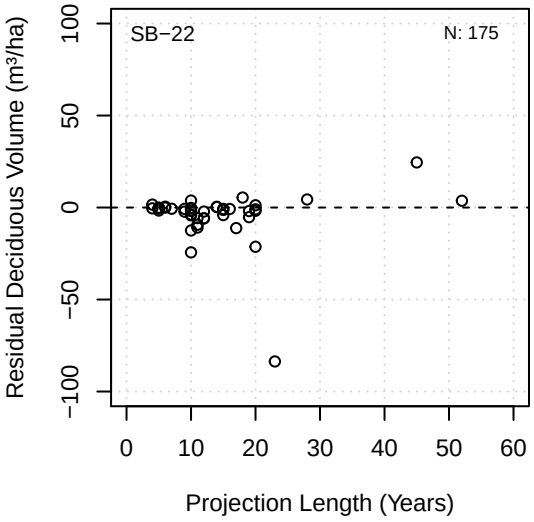

**DecResVol − Initial Deciduous Mean DBH − SB**



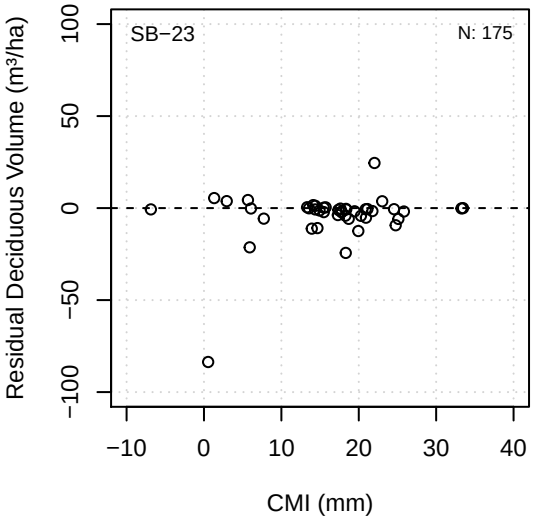

**DecResVol − Initial Stand Age − SB**



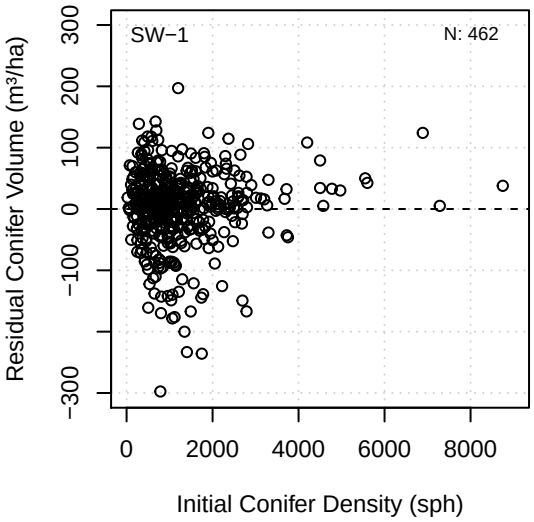

**DecResVol − Projection Length − SB**



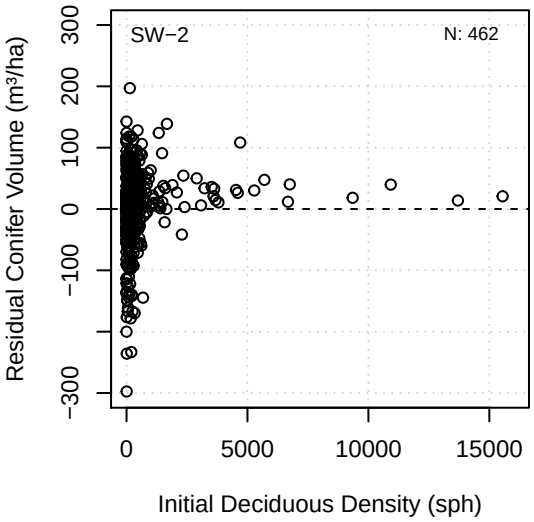

**DecResVol − CMI − SB**



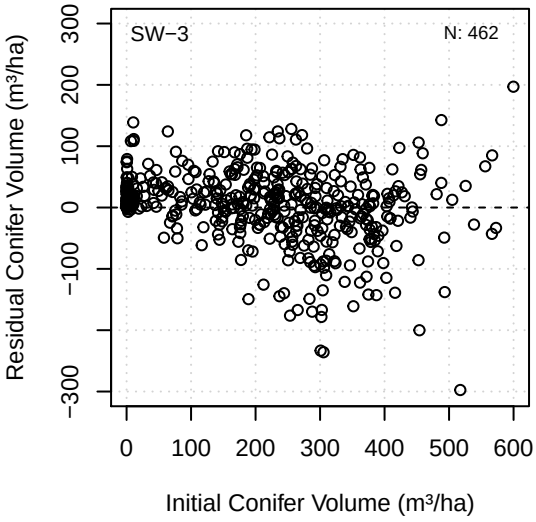
**ConResVol − Initial Conifer Density − SW**



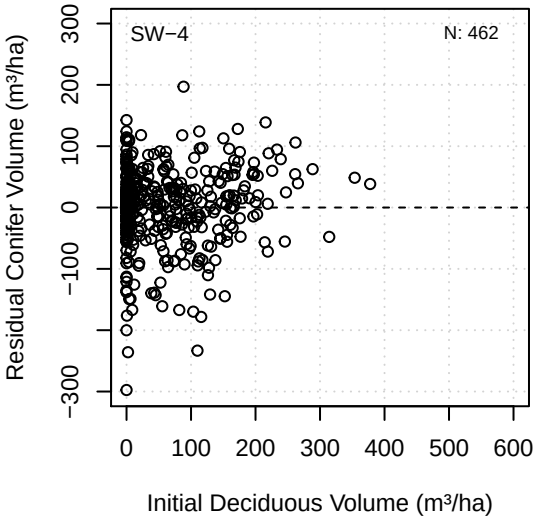

**ConResVol − Initial Deciduous Density − SW**



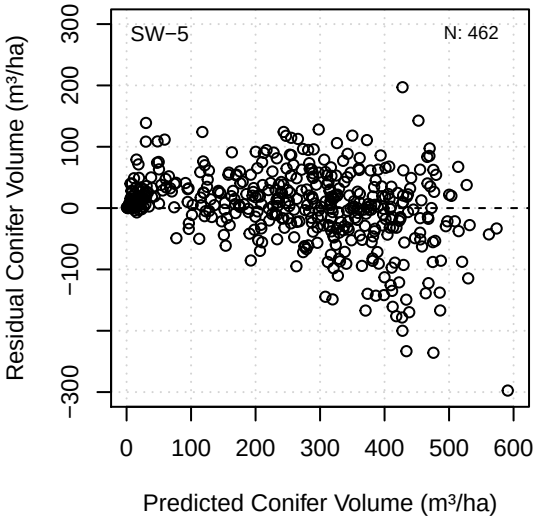

**ConResVol − Initial Conifer Volume − SW**



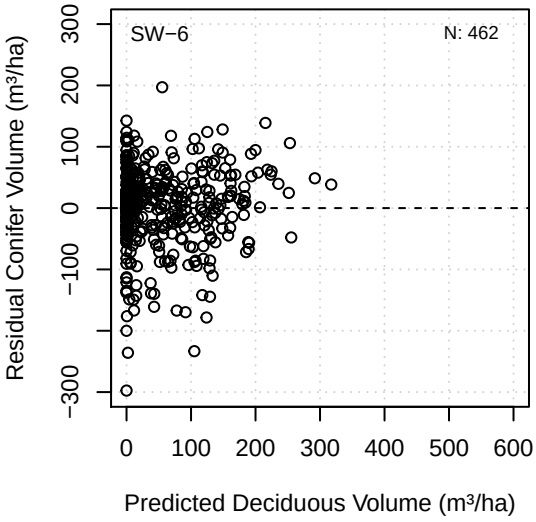

**ConResVol − Initial Deciduous Volume − SW**



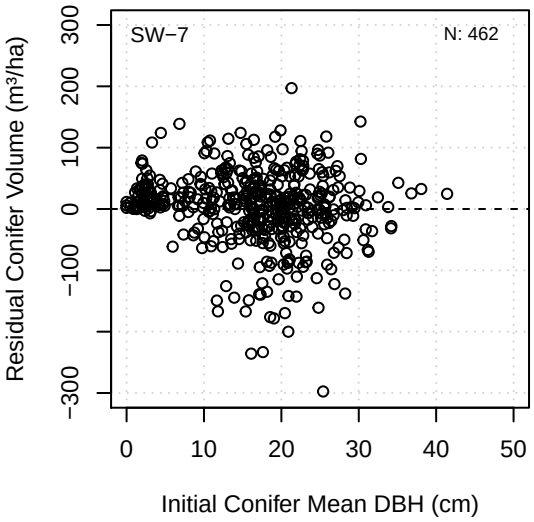

**ConResVol − Predicted Conifer Volume − SW**



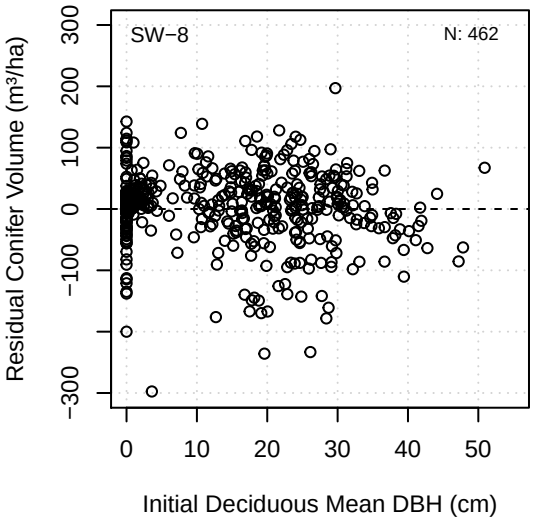

**ConResVol − Predicted Deciduous Volume − SW**



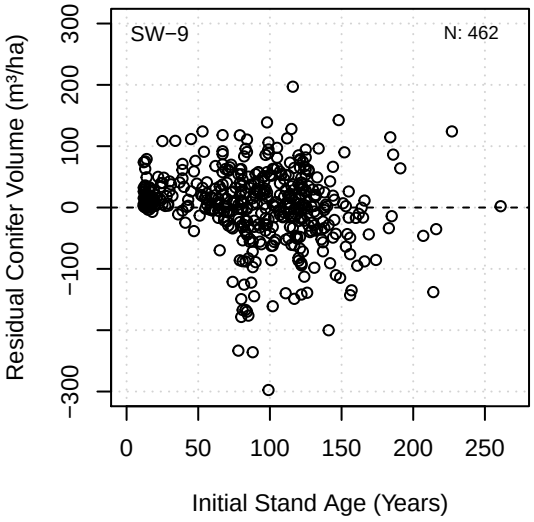
**ConResVol − Initial Conifer Mean DBH − SW**



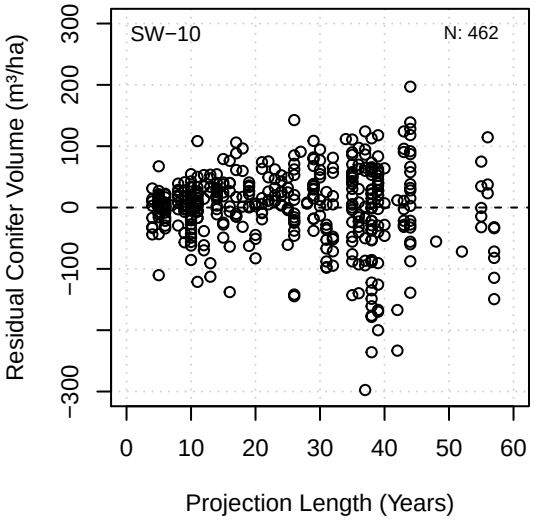

**ConResVol − Initial Deciduous Mean DBH − SW**



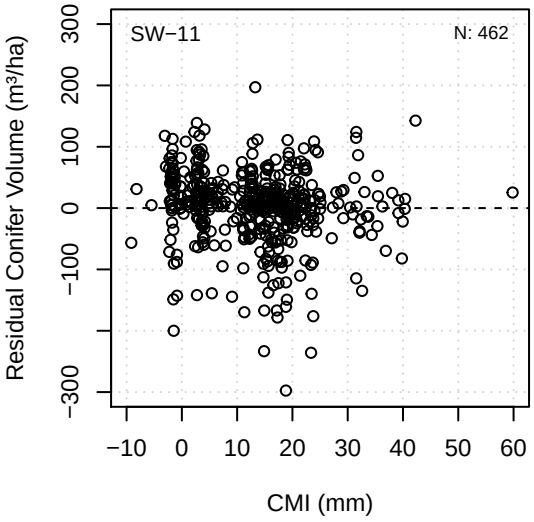

**ConResVol − Initial Stand Age − SW**



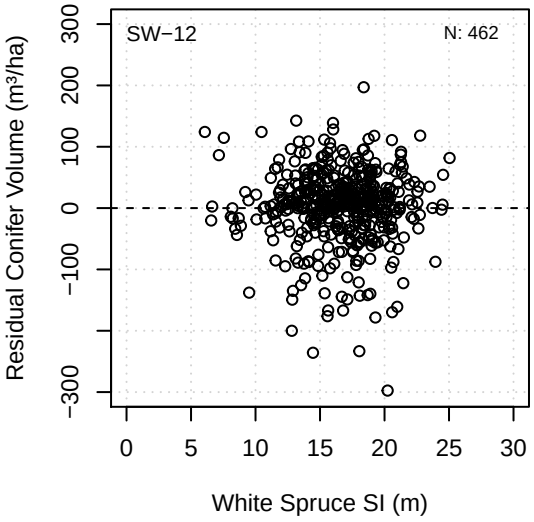

**ConResVol − Projection Length − SW**



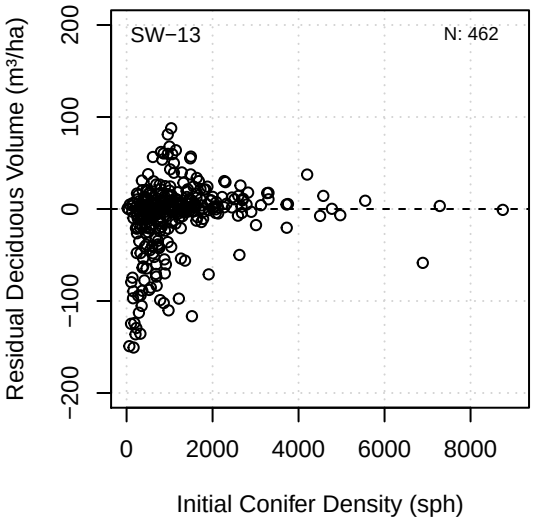

**ConResVol − CMI − SW**



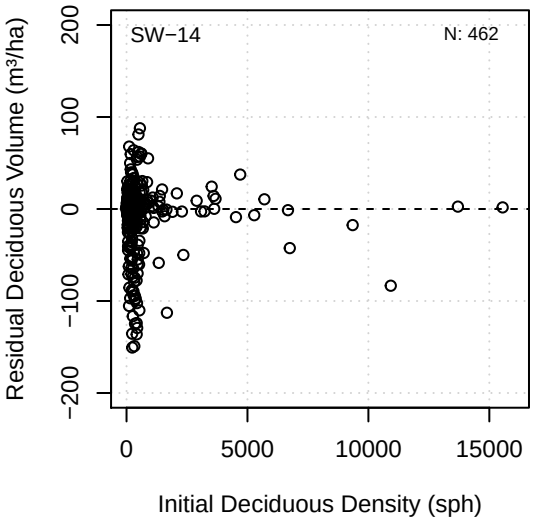

**ConResVol − White Spruce SI − SW**



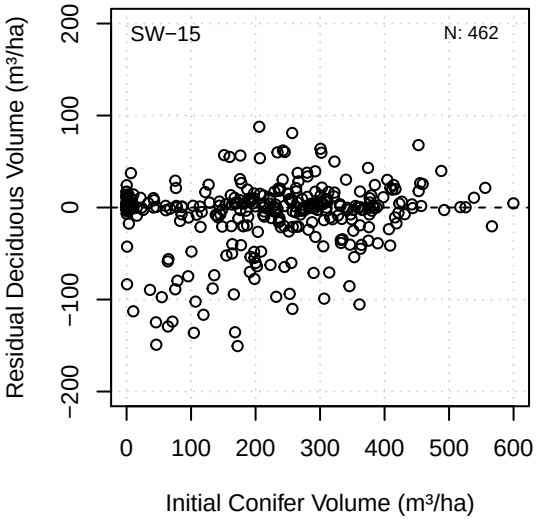
**DecResVol − Initial Conifer Density − SW**



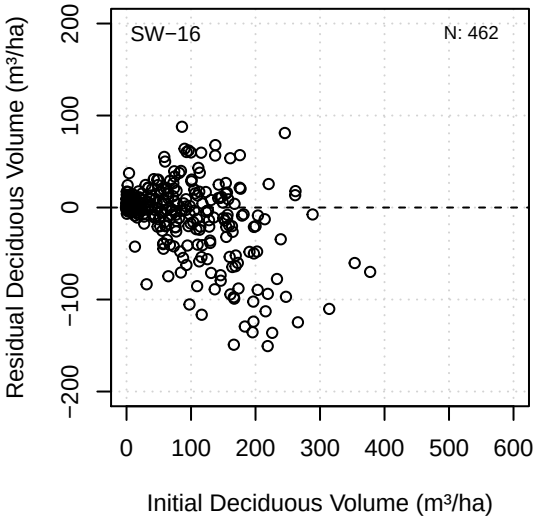

**DecResVol − Initial Deciduous Density − SW**



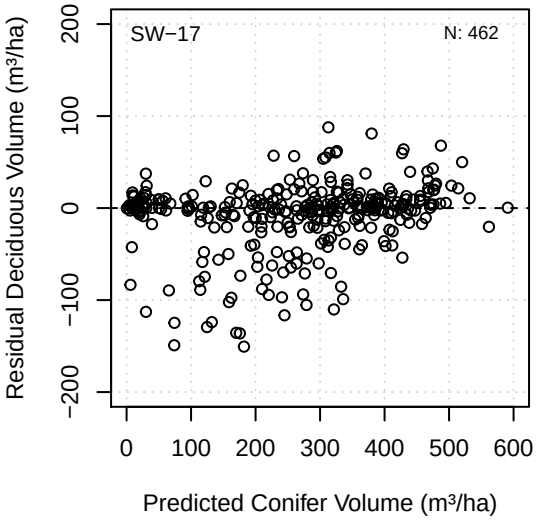

**DecResVol − Initial Conifer Volume − SW**



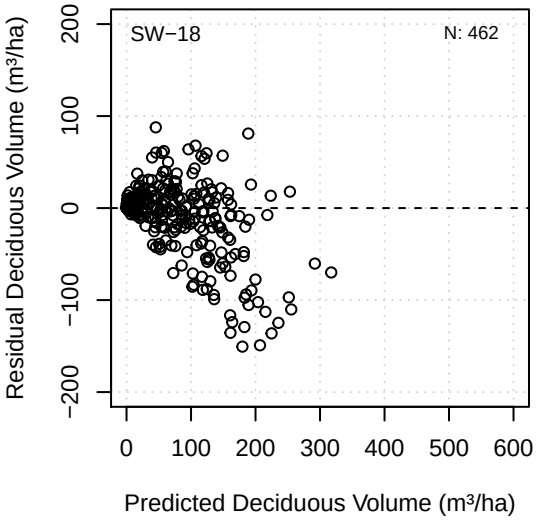

**DecResVol − Initial Deciduous Volume − SW**



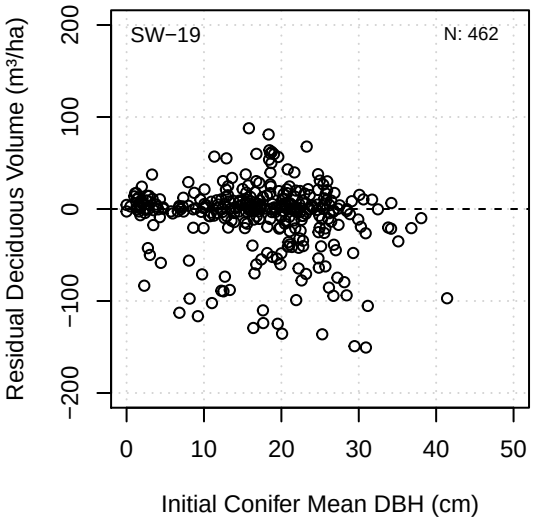

**DecResVol − Predicted Conifer Volume − SW**



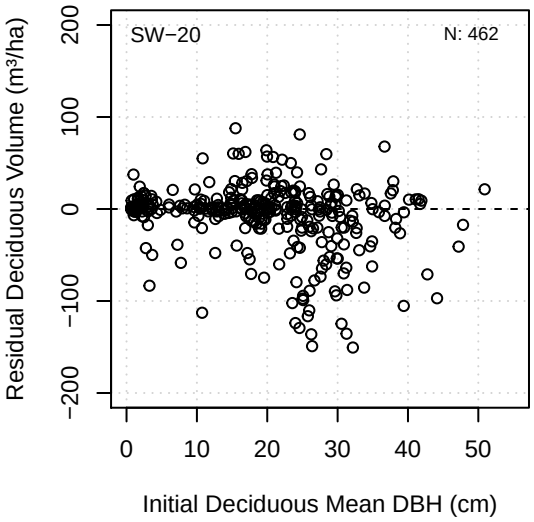

**DecResVol − Predicted Deciduous Volume − SW**



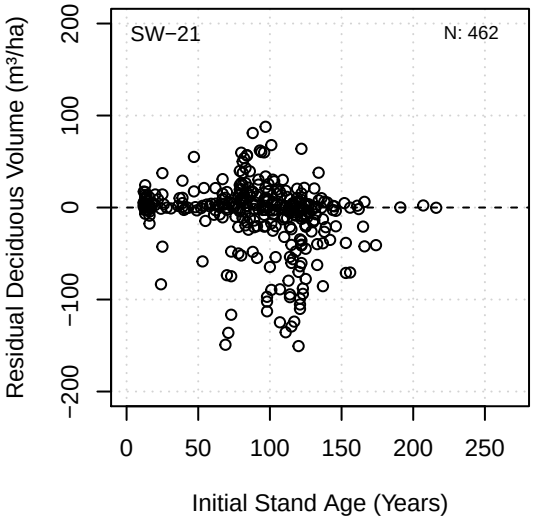
**DecResVol − Initial Conifer Mean DBH − SW**



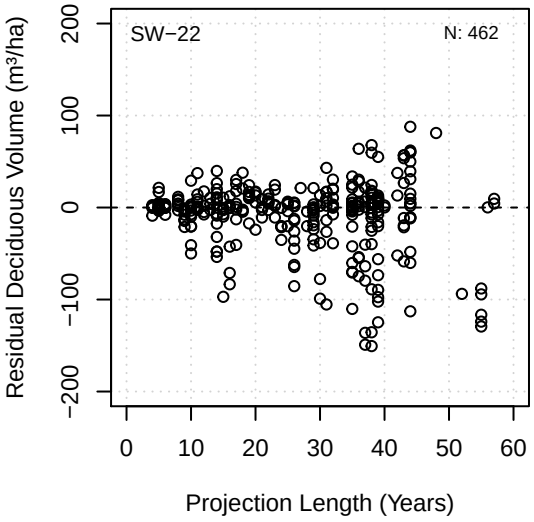

**DecResVol − Initial Deciduous Mean DBH − SW**



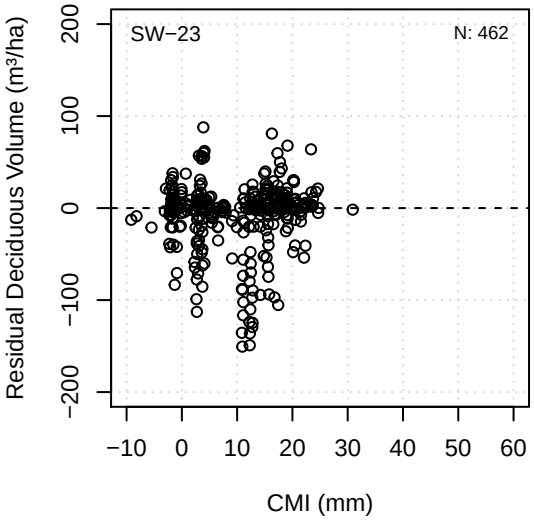

**DecResVol − Initial Stand Age − SW**




**DecResVol − Projection Length − SW**

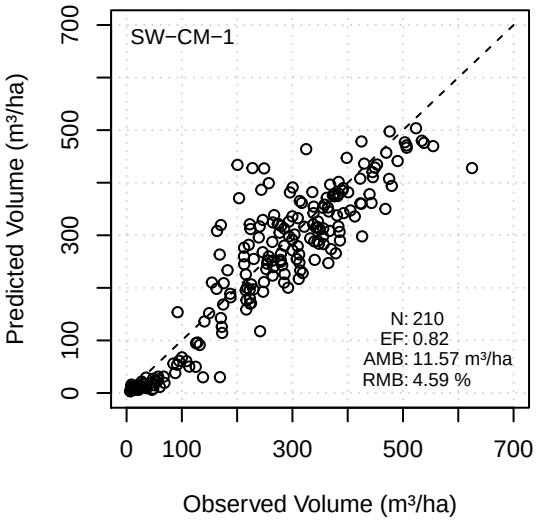



**DecResVol − CMI − SW**

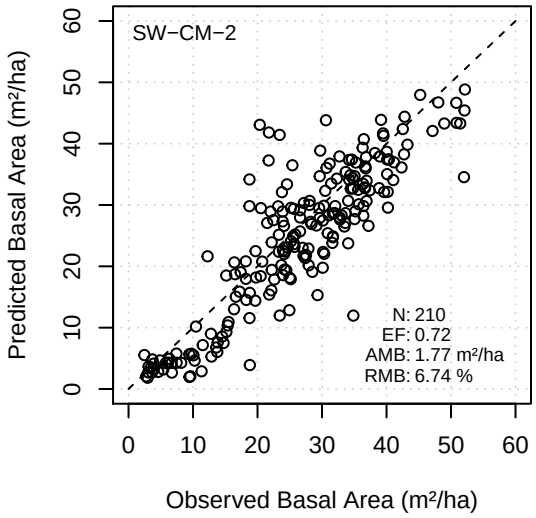


**Appendix C.** Scatterplots of predicted vs observed stand parameters (volume (m3), basal area (m2), dbh (cm), height (m), density (sph) and top height (m) for the conifer and deciduous components for white spruce dominated stands in each of 3 major Natural Subregions (CM=Central Mixedwoods, LF=Lower Foothills, UF=Upper Foothills).

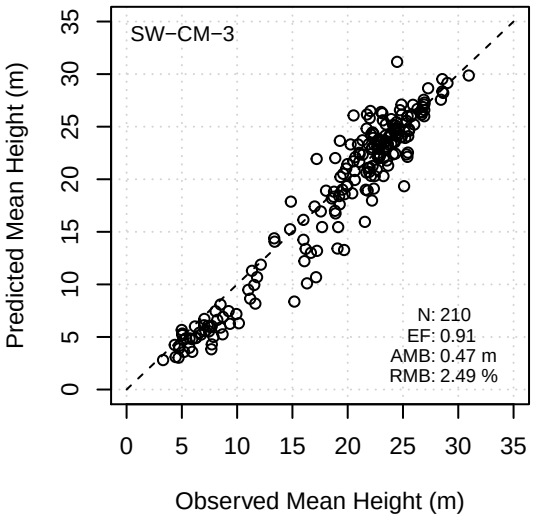
**Conifer Volume − SW−CM**



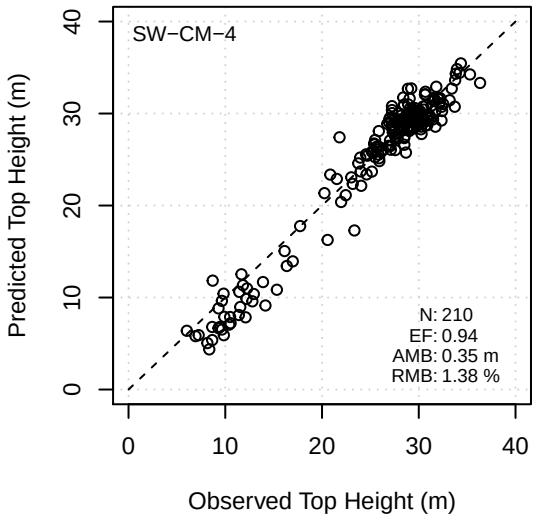

**Conifer Basal Area − SW−CM**



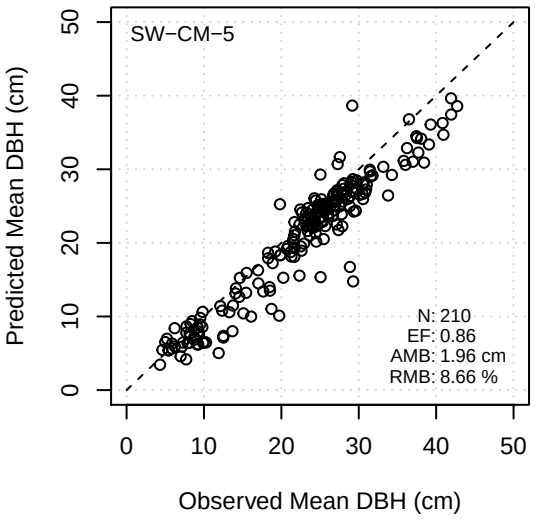

**Conifer Mean Height − SW−CM**



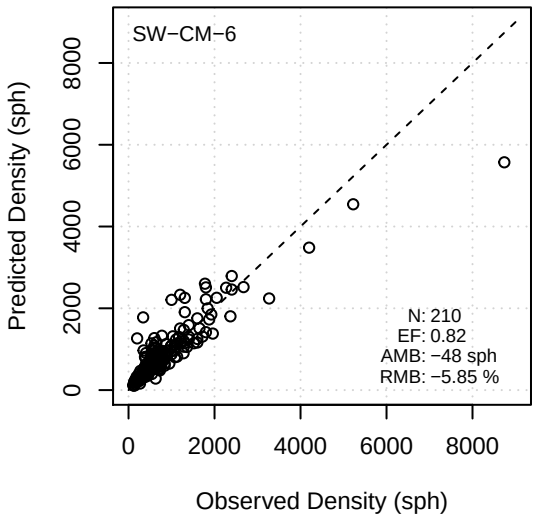

**Conifer Top Height − SW−CM**



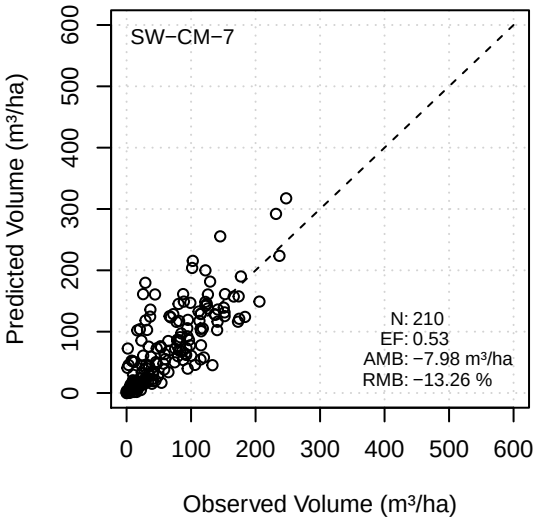

**Conifer Mean DBH − SW−CM**



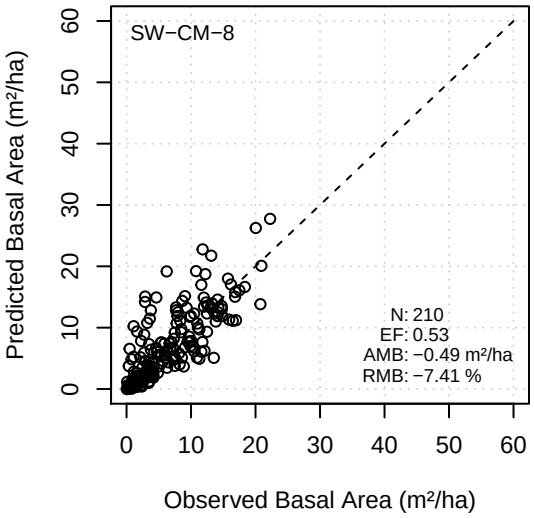

**Conifer Density − SW−CM**



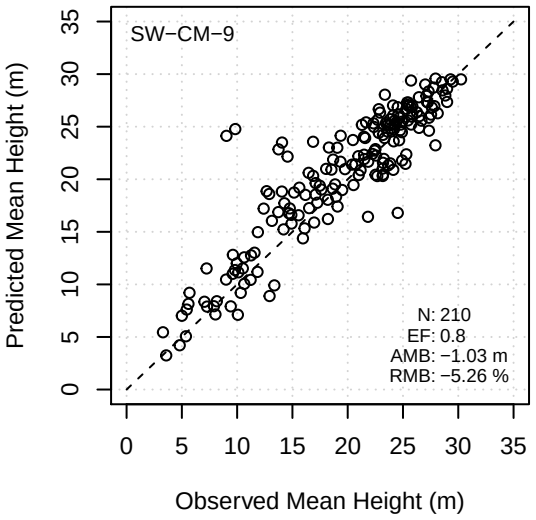
**Deciduous Volume − SW−CM**



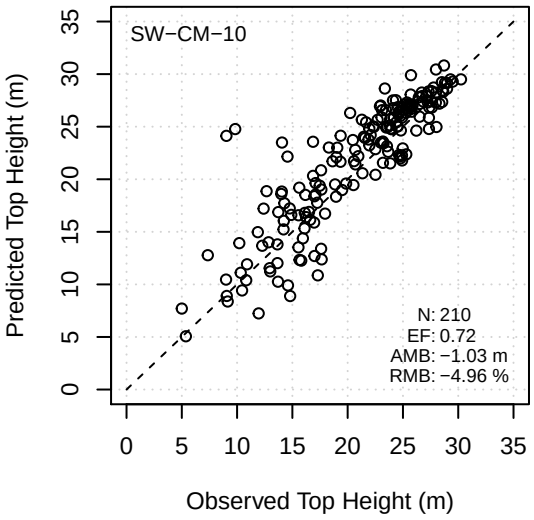

**Deciduous Basal Area − SW−CM**



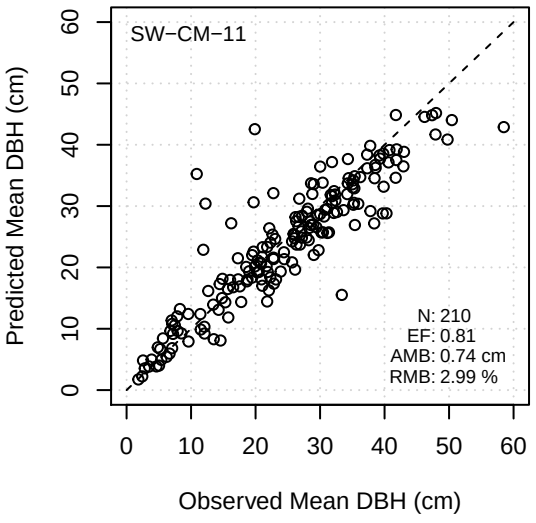

**Deciduous Mean Height − SW−CM**



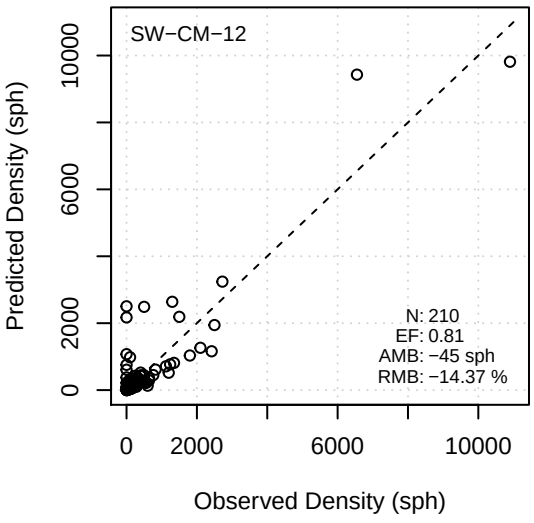

**Deciduous Top Height − SW−CM**



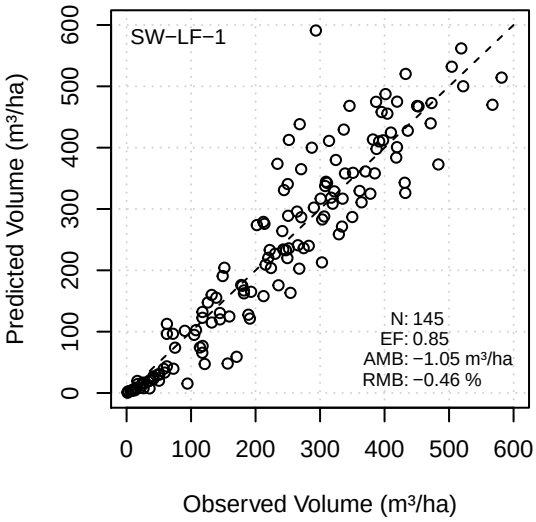

**Deciduous Mean DBH − SW−CM**



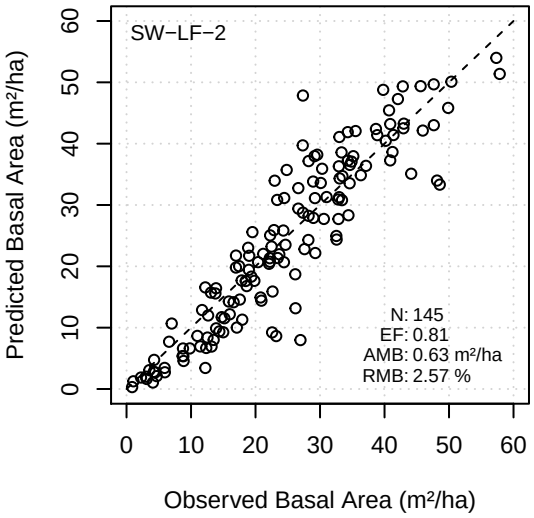

**Deciduous Density − SW−CM**



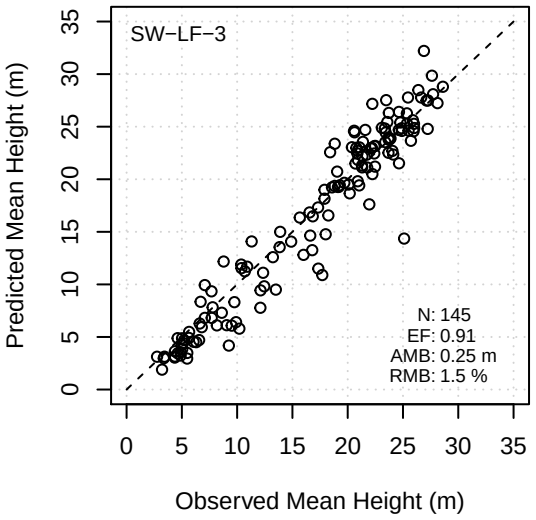
**Conifer Volume − SW−LF**



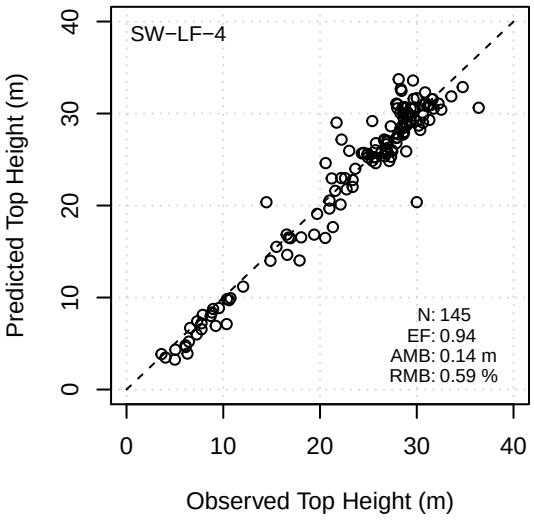

**Conifer Basal Area − SW−LF**



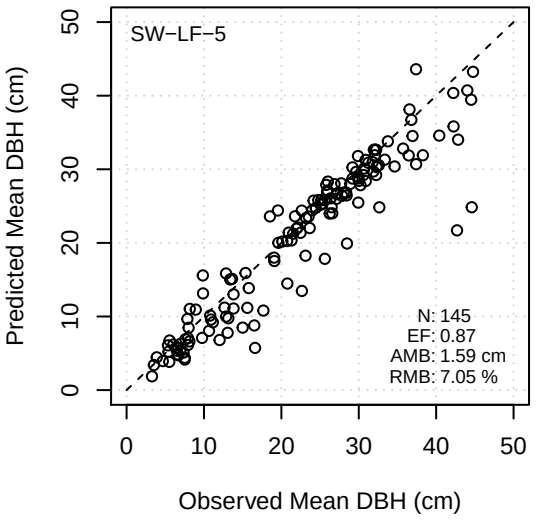

**Conifer Mean Height − SW−LF**



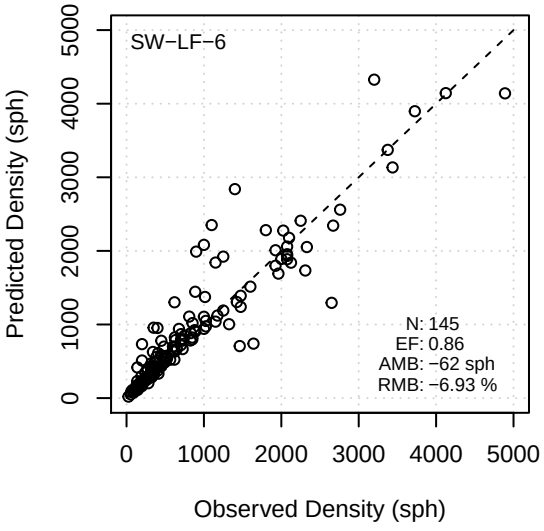

**Conifer Top Height − SW−LF**



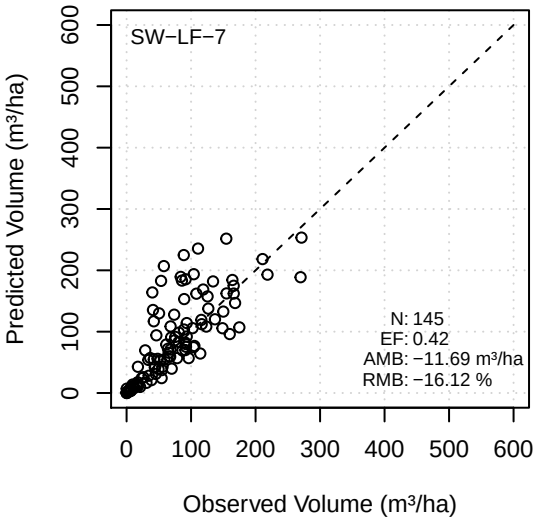

**Conifer Mean DBH − SW−LF**



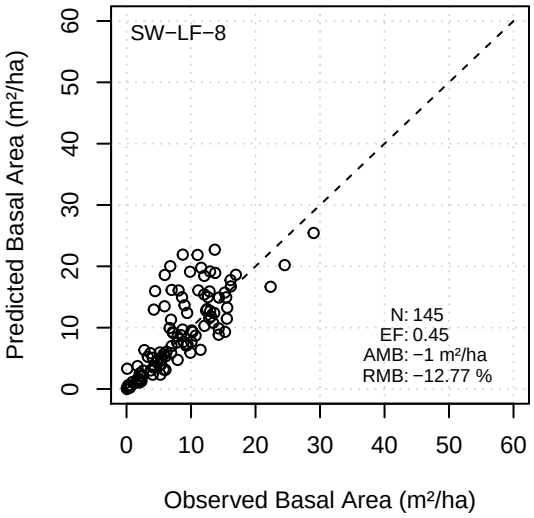

**Conifer Density − SW−LF**



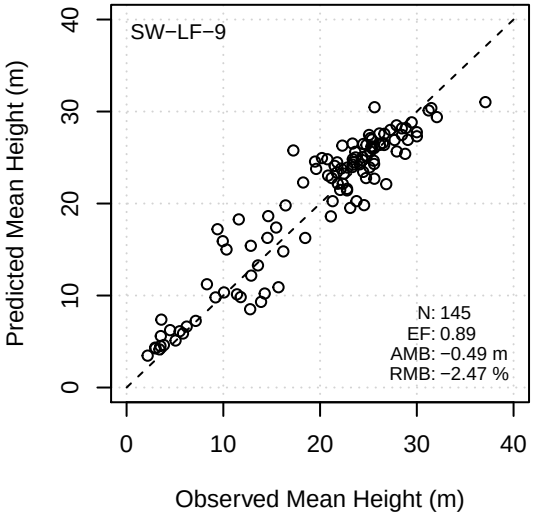
**Deciduous Volume − SW−LF**



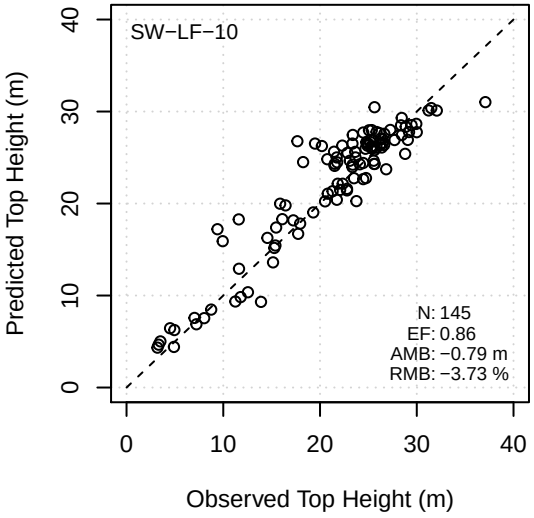

**Deciduous Basal Area − SW−LF**



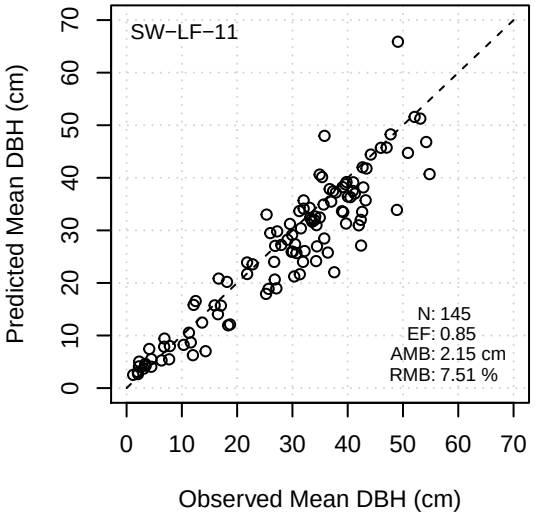

**Deciduous Mean Height − SW−LF**



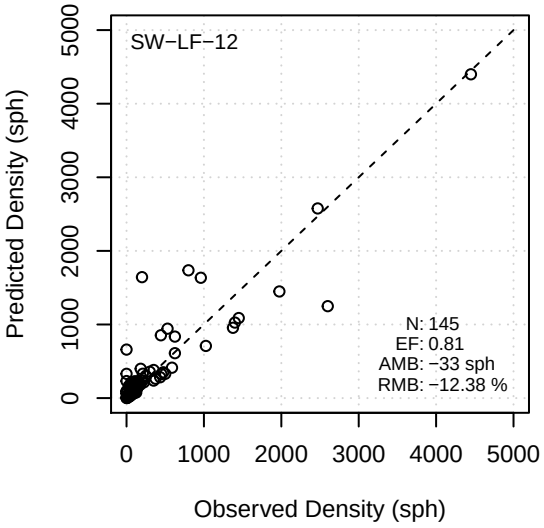

**Deciduous Top Height − SW−LF**



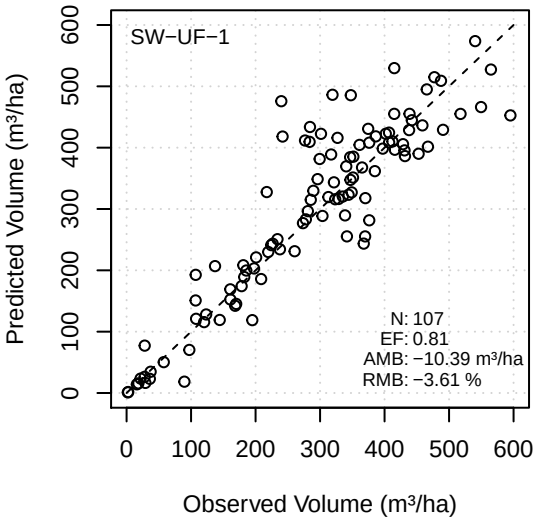

**Deciduous Mean DBH − SW−LF**



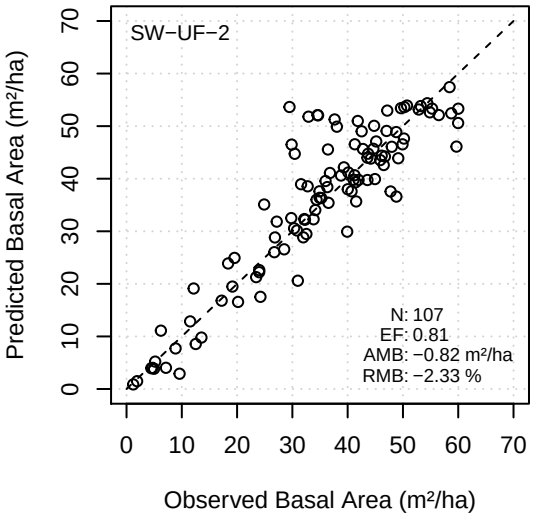

**Deciduous Density − SW−LF**



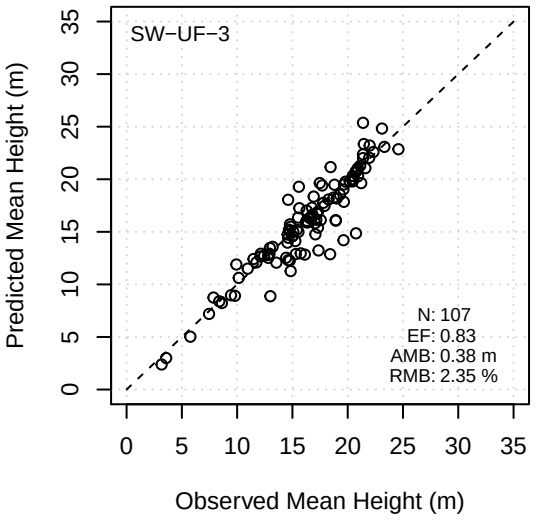
**Conifer Volume − SW−UF**



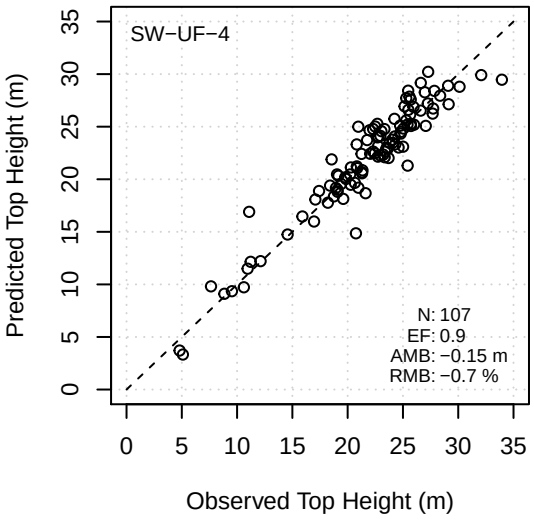

**Conifer Basal Area − SW−UF**



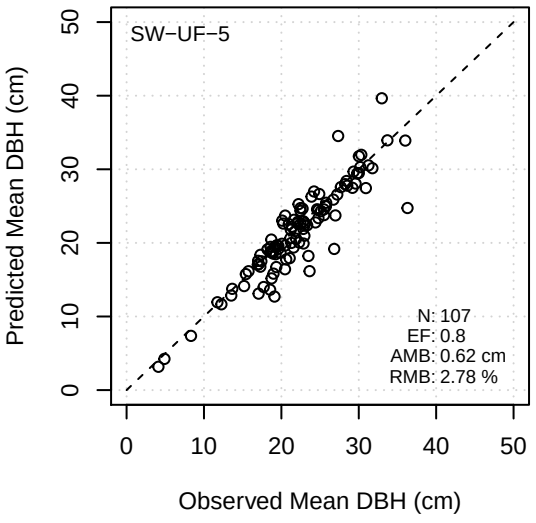

**Conifer Mean Height − SW−UF**



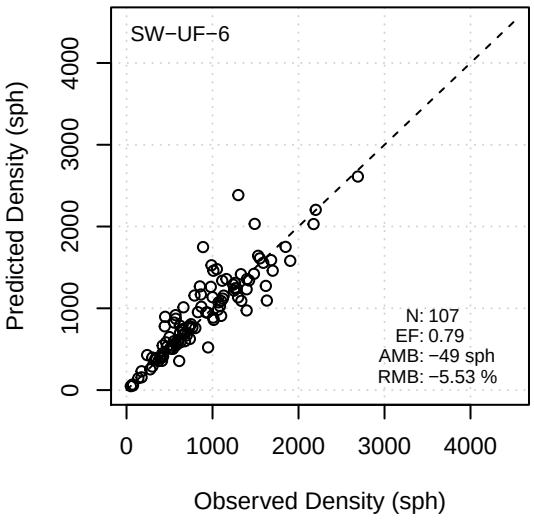

**Conifer Top Height − SW−UF**



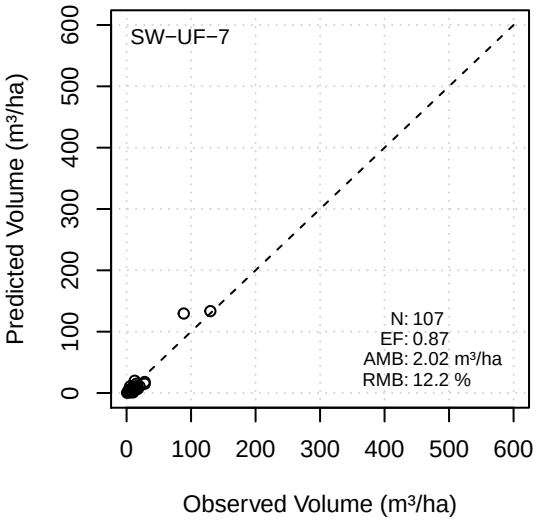

**Conifer Mean DBH − SW−UF**



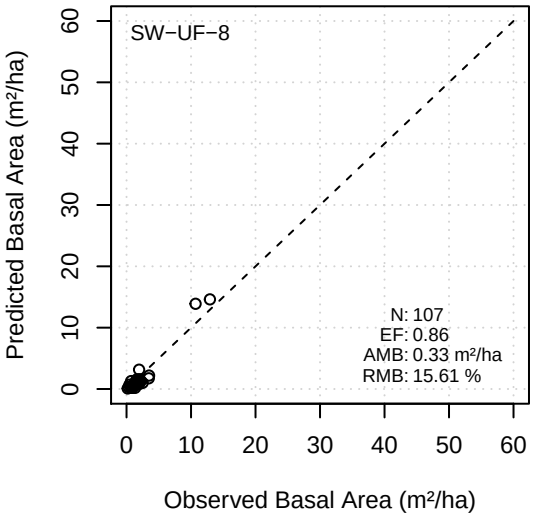

**Conifer Density − SW−UF**



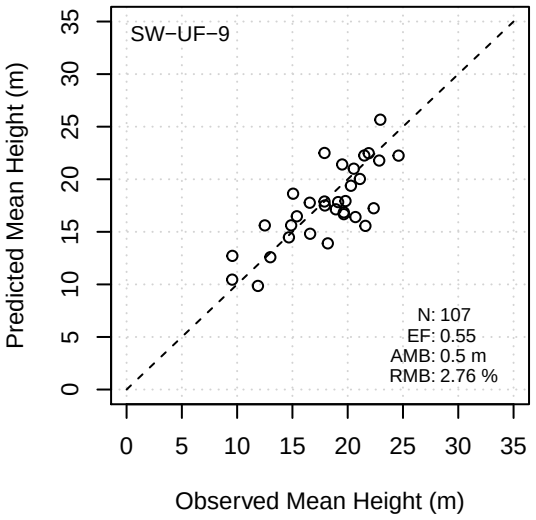
**Deciduous Volume − SW−UF**



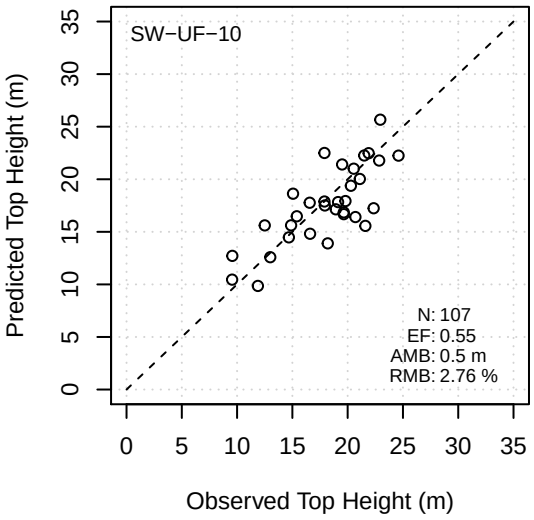

**Deciduous Basal Area − SW−UF**



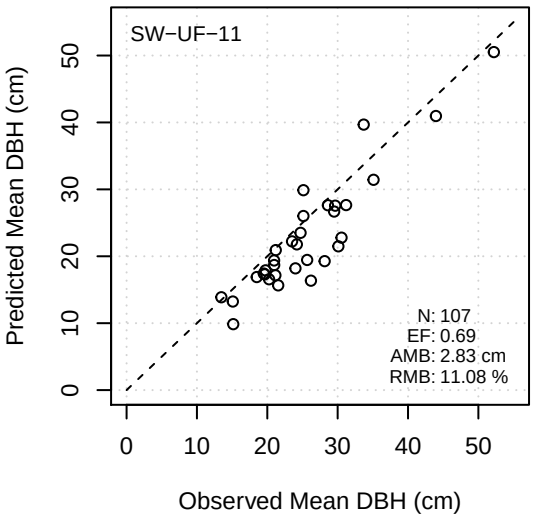

**Deciduous Mean Height − SW−UF**



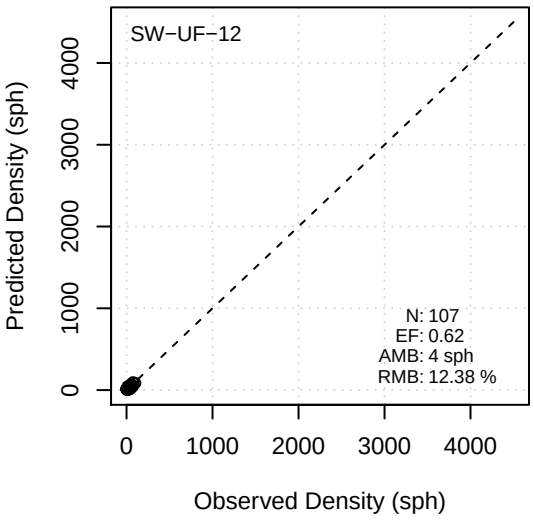

**Deciduous Top Height − SW−UF**




**Deciduous Mean DBH − SW−UF**

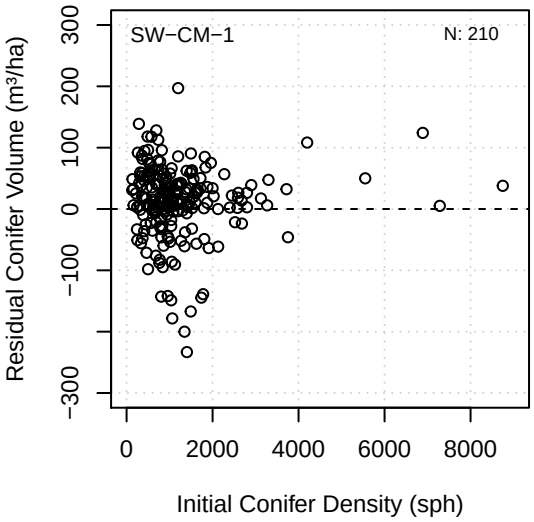



**Deciduous Density − SW−UF**

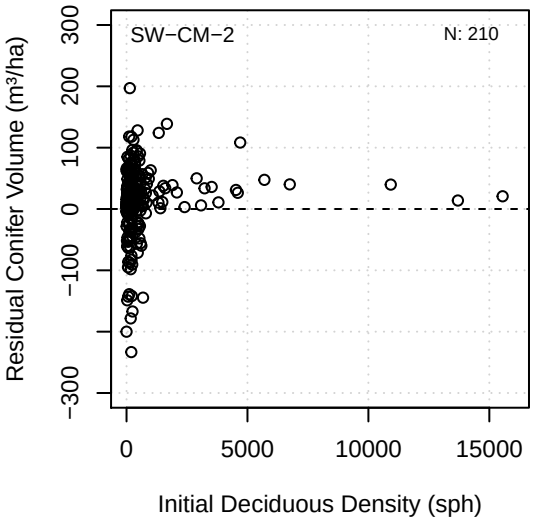


**Appendix D.** Plots of residuals (difference between actual and predicted) for conifer and deciduous volume against 12 variables: Initial conifer and deciduous density, initial conifer and deciduous volume, predicted conifer and deciduous volume, initial conifer and deciduous DBH, initial stand age, projection length, CMI, and site index for white spruce dominated stands in each of 3 major Natural Subregions (CM=Central Mixedwoods, LF=Lower Foothills, UF=Upper Foothills).

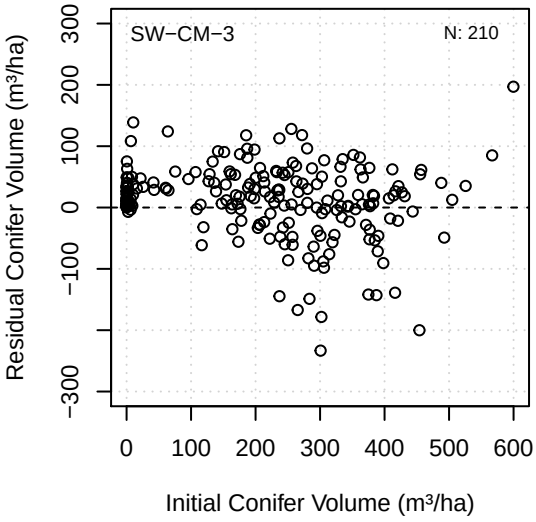
**ConResVol−Initial Conifer Density−SW−CM**



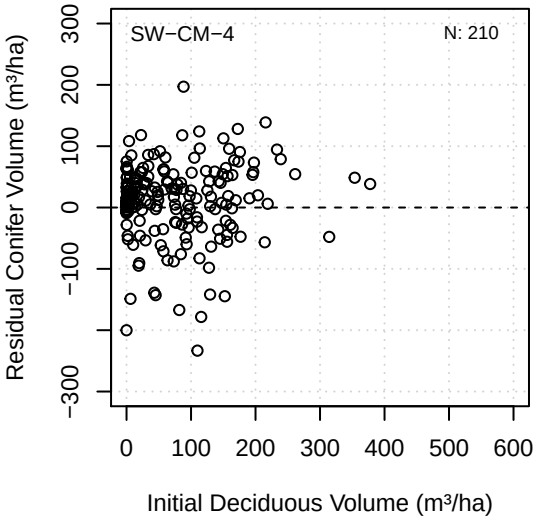

**ConResVol−Initial Deciduous Density−SW−CM**



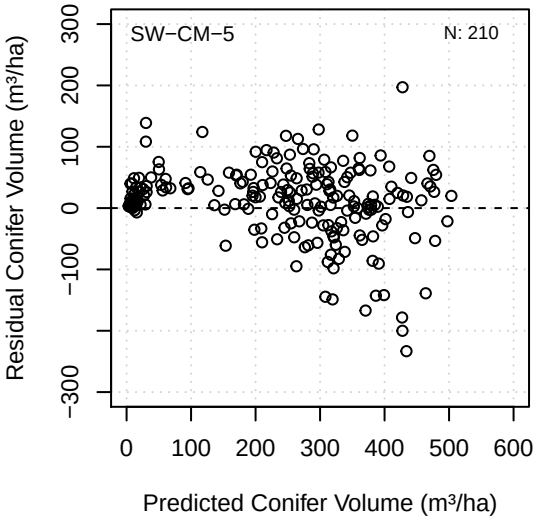

**ConResVol−Initial Conifer Volume−SW−CM**



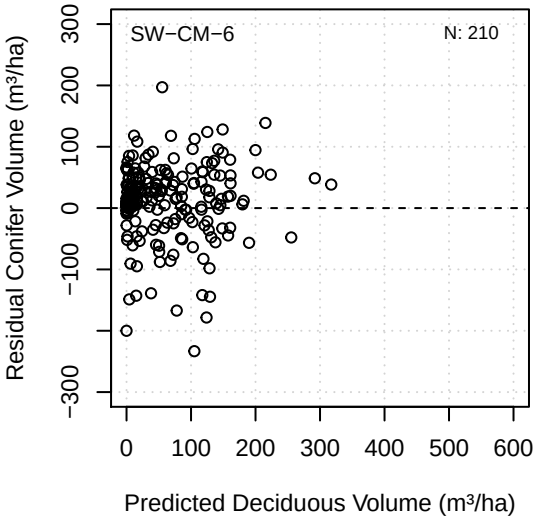

**ConResVol−Initial Deciduous Volume−SW−CM**



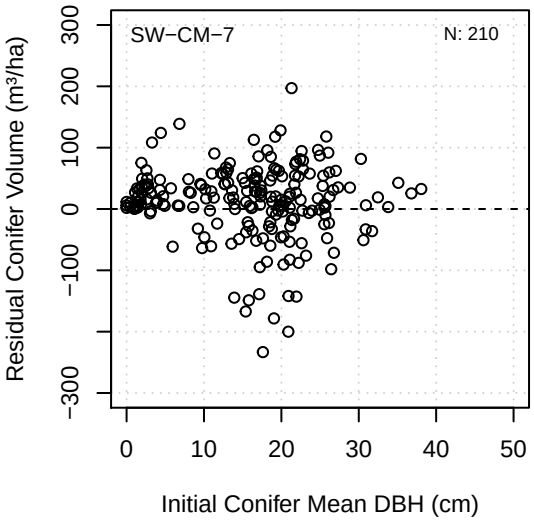

**ConResVol−Predicted Conifer Volume−SW−CM**



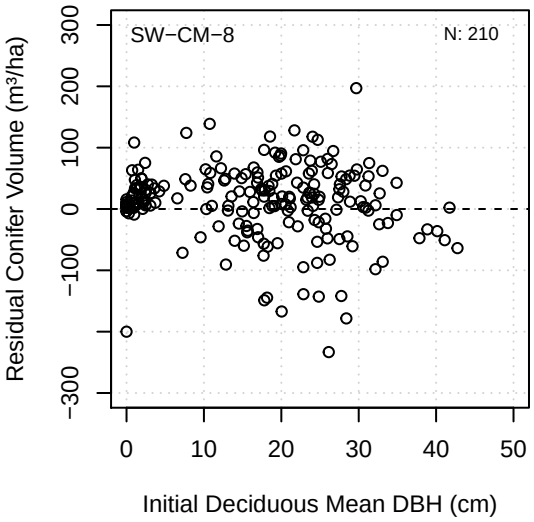

**ConResVol−Predicted Deciduous Volume−SW−CM**



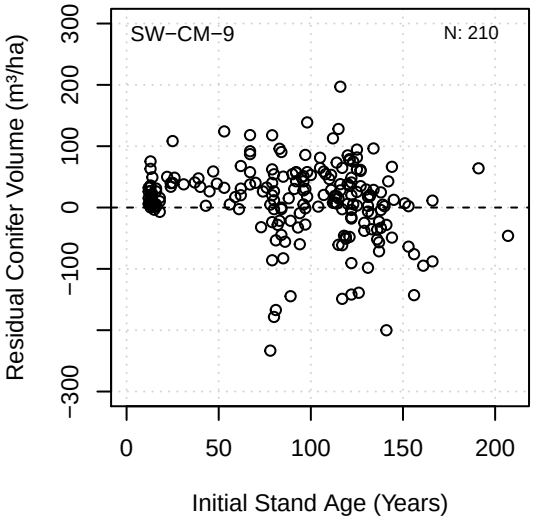
**ConResVol−Initial Conifer Mean DBH−SW−CM**



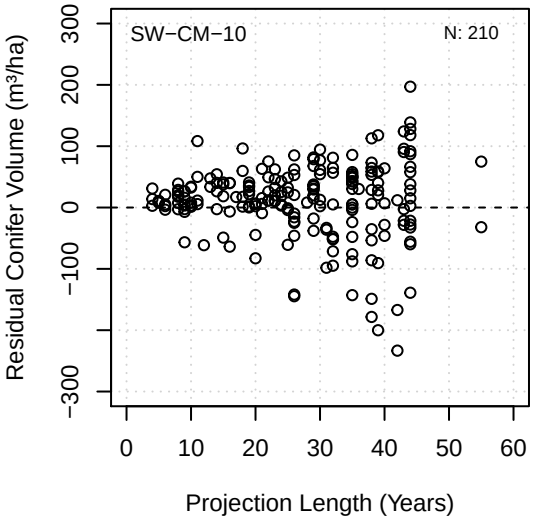

**ConResVol−Initial Deciduous Mean DBH−SW−CM**



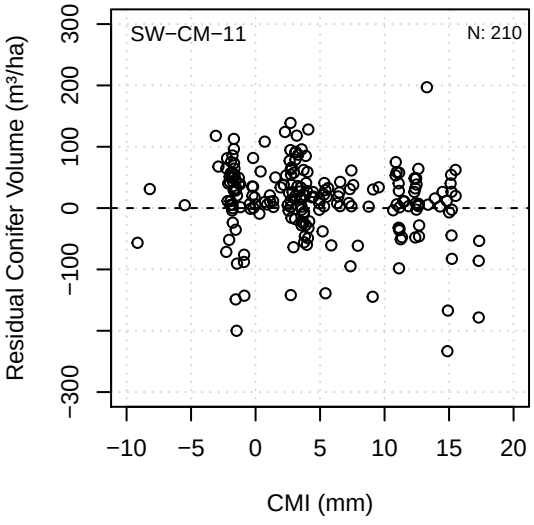

**ConResVol−Initial Stand Age−SW−CM**



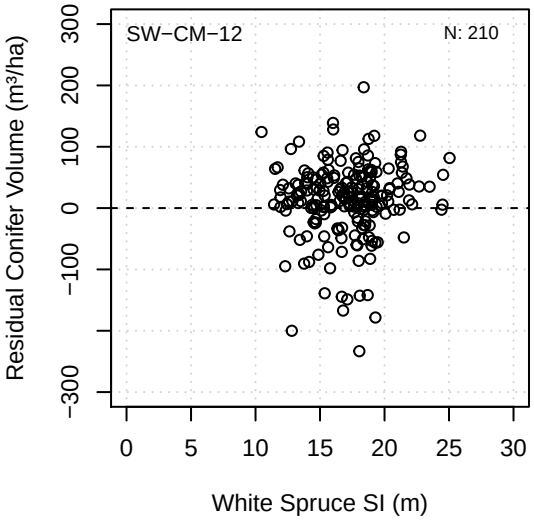

**ConResVol−Projection Length−SW−CM**



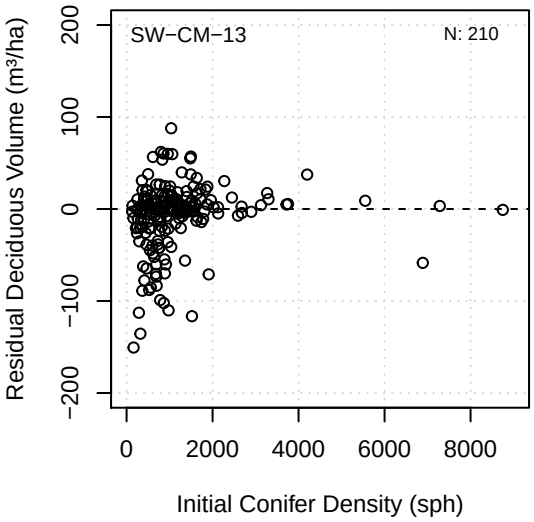

**ConResVol−CMI−SW−CM**



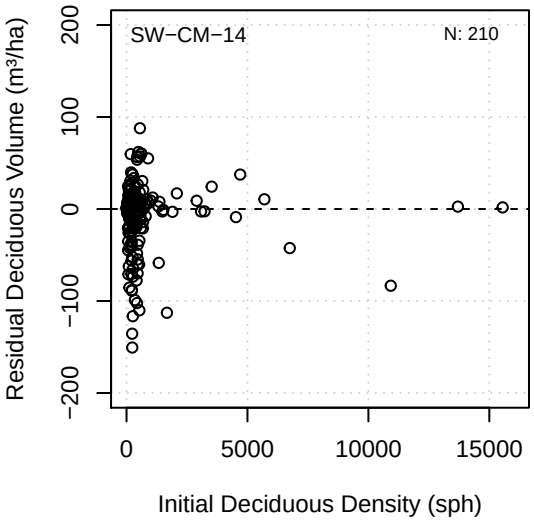

**ConResVol−White Spruce SI−SW−CM**



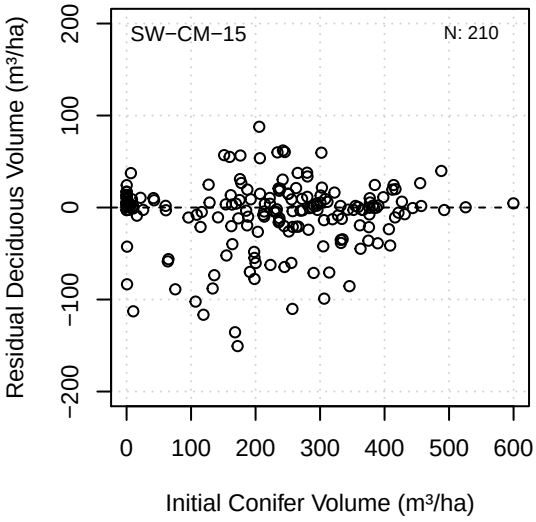
**DecResVol−Initial Conifer Density−SW−CM**



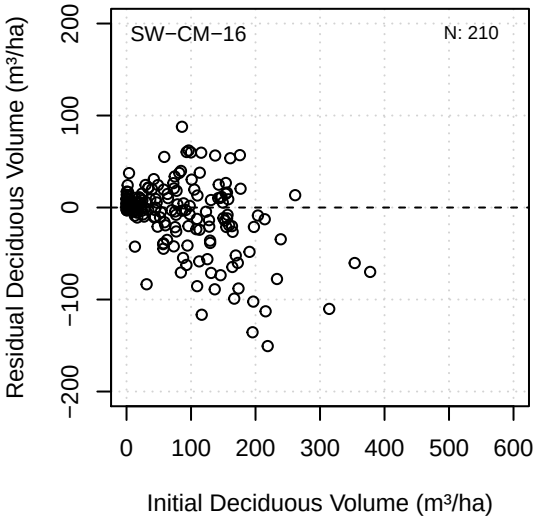

**DecResVol−Initial Deciduous Density−SW−CM**



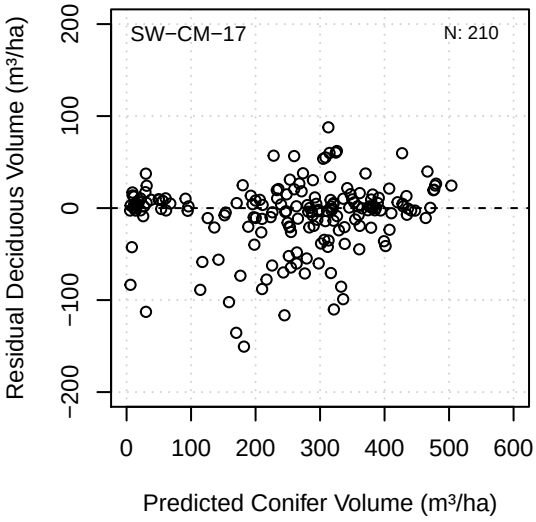

**DecResVol−Initial Conifer Volume−SW−CM**



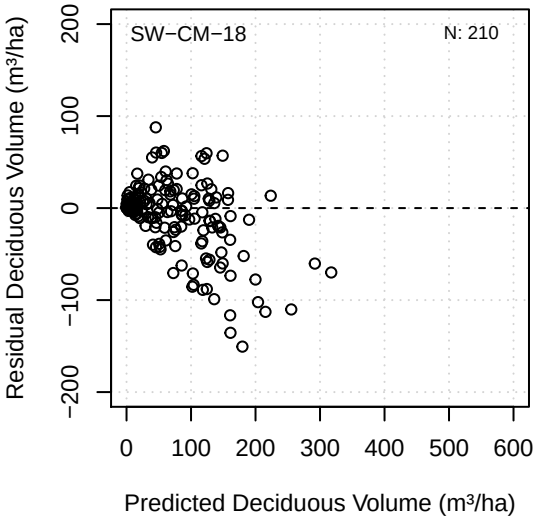

**DecResVol−Initial Deciduous Volume−SW−CM**



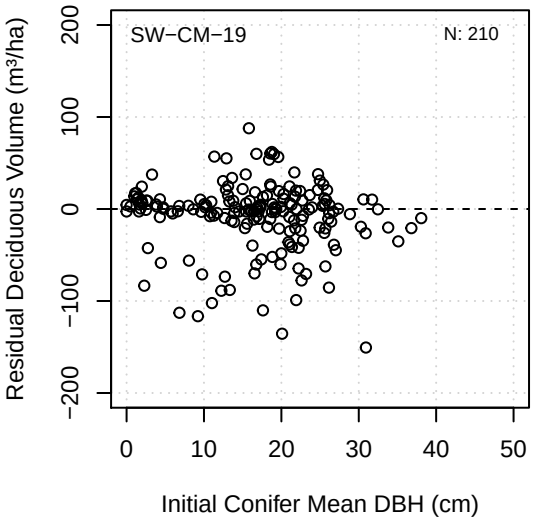

**DecResVol−Predicted Conifer Volume−SW−CM**



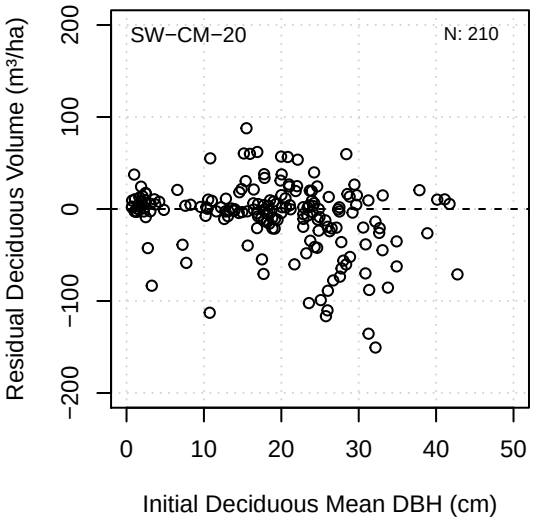

**DecResVol−Predicted Deciduous Volume−SW−CM**



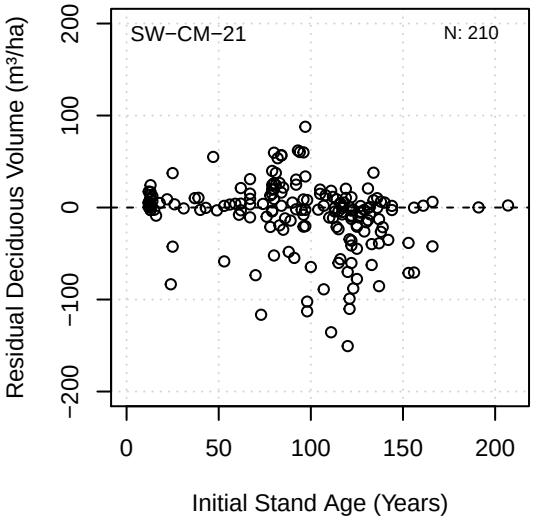
**DecResVol−Initial Conifer Mean DBH−SW−CM**



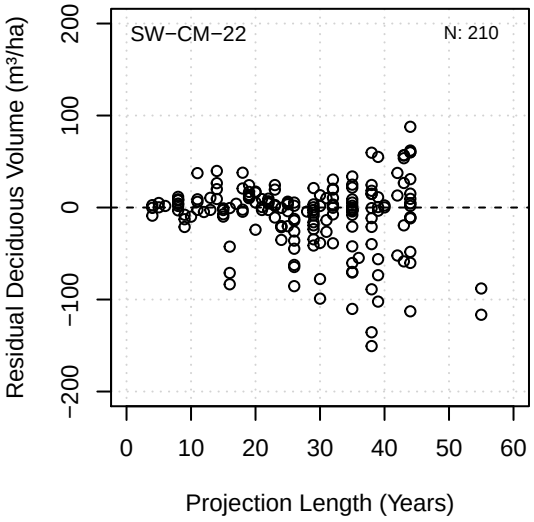

**DecResVol−Initial Deciduous Mean DBH−SW−CM**



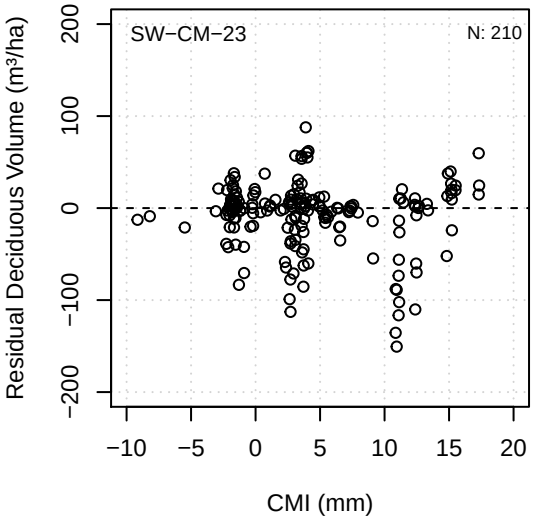

**DecResVol−Initial Stand Age−SW−CM**



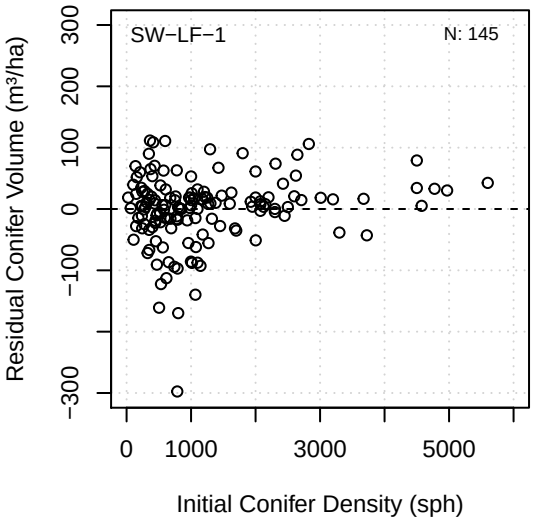

**DecResVol−Projection Length−SW−CM**



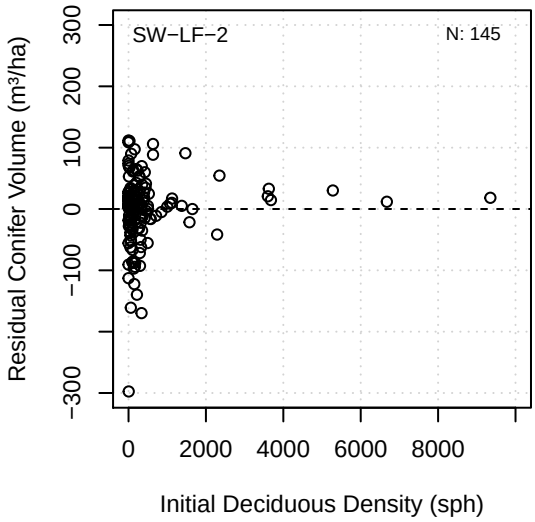

**DecResVol−CMI−SW−CM**



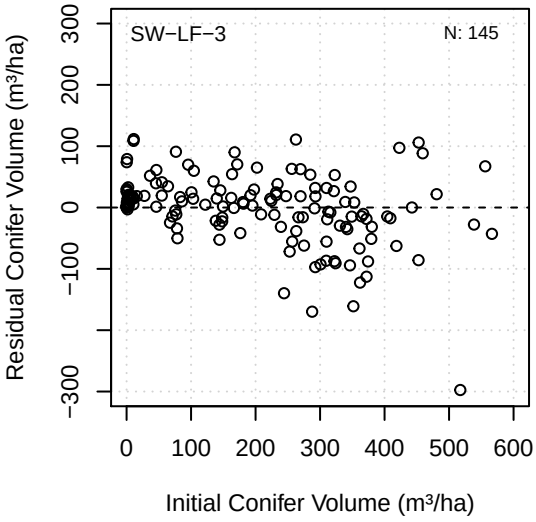
**ConResVol−Initial Conifer Density−SW−LF**



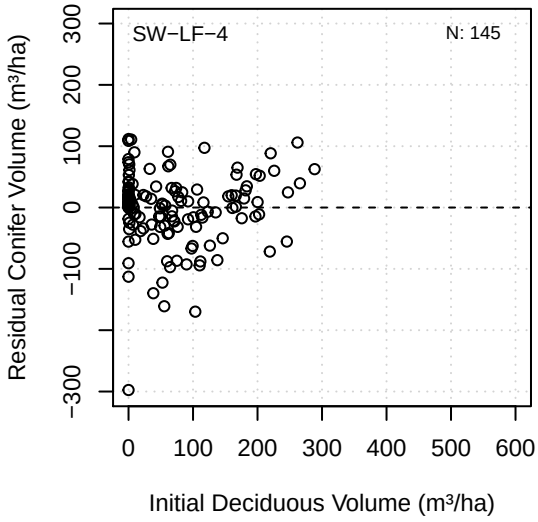

**ConResVol−Initial Deciduous Density−SW−LF**



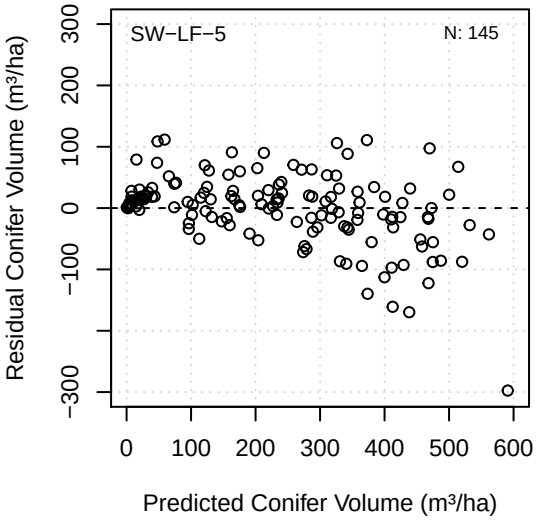

**ConResVol−Initial Conifer Volume−SW−LF**



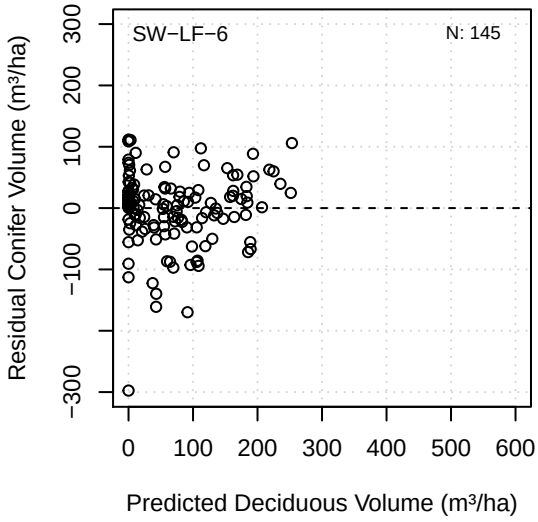

**ConResVol−Initial Deciduous Volume−SW−LF**



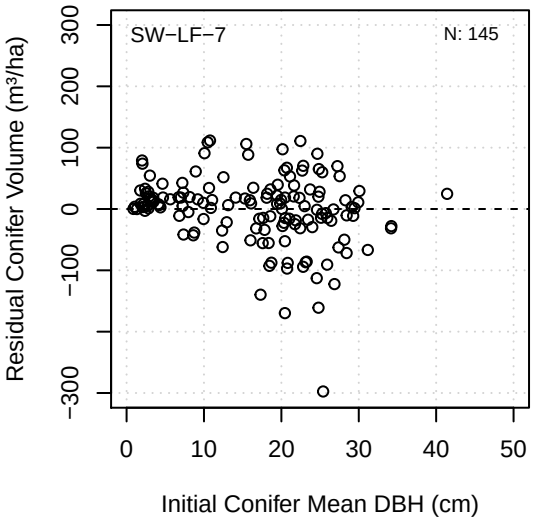

**ConResVol−Predicted Conifer Volume−SW−LF**



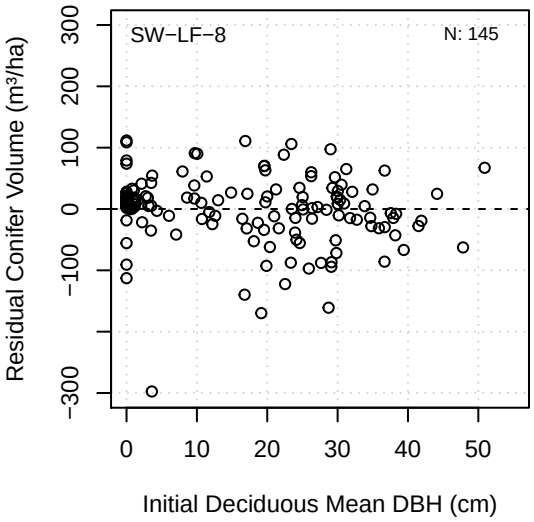

**ConResVol−Predicted Deciduous Volume−SW−LF**



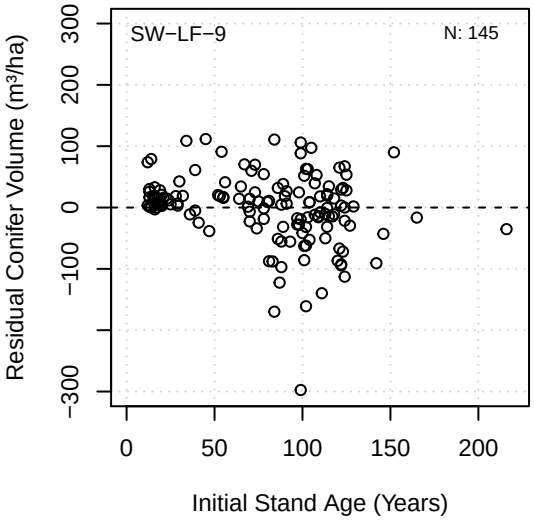
**ConResVol−Initial Conifer Mean DBH−SW−LF**



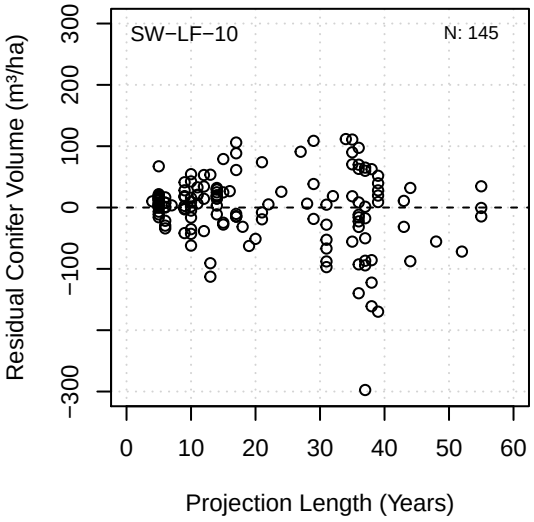

**ConResVol−Initial Deciduous Mean DBH−SW−LF**



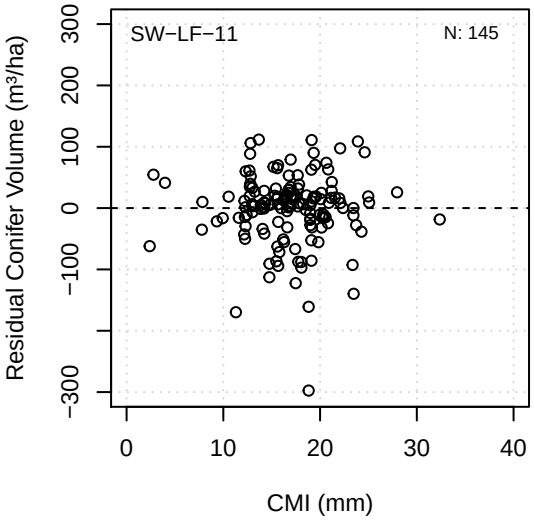

**ConResVol−Initial Stand Age−SW−LF**



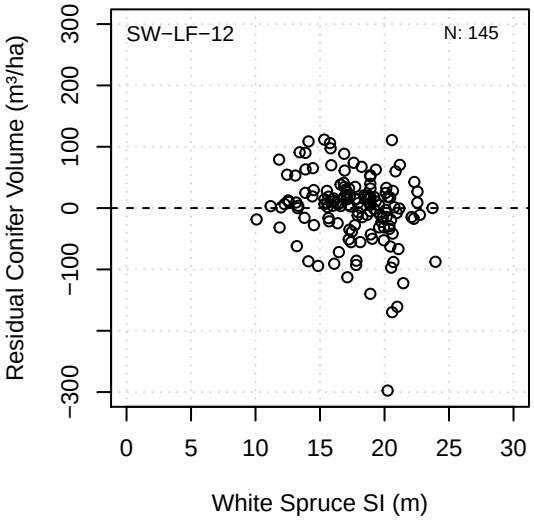

**ConResVol−Projection Length−SW−LF**



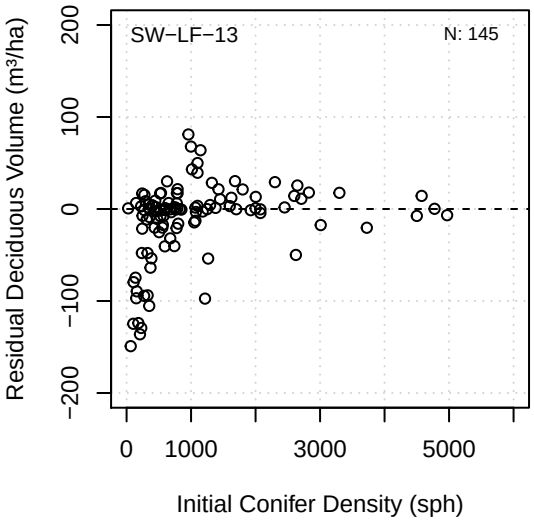

**ConResVol−CMI−SW−LF**



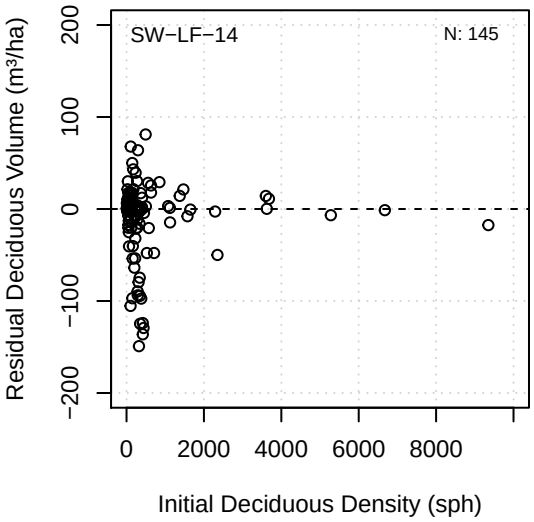

**ConResVol−White Spruce SI−SW−LF**



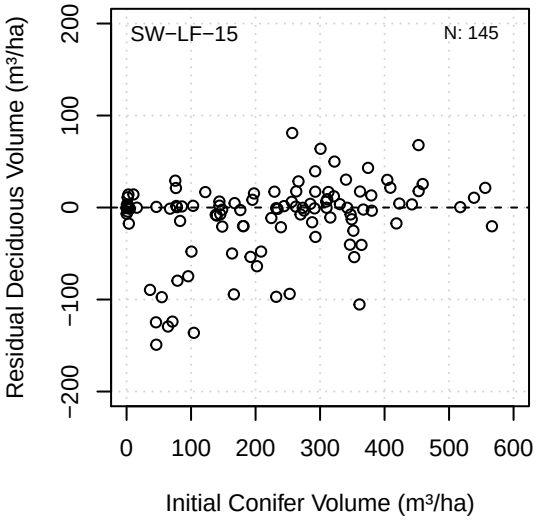
**DecResVol−Initial Conifer Density−SW−LF**



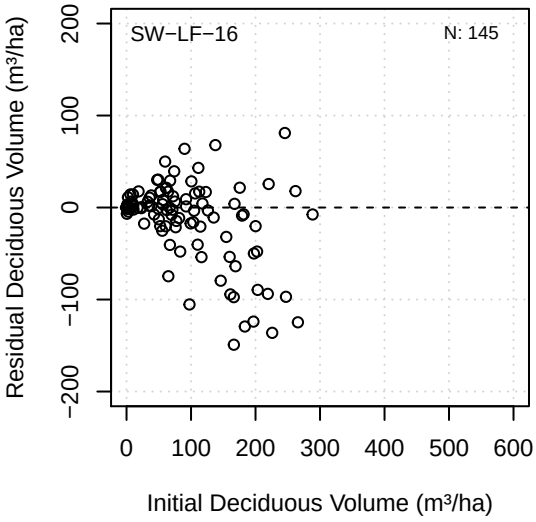

**DecResVol−Initial Deciduous Density−SW−LF**



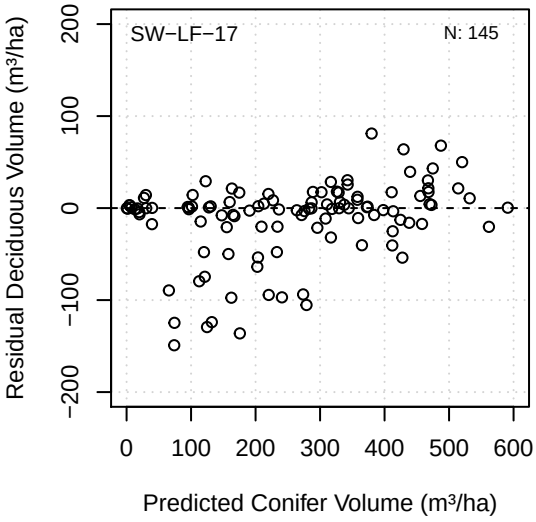

**DecResVol−Initial Conifer Volume−SW−LF**



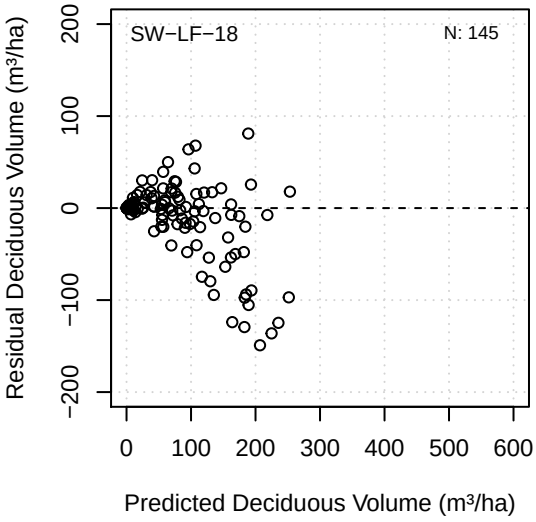

**DecResVol−Initial Deciduous Volume−SW−LF**



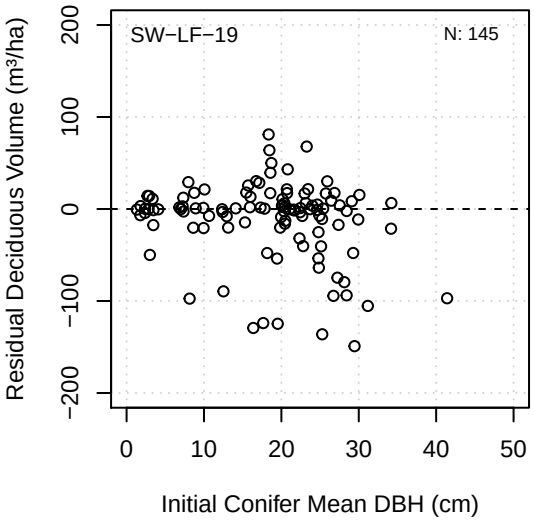

**DecResVol−Predicted Conifer Volume−SW−LF**



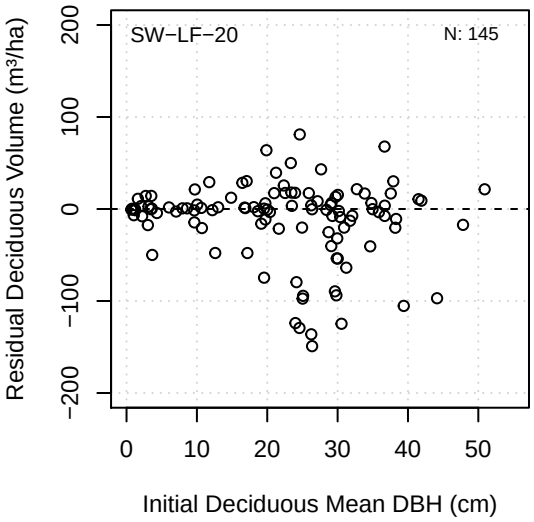

**DecResVol−Predicted Deciduous Volume−SW−LF**



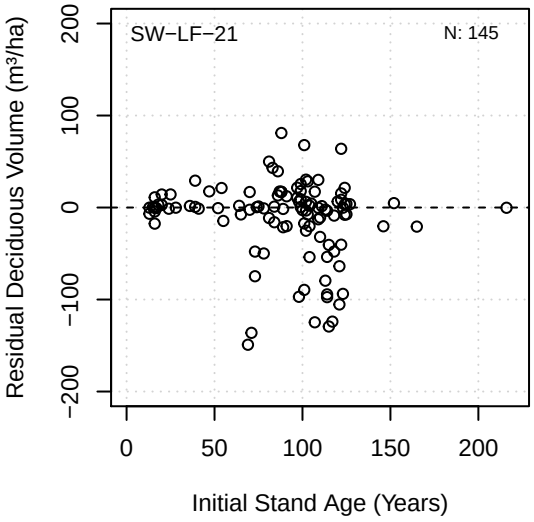
**DecResVol−Initial Conifer Mean DBH−SW−LF**



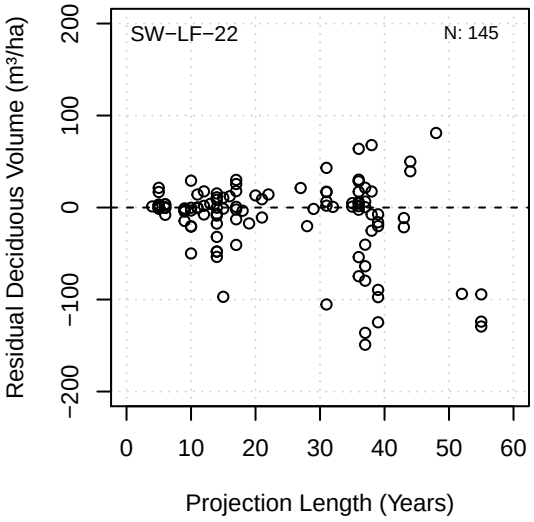

**DecResVol−Initial Deciduous Mean DBH−SW−LF**



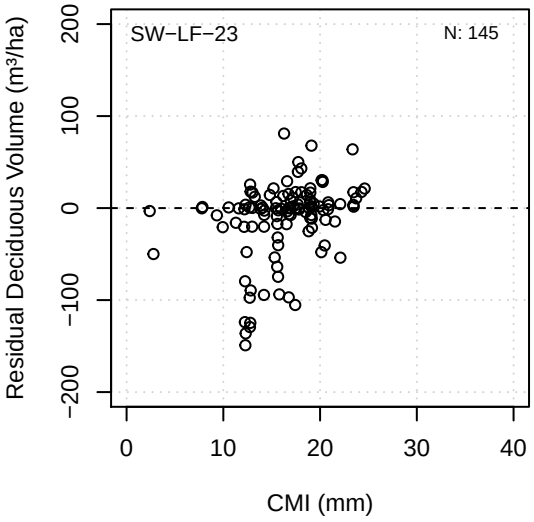

**DecResVol−Initial Stand Age−SW−LF**



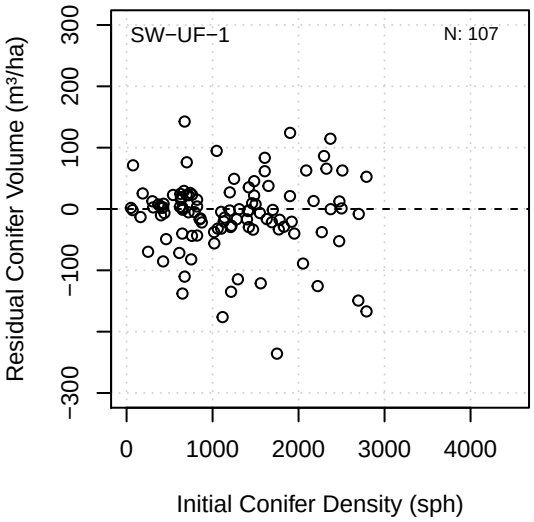

**DecResVol−Projection Length−SW−LF**



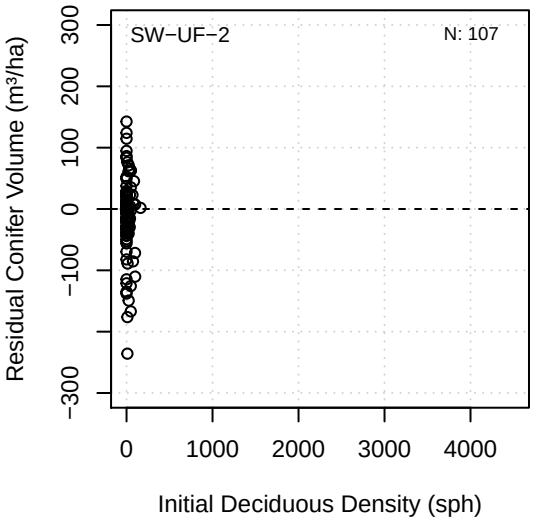

**DecResVol−CMI−SW−LF**



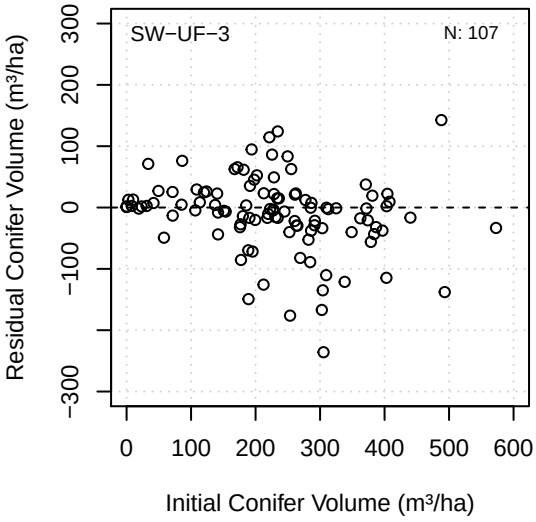
**ConResVol−Initial Conifer Density−SW−UF**



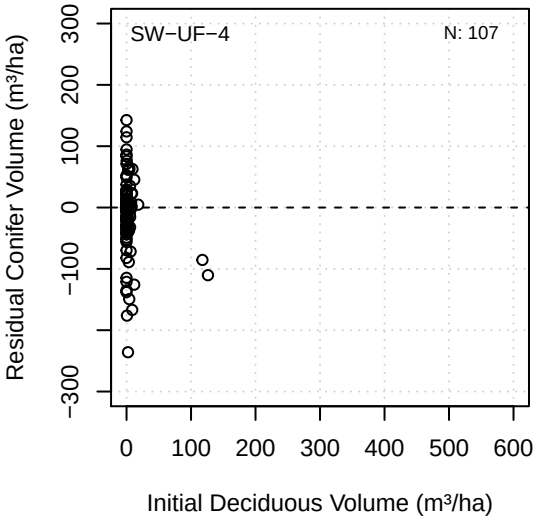

**ConResVol−Initial Deciduous Density−SW−UF**



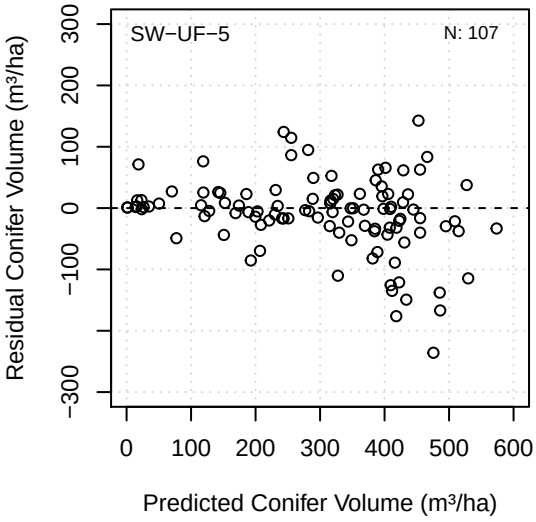

**ConResVol−Initial Conifer Volume−SW−UF**



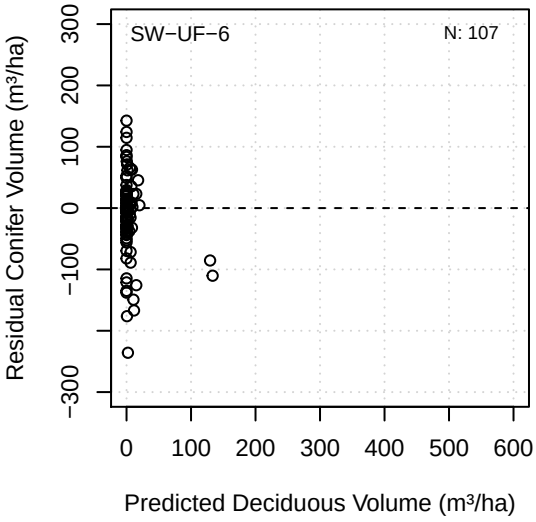

**ConResVol−Initial Deciduous Volume−SW−UF**



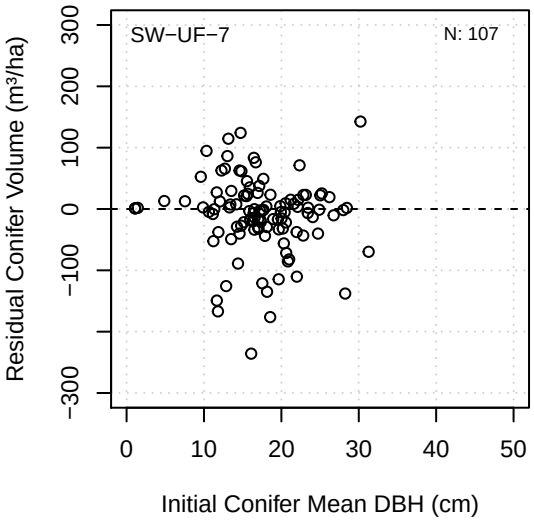

**ConResVol−Predicted Conifer Volume−SW−UF**



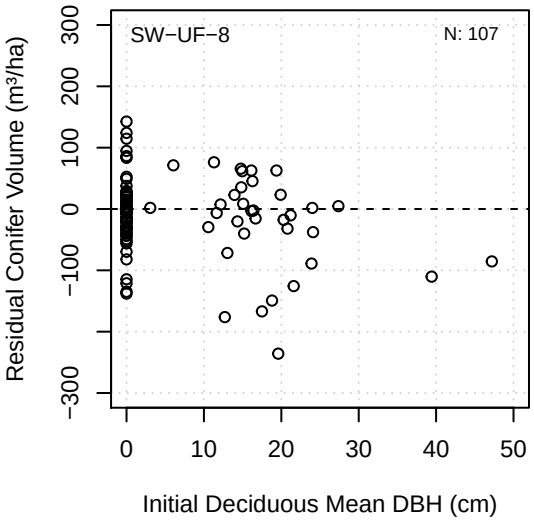

**ConResVol−Predicted Deciduous Volume−SW−UF**



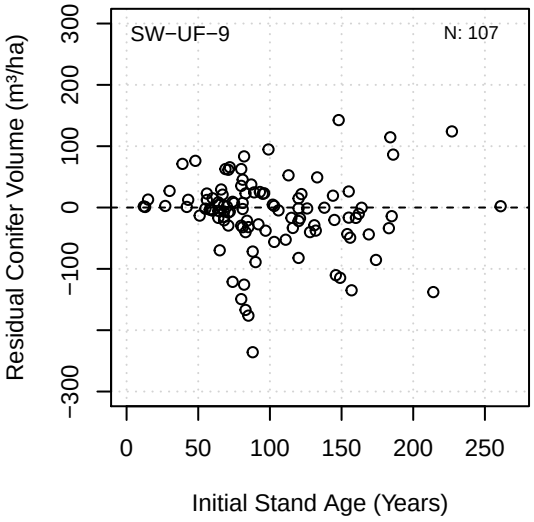
**ConResVol−Initial Conifer Mean DBH−SW−UF**



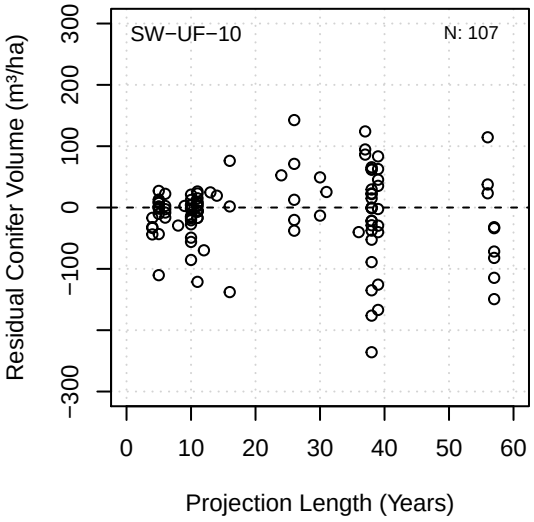

**ConResVol−Initial Deciduous Mean DBH−SW−UF**



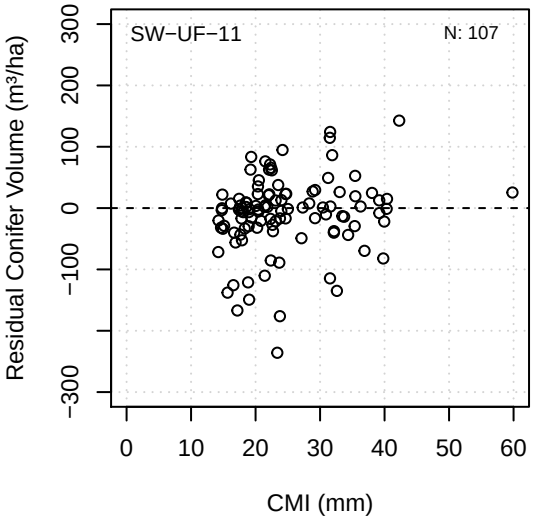

**ConResVol−Initial Stand Age−SW−UF**



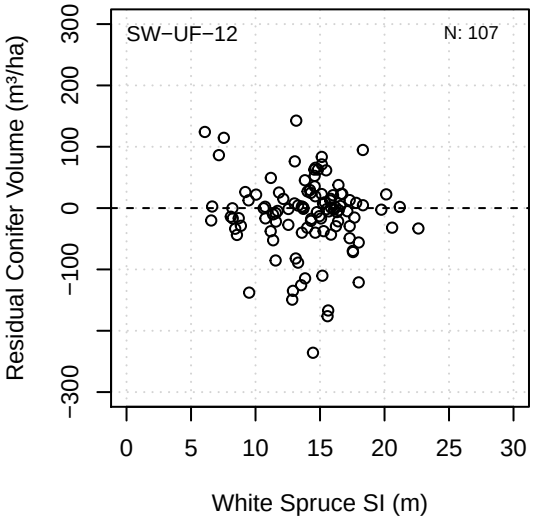

**ConResVol−Projection Length−SW−UF**



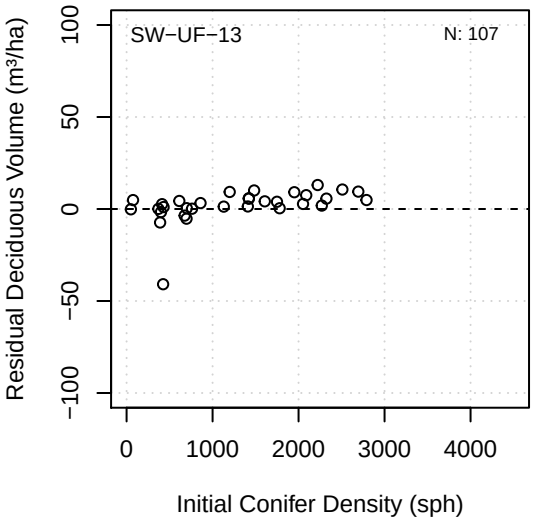

**ConResVol−CMI−SW−UF**



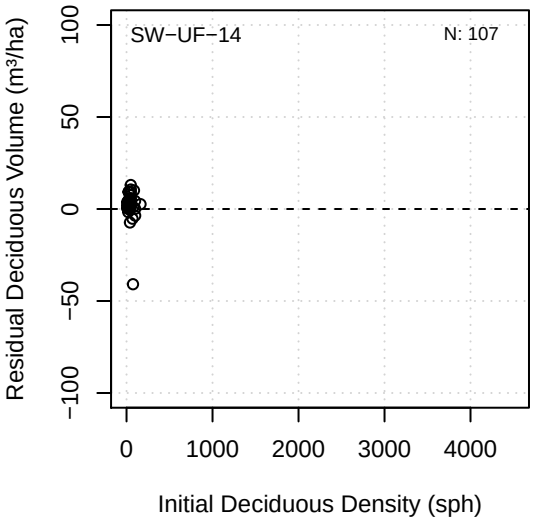

**ConResVol−White Spruce SI−SW−UF**



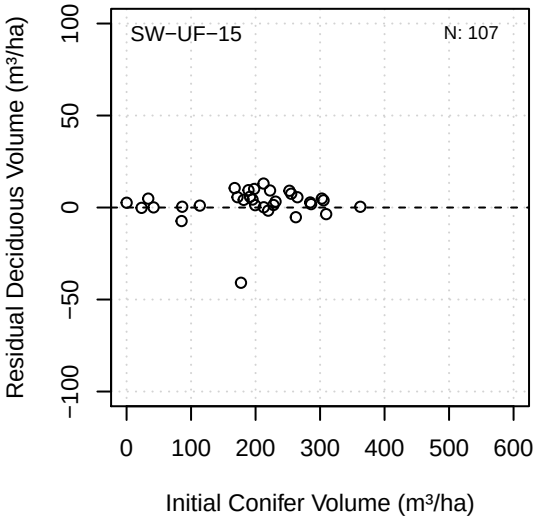
**DecResVol−Initial Conifer Density−SW−UF**



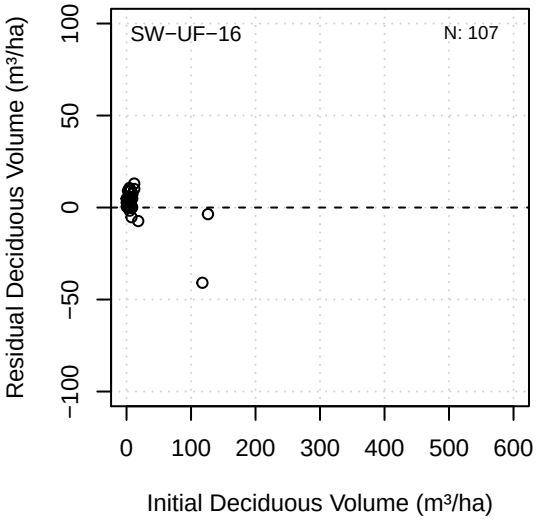

**DecResVol−Initial Deciduous Density−SW−UF**



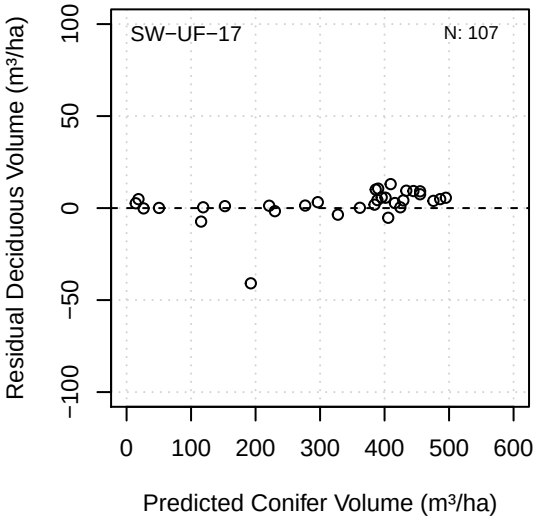

**DecResVol−Initial Conifer Volume−SW−UF**



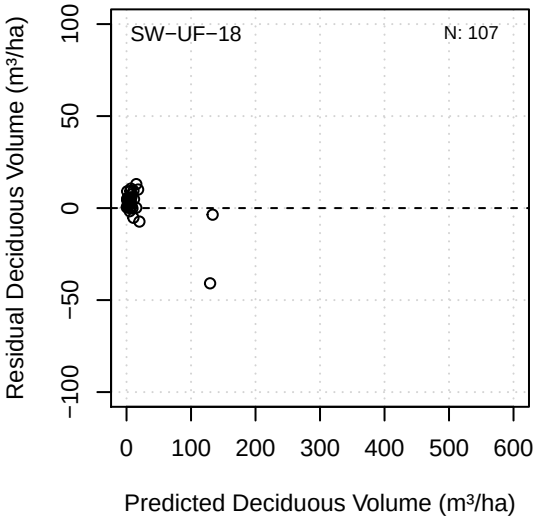

**DecResVol−Initial Deciduous Volume−SW−UF**



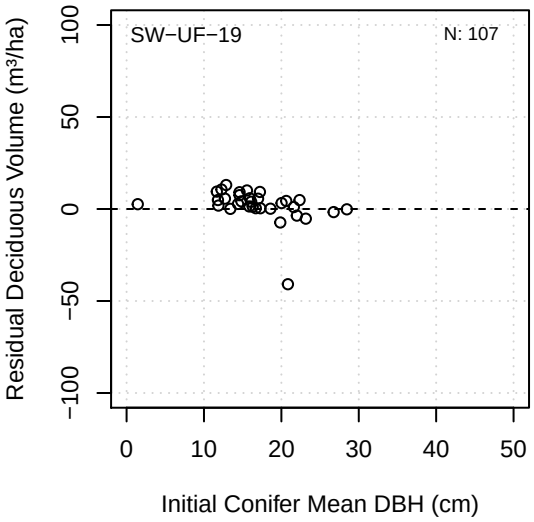

**DecResVol−Predicted Conifer Volume−SW−UF**



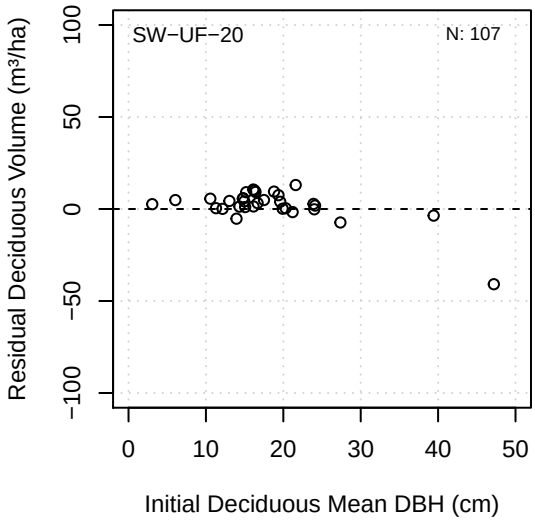

**DecResVol−Predicted Deciduous Volume−SW−UF**



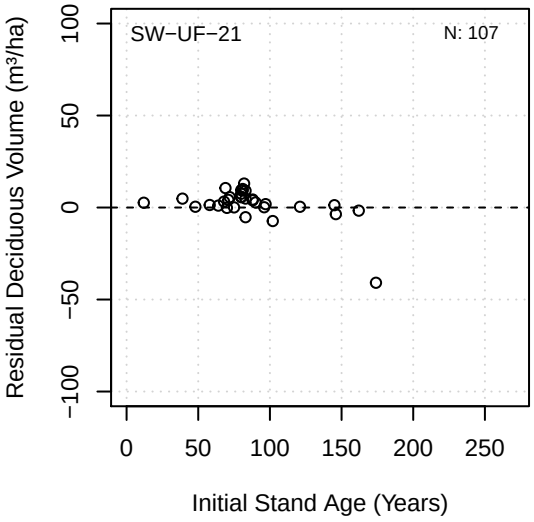
**DecResVol−Initial Conifer Mean DBH−SW−UF**



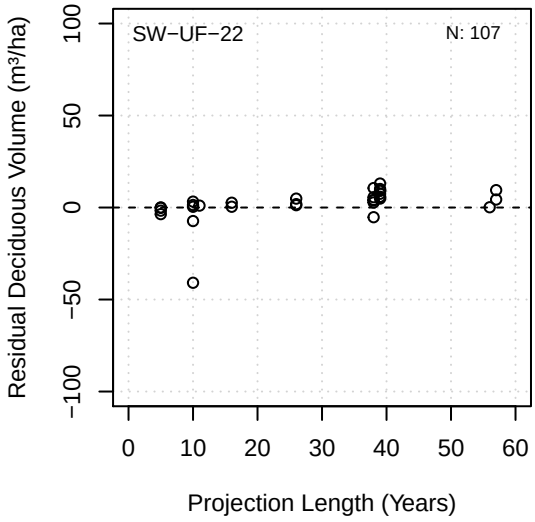

**DecResVol−Initial Deciduous Mean DBH−SW−UF**




**DecResVol−Initial Stand Age−SW−UF**




**DecResVol−Projection Length−SW−UF**




**DecResVol−CMI−SW−UF**