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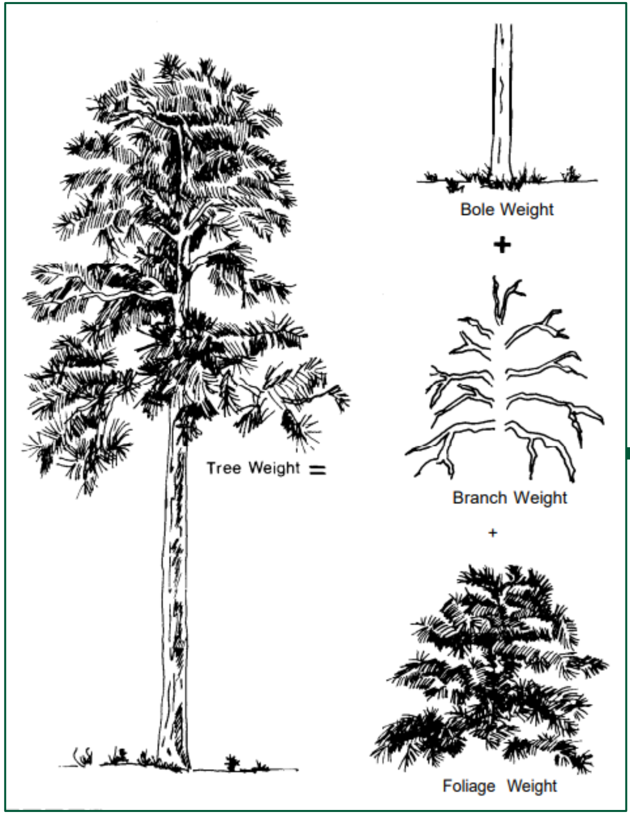

Application of the National Scale Volume and Biomass Estimators Framework

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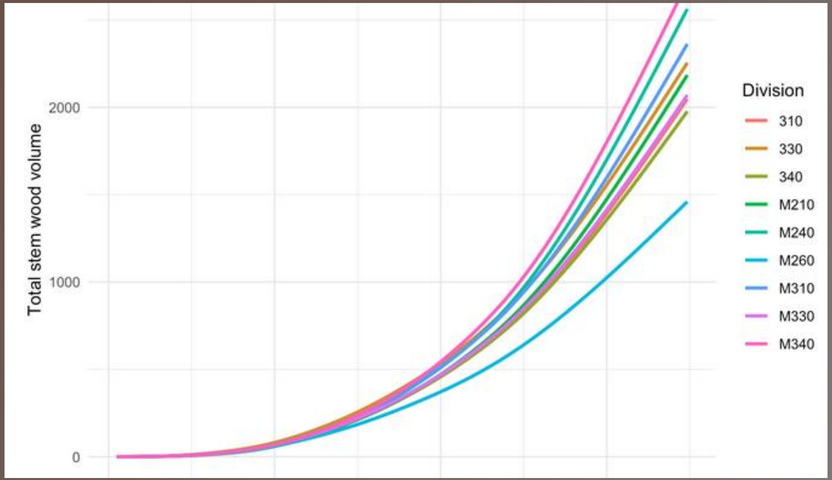


```
# outside bark volume
data$VTOTOB_GROSS <- data$VTOTIB_GROSS + data$VTOTBK_GROSS

# merch height
cat("finding merchantable height\n")
ht4 <- lapply(levels, applyAllLevels,
              data= data,
              coefs= list(all_coefs[["rcumob"]],
                          all_coefs[["volob"]]),
              lhs= 'HT4')

ht4 <- Reduce(combineLevels2, ht4)
```

Overview

- Introduction
- Overview of NSVB steps
- In-depth example

National Scale Volume and Biomass Framework

- Volume/biomass models applied at SPCD by DIVISION or SPCD level
    - 89% of volume
    - 72% of biomass
    - DIA and HT

- Remaining species use Jenkins Group level models
    - 9 groups (5 SW, 4 HW)
    - DIA, HT, and WDSG

NSVB Inputs

Observed and derived variables used in NSVB

- **ALL TREES**
  - –DIA
  - –HT
  - –SPCD
  - –ECOSUBCD
  - –STDORGCD (111/131 only)
- **DEFECT ADJUSTMENTS**
  - –CULL
  - –ACTUALHT
  - –CR
- **STANDING DEAD**
  - –DECAYCD
- **DERIVED VARIABLES**
  - –REF_SPECIES.JENKINS_SPGRPCD
  - –REF_SPECIES.WOOD_SPGR_GREENVOL_DRYWT
  - –REF_SPECIES.CARBON_RATIO_LIVE
  - –REF_TREE_DECAY_PROP.DENSITY_PROP
  - –REF_TREE_DECAY_PROP. BARK_LOSS_PROP
  - –REF_TREE_DECAY_PROP. BRANCH_LOSS_PROP
  - –REF_TREE_CARBON_RATIO_DEAD.CARBON_RATIO
  - –REF_STND_DEAD_CR_PROP.CR_MEAN

Equation Forms

1. $y_i = a * D_i^b * H_i^c + \varepsilon_i$ (Schumacher-Hall)

2. $y_i = \begin{cases} a * D_i^b * H_i^c + \varepsilon_i; D_i < k \\ a * k^{(b-b_1)} * D_i^{b_1} * H_i^c + \varepsilon_i; D_i \geq k \end{cases}$ (Segmented)

3. $y_i = a * D_i^{a_1 * \left(1-exp^{(-b*D_i)}\right)^{c_1}} * H_i^c + \varepsilon_i$ (Continuously Variable)

4. $y_i = a * D_i^b * H_i^c * exp^{(-(b_1*D_i))} + \varepsilon_i$ (Modified Wiley)

5. $y_i = a * D_i^b * H_i^c * WDSG_i + \varepsilon_i$ (Modified Schumacher-Hall)

6. $R_i = \left(1 - \left(1 - \frac{h_i}{H_i}\right)^{\alpha}\right)^{\beta} + \varepsilon_i$ (Volume Ratio)

Examples of tree-level calculations – An outline

1. Predict gross total stem wood volume as a function of diameter at breast height (*D*) and total height (*H*)
2. Predict gross total stem bark volume as a function of *D* and *H*
3. Obtain gross total stem volume outside-bark as the sum of wood and bark gross volumes
4. Estimate heights to merchantable (4-in.) top diameter and, if present, sawlog top diameter (9 in. for softwoods ($SPCD < 300$) and 11 in. for hardwoods ($SPCD \geq 300$)). Make adjustments to these values as needed for trees with a broken top
5. Estimate stem component gross volumes (stump, merchantable stem, sawlog (if present), and stem-top) using a cumulative-ratio function

Examples of tree-level calculations – An outline

6. Estimate stem component sound volumes to account for any cull present or dead tree density reductions

7. Convert total stem wood gross volume to biomass weight using published wood density values (Miles and Smith 2009). Reduce stem wood weight due to broken top, cull deductions (accounting for nonzero weight of cull), and dead tree wood density reduction

8. Predict total stem bark biomass as a function of *D* and *H*. Reduce the prediction if necessary for missing bark due to a broken top and/or dead tree structural loss

9. Predict total branch biomass as a function of *D* and *H*. Reduce the prediction if necessary for missing branches due to a broken top and/or dead tree wood density reduction and structural loss

Examples of tree-level calculations – An outline

10. Predict total aboveground biomass as a function of *D* and *H*. Reduce the prediction if necessary using the overall proportional reduction obtained from the stem wood, bark, and branch component reductions. This biomass value is considered the ‘optimal’ biomass estimate
11. Sum total stem wood biomass, total stem bark biomass, and total branch biomass (with each component reduced for broken tops, cull, and dead tree density loss as appropriate) to obtain a second total aboveground biomass
12. Proportionally distribute the difference between the directly predicted total biomass and the total from the component estimates across total stem wood, total stem bark, and total branch weights to create an adjusted total stem wood weight, an adjusted total stem bark weight, and an adjusted total branch weight
13. Calculate an adjusted wood density by dividing the adjusted total stem wood weight by the predicted total stem wood volume. This adjusted wood density can be used to convert any subsection of the main stem wood volume to biomass

Examples of tree-level calculations – An outline

14. Calculate an adjusted bark density by dividing the adjusted total stem bark weight by the predicted total stem bark volume. This value can be used to convert any subsection of the main stem bark volume to biomass
15. Directly predict total foliage dry weight as a function of *D* and *H*
16. Estimate total aboveground carbon using total aboveground biomass (excluding foliage) and the species-specific carbon fraction

Examples of tree-level calculations – Specifics

- Assume the following measurements were taken for a Douglas-fir (*SPCD* = 202) tree (TREE.CN = 504417228126144) having *D* = 20.0 in. and *H* = 110 ft with no cull growing in the Marine Division (*DIVISION* = 240)

1. Total stem wood volume (*VOLTSGRS*)

   – $Vtot_{ib}Gross = a_0 \times k^{(b0-b1)} \times D^{b_1} \times H^c$

   – $Vtot_{ib}Gross = 0.001929099 \times 9^{(2.162413104-1.690400253)} \times 20^{1.690400253} * 110^{0.985444005}$

   – $Vtot_{ib}Gross$ = 88.452275544 ft^3

Examples of tree-level calculations – Specifics

2. Total stem bark volume (*VOLTSGRS_BARK*)
   - $Vtot_{bk}Gross = a \times D^b \times H^c$
   - $Vtot_{bk}Gross = 0.000031886 \times 20^{1.21260513} \times 110^{1.978577263}$
   - $Vtot_{bk}Gross = 13.191436232$ ft^3

3. Total stem wood+bark volume
   - $Vtot_{ob}Gross = Vtot_{ib}Gross + Vtot_{bk}Gross$
   - $Vtot_{ob}Gross = 88.452275544 + 13.191436232$
   - $Vtot_{ob}Gross = 101.643711776$ ft^3

Examples of tree-level calculations – Specifics

4. Merchantable heights – estimating the height to the 4” top
   - $h_m = |4 - (0.002916157 \times 20^{1.778795704} \times 110^{1.085526548} / 0.005454) / 110 \times 2.386864288 \times 0.907607415 \times (1 - h_m/110)^{(2.386864288-1)} \times (1 - (1 - h_m/110)^{2.386864288})^{(0.907607415-1)})^{0.5} /$
   - $h_m = 98.28126765402$ ft
5. Merchantable wood volume – volume ratios to stump and merchantable top
   - Stump:
   - $R_1 = (1 - (1 - h_1/H)^{alpha})^{beta}$
   - $R_1 = (1 - (1 - 1/110)^{2.220714200})^{0.952218706} = 0.024198309$
   - $R_1 = 0.024198309$
   - Merchantable top:
   - $R_m = (1 - (1 - h_m/H)^{alpha})^{beta}$
   - $R_m = (1 - (1 - 98.28126765402/110)^{2.220714200464})^{0.952218706779}$
   - $R_m = 0.993406175350$

Examples of tree-level calculations – Specifics

5. Merchantable wood volume (*VOLCFGRS)*
   - $Vmer_{ib}Gross = (R_m \times Vtot_{ib}Gross) - (R_1 \times Vtot_{ib}Gross)$
   - $Vmer_{ib}Gross = (0.993406175 \times 88.452275544) - (0.024198309 \times 88.452275544288)$
   - $Vmer_{ib}Gross = 85.728641209612$ ft^3

- Merchantable wood+bark volume
  - $Vmer_{ob}Gross = (R_m \times V\,tot_{ob}Gross) - (R_1 \times V\,tot_{ob}Gross)$
  - $Vmer_{ob}Gross = (0.99340617535 \times 101.643711776594) - (0.024198309503 \times 101.643711776594)$
  - $Vmer_{ob}Gross = 98.513884967785$ ft^3

- Merchantable bark volume (*VOLCFGRS_BARK*)
  - $Vmer_{bk}Gross = Vmer_{ob}Gross - Vmer_{ib}Gross$
  - $Vmer_{bk}Gross = 98.513884967785 - 85.728641209612$
  - $Vmer_{bk}Gross = 12.785243758174$ ft^3

Examples of tree-level calculations – Specifics

6. Accounting for cull – sound volumes (*VOLTSSND*, *VOLCFSND*, etc.)
   - $Vtot_{ib}Sound = Vtot_{ib}Gross \times (1 - CULL/100)$
   - $Vtot_{ib}Sound = 88.452275544288 \times (1 - 0/100)$
   - $Vtot_{ib}Sound = 88.452275544288$ lb

- Wood+bark:
   - $Vtot_{ob}Sound = Vtot_{ib}Sound + Vtot_{bk}Sound$
   - $Vtot_{ob}Sound = 88.452275544288 + 13.191436232306$
   - $Vtot_{ob}Sound = 101.643711776594$ lb

7. Stem biomass – volume x density
   - $Wtot_{ib} = Vtot_{ib}Gross \times WDSG \times 62.4$
   - $Wtot_{ib} = 88.452275544288 \times 0.45 \times 62.4$
   - $Wtot_{ib} = 2483.739897283610$ lb

Examples of tree-level calculations – Specifics

7. Stem biomass – accounting for cull
   - $Wtot_{ib}red = Vtot_{ib}Gross \times (1 - CULL/100 \times (1 - DensProp)) \times WDSG \times 62.4$
   - $Wtot_{ib}red = 88.452275544288 \times (1 - 0/100 \times (1 - 0.54)) \times 0.45 \times 62.4$
   - $Wtot_{ib}red = 2483.739897283610$ lb
8. Total stem bark weight
   - $Wtot_{bk} = a \times D^b \times H^c$
   - $Wtot_{bk} = 0.009106538193 \times 20^{1.437894424586} \times 110^{1.336514272981}$
   - $Wtot_{bk} = 361.782496100100$ lb
9. Total branch weight
   - $Wbranch = a \times D^b \times H^c$
   - $Wbranch = 9.521330809106 \times 20^{1.762316117442} \times 110^{-0.40574259177}$
   - $Wbranch = 277.487756904646$ lb

- Note: Reductions to bark and branch only for dead trees or trees with broken tops
- Therefore, $Wtot_{bk}red = Wtot_{bk}$ and $Wbranchred = Wbranch$

Examples of tree-level calculations – Specifics

10. Total aboveground biomass (*DRYBIO_AG*)

- $AGB_{Predicted} = a \times D^{b} \times H^{c}$
- $AGB_{Predicted} = 0.135206506787 \times 20^{1.713527048035} \times 110^{1.047613377046}$
- $AGB_{Predicted} = 3154.5539926725$ lb

11. Ensuring additivity

- $AGB_{Component}red = Wtot_{ib}red + Wtot_{bk}red + Wbranchred$
- $AGB_{Component}red = 2483.739897283 + 361.7824961000 + 277.487756904646$
- $AGB_{Component}red = 3123.010150288360$ lb

- Accounting for cull/loss in predicted AGB
  - $AGB_{Reduce} = AGB_{Component}red / (Wtot_{ib} + Wtot_{bk} + Wbranch)$
  - $AGB_{Reduce} = 3123.010150288/(2483.739897283 + 361.782496100 + 277.487756904)$
  - $AGB_{Reduce} = 1$

Examples of tree-level calculations – Specifics

12. Ensuring additivity – distribute AGB diff across components

- $AGB_{Diff} = AGB_{Predicted}red - AGB_{Component}red$
- $AGB_{Diff} = 3154.5539926725 - 3123.0101502883$
- $AGB_{Diff} = 31.543842384153$ lb
- $Wood_{Harmonized} = AGB_{Predicted}red \times (Wtot_{ib}red / AGB_{Component}red)$
- $Wood_{Harmonized} = 3154.5539926725 \times (2483.7398972836 / 3123.01015028834)$
- $Wood_{Harmonized} = 2508.826815376370$ lb
- $Bark_{Harmonized} = AGB_{Predicted}red \times (Wtot_{bk}red / AGB_{Component}red)$
- $Bark_{Harmonized} = 3154.5539926725 \times (361.7824961001 / 3123.01015028834)$
- $Bark_{Harmonized} = 365.436666110811$ lb
- $Branch_{Harmonized} = AGB_{Predicted}red \times (Wbranchred / AGB_{Component}red)$
- $Branch_{Harmonized} = 3154.5539926725 \times (277.487756904647 / 3123.01015028834)$
- $Branch_{Harmonized} = 280.290511185328$ lb

Examples of tree-level calculations – Specifics

13. Adjusted wood density – bole wood weight (*DRYBIO_BOLE*)
    - $WDSG_{Adj} = Wood_{Harmonized} / Vtot_{ib}Gross / 62.4$
    - $WDSG_{Adj} = 2508.826815376370 / 88.452275544288 / 62.4$
    - $WDSG_{Adj} = 0.454545207473$
    - $Wmer_{ib} = Vmer_{ib}Gross \times WDSG_{Adj} \times 62.4$
    - $Wmer_{ib} = 85.728641209612 \times 0.454545207473 \times 62.4$
    - $Wmer_{ib} = 2431.57468351127$ lb
14. Adjusted bark density – bole bark weight (*DRYBIO_BOLE_BARK*)
    - $BKSG_{Adj} = Bark_{Harmonized} / Vtot_{bk}Gross / 62.4$
    - $BKSG_{Adj} = 365.436666110811 / 13.191436232306 / 62.4$
    - $BKSG_{Adj} = 0.4439514186$
    - $Wmer_{bk} = Vmer_{bk}Gross \times BKSG_{Adj} \times 62.4$
    - $Wmer_{bk} = 12.785243758174 \times 0.4439514186 \times 62.4$
    - $Wmer_{bk} = 354.184091263592$ lb

- Old *DRYBIO_BOLE* via addition

Examples of tree-level calculations – Specifics

15. Foliage dry weight (*DRYBIO_FOLIAGE*)
   - $Wfoliage = a_0 \times k^{(b0-b1)} \times D^{b1} \times H^{c}$
   - $Wfoliage = 0.477184595914 \times 9^{(2.592670351881-1.249237428914)} \times 20^{1.249237428914} \times 110^{-0.325050455055}$
   - $Wfoliage = 83.634788855934$ lb

16. Aboveground carbon (*CARBON_AG*)
   - $C = AGB_{Predicted}red \times CF$
   - $C = 3154.5539926725 \times 0.515595833333$
   - $C = 1626.474894645920$ lb

Regional/CRM vs NSVB

Component	CRM	NSVB
VOLTSGRS	NULL	88.5
VOLTSGRS_BARK	NULL	13.2
VOLTSSND	NULL	88.5
VOLTSSND_BARK	NULL	13.2
VOLCFGRS_STUMP	NULL	2.1
VOLCFGRS_STUMP_BARK	NULL	0.3
VOLCFSND_STUMP	NULL	2.1
VOLCFSND_STUMP_BARK	NULL	0.3
VOLCFGRS	83.9	85.7
VOLCFGRS_BARK	NULL	12.8
VOLCFGRS_TOP	NULL	0.6
VOLCFGRS_TOP_BARK	NULL	0.1
VOLCFSND	83.9	85.7
VOLCFSND_BARK	NULL	12.8
VOLCFSND_TOP	NULL	0.6
VOLCFSND_TOP_BARK	NULL	0.1
DRYBIO_STUMP	113.6	69.6
DRYBIO_STUMP_BARK	NULL	8.8

Component	CRM	NSVB
DRYBIO_BOLE	2755	2785.8
DRYBIO_BOLE_BARK	NULL	354.2
DRYBIO_TOP_STEM	NULL	19
DRYBIO_TOP_BARK	NULL	2.4
DRYBIO_TOP	445.7	299.2
DRYBIO_BRANCH	NULL	280.3
DRYBIO_FOLIAGE	NULL	83.6
DRYBIO_AG	3314.3	3154.6
DRYBIO_STEM	NULL	2874.3
DRYBIO_STEM_BARK	NULL	365.4
VOLCSGRS	83.2	82.8
VOLCSGRS_BARK	NULL	12.4
VOLCSSND	83.2	82.8
VOLCSSND_BARK	NULL	12.4
CARBON_AG	1657.2	1626.5
DRYBIO_SAWLOG	NULL	2349.2
DRYBIO_SAWLOG_BARK	NULL	342.2