

Canada's National Forest Inventory

National Standards for Ground Plots

Compilation Procedures

March 2021
Version 2.4

Suggested citation format:

National Forest Inventory. 2021. Canada's National Forest Inventory - national standards for ground plots compilation procedures, version 2.4. Available from <http://nfi.nfis.org> (accessed DD.MM.YY).

Table of Contents

| | | |
|----|--|----|
| 1. | Introduction | 1 |
| 2. | Compiled Attributes..... | 1 |
| 3. | Notation and constants | 12 |
| 4. | Large Tree List..... | 12 |
| | HEIGHT_PRJ | 12 |
| | CROWN_LENGTH..... | 13 |
| | VOL_TOTAL, VOL_PRJ | 13 |
| | BIOMASS_TOTAL, BIOMASS_STEMWOOD, BIOMASS_STEMBARK, BIOMASS_BRANCHES, BIOMASS_FOLIAGE, BMEQ_WOOD, BMEQ_BARK, BMEQ_BRANCHES, BMEQ_FOLIAGE..... | 14 |
| 5. | Large Tree Plot Summary..... | 16 |
| | SITE_INDEX | 16 |
| | SITE_INDEX_GENUS..... | 18 |
| | SITE_INDEX_SPECIES..... | 18 |
| | SITE_HEIGHT..... | 18 |
| | LOREY_HEIGHT | 19 |
| | BASAL_AREA_STANDLIVE | 19 |
| | BASAL_AREA_STANDDEAD..... | 20 |
| | BASAL_AREA_FALLLIVE..... | 20 |
| | STEM_DENSITY_STANDLIVE | 21 |
| | STEM_DENSITY_STANDDEAD..... | 21 |
| | STEM_DENSITY_FALLLIVE | 22 |
| | PLOTBIO_STEMWOOD_LIVE..... | 22 |
| | PLOTBIO_STEMBARK_LIVE | 23 |
| | PLOTBIO_BRANCHES_LIVE | 23 |
| | PLOTBIO_FOLIAGE_LIVE | 23 |
| | PLOTBIO_STEMWOOD_DEAD | 24 |
| | PLOTBIO_STEMBARK_DEAD..... | 24 |
| | PLOTBIO_BRANCHES_DEAD | 25 |
| | PLOTVOL_STANDLIVE | 25 |
| | PLOTVOL_STANDDEAD..... | 25 |
| | PLOTVOL_FALLLIVE..... | 26 |
| | PLOTBIO_LGTR_LIVE..... | 26 |
| | PLOTBIO_LGTR_DEAD | 27 |
| | SITE_AGE, NUM_LAB, NUM_FIELD, AGE_CORR_YEARS, AGE_TOTAL | 27 |
| | GROSSVOL_INCR..... | 29 |
| | GROSSVOL_MAI..... | 30 |
| | PERCENT, SPECIES_NUM | 30 |
| 6. | Small Tree List..... | 31 |
| | SMTREE_VOL_TOTAL, SMTREE_HT_PRJ, SMTREE_VOL_PRJ..... | 31 |
| | SMTREE_BIOMASS, BIOMASS_STEMWOOD, BIOMASS_STEMBARK, BIOMASS_BRANCHES, BIOMASS_FOLIAGE, BMEQ_WOOD, BMEQ_BARK, BMEQ_BRANCHES, BMEQ_FOLIAGE..... | 31 |
| 7. | Small Tree Plot Summary..... | 32 |
| | PLOTVOL_SMTR_LIVE | 32 |
| | PLOTVOL_SMTR_DEAD..... | 33 |
| | PLOTBIO_SMTR_LIVE..... | 34 |
| | PLOTBIO_SMTR_DEAD | 34 |
| | PLOTBIO_SMT_STEMWOOD_LIVE..... | 34 |
| | PLOTBIO_SMT_STEMBARK_LIVE | 35 |
| | PLOTBIO_SMT_BRANCHES_LIVE | 35 |

| | |
|--|----|
| PLOTBIO_SMT_FOLIAGE_LIVE | 36 |
| PLOTBIO_SMT_STEMWOOD_DEAD | 36 |
| PLOTBIO_SMT_STEMBARK_DEAD | 36 |
| PLOTBIO_SMT_BRANCHES_DEAD | 37 |
| SMTREE_PERCENT, SMTREE_SPECIES_NUM | 37 |
| 8. Shrub List and Summary | 38 |
| BIOMASS_TOTAL, BIOMASS_WOOD, BIOMASS_FOLIAGE | 38 |
| PLOTBIO_LGSHRUB_LIVE, PLOTBIO_LGSHRUB_DEAD | 39 |
| 9. Stump List and Summary | 40 |
| STUMP_VOLUME, STUMP_BIOMASS | 40 |
| PLOTVOL_STUMP, PLOTBIO_STUMP | 41 |
| 10. Species list | 41 |
| 11. Biodiversity Indices – Number of Unique Species and Shannon, Pielou Evenness and Margalef Indices 42 | |
| 12. Fine Woody Debris, Small Shrubs, Small Stumps and Herbs | 46 |
| PLOTBIO_SMSHRUB | 46 |
| PLOTBIO_HERB | 47 |
| PLOTBIO_FWD | 47 |
| PLOTBIO_BRYO | 47 |
| PLOTBIO_SMSTUMP | 48 |
| 13. Coarse and Small Woody Debris – Plot-level Summary | 48 |
| DENSITY | 49 |
| PLOTVOL_ROUNDWD, PLOTBIO_ROUNDWD | 49 |
| CWD_LEAD_SPECIES | 52 |
| PLOTVOL_SWD, PLOTBIO_SWD | 54 |
| PLOTVOL_ODDWD, PLOTBIO_ODDWD | 55 |
| PLOTVOL_CWD, PLOTBIO_CWD | 57 |
| 14. Coarse and Small Woody Debris – Plot-Level Summary by Decay Class | 57 |
| PLOTVOL_ROUNDWD, PLOTBIO_ROUNDWD, PLOTVOL_ODDWD, PLOTBIO_ODDWD, PLOTVOL_WD, PLOTBIO_WD, PLOTVOL_SWD, PLOTBIO_SWD | 57 |
| 15. Soil Carbon | 58 |
| TALLY_SS_BED, TALLY_SS_ROCK, TALLY_SS_MIN, TALLY_SS_WATER, TALLY_SS_ORG, TALLY_SS_BURIED, TALLY_SS_DECAY, TOTAL_MEAS | 58 |
| BULK_DENSITY_2MM, BULK_DENSITY_TOTAL, CF_GRAV, CF_COBB, CF_STONE (mineral soil samples) | 60 |
| LAYER_CC (mineral soil samples) | 61 |
| CC_MIN0_15, CC_MIN15_35, CC_MIN35_55 | 62 |
| BULK_DENSITY_8MM, BULK_DENSITY_TOTAL (forest floor & organic soil samples) | 65 |
| LAYER_CC_8MM, LAYER_CC_TOTAL (forest floor & organic soil samples) | 66 |
| CC_FOR_FLOOR_8MM, CC_FOR_FLOOR_TOTAL, CC_ORGANIC0_15_8MM, CC_ORGANIC15_35_8MM, CC_ORGANIC35_55_8MM, CC_ORGANIC0_15_TOTAL, CC_ORGANIC15_35_TOTAL, CC_ORGANIC35_55_TOTAL | 67 |
| DEPTH_ORG, DEPTH_MIN | 75 |
| 16. Computational References for Tree Volume | 76 |
| 17. Computational References for Biomass | 85 |
| 18. Wood Density | 85 |

1. Introduction

This document outlines the equations and rules that have been developed to compile the National Forest Inventory (NFI) ground plot raw data. Raw data from ground plots include field measurements and descriptions made at a point inside or adjacent to a photo plot. These raw ground plot data include individual large-tree and small-tree measurements, shrub tallies, understory vegetation sampling, vegetation cover, stump assessments, woody debris data, surface substrates, site descriptions and soil measurements.

Compilation of the ground plot raw data involves aggregating the individual-tree, understory-vegetation, woody-debris, and soil-pit measurements into plot averages and per-hectare values. For example, the plot basal area of large trees is obtained as a sum of the individual large tree basal areas converted to a per hectare value.

[Section 2](#) provides a list of calculated attributes; [Section 3](#) gives some notation and the remaining sections outline the compilation algorithms (routines) for each attribute. Reference to the NFI's *National Standards for Ground Plots Data Dictionary* and *Ground Sampling Guidelines* can improve understanding of terminology and processes described below.

2. Compiled Attributes

Compilation routines were developed to derive the attributes listed in the tables below based on field measurements and other data sources. The definitions of these attributes are based on the descriptions in the NFI document *National Standards for Ground Plots Data Dictionary*. Definitions of input variables stated in this manual (upper case) such as DBH and HEIGHT can be found in the same document, unless otherwise stated.

Table 1. Site information (table site_info).

| Variable Name | Attribute (Units) |
|--------------------------------------|---|
| EC_REGION (Not yet implemented) | A subdivision of an ecoprovince characterized by distinctive regional ecological factors, including climate, physiography, vegetation, soil, water, and fauna. |
| EC_DISTRICT (Not yet implemented) | A subdivision of an ecoregion (different from ecoclimatic region) characterized by a distinctive assemblages of relief, landforms, geology, soil, vegetation, water bodies and fauna. |
| PLOTVOL_STANDLIVE | Total volume ($\text{m}^3 \text{ha}^{-1}$) of all trees that are longer than 1.3 m, having roots attached to the bole or an identifiable root collar; with DBH ≥ 9.0 cm. Includes volume inside bark of the main stem, including stump and top of all standing live trees . |
| PLOTVOL_STANDDEAD | Total volume ($\text{m}^3 \text{ha}^{-1}$) of all trees that are longer than 1.3 m, having roots attached to the bole or an identifiable root collar; and DBH ≥ 9.0 cm. Includes volume inside bark of the main stem, including stump and top of all standing dead trees . |
| PLOTVOL_FALLLIVE | Total volume ($\text{m}^3 \text{ha}^{-1}$) of all trees that are longer than 1.3 m, having roots attached to the bole or an identifiable root collar; and DBH ≥ 9.0 cm. Includes volume inside bark of the main stem, including stump and top of all fallen live trees . |
| PLOTVOL_SMTR_LIVE | Total volume ($\text{m}^3 \text{ha}^{-1}$) of all live small trees with a measurable DBH < 9.0 cm. For the purposes of this inventory attribute, a tree is defined as a woody plant, usually with a single stem and a |

| Variable Name | Attribute (Units) |
|--|---|
| PLOTVOL_SMTR_DEAD | definite crown that is capable of reaching a mature height of 5.0 m somewhere within its natural range. Total volume ($\text{m}^3 \text{ha}^{-1}$) of all dead small trees with a measurable DBH < 9.0 cm. For the purposes of this inventory attribute, a tree is defined as a woody plant, usually with a single stem and a definite crown that is capable of reaching a mature height of 5.0 m somewhere within its natural range. |
| GROSSVOL_INCR (Not yet implemented) | Current annual gross volume increment ($\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$) of the entire plot. Calculated from growth and yield models or tree measurement information. Calculation includes accretion, ingrowth and mortality. |
| GROSSVOL_MAI | Mean annual gross volume increment ($\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$) of the entire plot. Calculated from volume and age data summaries. Calculation includes standing live, standing fallen and standing dead trees. |
| PLOTVOL_STUMP | Total volume ($\text{m}^3 \text{ha}^{-1}$) of stumps ≤ 1.3 m in length and ≥ 4.0 cm top diameter inside bark. |
| PLOTBIO_STUMP | Total above ground biomass of stumps ≤ 1.3 m in length and ≥ 4.0 cm top diameter inside bark (Mg ha^{-1} oven-dry material). |
| PLOTBIO_LGTR_LIVE | Total above ground biomass (Mg ha^{-1} oven-dry material) of all standing live and fallen live trees that are longer than 1.3 m, having roots attached to the bole or an identifiable root collar; and DBH ≥ 9.0 cm. |
| PLOTBIO_LGTR_DEAD | Total above ground biomass (Mg ha^{-1} oven-dry material) of all standing dead trees that are longer than 1.3 m, having roots attached to the bole or an identifiable root collar; and DBH ≥ 9.0 cm. |
| PLOTBIO_SMTR_LIVE | Total above ground biomass (Mg ha^{-1} oven-dry material) of live small trees. For the purposes of this inventory attribute, a small tree is defined as a woody plant, usually with a single trunk and definite crown that is greater than 1.3 m in height and < 9.0 cm DBH. |
| PLOTBIO_SMTR_DEAD | Total above ground biomass (Mg ha^{-1} oven-dry material) of dead small trees. For the purposes of this inventory attribute, a small tree is defined as a woody plant, usually with a single trunk and definite crown that is greater than 1.3 m in height and < 9.0 cm DBH. |
| PLOTBIO_LGSHRUB_LIVE | Total above ground biomass of live shrubs ≥ 1.3 m in height. (Mg ha^{-1} oven-dry material). |
| PLOTBIO_LGSHRUB_DEAD | Total above ground biomass of dead shrubs ≥ 1.3 m in height. (Mg ha^{-1} oven-dry material). |
| PLOTBIO_SMSHRUB | Total above ground biomass of small shrubs (live and/or dead) < 1.3 m in height (Mg ha^{-1} oven-dry material). |
| PLOTBIO_HERB | Total above ground biomass of the herb layer (Mg ha^{-1} oven-dry material). |
| PLOTBIO_BRYO | Total above ground biomass of the bryophyte layer (Mg ha^{-1} oven-dry material). |
| PLOTBIO_SMSTUMP | Total above ground biomass of small stumps with a top diameter inside bark of < 4 cm (Mg ha^{-1} oven-dry material). |
| PLOTBIO_FWD | Total above ground biomass of fine woody debris (Mg ha^{-1} oven-dry material). Fine woody debris measurements obtained from |

| Variable Name | Attribute (Units) |
|-----------------------|--|
| PLOTVOL_CWD | destructive sampling of microplots. Defined as material 0.5 cm to < 1.0 cm in diameter. Includes bark where present. Total volume (m³ ha⁻¹) for all coarse woody debris > 7.5 cm in diameter. Includes all round and odd-shaped pieces. Includes bark where present. |
| PLOTBIO_CWD | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all coarse woody debris > 7.5 cm in diameter. Includes all round and odd-shaped pieces. Includes bark where present. |
| PLOTVOL_SWDD | Total volume (m³ ha⁻¹) for all small woody debris ≥ 1 cm and ≤ 7.5 cm in diameter. Includes bark where present. |
| PLOTBIO_SWDD | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all small woody debris ≥ 1 cm and ≤ 7.5 cm in diameter. Includes bark where present. |
| PLOTVOL_ROUNDWD | Total volume (m³ ha⁻¹) for all coarse woody debris round pieces > 7.5 cm in diameter. Includes bark where present. |
| PLOTBIO_ROUNDWD | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all coarse woody debris round pieces > 7.5 cm in diameter. Includes bark where present. |
| PLOTVOL_ODDWD | Total volume (m³ ha⁻¹) for all coarse woody debris odd-shaped pieces > 7.5 cm in diameter. Includes bark where present. |
| PLOTBIO_ODDWD | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all coarse woody debris odd-shaped pieces > 7.5 cm in diameter. Includes bark where present. |
| SAMPLE_DEPTH_MIN | Maximum depth to which carbon content was calculated for mineral soil samples (cm). |
| SAMPLE_DEPTH_ORG | Maximum depth to which carbon content was calculated for organic soil samples (cm). |
| CC_FOR_FLOOR_8MM | Carbon content of the ≤ 8 mm fraction of the forest floor, plot level (Mg C ha⁻¹) |
| CC_FOR_FLOOR_TOTAL | Carbon content of the total forest floor, plot level (Mg C ha⁻¹) |
| CC_MIN0_15 | Carbon content of the 0-15 cm mineral soil layer, plot level (Mg C ha⁻¹) |
| CC_MIN15_35 | Carbon content of the 15-35 cm mineral soil layer, plot level (Mg C ha⁻¹) |
| CC_MIN35_55 | Carbon content of the 35-55 cm mineral soil layer, plot level (Mg C ha⁻¹) |
| CC_ORGANIC0_15_8MM | Carbon content of the ≤ 8 mm fraction of the organic soil occurring 0 - 15 cm below surface, plot level (Mg C ha⁻¹) |
| CC_ORGANIC0_15_TOTAL | Carbon content of the organic soil occurring 0 - 15 cm below surface, plot level (Mg C ha⁻¹) |
| CC_ORGANIC15_35_8MM | Carbon content of the ≤ 8 mm fraction of the organic soil occurring 15 - 35 cm below surface, plot level (Mg C ha⁻¹) |
| CC_ORGANIC15_35_TOTAL | Carbon content of the organic soil occurring 15 - 35 cm below surface, plot level (Mg C ha⁻¹) |
| CC_ORGANIC35_55_8MM | Carbon content of the ≤ 8 mm fraction of the organic soil occurring 35 - 55 cm below surface, plot level (Mg C ha⁻¹) |
| CC_ORGANIC35_55_TOTAL | Carbon content of the organic soil occurring 35 - 55 cm below surface, plot level (Mg C ha⁻¹) |
| AVG_ORG_CARB | The average carbon concentration of ≤ 8 mm fraction organic soil and forest floor samples (g kg⁻¹) |

| Variable Name | Attribute (Units) |
|----------------------|--|
| AVG_BULK_DENSITY_ORG | The average bulk density of ≤ 8 mm fraction of organic soil and forest floor samples (g cm⁻³) |

Table 2. Large tree plot header (table ltp_header).

| Variable Name | Attribute (Units) |
|------------------------|---|
| SITE_INDEX | An expression of forest site quality based on the height (m), at a breast-height age of 50 years, of the dominant and co-dominant trees (site trees) in the large tree plot. |
| SITE_INDEX_GENUS | Site index genus code. Uses the first four letters of the scientific genus name. If unknown conifer, use code GENC , if unknown hardwood, use code GENH . For a list of acceptable genus codes, refer to the <i>NFI Tree Species List</i> . |
| SITE_INDEX_SPECIES | Site index species code. Uses the first three letters of the scientific species name. If unknown species, use code SPP . For a list of acceptable species codes, refer to the <i>NFI Tree Species List</i> . |
| SITE_HEIGHT | The average height (m) of intact live standing dominant and co-dominant trees forming the stand (site trees). |
| LOREY_HEIGHT | The average height (m) of all intact live trees (LF, LS) in the plot, weighted by their basal area. |
| SITE_AGE | The average total age (years) of the dominant and co-dominant trees forming the stand (site trees). |
| NUM_LAB | A field to indicate the number of lab-counted tree cores used in the determination of site age. |
| NUM_FIELD | A field to indicate the number of field-counted tree cores used in the determination of site age. |
| BASAL_AREA_STANDLIVE | Summed cross-sectional area (m² ha⁻¹), measured at breast height, of tree boles for all standing live trees within the LTP. Minimum DBH measured = 9.0 cm. |
| BASAL_AREA_STANDDEAD | Summed cross-sectional area (m² ha⁻¹), measured at breast height, of tree boles for all standing dead trees within the LTP. Minimum DBH measured = 9.0 cm. |
| BASAL_AREA_FALLLIVE | Summed cross-sectional area (m² ha⁻¹), measured at breast height, of tree boles for all fallen live trees within the LTP. Minimum DBH measured = 9.0 cm. |
| STEM_DENSITY_STANDLIVE | The number of standing live stems ha⁻¹ including stems with minimum DBH = 9.0 cm |
| STEM_DENSITY_STANDDEAD | The number of standing dead stems ha⁻¹ including stems with minimum DBH = 9.0 cm |
| STEM_DENSITY_FALLLIVE | The number of fallen live stems ha⁻¹ including stems with minimum DBH = 9.0 cm |
| SPECIES_LTNUM | This is the total number of unique species of live standing large tree in an area (species richness). |
| BINDEX_LTSHANNON | The Shannon diversity index, which is a measure of the species richness and evenness for live standing large trees. |
| BINDEX_LTEVEN | The Pielou evenness index, which measures how close the numbers of individual live large trees of each species are to each other. |
| BINDEX_LTMARGALEF | The Margalef richness index, which measures the total number of large tree species in an area. |

| Variable Name | Attribute (Units) |
|-----------------------|--|
| PLOTBIO_STEMWOOD_LIVE | Total biomass (Mg ha⁻¹ oven-dry material) of stem wood of all live standing and live fallen trees ≥ 1.3 m in height and DBH ≥ 9.0 cm. |
| PLOTBIO_STEMBARK_LIVE | Total biomass (Mg ha⁻¹ oven-dry material) of stem bark of all live standing and live fallen trees ≥ 1.3 m in height DBH ≥ 9.0 cm. |
| PLOTBIO_BRANCHES_LIVE | Total biomass (Mg ha⁻¹ oven-dry material) of branches of all live standing and live fallen trees ≥ 1.3 m in height and DBH ≥ 9.0 cm. |
| PLOTBIO_FOLIAGE_LIVE | Total biomass (Mg ha⁻¹ oven-dry material) of foliage of all live standing and live fallen trees ≥ 1.3 m in height and DBH ≥ 9.0 cm. |
| PLOTBIO_STEMWOOD_DEAD | Total biomass (Mg ha⁻¹ oven-dry material) of stem wood of all dead standing trees ≥ 1.3 m in height and DBH ≥ 9.0 cm. |
| PLOTBIO_STEMBARK_DEAD | Total biomass (Mg ha⁻¹ oven-dry material) of stem bark of all dead standing trees ≥ 1.3 m in height and DBH ≥ 9.0 cm. The biomass of stem bark is 0 for unidentifiable conifer or hardwood dead standing trees. |
| PLOTBIO_BRANCHES_DEAD | Total biomass (Mg ha⁻¹ oven-dry material) of branches of all dead standing trees ≥ 1.3 m in height and DBH ≥ 9.0 cm. The biomass of branches is 0 for unidentifiable conifer or hardwood dead standing trees. |

Table 3. Large tree species composition (table ltp_tree_species_comp).

| Variable Name | Attribute (Units) |
|---------------|---|
| SPECIES_NUM | Identifies the species ranked abundance in the plot by percentage of basal area per hectare. |
| PERCENT | Percentage (%) of the species in the plot determined by live basal area per hectare in the large tree plot. |

Table 4. Large tree list (table ltp_tree).

| Variable Name | Attribute (Units) |
|------------------|--|
| HEIGHT_PRJ | The projected height (m) to the top of the tree before the break occurred. Calculated for broken trees and trees with missing height values. Projected tree height is reported to the nearest 0.1 m. Reported if HEIGHT_PRJ \geq HEIGHT. |
| CROWN_LENGTH | The crown length (m) for all trees in the large tree plot with a HEIGHT_LIVE > 0 . |
| VOL_TOTAL | The total volume (m³) by tree for all trees in the large tree plot ≥ 1.3 m in height and DBH ≥ 9.0 cm. Includes volume inside bark of the main stem including stump and top. |
| VOL_PRJ | The total volume (m³) calculated to the projected height (HEIGHT_PRJ) by tree for all trees in the large tree plot ≥ 1.3 m in height and DBH ≥ 9.0 cm. Includes volume inside bark of the main stem including stump and reconstructed top. |
| BIOMASS_TOTAL | The total aboveground biomass (kg oven-dry material) by tree for all trees in the large tree plot ≥ 1.3 m in height having roots attached to the bole or an identifiable root collar and DBH ≥ 9.0 cm. |
| BIOMASS_STEMWOOD | The stem wood biomass (kg oven-dry material) by tree for all trees in the large tree plot ≥ 1.3 m in height having roots attached to the bole or an identifiable root collar and DBH ≥ 9.0 cm. |

| Variable Name | Attribute (Units) |
|------------------|---|
| BIOMASS_STEMBARK | The stem bark biomass (kg oven-dry material) by tree for all trees in the large tree plot ≥ 1.3 m in height having roots attached to the bole or an identifiable root collar and DBH ≥ 9.0 cm. |
| BIOMASS_BRANCHES | The branch biomass (kg oven-dry material) by tree for all trees in the large tree plot ≥ 1.3 m in height having roots attached to the bole or an identifiable root collar and DBH ≥ 9.0 cm. |
| BIOMASS_FOLIAGE | The foliage biomass (kg oven-dry material) by tree for all trees in the large tree plot ≥ 1.3 m in height having roots attached to the bole or an identifiable root collar and DBH ≥ 9.0 cm. Dead trees are assumed to have zero foliage biomass. |
| BMEQ_WOOD | The biomass equation ID for computing stem wood biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |
| BMEQ_BARK | The biomass equation ID for computing stem bark biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |
| BMEQ_BRANCHES | The biomass equation ID for computing branch biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |
| BMEQ_FOLIAGE | The biomass equation ID for computing foliage biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |

Table 5. Large tree plot, site tree and age information (table *ltp_tree_age*).

| Variable Name | Attribute (Units) |
|----------------|--|
| AGE_CORR_YEARS | Estimated number of full years of the tree growth below the boring height. |
| AGE_TOTAL | An estimate of the total age of the tree. |

Table 6. Small tree plot header (table *stp_header*).

| Variable Name | Attribute (Units) |
|---------------------------|--|
| SPECIES_SMTNUM | This is the total number of all unique live standing small tree species in an area (species richness). |
| BINDEX_STSHANNON | The Shannon diversity index, which is a measure of the species richness and evenness for small trees. |
| BINDEX_STEVEN | The Pielou evenness index, which measures how close the numbers of individual live small trees of each species are to each other. |
| BINDEX_STMARGALEF | The Margalef richness index, which measures the total number of small tree species in an area. |
| PLOTBIO_SMT_STEMWOOD_LIVE | Total biomass (Mg ha⁻¹ oven-dry material), of stem wood of all small live standing trees ≥ 1.3 m in height and DBH < 9.0 cm. |
| PLOTBIO_SMT_STEMBARK_LIVE | Total biomass (Mg ha⁻¹ oven-dry material), of stem bark of all small live standing trees ≥ 1.3 m in height and DBH < 9.0 cm. |
| PLOTBIO_SMT_BRANCHES_LIVE | Total biomass (Mg ha⁻¹ oven-dry material), of branches of all small live standing trees ≥ 1.3 m in height and DBH < 9.0 cm. |
| PLOTBIO_SMT_FOLIAGE_LIVE | Total biomass (Mg ha⁻¹ oven-dry material), of foliage of all small live standing trees ≥ 1.3 m in height and DBH < 9.0 cm. |
| PLOTBIO_SMT_STEMWOOD_DEAD | Total biomass (Mg ha⁻¹ oven-dry material), of stem wood of all small dead standing trees ≥ 1.3 m in height and DBH < 9.0 cm. |
| PLOTBIO_SMT_STEMBARK_DEAD | Total biomass (Mg ha⁻¹ oven-dry material), of bark of all small dead standing trees ≥ 1.3 m in height and DBH < 9.0 cm. The |

| Variable Name | Attribute (Units) |
|---------------------------|---|
| PLOTBIO_SMT_BRANCHES_DEAD | biomass of stem bark is 0 for unidentifiable conifer or hardwood dead standing trees. Total biomass (Mg ha⁻¹ oven-dry material), of branches of all small dead standing trees ≥ 1.3 m in height and DBH < 9.0 cm. The biomass of branches is 0 for unidentifiable conifer or hardwood dead standing trees. |

Table 7. Small tree list (table stp_tree).

| Variable Name | Attribute (Units) |
|------------------|--|
| SMTREE_VOL_TOTAL | The total volume (m³) by tree for all trees in the small tree plot ≥ 1.3 m in height and DBH < 9.0 cm. Includes volume inside bark of the main stem including stump and top. |
| SMTREE_HT_PRJ | The projected height (m) to the top of the small tree before the break occurred. Calculated for broken trees and for trees with missing height values. Projected height is reported to the nearest 0.1 m. SMTREE_HT_PRJ \geq SMTREE_HT. |
| SMTREE_BIOMASS | The total aboveground biomass (kg oven-dry material) by tree for all trees in the small tree plot ≥ 1.3 m in height and DBH < 9.0 cm having roots attached to the bole or an identifiable root collar. |
| BIOMASS_STEMWOOD | The stem wood biomass (kg oven-dry material) by tree for all trees in the small tree plot ≥ 1.3 m in height and DBH < 9.0 cm having roots attached to the bole or an identifiable root collar. |
| BIOMASS_STEMBARK | The stem bark biomass (kg oven-dry material) by tree for all trees in the small tree plot ≥ 1.3 m in height and DBH < 9.0 cm having roots attached to the bole or an identifiable root collar. |
| BIOMASS_BRANCHES | The branch biomass (kg oven-dry material) by tree for all trees in the small tree plot ≥ 1.3 m in height and DBH < 9.0 cm having roots attached to the bole or an identifiable root collar. |
| BIOMASS_FOLIAGE | The foliage biomass (kg oven-dry material) by tree for all trees in the small tree plot ≥ 1.3 m in height and DBH < 9.0 cm having roots attached to the bole or an identifiable root collar. |
| BMEQ_WOOD | The biomass equation ID for computing stem wood biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |
| BMEQ_BARK | The biomass equation ID for computing stem bark biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |
| BMEQ_BRANCHES | The biomass equation ID for computing branch biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |
| BMEQ_FOLIAGE | The biomass equation ID for computing foliage biomass (<i>eqid</i> from support table <i>gpcsd_tree_biom_eqs</i>) |
| SMTREE_VOL_PRJ | Total tree volume (m³) to the projected height of a broken top tree |

Table 8. Small tree species composition (table stp_tree_species_comp).

| Variable Name | Attribute (Units) |
|--------------------|--|
| SMTREE_SPECIES_NUM | Identifies the species ranked abundance in the plot by percentage of basal area per hectare |
| SMTREE_PERCENT | Percent (%) composition of the small tree species based on proportion of live basal area in the small tree plot. |

Table 9. Shrub plot, species list (table shrub_list).

| Variable Name | Attribute (Units) |
|-----------------|--|
| BIOMASS_TOTAL | Total above ground biomass (kg of oven dry material) |
| BIOMASS_WOOD | Total above ground woody biomass (kg of oven dry material) |
| BIOMASS_FOLIAGE | Total foliage biomass (kg of oven dry material) |
| BMEQ_TOTAL | Biomass equation ID for computing total above ground biomass |
| BMEQ_WOOD | Biomass equation ID for computing above ground woody biomass |
| BMEQ_FOLIAGE | Biomass equation ID for computing foliage biomass |

Table 10. Stump list (table stump_list).

| Variable Name | Attribute (Units) |
|---------------|--|
| STUMP_VOLUME | The total volume (m³) of each stump in the stump plot with diameter inside bark ≥ 4 cm. |
| STUMP_BIOMASS | The total aboveground biomass (kg oven-dry material) of each stump in the stump plot. |

Table 11. Ecological biodiversity (table biodiversity_ec).

| Variable Name | Attribute (Units) |
|------------------|---|
| SPECIES_ECNUM | Total number of all unique ecological species (species richness). Reported by ecological layer (trees, tall shrubs, low shrubs, herbs and bryoids). |
| BINDEX_ECSHANNON | Shannon diversity index for ecological species |
| BINDEX_ECEVEN | Pielou evenness index for ecological species, which measures how close, in percent cover, each species are within an ecological layer. |

Table 12. Round coarse woody debris (table woody_debris_round).

| Variable Name | Attribute (Units) |
|---------------|---|
| DENSITY | The wood density (g cm⁻³) associated with each piece of round woody debris, based on a combination of the species codes and wood condition (DECAY_CLASS). |

Table 13. Odd coarse woody debris (table woody_debris_odd).

| Variable Name | Attribute (Units) |
|---------------|---|
| DENSITY | The wood density (g cm⁻³) associated with each piece of odd woody debris, based on a combination of the species codes and wood condition (DECAY_CLASS). |

Table 14. Woody debris summary (table wd_summary).

| Variable Name | Attribute (Units) |
|---------------|---|
| PLOTVOL_SW_D | Total volume (m³ ha⁻¹) for all small woody debris ≥ 1 cm and ≤ 7.5 cm in diameter by decay class. Includes bark where present. |
| PLOTBIO_SW_D | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all small woody debris ≥ 1 cm and ≤ 7.5 cm in diameter by decay class. Includes bark where present. |
| PLOTVOL_WD | Total volume (m³ ha⁻¹) for all coarse woody debris > 7.5 cm in diameter by decay class. Includes all round and odd-shaped pieces. Includes bark where present. |

| Variable Name | Attribute (Units) |
|-----------------|---|
| PLOTBIO_WD | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all coarse woody debris > 7.5 cm in diameter by decay class. Includes all round and odd-shaped pieces. Includes bark where present. |
| PLOTVOL_ROUNDWD | Total volume (m³ ha⁻¹) for all coarse woody debris round pieces > 7.5 cm in diameter by decay class. Includes bark where present. |
| PLOTBIO_ROUNDWD | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all coarse woody debris round pieces > 7.5 cm in diameter by decay class. Includes bark where present. |
| PLOTVOL_ODDWD | Total volume (m³ ha⁻¹) for all coarse woody debris odd-shaped pieces > 7.5 cm in diameter by decay class. Includes bark where present. |
| PLOTBIO_ODDWD | Total above ground biomass (Mg ha⁻¹ oven-dry material) for all coarse woody debris odd-shaped pieces > 7.5 cm in diameter by decay class. Includes bark where present. |

Table 15. Surface substrate header (table surface_substrate_header).

| Variable Name | Attribute (Units) |
|------------------|---|
| TOTAL_MEAS | Total number of surface substrate measurements made along the transect. |
| TALLY_SS_ORG | Number of surface substrate measurements along the transect line with organic matter cover (includes: organic layers \geq 1 cm thick overlying mineral soil, cobbles, stones or bedrock; layers of decaying wood < 10 cm thick; large animal droppings; and areas covered by mats of bunchgrass [mats include L horizons]). |
| AVG_ORG_THICK | The average depth (cm) of the organic matter surface substrate (if present). |
| TALLY_SS_BURIED | Number of surface substrate measurements along the transect line with buried wood cover (includes: class 5 woody debris with > 50 % thickness below surrounding surface; may be covered with mosses, lichens, liverworts, or other plants; if an organic layer has developed over the wood, buried wood must be > 10 cm thick otherwise it is classed as 'organic matter'). |
| AVG_BURIED_THICK | The average depth (cm) of the buried wood surface substrate (if present). |
| TALLY_SS_DECAY | Number of surface substrate measurements along the transect line with decaying wood cover (includes: fallen trees, large branches on the ground surface, and partially buried stumps with an exposed edge; may be covered with mosses, lichens, liverworts, or other plants; if an organic layer developed over the wood, decaying wood must have > 50 % of its thickness above the surrounding surface, otherwise it is classed as 'buried wood'). |
| TALLY_SS_BED | Number of surface substrate measurements along the transect line with bedrock cover (includes: exposed consolidated mineral material; may have a partial covering of mosses, lichens, liverworts, or other epilithic plants; does not qualify as bedrock if covered by unconsolidated mineral material or organic matter \geq 1 cm in thickness). |

| Variable Name | Attribute (Units) |
|----------------|---|
| TALLY_SS_ROCK | Number of surface substrate measurements along the transect line with rock or cobble and stones cover (includes: exposed unconsolidated rock fragments > 7.5 cm in diameter; may be covered by mosses, lichens, liverworts, epilithic plants, or an organic layer < 1 cm in thickness; does not include gravels < 7.5 cm in diameter). |
| TALLY_SS_MIN | Number of surface substrate measurements along the transect line with mineral soil cover (includes: unconsolidated mineral material of variable texture not covered by organic matter; may have a partial cover of mosses, lichens, and liverworts; includes small cobbles and gravel < 7.5 cm in diameter; areas of living grass or forb cover where mineral soil is visible between stems are classed as mineral soil, as are exposed Ah or Ae horizons). |
| TALLY_SS_WATER | Number of surface substrate measurements along the transect line covered with streams, puddles, or areas of open water in bogs or fens (does not include 'casual' or non-permanent water) |

Table 16. Soil pit depth (table soil_pit_depth).

| Variable Name | Attribute (Units) |
|---------------|--|
| DEPTH_MIN | Total depth to which mineral soil samples were collected in a pit (cm). |
| DEPTH_ORG | Total depth to which forest floor and/or organic soil samples were collected in a pit (cm). |

Table 17. Forest floor organic sample (table for_flr_org_sample).

| Variable Name | Attribute (Units) |
|--------------------|--|
| BULK_DENSITY_8MM | The bulk density of the ≤ 8 mm portion of the forest floor (g cm⁻³ oven-dry material) |
| BULK_DENSITY_TOTAL | The bulk density of the total forest floor (g cm⁻³ oven-dry material) |
| LAYER_CC_8MM | Carbon content per unit area of the ≤ 8 mm component of the forest floor sample (kg m⁻²) |
| LAYER_CC_TOTAL | Carbon content per unit area of the total forest floor sample (kg m⁻²) |

Table 18. Mineral soil sample (table soil_mineral_sample).

| Variable Name | Attribute (Units) |
|--------------------|---|
| CF_GRAV | The % content of gravel (diameter < 7.5 cm or length < 15 cm) in the mineral horizon represented by the sample. |
| CF_COBB | The % content of cobble (diameter = 7.5 to 25 cm or length = 15 to 38 cm) in the mineral horizon represented by the sample. |
| CF_STONE | The % content of stone (diameter > 25 cm or length > 38 cm) in the mineral horizon represented by the sample. |
| BULK_DENSITY_2MM | The bulk density of the ≤ 2 mm portion of the mineral soil (g cm⁻³ oven-dry material) |
| BULK_DENSITY_TOTAL | The bulk density of the total mineral soil sample (g cm⁻³ oven-dry material) |
| LAYER_CC | Carbon content per unit area of the mineral soil sample (kg m⁻²) |

Table 19. Organic soil sample (table soil_org_sample).

| Variable Name | Attribute (Units) |
|--------------------|---|
| BULK_DENSITY_8MM | The bulk density of the ≤ 8 mm portion of the organic soil (g cm^{-3} oven-dry material) |
| BULK_DENSITY_TOTAL | The bulk density of the total organic soil sample (g cm^{-3} oven-dry material) |
| LAYER_CC_8MM | Carbon content per unit area of the ≤ 8 mm component of the organic soil sample (kg m^{-2}) |
| LAYER_CC_TOTAL | Carbon content per unit area of the total organic soil sample (kg m^{-2}) |

Table 20. Relative abundance of large tree species (table rel_abundance_lgtree).

| Variable Name | Attribute (Units) |
|---------------|--|
| SPECIES_NUM | Ranked abundance number |
| SPECIES_LTREL | The relative abundance of each large tree taxon in an area, expressed as a proportion. |

Table 21. Relative abundance of small tree species (table rel_abundance_smtree).

| Variable Name | Attribute (Units) |
|---------------|--|
| SPECIES_NUM | Ranked abundance number |
| SPECIES_STREL | The relative abundance of each small tree taxon in an area, expressed as a proportion. |

Table 22. Relative abundance of ecological species (table rel_abundance_ec).

| Variable Name | Attribute (Units) |
|---------------|---|
| SPECIES_NUM | Ranked abundance number |
| SPECIES_ECREL | The relative abundance, by taxon, in an ecological layer, based on forest cover |

Table 23. Unique species list (table species_list).

| Variable Name | Attribute (Units) |
|---------------|---|
| SPECIES_INDEX | A unique number assigned to each taxon in the NFI plot. |
| GENUS | The genus of each plant taxon detected in the NFI plot. |
| SPECIES | The species of each plant taxon detected in the NFI plot. |
| VARIETY | The variety of each plant taxon detected in the NFI plot. |

3. Notation and constants

Throughout this document, the following conventions are observed:

The value of π (pi) has been set to the constant 3.14159265.

Tree, shrub and stump biomass estimates are all above ground and expressed on an oven-dry basis. Tree volume refers only to the above-ground volume inside bark of the main stem, from the base of the stump to the top of the main leader, excluding branches and other bifurcations.

The scaling of units to per-hectare values make use of measured plot sizes (MEAS_PLOT_SIZE) when these are available, else nominal plot sizes (NOM_PLOT_SIZE) are used and, if information was collected before August 1, 2007, adjusted accordingly when plot measurement was split by half or a quarter (PLOT_SPLIT).

```
IF MEAS_PLOT_SIZE > 0 then PLOT_SIZE = MEAS_PLOT_SIZE
ELSE IF PLOT_SPLIT = 'F' then PLOT_SIZE = NOM_PLOT_SIZE
ELSE IF PLOT_SPLIT = 'H' then PLOT_SIZE = NOM_PLOT_SIZE * 0.5
ELSE IF PLOT_SPLIT = 'Q' then PLOT_SIZE = NOM_PLOT_SIZE * 0.25
```

Wood density (DENSITY; g cm^{-3}) coefficients are used to convert woody debris volume to biomass. These coefficients vary by genus, species and variety (WD_GENUS, WD_SPECIES, WD_VARIETY) and decay class (DECAY_CLASS) and are contained in the wood_density dataset. More information regarding the source and derivation of these coefficients is contained in [section 18](#).

Carbon content in soil samples and soil layers were reported on an oven-dry basis, where soil samples were dried in a forced-air oven (at $105^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for mineral soil and $70^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for forest floor, organic soil and other organic matter) for 24 to 48 hours or until no change in sample mass was detected (Alemdag, I.S. 1980. Manual of data collection and processing for the development of forest biomass relationships. Canadian Forestry Service Information Report PI-X-4. 38p). The mass of mineral soil fractions used in compilations were reported on an air-dried basis (25°C) and adjusted for moisture content in the fraction less than 2 mm after oven drying at $105^{\circ}\text{C} \pm 3^{\circ}\text{C}$.

Given the quasi-ubiquitous requirement for plot number (NFI_PLOT) and measurement period (MEAS_NUM) in computing the values listed below, these two attributes were omitted from 'inputs' subsections.

4. Large Tree List

Compiler routines

lgtree_volume_all.sas
lgtree_biomass.sas

Output written to:

ltp_tree

HEIGHT_PRJ

Compiler routines

gp_ht_dbh_prj.sas (called from the large tree volume routines gp_tree_volume_ab.sas, gp_tree_volume_bc.sas, etc. which are called from lgtree_volume_all.sas; also called from the large tree biomass routines)

Inputs

TREE_NUM; LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY; LGTREE_STATUS; STEM_COND;
DBH; HEIGHT

Computations

If the tree has a broken top (STEM_COND = 'B') or is missing height value (HEIGHT = -1), estimate the projected total height of the tree in meters (HEIGHT_PRJ). The computations are described in more detail in [section 16](#).

Output

HEIGHT_PRJ

CROWN_LENGTH

Compiler routines

Lgtree_volume_all.sas

Inputs

TREE_NUM; CROWN_BASE; CROWN_TOP; HEIGHT

Computations

Set crown length (CROWN_LENGTH) to missing when the height to the base of the live crown (CROWN_BASE) is missing (i.e. -1) or not applicable (i.e. -9) (e.g. when tree status is dead standing). If the height to the top of the live crown (CROWN_TOP) is missing or not applicable yet the height to the base of the live crown is measured then assume the height of the top of the live crown is equal to the height of the tree. Calculate crown length (m) as the difference between the top and base of the live crown.

$$\begin{aligned} & \text{If } CROWN_BASE_{mpt} = -9 \text{ then } CROWN_LENGTH_{mpt} = -9 \\ & \text{If } CROWN_TOP_{mpt} \leq 0 \text{ and } CROWN_BASE_{mpt} \geq 0 \text{ then } CROWN_TOP_{mpt} = HEIGHT_{mpt} \\ & \text{If } (CROWN_BASE_{mpt} = -1 \text{ or } CROWN_TOP_{mpt} = -1) \text{ then } CROWN_LENGTH_{mpt} = -1 \\ & \text{If } CROWN_BASE_{mpt} \geq 0 \text{ and } CROWN_TOP_{mpt} > 0 \text{ then } CROWN_LENGTH_{mpt} \\ & \quad = CROWN_TOP_{mpt} - CROWN_BASE_{mpt} \end{aligned}$$

where t is a unique tree (TREE_NUM) within a plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

CROWN_LENGTH

VOL_TOTAL, VOL_PRJ

Compiler routines

Tree volumes use provincial volume estimation routines, gp_tree_volume_ab.sas, gp_tree_volume_bc.sas etc., which are called from lgtree_volume_all.sas)

Inputs

TREE_NUM; LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY; LGTREE_STATUS; STEM_COND;
DBH; HEIGHT; HEIGHT_PRJ

Computations

The computations are described in more detail in [section 16](#).

1) Calculate the total tree volume (m³) of each tree ≥ 1.3 m in height. If the tree has a broken top (STEM_COND = 'B'), the volume to the estimated projected height of the tree before the break occurred is labelled VOL_PRJ and the volume to the break is VOL_TOTAL.

Output

VOL_TOTAL, VOL_PRJ

**BIOMASS_TOTAL, BIOMASS_STEMWOOD, BIOMASS_STEMBARK,
BIOMASS_BRANCHES, BIOMASS_FOLIAGE, BMEQ_WOOD, BMEQ_BARK,
BMEQ_BRANCHES, BMEQ_FOLIAGE**

Compiler routines

Lgtree_biomass.sas

Inputs

TREE_NUM; LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY; LGTREE_STATUS; DBH; HEIGHT;
HEIGHT_PRJ; PROVINCE; ECOZONE; STEM_COND; VOL_TOTAL; VOL_PRJ

Computations

The computations are described in more detail in [section 17](#). In some cases biomass equations jointly treat stem wood with stem bark or branches with foliage. In such cases, biomass for stem bark (BIOMASS_STEMBARK) or foliage (BIOMASS_FOLIAGE) is set to zero, however these components are included in stem wood (BIOMASS_STEMWOOD) or branches (BIOMASS_BRANCHES) components, respectively.

1) Estimate the total biomass (kg) of each tree using existing tree biomass equations and coefficients. For broken top trees, use the projected height. Keep track of which equation number (eqid) is used (reported as BMEQ_WOOD, BMEQ_BARK, BMEQ_BRANCHES and BMEQ_FOLIAGE).

$$\begin{aligned} BIOMASS_STEMWOOD_{mpt} &= f(DBH_{pmt}, HEIGHT_{mpt}) \\ BIOMASS_STEMBARK_{mpt} &= f(DBH_{pmt}, HEIGHT_{mpt}) \\ BIOMASS_BRANCHES_{mpt} &= f(DBH_{pmt}, HEIGHT_{mpt}) \\ BIOMASS_FOLIAGE_{mpt} &= f(DBH_{pmt}, HEIGHT_{mpt}) \end{aligned}$$

where t is a unique tree (TREE_NUM) within a plot p (NFI_PLOT) at measurement m (MEAS_NUM) and equation forms and coefficients are based on genus, species, variety, province and ecozone. Note that some species use only diameter as the predictor for biomass

2) For broken top trees (STEM_COND = 'B'), multiply each biomass component by a correction factor to correct biomass estimates to the height of the break. The correction for broken top trees is the ratio between the volume to the broken top and the volume to the projected height ($VOL_TOTAL_{mpt}/VOL_PRJ_{mpt}$).

3) Add some logic checks:

Set foliage biomass to zero for dead standing (DS) trees when information on crown condition is missing (CROWN_COND = -1).

If LGTREE_STATUS_{mpt} = 'DS' and CROWN_COND_{mpt} = -1 then BIOMASS_FOLIAGE_{mpt} = 0

When missing information on bark retention or crown condition, set bark or branch biomass, respectively, to zero for dead standing (DS) trees if the genus is unknown (it is assumed that if the genus is unknown, there was no bark or branches to identify the species).

*If LGTREE_STATUS_{mpt}
= 'DS' and LGTREE_GENUS_{mpt} in ('GENC', 'GENH', 'UNKN') and CROWN_COND_{mpt}
= -1 then BIOMASS_FOLIAGE_{mpt} = 0*

*If LGTREE_STATUS_{mpt}
= 'DS' and LGTREE_GENUS_{mpt} in ('GENC', 'GENH', 'UNKN') and BARK_RET_{mpt}
= -1 then BIOMASS_STEMBARK_{mpt} = 0*

Set biomass values less than zero to missing ('.')

*If BIOMASS_STEMWOOD_{mpt} < 0 then BIOMASS_STEMWOOD_{mpt} = .
If BIOMASS_STEMBARK_{mpt} < 0 then BIOMASS_STEMBARK_{mpt} = .
If BIOMASS_BRANCHES_{mpt} < 0 then BIOMASS_BRANCHES_{mpt} = .
If BIOMASS_FOLIAGE_{mpt} < 0 then BIOMASS_FOLIAGE_{mpt} = .*

Set foliage biomass (BIOMASS_FOLIAGE) to zero when crown condition (CROWN_COND) is greater or equal to 3. Reduce foliage biomass by 50% when crown condition is equal to 2.

*If CROWN_COND_{mpt} = 2 then BIOMASS_FOLIAGE_{mpt} = BIOMASS_FOLIAGE_{mpt} * 0.5
If CROWN_COND_{mpt} ≥ 3 then BIOMASS_FOLIAGE_{mpt} = 0*

Set branch biomass (BIOMASS_BRANCHES) to zero when crown condition is 6. Adjust branch biomass to 75% or 25% when crown condition is 4 or 5 respectively.

*If CROWN_COND_{mpt} = 4 then BIOMASS_BRANCHES_{mpt} = BIOMASS_BRANCHES_{mpt} * 0.75
If CROWN_COND_{mpt} = 5 then BIOMASS_BRANCHES_{mpt} = BIOMASS_BRANCHES_{mpt} * 0.25
If CROWN_COND_{mpt} = 6 then BIOMASS_BRANCHES_{mpt} = 0*

Set stem bark biomass (BIOMASS_STEMBARK) to zero when bark retention (BARK_RET) is equal to 7. When the bark retention is 2-6, adjust the stem bark biomass by the midpoint of the range of % stem bark remaining defined by a given bark retention class.

*If BARK_RET_{mpt} = 2 then BIOMASS_STEMBARK_{mpt} = BIOMASS_STEMBARK_{mpt} * (1 - 0.025)
If BARK_RET_{mpt} = 3 then BIOMASS_STEMBARK_{mpt} = BIOMASS_STEMBARK_{mpt} * (1 - 0.15)
If BARK_RET_{mpt} = 4 then BIOMASS_STEMBARK_{mpt} = BIOMASS_STEMBARK_{mpt} * (1 - 0.38)
If BARK_RET_{mpt} = 5 then BIOMASS_STEMBARK_{mpt} = BIOMASS_STEMBARK_{mpt} * (1 - 0.63)
If BARK_RET_{mpt} = 6 then BIOMASS_STEMBARK_{mpt} = BIOMASS_STEMBARK_{mpt} * (1 - 0.875)
If BARK_RET_{mpt} = 7 then BIOMASS_STEMBARK_{mpt} = 0*

where t is a unique tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) Sum the biomass components for each tree:

$$\begin{aligned} BIOMASS_TOTAL_{mpt} \\ &= BIOMASS_STEMWOOD_{mpt} + BIOMASS_STEMBARK_{mpt} \\ &+ BIOMASS_BRANCHES_{mpt} + BIOMASS_FOLIAGE_{mpt} \end{aligned}$$

where t is a unique tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

BIOMASS_STEMWOOD, BIOMASS_STEMBARK, BIOMASS_BRANCHES, BIOMASS_FOLIAGE,
BIOMASS_TOTAL, BMEQ_WOOD, BMEQ_BARK, BMEQ_BRANCHES, BMEQ_FOLIAGE

5. Large Tree Plot Summary

Compiler routines

gp_compile_lgtree.sas
gp_ltp_tree_age_corr_years.sas
gp_ltp_tree_age_total.sas
gp_siteindex_macro.sas (which calls upon gp_siteindex_bc.sas and a temporary output table from
gp_ltp_tree_age_corr_years.sas)

Output written to:

ltp_header
site_info
ltp_tree_species_comp
ltp_tree_age

SITE_INDEX

Inputs

TREE_NUM; AGE_TOTAL; HEIGHT

Computations

1) For each tree deemed suitable for compiling site height (SUIT_HT = 'Y' or 'M') and site age (SUIT_AGE = 'Y' or 'M'), of dominant or co-dominant crown class (CROWN_CLASS = 'D' or 'C') and not selected as a residual or non-standard tree (SITE_TYPE = 'T', 'TL', 'TS', 'TO', 'TR', 'L', 'S', 'O', or 'U'), calculate site index at breast-height age of 50 years using the appropriate tree age specified by each site index equation (i.e. breast-height age, stump-height age or total age) or geospatial coordinates of plot centers in the case of trees in British Columbia. Tree age for calculating site-index (SI_AGE) is based on total tree age (AGE_TOTAL) minus the proportion of appropriate species- and jurisdiction-specific age correction factors (AGE_CORR_YEARS unadjusted for boring height) between total age and breast-height age (i.e. 1.3m). Tree height (HEIGHT) was used for calculating site index per tree:

$$SITE_INDEX_{mpt} = f(SI_AGE_{mpt}; HEIGHT_{mpt}; LGTREE_GENUS_{mpt}; LGTREE_SPECIES_{mpt})$$

Or in the case of trees in British Columbia:

$$\begin{aligned} SITE_INDEX_{mpt} \\ &= f(UTM_E_{mpt}; UTM_N_{mpt}; UTM_ZONE_{mpt}; LGTREE_GENUS_{mpt}; LGTREE_SPECIES_{mpt}) \end{aligned}$$

where t is a unique site tree (SUIT_HT = 'Y' or 'M' and SUIT_AGE = 'Y' or 'M' and CROWN_CLASS = 'D' or 'C' and SITE_TYPE = 'T', 'TL', 'TS', 'TO', 'TR', 'L', 'S', 'O', or 'U') within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate the average site index for the plot regardless of species by summing the site indices of all trees within a plot and dividing by the number of site trees:

$$SITE_INDEX_{mp} = \left[\sum_{t=1}^n SITE_INDEX_{mpt} \right] / n_{mp}$$

where t is a unique site tree (SUIT_HT = 'Y' or 'M' and SUIT_AGE = 'Y' or 'M' and CROWN_CLASS = 'D' or 'C' and SITE_TYPE = 'T', 'TL', 'TS', 'TO', 'TR', 'L', 'S', 'O', or 'U') among n number of site trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Site index calculations use jurisdiction-based and taxon-specific equations or maps provided by jurisdictions (Cieszewski et al. 1993; Huang et al. 1994; Ker 1991; NS Forest Research Section 1987; Pothier and Savard 1998). When a species-specific equation or map does not exist for a particular species, then substitutions are done based on genus or vegetation type (hardwood versus softwood). Site index calculations for species in BC make use of the 'SIInBC' function of the 'FAIBBase' package for R (Y. Luo 2020). Site indexes were only calculated for trees with breast-height age greater or equal to 3, except for plots within British Columbia, and height greater or equal to 1.3 m. Site index was capped at 45 m except for plots within British Columbia. Short trees and really old trees can lead to misleading site index values (Comeau 2020), however these were included in our calculations due to the limited number of site trees in some plots and the plot selection design that includes non-productive stands (i.e. plots where site index could realistically be small). Tests of our site index calculations indicate values are within expected ranges for jurisdictions (e.g. 2 – 35 m for New Brunswick, Hennigar et al. 2017) or reasonable given site tree attributes (e.g. 1.5 m tall 50 year old tree).

References:

- Cieszewski, C. J., I. E. Bella and D. P. Yeung. 1993. Preliminary site-index height growth curves for eleven timber species in Saskatchewan. Draft unpublished project report. Saskatchewan Forest Centre, Prince Albert, SK.
- Comeau, P. 2020. Estimating site index using ecosite guides for Western Canada. University of Alberta, Department of Renewable Resources, Edmonton, AB. MGM Research Note #2020-1.
- Hennigar, C., A. Weiskittel, H. L. Allen and D. A. MacLean. 2017. Development and evaluation of a biomass increment based index for site productivity. *Can. J. For. Res.* 47:400-410.
- Huang, S., S. J. Titus and T.W. Lakusta. 1994. Ecologically based site index curves and tables for major Alberta tree species. Alberta Environmental Protection Land and Forest Services, Forest Management Division, Edmonton, AB. T/307, 0-7732-1398-8.
- Luo, Yong. 2020. Package FAIBBase: basic functions for forest mensuration and ecology. Version 0.0.0.9000.
- Nova Scotia Forest Research Section. 1987. Site index curves for hardwoods in Nova Scotia. Nova Scotia Department of Lands and Forests, Truro, NS. Forest Research Report 1.
- Ker, M. F. and C. Bowling. 1991. Polymorphic site index equations for four New Brunswick softwood species. *Can. J. For. Res.* 21(5):728-732.
- Pothier, D. and F. Savard. 1998. Actualisation des tables de production pour les principales espèces forestières du Québec. Gouvernement du Québec, Ministère des Ressources Naturelles. 183p.

Output

SITE_INDEX

SITE_INDEX_GENUS

Inputs

LGTREE_GENUS of site trees; DBH

Computations

Site index genus (SITE_INDEX_GENUS) was assigned as the genus of the most abundant taxon, by basal area, of site index trees used in calculations of site index (SITE_INDEX).

Output

SITE_INDEX_GENUS

SITE_INDEX_SPECIES

Inputs

LGTREE_SPECIES of site trees

Computations

Site index species (SITE_INDEX_SPECIES) was assigned as the species of the most abundant taxon, by basal area, of site index trees used in calculations of site index (SITE_INDEX).

Output

SITE_INDEX_SPECIES

SITE_HEIGHT

Inputs

TREE_NUM; HEIGHT; LGTREE_STATUS; CROWN_CLASS; MEAS_EST_HEIGHT; STEM_COND

Computations

NOTE: This should only use the trees suitable for calculating height and site indices from the LTP_TREE_AGE table (i.e. SUIT_HT = 'Y'), however there were not always enough suitable site trees in the LTP_TREE_AGE table for this calculation so trees meeting conditions to be a site-representative tree (see below) and with missing indicators of site height suitability (i.e. SUIT_HT = 'M') were also used following the constraint.

1) Calculate the arithmetic average height (m) of all large site trees with live standing status (LGTREE_STATUS = 'LS'), dominant or co-dominant crown class (CROWN_CLASS = 'C' or 'D'), intact stems (STEM_COND not = 'B'), measured (or not specified) height values (MEAS_EST_HEIGHT = 'M' or 'S') and not selected as a residual or non-standard tree (SITE_TYPE not = 'N' or 'R'). Site height considered trees within the plot with height suitable for calculating site height (SUIT_HT = 'Y') or with missing suitable height indicator (SUIT_HT = 'M') and no recorded damage (damage_agent = 'O' or 'S'). Site height also considered site trees outside the plot when trees were suitable for calculating site height (SUIT_HT = 'Y' or 'M') and dominant, co-dominant or missing crown class (CROWN_CLASS = 'C', 'D' or 'M'):

$$SITE_HEIGHT_{mp} = \left[\sum_{t=1}^n HEIGHT_{mpt} \right] / n_{mp}$$

where t is a unique tree among n number of site-representative trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

SITE_HEIGHT

LOREY_HEIGHT

Inputs

TREE_NUM; LGTREE_STATUS; DBH; HEIGHT; STEM_COND

Computations

1) Estimate the basal area of each intact (STEM_COND not = 'B') live fallen and live standing (LGTREE_STATUS = 'LF' or 'LS') tree, using DBH (cm) and converting basal area to m²:

$$BASAL_AREA_{mpt} = \frac{\pi * DBH_{mpt}^2}{40,000}$$

where t is a unique intact live fallen and live standing tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate Lorey height (m) as a basal area-weighted average of HEIGHT for intact live fallen and live standing trees. If tree height is missing (HEIGHT = -1), then it is set equal to the projected height of that tree (HEIGHT = HEIGHT_PRJ):

$$LOREY_HEIGHT_{mp} = \left[\sum_{t=1}^n BASAL_AREA_{mpt} * HEIGHT_{mpt} \right] / \sum_{t=1}^n BASAL_AREA_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of intact live fallen and live standing trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

LOREY_HEIGHT

BASAL_AREA_STANDLIVE

Inputs

TREE_NUM; LGTREE_STATUS; DBH; MEAS_PLOT_SIZE

Computations

1) Estimate the basal area of each live standing (LGTREE_STATUS = 'LS') large tree in large tree plot, using DBH (cm) and converting basal area to m²:

$$BASAL_AREA_{mpt} = \frac{\pi * DBH_{mpt}^2}{40,000}$$

where t is a unique live standing tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Sum the basal area estimates of all live standing (LGTREE_STATUS = 'LS') large trees in the large tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare basal area ($m^2 ha^{-1}$):

$$BASAL_AREA_STANDLIVE_{mp} = \left[\sum_{t=1}^n BASAL_AREA_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique tree (TREE_NUM) among n number of live standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

BASAL_AREA_STANDLIVE

BASAL_AREA_STANDDEAD

Inputs

TREE_NUM; LGTREE_STATUS; DBH; MEAS_PLOT_SIZE

Computations

1) Estimate the basal area of each dead standing (LGTREE_STATUS = 'DS') large tree in the large tree plot, using DBH (cm) and converting basal area to m^2 :

$$BASAL_AREA_{mpt} = \frac{\pi * DBH_{mpt}^2}{40,000}$$

where t is a unique dead standing tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Sum the basal area estimates of all dead standing (LGTREE_STATUS = 'DS') large trees in the large tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare basal area ($m^2 ha^{-1}$):

$$BASAL_AREA_STANDDEAD_{mp} = \left[\sum_{t=1}^n BASAL_AREA_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique tree (TREE_NUM) among n number of dead standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

BASAL_AREA_STANDDEAD

BASAL_AREA_FALLLIVE

Inputs

TREE_NUM; LGTREE_STATUS; DBH; MEAS_PLOT_SIZE

Computations

1) Estimate the basal area of each live fallen (LGTREE_STATUS = 'LF') large tree in the large tree plot, using DBH (cm) and converting basal area to m²:

$$BASAL_AREA_{mpt} = \frac{\pi * DBH_{mpt}^2}{40,000}$$

where t is a unique live fallen tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Sum the basal area estimates of all live fallen (LGTREE_STATUS = 'LF') large trees in the large tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare basal area (m² ha⁻¹):

$$BASAL_AREA_FALLLIVE_{mp} = \left[\sum_{t=1}^n BASAL_AREA_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique tree (TREE_NUM) among n number of live fallen large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

BASAL_AREA_FALLLIVE

STEM_DENSITY_STANDLIVE

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE

Computations

Count the number of live standing (LGTREE_STATUS = 'LS') large trees in the large tree plot, and then divide by measured plot size (MEAS_PLOT_SIZE) to calculate per-hectare stem density (trees ha⁻¹):

$$STEM_DENSITY_STANDLIVE_{mp} = \frac{n_{mp}}{MEAS_PLOT_SIZE_{mp}}$$

where n is the number of live standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

STEM_DENSITY_STANDLIVE

STEM_DENSITY_STANDDEAD

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE

Computations

Count the number of dead standing (LGTREE_STATUS = 'DS') large trees in the large tree plot, and then divide by measured plot size (MEAS_PLOT_SIZE) to calculate per-hectare stem density (trees ha⁻¹):

$$STEM_DENSITY_STANDDEAD_{mp} = \frac{n_{mp}}{MEAS_PLOT_SIZE_{mp}}$$

where n is the number of dead standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

STEM_DENSITY_STANDDEAD

STEM_DENSITY_FALLLIVE

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE

Computations

Count the number of live fallen (LGTREE_STATUS = 'LF') large trees in the large tree plot, and then divide by measured plot size (MEAS_PLOT_SIZE) to calculate per-hectare stem density (trees ha⁻¹):

$$STEM_DENSITY_FALLLIVE_{mp} = \frac{n_{mp}}{MEAS_PLOT_SIZE_{mp}}$$

where n is the number of live fallen large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

STEM_DENSITY_FALLLIVE

PLOTBIO_STEMWOOD_LIVE

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE; BIOMASS_STEMWOOD

Computations

Sum the stem wood biomass estimates (BIOMASS_STEMWOOD) of all live large trees (LGTREE_STATUS = 'LS' or 'LF') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the per-hectare biomass of live large tree stem wood (Mg ha⁻¹):

$$PLOTBIO_STEMWOOD_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMWOOD_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of live large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_STEMWOOD_LIVE

PLOTBIO_STEMBARK_LIVE

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE; BIOMASS_STEMBARK

Computations

Sum the stem bark biomass estimates (BIOMASS_STEMBARK) of all live large trees (LGTREE_STATUS = 'LS' or 'LF') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the per-hectare biomass of live large tree stem bark (Mg ha⁻¹):

$$PLOTBIO_STEMBARK_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMBARK_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of live large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_STEMBARK_LIVE

PLOTBIO_BRANCHES_LIVE

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE; BIOMASS_BRANCHES

Computations

Sum the branches biomass estimates (BIOMASS_BRANCHES) of all live large trees (LGTREE_STATUS = 'LS' or 'LF') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the per-hectare biomass of live large tree branches (Mg ha⁻¹):

$$PLOTBIO_BRANCHES_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_BRANCHES_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of live large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_BRANCHES_LIVE

PLOTBIO_FOLIAGE_LIVE

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE; BIOMASS_FOLIAGE

Computations

Sum the foliage biomass estimates (BIOMASS_FOLIAGE) of all live large trees (LGTREE_STATUS = 'LS' or 'LF') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the per-hectare biomass of live large tree foliage (Mg ha⁻¹):

$$PLOTBIO_FOLIAGE_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_FOLIAGE_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of live large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_FOLIAGE_LIVE

PLOTBIO_STEMWOOD_DEAD

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE; BIOMASS_STEMWOOD

Computations

Sum the stem wood biomass estimates (BIOMASS_STEMWOOD) of all dead standing large trees (LGTREE_STATUS = 'DS') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the per-hectare biomass of dead standing large tree stem wood (Mg ha⁻¹):

$$PLOTBIO_STEMWOOD_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMWOOD_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of dead standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_STEMWOOD_DEAD

PLOTBIO_STEMBARK_DEAD

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE; BIOMASS_STEMBARK; LGTREE_GENUS

Computations

Sum the stem bark biomass estimates (BIOMASS_STEMBARK) of all dead standing large trees (LGTREE_STATUS = 'DS') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the per-hectare biomass of dead standing large tree stem bark (Mg ha⁻¹):

$$PLOTBIO_STEMBARK_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMBARK_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of dead standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Note that the biomass of stem bark is 0 for unidentifiable conifer or hardwood dead standing trees (LGTREE_STATUS = 'DS' and LGTREE_GENUS = 'GENC', 'GENH' or 'UNKN').

Output

PLOTBIO_STEMBARK_DEAD

PLOTBIO_BRANCHES_DEAD

Inputs

TREE_NUM; LGTREE_STATUS; MEAS_PLOT_SIZE; BIOMASS_BRANCHES

Computations

Sum the branches biomass estimates (BIOMASS_BRANCHES) of all dead standing large trees (LGTREE_STATUS = 'DS') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the per-hectare biomass of dead standing large tree branches (Mg ha⁻¹):

$$PLOTBIO_BRANCHES_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_BRANCHES_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of dead standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Note that the biomass of branches is 0 for unidentifiable conifer or hardwood dead standing trees (LGTREE_STATUS = 'DS' and LGTREE_GENUS = 'GENC', 'GENH' or 'UNKN').

Output

PLOTBIO_BRANCHES_DEAD

PLOTVOL_STANDLIVE

Inputs

TREE_NUM; LGTREE_STATUS; VOL_TOTAL; MEAS_PLOT_SIZE

Computations

Sum the volume estimates (VOL_TOTAL) of all live standing trees (LGTREE_STATUS = 'LS') in the large tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare volume (m³ ha⁻¹):

$$PLOTVOL_STANDLIVE_{mp} = \left[\sum_{t=1}^n VOL_TOTAL_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique tree (TREE_NUM) among n number of live standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_STANDLIVE

PLOTVOL_STANDDEAD

Inputs

TREE_NUM; LGTREE_STATUS; VOL_TOTAL; MEAS_PLOT_SIZE

Computations

Sum the volume estimates (VOL_TOTAL) of all dead standing trees (LGTREE_STATUS = 'DS') in the large tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare volume (m³ ha⁻¹):

$$PLOTVOL_STANDDEAD_{mp} = \left[\sum_{t=1}^n VOL_TOTAL_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique tree (TREE_NUM) among n number of dead standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_STANDDEAD

PLOTVOL_FALLLIVE

Inputs

TREE_NUM; LGTREE_STATUS; VOL_TOTAL; MEAS_PLOT_SIZE

Computations

Sum the volume estimates (VOL_TOTAL) of all live fallen trees (LGTREE_STATUS = 'LF') in the large tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare volume (m³ ha⁻¹):

$$PLOTVOL_FALLLIVE_{mp} = \left[\sum_{t=1}^n VOL_TOTAL_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique tree (TREE_NUM) among n number of live fallen large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_FALLLIVE

PLOTBIO_LGTR_LIVE

Inputs

TREE_NUM; BIOMASS_TOTAL; LGTREE_STATUS; MEAS_PLOT_SIZE.

Computations

Sum the biomass estimates (BIOMASS_TOTAL) of all live large trees (LGTREE_STATUS = 'LS' or 'LF') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_LGTR_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_TOTAL_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of live large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_LGTR_LIVE

PLOTBIO_LGTR_DEAD

Inputs

TREE_NUM; BIOMASS_TOTAL; LGTREE_STATUS; MEAS_PLOT_SIZE.

Computations

Sum the biomass estimates (BIOMASS_TOTAL) of all dead standing large trees (LGTREE_STATUS = 'DS') in the large tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_LGTR_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_TOTAL_{mpt}$$

where t is a unique tree (TREE_NUM) among n number of dead standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_LGTR_DEAD

SITE_AGE, NUM_LAB, NUM_FIELD, AGE_CORR_YEARS, AGE_TOTAL

Inputs

TREE_NUM; LAB_AGE; FIELD_AGE; SUIT_AGE; BORE_HT; BORE_DOB; DBH; LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY; PROVINCE; ECOZONE

Computations

1) Calculate age correction factor (AGE_CORR_YEARS) according to bore height (BORE_HT), tree taxon (LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY), province (PROVINCE) and ecozone (ECOZONE):

A lookup table of age correction factors, derived from jurisdictional years-to-breast-height values, were used to compute age correction years for most jurisdictions, except for BC, NL, and NS where age correction factors were not provided or readily available. While species-specific 'years-to-breast-height' equations are provided for BC, the equations require site index as an input parameter, which can only be compiled with site age (i.e. total age of trees in the plot). Similarly, age correction factors provided by NL require site index as an input parameter. Therefore, age correction years provided during baseline sampling (provided by jurisdictions for all established NFI plots [NFI_PLOT]) are used to calculate age correction years for trees in BC, NL and NS, as well as for cases where years-to-breast-height values for particular species-location combinations were unavailable. To this end, mean age correction years by plot (NFI_PLOT) or ecozone and species or vegetation type (hardwood versus softwood) provided by jurisdictions during baseline sampling were considered to estimate age correction years (AGE_CORR_YEARS) for BC, NL, and NS. When estimating age correction years from baseline data, only age corrections years less than 100 years were used for particular combinations of plot or ecozone and species or vegetation type. Age correction years assigned to each tree is then adjusted (BORE_HT_ADJ) using the ratio of bore height (BORE_HT) to breast height (1.3 m). When a tree core was collected during a

previous sampling period and can be used for calculating the tree's age during a subsequent sampling period (i.e. FIELD_AGE = -8), then the bore height (BORE_HT) of the site tree during the previous sampling period is used in lieu of current missing bore height:

$$BORE_HT_ADJ_{mpt} = \frac{BORE_HT_{mpt}}{1.3}$$

$$AGE_CORR_YEARS_{mpt} = f(BORE_HT_{mpt}; LGTREE_GENUS\ SPECIES\ VARIETY_{mpt}; PROVINCE_{mp}; ECOZONE_{mp})$$

$$* BORE_HT_ADJ_{mpt}$$

where t is a unique aged site tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate estimated total age (AGE_TOTAL) using age correction factors (AGE_CORR_YEARS) and age calculated in the lab (LAB_AGE) or, if not available, age determined in the field (FIELD_AGE). If age determined in both the lab and field are missing then total age is recorded as missing. When a tree core was collected during a previous sampling period and can be used for calculating the tree's age during a subsequent sampling period (i.e. FIELD_AGE = -8), then the lab age (LAB_AGE) and field age (FIELD_AGE) of the site tree during the previous sampling period plus the time elapsed between sampling periods are used in lieu of current missing lab and field ages:

$$\text{if } FIELD_AGE_{mpt} = -8, \text{ then } LAB_AGE_{mpt} = LAB_AGE_{(m-1)pt} + (MEAS_DATE_{mpt} - MEAS_DATE_{(m-1)pt}) \text{ and } FIELD_AGE_{mpt} = FIELD_AGE_{(m-1)pt} + (MEAS_DATE_{mpt} - MEAS_DATE_{(m-1)pt})$$

$$\text{if } LAB_AGE_{mpt} > 0, \text{ then } AGE_TOTAL_{mpt} = LAB_AGE_{mpt} + AGE_CORR_YEARS_{mpt}$$

$$\text{if } LAB_AGE_{mpt} = -1 \text{ and } FIELD_AGE_{mpt} \neq -1, \text{ then } AGE_TOTAL_{mpt} = FIELD_AGE_{mpt} + AGE_CORR_YEARS_{mpt}$$

$$\text{if } LAB_AGE_{mpt} = -1 \text{ and } FIELD_AGE_{mpt} = -1, \text{ then } AGE_TOTAL_{mpt} = -1$$

where t is a unique tree (TREE_NUM) among n number of suitable aged site trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate the arithmetic average age of trees deemed suitable for compiling site age (SUIT_AGE = 'Y' or 'M' and CROWN_CLASS = 'D', 'C', or 'M' and SITE_TYPE = 'T', 'TL', 'TS', 'TO', 'TR', 'L', 'S', 'O', or 'U'):

$$SITE_AGE_{mp} = \left[\sum_{t=1}^n AGE_TOTAL_{mpt} \right] / n_{mp}$$

where t is a unique tree (TREE_NUM) among n number of suitable aged site trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Count the number of suitable aged site trees with available lab calculated ages (LAB_AGE \neq -1) to determine the number of lab-counted tree cores used in the determination of site age (NUM_LAB):

$$NUM_LAB_{mp} = n_{mp}$$

where n is the number of suitable aged site trees with available lab calculated ages (LAB_AGE \neq -1) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) Count the number of suitable aged site trees with available field calculated ages and no concurrent lab calculated ages (LAB_AGE = -1 and FIELD_AGE ≠ -1) to determine the number of lab-counted tree cores used in the determination of site age (NUM_FIELD):

$$NUM_FIELD_{mp} = n_{mp}$$

where n is the number of suitable aged site trees with available field calculated ages and no concurrent lab calculated ages (LAB_AGE = -1 and FIELD_AGE ≠ -1) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

SITE_AGE, NUM_LAB, NUM_FIELD, AGE_CORR_YEARS, AGE_TOTAL

GROSSVOL_INCR

Not yet implemented (requires multiple measurement cycles)

Inputs

SITE_AGE; PLOTVOL_STANDLIVE; PLOTVOL_STANDDEAD; PLOTVOL_FALLLIVE;
PLOTVOL_SMTR_LIVE; PLOTVOL_SMTR_DEAD

Growth & yield models

Computations

1) Sum large (PLOTVOL_STANDLIVE, PLOTVOL_STANDDEAD and PLOTVOL_FALLLIVE) and small (PLOTVOL_SMTR_LIVE and PLOTVOL_SMTR_DEAD) tree volumes to calculate total stand-level tree volume:

$$TREE_VOL_{mp} = PLOTVOL_STANDLIVE_{mp} + PLOTVOL_STANDDEAD_{mp} + PLOTVOL_FALLLIVE_{mp} \\ + PLOTVOL_SMTR_LIVE_{mp} + PLOTVOL_SMTR_DEAD_{mp}$$

where m is a specific measurement (MEAS_NUM) of plot p (NFI_PLOT)

2) Develop appropriate cumulative volume-age relationship or growth-yield model (GROSSVOL) for a given plot using data from multiple measurement cycles (i.e. MEAS_NUM):

$$GROSSVOL_p = f(SITE_AGE, TREE_VOL, MEAS_NUM \dots) \\ GROSSVOL_p = \alpha e^{-\beta t^{-1}}$$

Where p is a unique plot (NFI_PLOT)

3) Calculate current annual increment for the plot (GROSSVOL_INCR) as the value of the first derivative of the volume-age relationship evaluated at time of sampling (SITE_AGE) for each major taxon in the large plot:

$$GROSSVOL_INCR_{mp} = \frac{dGROSSVOL_p}{dSITE_AGE_{mp}} = f(SITE_AGE_{mp}, \dots)$$

Where m is a specific measurement (MEAS_NUM) of plot p (NFI_PLOT)

Output

GROSSVOL_INCR

GROSSVOL_MAI

Inputs

PLOTVOL_STANDLIVE; PLOTVOL_STANDDEAD; PLOTVOL_FALLLIVE; SITE_AGE

Computations

1) Sum plot-level volumes of live (PLOTVOL_STANDLIVE and PLOTVOL_FALLLIVE) and dead (PLOTVOL_STANDDEAD) large trees and divide by site age (SITE_AGE) to estimate mean gross volume annual increment (GROSSVOL_MAI) in $\text{m}^3 \text{ha}^{-1} \text{yr}^{-1}$:

$$\text{GROSSVOL_MAI}_{mp} = \frac{\text{PLOTVOL_STANDLIVE}_{mp} + \text{PLOTVOL_STANDDEAD}_{mp} + \text{PLOTVOL_FALLLIVE}_{mp}}{\text{SITE_AGE}_{mp}}$$

Output

GROSSVOL_MAI

PERCENT, SPECIES_NUM

Inputs

TREE_NUM; LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY; LGTREE_STATUS; DBH

Computations

1) Estimate the basal area (BASAL_AREA) of each live large tree (LGTREE_STATUS = 'LS' or 'LF') without missing DBH (DBH not equal to -1), using DBH (cm) and converting basal area to m^2 :

$$\text{BASAL_AREA}_{mpt} = \frac{\pi * \text{DBH}_{mpt}^2}{40,000}$$

where t is a unique tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Sum the basal area estimates of live large trees by taxon (i.e. unique genus-species-variety combinations):

$$\text{BASAL_AREA}_{mps} = \sum_{t=1}^n \text{BASAL_AREA}_{mpst}$$

where t is a unique tree (TREE_NUM) among n number of trees belonging to taxon s (LGTREE_GENUS, LGTREE_SPECIES and LGTREE_VARIETY) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Divide the basal area of each taxon by the summed basal area of all live large trees (LGTREE_STATUS = 'LS' or 'LF') within the large tree plot and multiply by 100% to calculate percent basal area cover of each species in the large tree plot (PERCENT):

$$\text{PERCENT}_{mps} = \text{BASAL_AREA}_{mps} / \sum_{s=1}^n \text{BASAL_AREA}_{mps} * 100\%$$

where s is a unique taxon (LGTREE_GENUS, LGTREE_SPECIES and LGTREE_VARIETY) among n number of taxa within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) Assign a ranked abundance number (SPECIES_NUM) to each large tree taxon (i.e. combination of genus, species and variety) in the large tree plot, from greatest to smallest percent basal area

Output

PERCENT, SPECIES_NUM

6. Small Tree List

Compiler routines

smtree_volume_all.sas
smtree_biomass.sas

Output written to:

stp_tree

SMTREE_VOL_TOTAL, SMTREE_HT_PRJ, SMTREE_VOL_PRJ

Compiler routines

Provincial volume estimation routines, gp_tree_volume_ab.sas, gp_tree_volume_bc.sas etc., which are called from smtree_volume_all.sas

Inputs

SMTREE_NUM; SMTREE_GENUS; SMTREE_SPECIES; SMTREE_VARIETY; SMTREE_STATUS;
SMTREE_DBH; SMTREE_HT

Computations

For measurements prior to August 1, 2007: In the small tree plots, some jurisdictions tallied smaller trees into height and DBH classes rather than recording actual height and DBH values. These classes were converted to specific DBH and height values (midpoint of the class used) before submitting the data to the CFS.

Trees are processed by the volume compiler and individual tree volumes calculated in the same manner as the large trees with the following exceptions:

1. There are no allowances for trees with broken tops in baseline measurement cycle prior to August 1, 2007.
2. There is no merchantable volume.

Output

SMTREE_VOL_TOTAL, SMTREE_HT_PRJ, SMTREE_VOL_PRJ

**SMTREE_BIOMASS, BIOMASS_STEMWOOD, BIOMASS_STEMBARK,
BIOMASS_BRANCHES, BIOMASS_FOLIAGE, BMEQ_WOOD, BMEQ_BARK,
BMEQ_BRANCHES, BMEQ_FOLIAGE**

Compiler routines

smtree_biomass.sas
gp_smtree_biomass.sas

Inputs

SMTREE_NUM; SMTREE_GENUS; SMTREE_SPECIES; SMTREE_VARIETY; SMTREE_STATUS;
SMTREE_DBH; SMTREE_HT; SMTREE_HT_PRJ; SMTREE_VOL_TOTAL; SMTREE_VOL_PRJ;
PROVINCE; ECOZONE

Computations

- 1) The computations for small tree biomass are the same as those for large tree biomass with one exception:
-There are no allowances for trees with broken tops in baseline measurement cycle prior to August 1, 2007.

$$\begin{aligned}BIOMASS_STEMWOOD_{mpt} &= f(SMTREE_DBH_{mpt}, SMTREE_HEIGHT_{mpt}) \\BIOMASS_STEMBARK_{mpt} &= f(SMTREE_DBH_{mpt}, SMTREE_HEIGHT_{mpt}) \\BIOMASS_BRANCHES_{mpt} &= f(SMTREE_DBH_{mpt}, SMTREE_HEIGHT_{mpt}) \\BIOMASS_FOLIAGE_{mpt} &= f(SMTREE_DBH_{mpt}, SMTREE_HEIGHT_{mpt})\end{aligned}$$

where t is a unique tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

- 2) Sum the biomass components for each tree:

$$\begin{aligned}SMTREE_BIOMASS_{mpt} \\&= BIOMASS_STEMWOOD_{mpt} + BIOMASS_STEMBARK_{mpt} \\&+ BIOMASS_BRANCHES_{mpt} + BIOMASS_FOLIAGE_{mpt}\end{aligned}$$

where t is a unique tree (TREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

BIOMASS_STEMWOOD, BIOMASS_STEMBARK, BIOMASS_BRANCHES, BIOMASS_FOLIAGE,
SMTREE_BIOMASS, BMEQ_WOOD, BMEQ_BARK, BMEQ_BRANCHES, BMEQ_FOLIAGE

7. Small Tree Plot Summary

Compiler routines

gp_compile_smtree.sas

Output written to

stp_header
site_info
stp_tree_species_comp

PLOTVOL_SMTR_LIVE

Inputs

SMTREE_NUM; SMTREE_VOL_TOTAL; SMTREE_STATUS; MEAS_PLOT_SIZE

Volume equations: See [Section 16](#).

Computations

1) For measurements prior to August 1, 2007: In the small tree plots, some jurisdictions tallied smaller trees into height and DBH classes rather than recording actual height and DBH values. These classes were converted to specific DBH and height values (midpoint of the class used) before submitting the data to the CFS. These trees are then processed by the volume compiler and individual tree volumes calculated in the same manner as the large trees.

2) Sum the volume estimates (SMTREE_VOL_TOTAL) of all live small trees (SMTREE_STATUS = 'LS' or 'LF') in the small tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare volume (m³ ha⁻¹):

$$PLOTVOL_SMTR_LIVE_{mp} = \left[\sum_{t=1}^n SMTREE_VOL_TOTAL_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique small tree (SMTREE_NUM) among n number of live small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_SMTR_LIVE

PLOTVOL_SMTR_DEAD

Inputs

SMTREE_NUM; SMTREE_VOL_TOTAL; SMTREE_STATUS; MEAS_PLOT_SIZE

Volume equations: See [Section 16](#).

Computations

1) For measurements prior to August 1, 2007: In the small tree plots, some jurisdictions tallied smaller trees into height and DBH classes rather than recording actual height and DBH values. These classes were converted to specific DBH and height values (midpoint of the class used) before submitting the data to the CFS. These trees are then processed by the volume compiler and individual tree volumes calculated in the same manner as the large trees.

2) Sum the volume estimates (SMTREE_VOL_TOTAL) of all dead standing small trees (SMTREE_STATUS = 'DS') in the small tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare volume (m³ ha⁻¹):

$$PLOTVOL_SMTR_DEAD_{mp} = \left[\sum_{t=1}^n SMTREE_VOL_TOTAL_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique small tree (SMTREE_NUM) among n number of dead standing small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_SMTR_DEAD

PLOTBIO_SMTR_LIVE

Inputs

SMTREE_NUM; SMTREE_STATUS; SMTREE_BIOMASS; MEAS_PLOT_SIZE

Computations

Sum the biomass estimates (SMTREE_BIOMASS) of all live small trees (SMTREE_STATUS = 'LS' or 'LF') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMTR_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n SMTREE_BIOMASS_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of live small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMTR_LIVE

PLOTBIO_SMTR_DEAD

Inputs

SMTREE_NUM; SMTREE_STATUS; SMTREE_BIOMASS; MEAS_PLOT_SIZE

Computations

Sum the biomass estimates (SMTREE_BIOMASS) of all dead standing small trees (SMTREE_STATUS = 'DS') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMTR_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n SMTREE_BIOMASS_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of live small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMTR_DEAD

PLOTBIO_SMT_STEMWOOD_LIVE

Inputs

SMTREE_NUM; SMTREE_STATUS; BIOMASS_STEMWOOD; MEAS_PLOT_SIZE

Computations

Sum the stem wood biomass estimates (BIOMASS_STEMWOOD) of all live small trees (SMTREE_STATUS = 'LS' or 'LF') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMT_STEMWOOD_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMWOOD_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of live small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMT_STEMWOOD_LIVE

PLOTBIO_SMT_STEMBARK_LIVE

Inputs

SMTREE_NUM; SMTREE_STATUS; BIOMASS_STEMBARK; MEAS_PLOT_SIZE

Computations

Sum the stem bark biomass estimates (BIOMASS_STEMBARK) of all live small trees (SMTREE_STATUS = 'LS' or 'LF') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMT_STEMBARK_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMBARK_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of live small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMT_STEMBARK_LIVE

PLOTBIO_SMT_BRANCHES_LIVE

Inputs

SMTREE_NUM; SMTREE_STATUS; BIOMASS_BRANCHES; MEAS_PLOT_SIZE

Computations

Sum the branches biomass estimates (BIOMASS_BRANCHES) of all live small trees (SMTREE_STATUS = 'LS' or 'LF') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMT_BRANCHES_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_BRANCHES_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of live small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMT_BRANCHES_LIVE

PLOTBIO_SMT_FOLIAGE_LIVE

Inputs

SMTREE_NUM; SMTREE_STATUS; BIOMASS_FOLIAGE; MEAS_PLOT_SIZE

Computations

Sum the foliage biomass estimates (BIOMASS_FOLIAGE) of all live small trees (SMTREE_STATUS = 'LS' or 'LF') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMT_FOLIAGE_LIVE_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_FOLIAGE_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of live small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMT_FOLIAGE_LIVE

PLOTBIO_SMT_STEMWOOD_DEAD

Inputs

SMTREE_NUM; SMTREE_STATUS; BIOMASS_STEMWOOD; MEAS_PLOT_SIZE

Computations

Sum the stem wood biomass estimates (BIOMASS_STEMWOOD) of all dead standing small trees (SMTREE_STATUS = 'DS') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMT_STEMWOOD_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMWOOD_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of dead standing small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMT_STEMWOOD_DEAD

PLOTBIO_SMT_STEMBARK_DEAD

Inputs

SMTREE_NUM; SMTREE_STATUS; BIOMASS_STEMBARK; MEAS_PLOT_SIZE.

Computations

Sum the stem bark biomass estimates (BIOMASS_STEMBARK) of all dead standing small trees (SMTREE_STATUS = 'DS') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMT_STEMBARK_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_STEMBARK_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of dead standing small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMT_STEMBARK_DEAD

PLOTBIO_SMT_BRANCHES_DEAD

Inputs

SMTREE_NUM; SMTREE_STATUS; BIOMASS_BRANCHES; MEAS_PLOT_SIZE

Computations

Sum the branches biomass estimates (BIOMASS_BRANCHES) of all dead standing small trees (SMTREE_STATUS = 'DS') in the small tree plot, convert units from kg to Mg and divide by measured plot size (MEAS_PLOT_SIZE) to get the total per-hectare biomass (Mg ha⁻¹):

$$PLOTBIO_SMT_BRANCHES_DEAD_{mp} = \frac{0.001}{MEAS_PLOT_SIZE_{mp}} * \sum_{t=1}^n BIOMASS_BRANCHES_{mpt}$$

where t is a unique tree (SMTREE_NUM) among n number of dead standing small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMT_BRANCHES_DEAD

SMTREE_PERCENT, SMTREE_SPECIES_NUM

Inputs

SMTREE_NUM; SMTREE_GENUS; SMTREE_SPECIES; SMTREE_VARIETY; SMTREE_STATUS; DBH

Computations

1) Estimate the basal area (BASAL_AREA) of each live small tree (SMTREE_STATUS = 'LS' or 'LF') without missing DBH (SMTREE_DBH not equal to -1), using DBH (cm) and converting basal area to m²:

$$BASAL_AREA_{mpt} = \frac{\pi * DBH_{mpt}^2}{40,000}$$

where t is a unique tree (SMTREE_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Sum the basal area estimates of live small trees by taxon (i.e. unique genus-species-variety combinations):

$$BASAL_AREA_{mps} = \sum_{t=1}^n BASAL_AREA_{mpst}$$

where t is a unique tree (TREE_NUM) among n number of trees belonging to taxon s (SMTREE_GENUS, SMTREE_SPECIES and SMTREE_VARIETY) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Divide the basal area of each taxon by the summed basal area of all live small trees (LGTREE_STATUS = 'LS' or 'LF') within the small tree plot and multiply by 100% to calculate percent basal area cover of each species in the small tree plot (PERCENT):

$$PERCENT_{mps} = BASAL_AREA_{mps} / \sum_{s=1}^n BASAL_AREA_{mps} * 100\%$$

where s is a unique taxon (SMTREE_GENUS, SMTREE_SPECIES and SMTREE_VARIETY) among n number of taxa within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) Assign a ranked abundance number (SMTREE_SPECIES_NUM) to each small tree taxon (i.e. combination of genus, species and variety) in the small tree plot, from greatest to smallest percent basal area

Output

SMTREE_PERCENT, SMTREE_SPECIES_NUM

8. Shrub List and Summary

Compiler routines

gp_shrub_biomass.sas

Output written to

shrub_list
site_info

BIOMASS_TOTAL, BIOMASS_WOOD, BIOMASS_FOLIAGE

Inputs

SHRUB_GENUS; SHRUB_SPECIES; SHRUB_VARIETY; SHRUB_STATUS; BD_CLASS; FREQUENCY

Computations

1) Estimate the total (BIOMASS_TOTAL), wood (BIOMASS_WOOD) and foliage (BIOMASS_FOLIAGE) biomasses in kg for each shrub record (RECORD_NUM). The midpoint of a basal diameter class (BD_CLASS) is used in each component- and taxon-specific biomass equations for each measured shrub record. Biomass equations are sourced from peer-reviewed publications and reports generated by jurisdictions or the US department of agriculture. When a taxon-specific biomass equation does not exist for a measured shrub, the equation for a similar taxon with equivalent genus, species, vegetation type,

and / or growth form is used. Biomass estimates for each basal diameter class of measured shrubs is then multiplied by the frequency of the shrub record to obtain plot-level biomasses.

$$\begin{aligned}
 BIOMASS_TOTAL_{mpt} &= f(SHRUB_GENUS_{mpt}, SHRUB_SPECIES_{mpt}, SHRUB_VARIETY_{mpt}, BD_CLASS_{mpt}) \\
 &\quad * FREQUENCY_{mpt} \\
 BIOMASS_WOOD_{mpt} &= f(SHRUB_GENUS_{mpt}, SHRUB_SPECIES_{mpt}, SHRUB_VARIETY_{mpt}, BD_CLASS_{mpt}) \\
 &\quad * FREQUENCY_{mpt} \\
 BIOMASS_FOLIAGE_{mpt} &= f(SHRUB_GENUS_{mpt}, SHRUB_SPECIES_{mpt}, SHRUB_VARIETY_{mpt}, BD_CLASS_{mpt}) \\
 &\quad * FREQUENCY_{mpt}
 \end{aligned}$$

where t is a unique shrub record (RECORD_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Foliage biomass (BIOMASS_FOLIAGE) was set equal to zero and total biomass (BIOMASS_TOTAL) was set equal to only woody biomass (BIOMASS_WOOD) when shrubs are deemed dead standing (SHRUB_STATUS = 'DS').

$$\begin{aligned}
 & \text{if } SHRUB_STATUS_{mpt} = 'DS' \text{ then } BIOMASS_FOLIAGE_{mpt} = 0 \\
 & \text{and } BIOMASS_TOTAL_{mpt} = BIOMASS_WOOD_{mpt}
 \end{aligned}$$

where t is a unique shrub record (RECORD_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) When an equation for total biomass, woody biomass or foliage biomass is not available but the other two are, the biomass of the missing component is calculated from the two others. Total biomass is constrained to be equal or greater than the sum of woody biomass and foliage biomass. Total biomass is set to 0.01 when small values (i.e. less or equal to 0.005) round to zero, hence in these cases total biomass may not be equal to wood biomass for dead standing shrubs.

Output

BIOMASS_TOTAL, BIOMASS_WOOD, BIOMASS_FOLIAGE, BMEQ_TOTAL, BMEQ_WOOD, BMEQ_FOLIAGE

PLOTBIO_LGSHRUB_LIVE, PLOTBIO_LGSHRUB_DEAD

Inputs

BIOMASS_TOTAL; SHRUB_STATUS; MEAS_PLOT_SIZE

Computations

1) Total biomass records (BIOMASS_TOTAL) of dead and live shrubs ≥ 1.3 m in height (SHRUB_STATUS = 'DS' or 'LV') are summed separately to the plot level, divided by 1000 to convert kg to Mg and divided by measured plot size (MEAS_PLOT_SIZE) to compute per-hectare large shrub live biomass (PLOTBIO_LGSHRUB_LIVE) and large shrub dead biomass (PLOTBIO_LGSHRUB_DEAD):

$$PLOTBIO_LGSHRUB_LIVE_{mp} = \left[\sum_{t=1}^n BIOMASS_TOTAL_{mpt} / 1000 \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique shrub record (RECORD_NUM) among n number of live shrub records (SHRUB_STATUS = 'LV') within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

$$PLOTBIO_LGSHRUB_DEAD_{mp} = \left[\sum_{t=1}^n BIOMASS_TOTAL_{mpt} / 1000 \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique shrub record (RECORD_NUM) among n number of dead shrub records (SHRUB_STATUS = 'DS') within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_LGSHRUB_LIVE, PLOTBIO_LGSHRUB_DEAD

9. Stump List and Summary

Compiler routines

gp_compile_stump.sas

Output written to

stump_list
site_info

STUMP_VOLUME, STUMP_BIOMASS

Inputs

STUMP_NUM; STUMP_DIB; STUMP_DIAMETER; STUMP_LENGTH; STUMP_DECAY;
STUMP_GENUS; STUMP_SPECIES; STUMP_VARIETY; PROVINCE

Computations

1) Estimate the inside-bark volume of each stump with diameter inside bark ≥ 4 cm in m^3 (STUMP_VOLUME) assuming a cylindrical shape, using top diameter inside bark (STUMP_DIB) to calculate basal area, converting basal area units to m^2 and multiplying by stump height (STUMP_LENGTH). The top diameter outside bark (STUMP_DIAMETER) is used if the value for diameter inside bark is missing:

$$STUMP_VOLUME_{mpt} = \frac{\pi * STUMP_DIB_{mpt}^2 * STUMP_LENGTH_{mpt}}{40,000}$$

where t is a unique stump (STUMP_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) The minimum stump volume (STUMP_VOLUME) is set to $0.0001 m^3$, so smaller non-missing stump volumes are set equal to $0.0001 m^3$.

3) Estimate the biomass of each stump with diameter inside bark ≥ 4 cm in kg (STUMP_BIOMASS) from the stump volume and the wood density (DENSITY) associated with the stump's decay class, taxon (i.e. unique genus-species-variety combinations) and province, converting units to kg:

$$STUMP_BIOMASS_{mpt} = STUMP_VOLUME_{mpt} * DENSITY_{jsd} * 1000$$

where t is a unique stump (STUMP_NUM) of taxon s (STUMP_GENUS, STUMP_SPECIES and STUMP_VARIETY) and decay class d (STUMP_DECAY) within province j (PROVINCE) and plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

STUMP_VOLUME, STUMP_BIOMASS

PLOTVOL_STUMP, PLOTBIO_STUMP

Inputs

STUMP_NUM; STUMP_VOLUME; STUMP_BIOMASS; MEAS_PLOT_SIZE

Computations

1) Sum the volume estimates (STUMP_VOLUME) of all stumps with diameter inside bark ≥ 4 cm in the small tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare volume ($\text{m}^3 \text{ha}^{-1}$):

$$PLOTVOL_STUMP_{mp} = \left[\sum_{t=1}^n STUMP_VOLUME_{mpt} \right] / MEAS_PLOT_SIZE_{mp}$$

where t is a unique stump (STUMP_NUM) among n number of stumps within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Sum the biomass estimates (STUMP_BIOMASS) of all stumps with diameter inside bark ≥ 4 cm in the small tree plot and divide by measured plot size (MEAS_PLOT_SIZE) to get per-hectare biomass (Mg ha^{-1}):

$$PLOTBIO_STUMP_{mp} = \left[\sum_{t=1}^n STUMP_BIOMASS_{mpt} \right] / (MEAS_PLOT_SIZE_{mp} * 1000)$$

where t is a unique stump (STUMP_NUM) among n number of stumps within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_STUMP, PLOTBIO_STUMP

10. Species list

Compiler routines

gp_unique_species_list.sas

Output written to

species_list

Inputs

LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY; SMTREE_GENUS; SMTREE_SPECIES;
SMTREE_VARIETY; EC_GENUS; EC_SPECIES; EC_VARIETY; EC_LAYERID; PROVINCE

Computations

1) Extract list of live taxa (LGTREE_STATUS not = 'DS') from the large tree plot (LGTREE_GENUS, LGTREE_SPECIES and LGTREE_VARIETY; TREE_NUM < 8000). Extract list of live taxa (SMTREE_STATUS not = 'DS') from the small tree plot (SMTREE_GENUS, SMTREE_SPECIES and SMTREE_VARIETY). Extract list of live taxa (SHRUB_STATUS not = 'DS') from the shrub plot (SHRUB_GENUS, SHRUB_SPECIES and SHRUB_VARIETY). Extract list of taxa from the ecological plot (EC_GENUS, EC_SPECIES and EC_VARIETY), however for records collected before August 1, 2007 exclude taxa associated with woody debris (EC_LAYERID = 4) that were recorded in Alberta reports (PROVINCE = 'AB') and exclude taxa associated with aquatic plants (EC_LAYERID = 8-15) that were recorded in Saskatchewan reports (PROVINCE = 'SK').

2) Translate all NFI codes to full latin names.

3) Bind the three lists of taxa, sort by GENUS, SPECIES and VARIETY and remove any duplicates.

4) Assign sequential numbers to each unique taxon detected in a plot, listed alphabetically by genus, species then variety (SPECIES_INDEX)

Output

GENUS, SPECIES, VARIETY, SPECIES_INDEX

11. Biodiversity Indices – Number of Unique Species and Shannon, Pielou Evenness and Margalef Indices

Compiler routines

Gp_biodiversity.sas

Output written to

ltp_header

stp_header

rel_abundance_lgtree

rel_abundance_smtree

**SPECIES_LTNUM, SPECIES_LTREL, SPECIES_NUM,
BINDEX_LTSHANNON, BINDEX_LTEVEN, BINDEX_LTMARGALEF**

Inputs

LGTREE_GENUS; LGTREE_SPECIES; LGTREE_VARIETY; LGTREE_STATUS

Computations

1) Count the number of live standing (LGTREE_STATUS = 'LS') large tree taxa (i.e. combination LGTREE_GENUS, LGTREE_SPECIES and LGTREE_VARIETY) in the large tree plot (SPECIES_LTNUM)

2) Calculate the relative stem abundance (SPECIES_LTREL) of each live standing (LGTREE_STATUS = 'LS') large tree taxa in the large tree plot:

$$SPECIES_LTREL_{mps} = \frac{n_{mps}}{N_{mp}}$$

Where n is the number of live standing large trees of taxon s (LGTREE_GENUS, LGTREE_SPECIES and LGTREE_VARIETY) and N is the total number of live standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Assign a ranked abundance number (SPECIES_NUM) to each large tree taxon (i.e. combination of genus, species and variety) in the large tree plot, from most abundant to least abundant number of stems

4) Calculate the Shannon diversity index (BINDEX_LTSHANNON) for live standing (LGTREE_STATUS = 'LS') large tree taxa in the large tree plot by summing the negative product of the relative abundance and natural log of the relative abundance of each taxon:

$$BINDEX_LTSHANNON_{mp} = - \sum_{s=1}^n SPECIES_LTREL_{mps} * \ln(SPECIES_LTREL_{mps})$$

where s is a unique large tree taxon (LGTREE_GENUS, LGTREE_SPECIES and LGTREE_VARIETY) among n number of taxa within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

5) Calculate the Pielou evenness index (BINDEX_LTEVEN) for live standing (LGTREE_STATUS = 'LS') large tree taxa in the large tree plot by dividing Shannon index (BINDEX_LTSHANNON) by the natural log of large tree richness (SPECIES_LTNUM); the index is recorded as missing when the number of taxa is equal to 1:

$$BINDEX_LTEVEN_{mp} = \frac{BINDEX_LTSHANNON_{mp}}{\ln(SPECIES_LTNUM_{mp})}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

6) Calculate the Margalef richness index (BINDEX_LTMARGALEF) for live standing (LGTREE_STATUS = 'LS') large tree taxa in the large tree plot by dividing the total number of taxa (SPECIES_LTNUM) less 1 by the natural log of the total number of live standing large trees; the index is recorded as 0 when the number of live standing large trees is equal to 1:

$$BINDEX_LTMARGALEF_{mp} = \frac{SPECIES_LTNUM_{mp} - 1}{\ln(N_{mp})}$$

Where N is the total number of live standing large trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

SPECIES_LTNUM, SPECIES_LTREL, SPECIES_NUM, BINDEX_LTSHANNON, BINDEX_LTEVEN, BINDEX_LTMARGALEF

References

The formulae for estimating the biodiversity indices are as follows:

Shannon diversity index (Shannon, C.E. 1948. A mathematical theory of communication. Bell System Technical Journal, 27, 379-423), H :

$$H = - \sum_{i=1}^s p_i \ln(p_i)$$

Pielou evenness index (Pielou, E.C. 1969. An introduction to mathematical ecology. Wiley-Interscience, NEW York. 286 p.), J :

$$J = \frac{H}{\ln(S)}$$

Margalef richness index (Margalef, R. 1958. Information theory in ecology. Gen. Syst. 3:36-71), M :

$$M = \frac{S-1}{\ln(N)}$$

where

S = Number of species in the plot.

N = Total number of individuals in the plot.

n_i = Number of individuals of i th species.

p_i = Relative frequency of the i th species = n_i/N .

SPECIES_SMTNUM, SPECIES_STREL, SPECIES_NUM, BINDEX_STSHANNON, BINDEX_STEVEN, BINDEX_STMARGALEF

Inputs

SMTREE_GENUS; SMTREE_SPECIES; SMTREE_VARIETY; SMTREE_STATUS

Computations

1) Count the number of live standing (SMTREE_STATUS = 'LS') small tree taxa (i.e. combination SMTREE_GENUS, SMTREE_SPECIES and SMTREE_VARIETY) in the small tree plot (SPECIES_SMTNUM)

2) Calculate the relative stem abundance (SPECIES_STREL) of each live standing (SMTREE_STATUS = 'LS') small tree taxon in the small tree plot:

$$SPECIES_STREL_{mps} = \frac{n_{mps}}{N_{mp}}$$

Where n is the number of live standing small trees of taxon s (SMTREE_GENUS, SMTREE_SPECIES and SMTREE_VARIETY) and N is the total number of live standing small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Assign a ranked abundance number (SPECIES_NUM) to each small tree taxon (i.e. combination of genus, species and variety) in the small tree plot, from most abundant to least abundant number of stems

4) Calculate the Shannon diversity index (BINDEX_STSHANNON) for live standing (SMTREE_STATUS = 'LS') small tree taxa in the small tree plot by summing the negative product of the relative abundance and natural log of the relative abundance of each taxon:

$$BINDEX_STSHANNON_{mp} = - \sum_{s=1}^n SPECIES_STREL_{mps} * \ln(SPECIES_STREL_{mps})$$

where s is a unique small tree taxon (SMTREE_GENUS, SMTREE_SPECIES and SMTREE_VARIETY) among n number of taxa within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

5) Calculate the Pielou evenness index (BINDEX_STEVEN) for live standing (SMTREE_STATUS = 'LS') small tree taxa in the small tree plot by dividing Shannon index (BINDEX_STSHANNON) by the natural log of

small tree richness (SPECIES_STNUM); the index is recorded as missing when the number of taxa is equal to 1:

$$BINDEX_STEVEN_{mp} = \frac{BINDEX_STSHANNON_{mp}}{\ln(SPECIES_STNUM_{mp})}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

6) Calculate the Margalef richness index (BINDEX_STMARGALEF) for live standing (SMTREE_STATUS = 'LS') small tree taxa in the small tree plot by dividing the total number of taxa (SPECIES_STNUM) less 1 by the natural log of the total number of live standing small trees; the index is recorded as 0 when the number of live standing large trees is equal to 1:

$$BINDEX_STMARGALEF_{mp} = \frac{SPECIES_STNUM_{mp} - 1}{\ln(N_{mp})}$$

Where N is the total number of live standing small trees within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

SPECIES_SMTNUM, SPECIES_STREL, SPECIES_NUM, BINDEX_STSHANNON, BINDEX_STEVEN, BINDEX_STMARGALEF

SPECIES_ECNUM, SPECIES_ECREL, SPECIES_NUM, BINDEX_ECSHANNON, BINDEX_ECEVEN

Inputs

EC_GENUS; EC_SPECIES; EC_VARIETY; EC_LAYER

Computations

1) Count the number of unique taxa (i.e. combination EC_GENUS, EC_SPECIES and EC_VARIETY) in each ecological layer (EC_LAYERID) to calculate taxa richness in an area (SPECIES_ECNUM)

2) Calculate the relative percent cover (SPECIES_ECREL) of each taxon in an ecological layer:

$$SPECIES_ECEREL_{mpls} = \frac{n_{mpls}}{N_{mpt}}$$

Where n is the percent cover of taxon s (EC_GENUS, EC_SPECIES and EC_VARIETY) and N is the plant cover within ecological layer l (EC_LAYER) of plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Assign a ranked abundance number (SPECIES_NUM) to each taxon (i.e. combination of genus, species and variety) in an ecological layer, from most abundant to least abundant percent cover

4) Calculate the Shannon diversity index (BINDEX_ECSHANNON) for taxa in each ecological layer by summing the negative product of the relative abundance and natural log of the relative abundance of each taxon:

$$BINDEX_ECSHANNON_{mpl} = - \sum_{s=1}^n SPECIES_ECREL_{mpls} * \ln(SPECIES_ECREL_{mpls})$$

where s is a unique ecological taxon (EC_GENUS, EC_SPECIES and EC_VARIETY) among n number of taxa within ecological layer l (EC_LAYER) of plot p (NFI_PLOT) at measurement m (MEAS_NUM)

5) Calculate the Pielou evenness index (BINDEX_ECEVEN) for taxa in each ecological layer by dividing Shannon index (BINDEX_ECSHANNON) by the natural log of ecological taxa richness (SPECIES_ECNUM); the index is recorded as missing when the number of taxa is equal to 1 while species with missing percent ground cover were included in calculations of taxa richness:

$$BINDEX_ECEVEN_{mpl} = \frac{BINDEX_ECSHANNON_{mpl}}{\ln(SPECIES_ECNUM_{mpl})}$$

Where l is an ecological layer (EC_LAYER) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

SPECIES_ECNUM, SPECIES_ECREL, SPECIES_NUM, BINDEX_ECSHANNON, BINDEX_ECEVEN

12. Fine Woody Debris, Small Shrubs, Small Stumps and Herbs

Compiler routines

gp_fwd_shrubherb.sas

Output written to

site_info

PLOTBIO_SMSHRUB

Inputs

MICRO_LAYER_BIOMASS; MICRO_LAYER_ID; MEAS_PLOT_SIZE; MICRO_PLOT_NUM

Computations

For each microplot, divide the biomass of small shrubs (MICRO_LAYER_ID = 1) by the measured microplot size (MEAS_PLOT_SIZE) and convert units from g to Mg. Sum these ratios across all microplots (usually 4) and divide by the number of measured microplots to get per-hectare small shrub biomass (Mg ha⁻¹):

$$PLOTBIO_SMSHRUB_{mp} = \left[\sum_{u=1}^n (MICRO_LAYER_BIOMASS_{mpu} / [1,000,000 * MEAS_PLOT_SIZE_{mpu}]) \right] / n_{mp}$$

Where u is a unique microplot (MICRO_PLOT_NUM) among n number of microplots where the biomass of small shrubs was measured, within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMSHRUB

PLOTBIO_HERB

Inputs

MICRO_LAYER_BIOMASS; MICRO_LAYER_ID; MEAS_PLOT_SIZE; MICRO_PLOT_NUM

Computations

For each microplot, divide the biomass of herbs (MICRO_LAYER_ID = 2) by the measured microplot size (MEAS_PLOT_SIZE) and convert units from g to Mg. Sum these ratios across all microplots (usually 4) and divide by the number of measured microplots to get per-hectare herb biomass (Mg ha⁻¹):

$$PLOTBIO_HERB_{mp} = \left[\sum_{u=1}^n (MICRO_LAYER_BIOMASS_{mpu} / [1,000,000 * MEAS_PLOT_SIZE_{mpu}]) \right] / n_{mp}$$

Where u is a unique microplot (MICRO_PLOT_NUM) among n number of microplots where the biomass of herbs was measured, within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_HERB

PLOTBIO_FWD

Inputs

MICRO_LAYER_BIOMASS; MICRO_LAYER_ID; MEAS_PLOT_SIZE; MICRO_PLOT_NUM

Computations

For each microplot, divide the biomass of fine woody debris (MICRO_LAYER_ID = 4) by the measured microplot size (MEAS_PLOT_SIZE) and convert units from g to Mg. Sum these ratios across all microplots (usually 4) and divide by the number of measured microplots to get per-hectare fine woody debris biomass (Mg ha⁻¹):

$$PLOTBIO_FWD_{mp} = \left[\sum_{u=1}^n (MICRO_LAYER_BIOMASS_{mpu} / [1,000,000 * MEAS_PLOT_SIZE_{mpu}]) \right] / n_{mp}$$

Where u is a unique microplot (MICRO_PLOT_NUM) among n number of microplots where the biomass of fine woody debris was measured, within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_FWD

PLOTBIO_BRYO

Inputs

MICRO_LAYER_BIOMASS; MICRO_LAYER_ID; MEAS_PLOT_SIZE; MICRO_PLOT_NUM

Computations

For each microplot, divide the biomass of bryoids (MICRO_LAYER_ID = 3) by the measured microplot size (MEAS_PLOT_SIZE) and convert units from g to Mg. Sum these ratios across all microplots (usually 4) and divide by the number of measured microplots to get per-hectare bryoid biomass (Mg ha⁻¹):

$$PLOTBIO_BRYO_{mp} = \left[\sum_{u=1}^n (MICRO_LAYER_BIOMASS_{mpu} / [1,000,000 * MEAS_PLOT_SIZE_{mpu}]) \right] / n_{mp}$$

Where u is a unique microplot (MICRO_PLOT_NUM) among n number of microplots where the biomass of bryoids was measured, within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_BRYO

PLOTBIO_SMSTUMP

Inputs

MICRO_LAYER_BIOMASS; MICRO_LAYER_ID; MEAS_PLOT_SIZE; MICRO_PLOT_NUM

Computations

For each microplot, divide the biomass of small stumps (MICRO_LAYER_ID = 5) by the measured microplot size (MEAS_PLOT_SIZE) and convert units from g to Mg. Sum these ratios across all microplots (usually 4) and divide by the number of measured microplots to get per-hectare small stump biomass (Mg ha⁻¹):

$$PLOTBIO_SMSTUMP_{mp} = \left[\sum_{u=1}^n (MICRO_LAYER_BIOMASS_{mpu} / [1,000,000 * MEAS_PLOT_SIZE_{mpu}]) \right] / n_{mp}$$

Where u is a unique microplot (MICRO_PLOT_NUM) among n number of microplots where the biomass of small stumps was measured, within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_SMSTUMP

13. Coarse and Small Woody Debris – Plot-level Summary

Compiler routines

gp_woody_debris.sas
gp_cwd_lead_species.sas

Output written to

woody_debris_round
woody_debris_odd
site_info

DENSITY

Inputs

TRANSECT_NUM; WD_PIECE_NUM; WD_GENUS; WD_SPECIES; DECAY_CLASS; PROVINCE (from each woody_debris_round and woody_debris_odd tables)
GENUS; SPECIES; VARIETY; PERCENT (from gp_ltp_tree_species_comp table)
SMTREE_GENUS; SMTREE_SPECIES; SMTREE_VARIETY; SMTREE_PERCENT (from gp_stp_tree_species_comp table)

Computations

Assign variety classifications (WD_VARIETY) to woody-debris species (WD_GENUS and WD_SPECIES) when the most abundant associated taxon (LGTREE_GENUS, LGTREE_SPECIES and LGTREE_VARIETY or SMTREE_GENUS, SMTREE_SPECIES and SMTREE_VARIETY) by basal area (PERCENT or SMTREE_PERCENT) in the large or small tree species composition tables (LTP_TREE_SPECIES_COMP; STP_TREE_SPECIES_COMP) define this level of classification.

For each piece of round woody debris, attribute a wood density value (g cm^{-3}) according to the 'wood_density' support-data table (gpcsd_wood_density) based on the province (PROVINCE), genus (WD_GENUS), species (WD_SPECIES), variety (WD_VARIETY) and decay class (DECAY_CLASS) of the piece.

For each piece of odd woody debris, attribute a wood density value (g cm^{-3}) according to the 'wood_density' support-data table (gpcsd_wood_density) based on the province (PROVINCE), genus (WD_GENUS), species (WD_SPECIES), variety (WD_VARIETY) and decay class (DECAY_CLASS) of the piece.

The methods used to derive wood density by decay class (i.e. 'wood_density' support-data table) are described in [section 18](#). The average wood density for decay classes 1 to 5 is used when the decay class is not specified for a piece of woody debris.

Output

DENSITY

PLOTVOL_ROUNDWD, PLOTBIO_ROUNDWD

Inputs

TRANSECT_NUM; WD_PIECE_NUM; WD_DIAMETER; DENSITY; TILT_ANGLE; MCWD_MEASLEN; LCWD_MEASLEN

Computations

1) Calculate a volume proxy (V_ROUND) for each round coarse woody debris, using woody debris diameter ($WD_DIAMETER$) and tilt angle (in degrees) of woody debris with the soil plane ($TILT_ANGLE$). The tilt angle is constrained to be $\leq 80^\circ$, namely tilts greater than 80° are set equal to 80° :

$$V_ROUND_{mpzw} = \frac{WD_DIAMETER_{mpzw}^2}{\cos(\pi * TILT_ANGLE_{mpzw}/180)}$$

where w is a unique round coarse woody debris (WD_PIECE_NUM) along transect z ($TRANSECT_NUM$) within plot p (NFI_PLOT) at measurement m ($MEAS_NUM$)

2) Calculate a biomass proxy (BIOM_ROUND) for each round coarse woody debris, using the product of volume proxy estimates (V_ROUND) and wood density (DENSITY):

$$BIOM_ROUND_{mpzw} = V_ROUND_{mpzw} * DENSITY_{jzd}$$

where w is a unique round coarse woody debris (WD_PIECE_NUM) of taxon s (WD_GENUS, WD_SPECIES and WD_VARIETY) and decay class d (DECAY_CLASS) along transect z (TRANSECT_NUM) within province j (PROVINCE) and plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) The per-hectare volume and biomass estimates for each size class of round coarse woody debris is then calculated using values to complete volume calculations ($\pi * \text{length of debris} / 4$), convert units to meters (1/10,000) and account for the probability of intersecting a transect given an area of interest [$10,000 * \pi / (2 * \text{transect length} * \text{length of debris})$]. The round coarse woody debris are stratified into two size classes: medium ($7.5 < \text{WD_DIAMETER} \leq 30$ cm) and large ($\text{WD_DIAMETER} > 30$ cm) according to diameter size (WD_DIAMETER); and appropriate transect lengths for medium (MCWD_MEASLEN) and large (LCWD_MEASLEN) size classes are used to calculate per-hectare estimates.

For large round pieces (weighted by transect length)

$$WD_ROUND_LARGE_VOLUME_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n \frac{V_ROUND_{mpzw} * \pi^2}{8} \right] / \sum_{z=1}^k LCWD_MEASLEN_{mpz}$$

$$WD_ROUND_LARGE_BIOMASS_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n \frac{BIOM_ROUND_{mpzw} * \pi^2}{8} \right] / \sum_{z=1}^k LCWD_MEASLEN_{mpz}$$

where w is a unique round coarse woody debris (WD_PIECE_NUM) among n number of round coarse woody debris along transect z (TRANSECT_NUM) among k number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

For medium round pieces (weighted by transect length)

$$WD_ROUND_MED_VOLUME_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n \frac{V_ROUND_{mpzw} * \pi^2}{8} \right] / \sum_{z=1}^k MCWD_MEASLEN_{mpz}$$

$$WD_ROUND_MED_BIOMASS_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n \frac{BIOM_ROUND_{mpzw} * \pi^2}{8} \right] / \sum_{z=1}^k MCWD_MEASLEN_{mpz}$$

where w is a unique round coarse woody debris (WD_PIECE_NUM) among n number of round coarse woody debris along transect z (TRANSECT_NUM) among k number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Sum the volumes and biomass estimates across medium and large size classes to calculate total round coarse woody debris volume (PLOTVOL_ROUNDWD) and biomass (PLOTBIO_ROUNDWD) per hectare:

$$PLOTVOL_ROUNDWD_{mp} = WD_ROUND_LARGE_VOLUME_{mp} + WD_ROUND_MED_VOLUME_{mp}$$

$$PLOTBIO_ROUNDWD_{mp} = WD_ROUND_LARGE_BIOMASS_{mp} + WD_ROUND_MED_BIOMASS_{mp}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTBIO_ROUNDWD, PLOTVOL_ROUNDWD

References

The per-hectare biomass and volume calculations for round woody debris described above are based on the following line-intersect sampling formulae:

$$volume (m^3 ha^{-1}) = 10,000 * \frac{\pi}{2} * \frac{\pi}{4} * \frac{1}{L_i} * \sum_{j=1}^{m_i} \frac{1}{\cos(\pi * h_{ij}/180)} * \left[\frac{d_{ij}}{100} \right]^2$$

$$biomass (Mg ha^{-1}) = \sum_{j=1}^{m_i} volume_{ij} * \rho_{ij}$$

where,

ρ_{ij} = wood density (**g cm⁻³**) of the j th piece in the i th plot

m_i = number of pieces intersected by transect in the i th plot

h_{ij} = tilt angle (**degrees**) of the j th piece in the i th plot

d_{ij} = diameter (**cm**) of the j th piece in the i th plot

L_i = total measured transect length (**m**)

The corresponding equations for odd pieces and accumulations (attributes calculated below) are:

$$volume (m^3 ha^{-1}) = 10,000 * \frac{1}{L} * \sum_{j=1}^{m_i} \frac{Length}{100} * \frac{Depth}{100}$$

$$biomass (Mg ha^{-1}) = \sum_{j=1}^{m_i} volume_{ij} * \rho_{ij}$$

Notes:

1. The value $\pi/2$ in is a constant for horizontal tilt correction. This correction accounts for the fact that we do not always cross the woody debris at right angles to the line intersect. That is why we do not measure the horizontal tilt angle.
2. The vertical tilt correction is $[1 / \cos(\pi * h_{ij} / 180)]$. This correction accounts for the fact that the woody debris does not always lie horizontally on the forest floor or ground, and converts degrees into radians.
3. The value $\pi/4$ converts the cross-sectional diameters d_{ij} into circular cross-sectional areas.
4. The numerator 10,000 in all the equations converts the biomass and volumes onto a one-hectare basis (1 hectare = 10,000 m²).
5. Be careful about the units of L , d , and ρ_{ij} ; they are **m**, **cm** and **g cm⁻³**, respectively. The equations must be modified if the units are changed.
6. For odd pieces and accumulations, *Length* and *Depth* of are in **cm**.

Source literature:

Marshall, P.L., Davis, G. and LeMay, V.M., 2000. Using line intersect sampling for coarse woody debris. Research Section, Vancouver Forest Region, BC Ministry of Forests, Nanaimo, BC, Canada.

Technical Report TR-003. 34 pp. See equations 8 and 16.
(www.for.gov.bc.ca/rco/research/cwd/tr003.pdf)

Van Wagner, C.E., 1982. Practical aspects of the line intersect sampling method. Canadian Forest Service. Information Report PI-X-12. See equations 1 and 2 (page 2).

CWD_LEAD_SPECIES

Compiler routines

gp_cwd_lead_species.sas

Inputs

TRANSECT_NUM, LCWD_MEASLEN, MCWD_MEASLEN (from woody_debris_header table)
TRANSECT_NUM, WD_PIECE_NUM; WD_GENUS; WD_SPECIES; WD_DIAMETER; TILT_ANGLE
(from woody_debris_round table)
TRANSECT_NUM, WD_PIECE_NUM; WD_GENUS; WD_SPECIES; HOR_LENGTH; VER_DEPTH (from
woody_debris_odd table)

Computations

1) Calculate the volume of round coarse woody debris by species for medium (V_ROUND_MED) and large (V_ROUND_LARGE) pieces by stratifying debris into medium ($7.5 < \text{WD_DIAMETER} \leq 30$ cm) and large ($\text{WD_DIAMETER} > 30$ cm) size classes according to diameter size (WD_DIAMETER) and using appropriate transect lengths for medium (MCWD_MEASLEN) and large (LCWD_MEASLEN) size classes to calculate per-hectare estimates:

For large round coarse woody debris:

$$V_ROUND_LARGE_{mps} = \left[\sum_{z=1}^k \sum_{w=1}^n \frac{WD_DIAMETER_{mpsw}^2}{\cos(\pi * TILT_ANGLE_{mpsw}/180)} * \frac{\pi^2}{8} \right] * \sum_{z=1}^k \frac{1}{LCWD_MEASLEN_{mpz}}$$

For medium round coarse woody debris:

$$V_ROUND_MED_{mps} = \left[\sum_{z=1}^k \sum_{w=1}^n \frac{WD_DIAMETER_{mpsw}^2}{\cos(\pi * TILT_ANGLE_{mpsw}/180)} * \frac{\pi^2}{8} \right] * \sum_{z=1}^k \frac{1}{MCWD_MEASLEN_{mpz}}$$

where w is a unique round coarse woody debris (WD_PIECE_NUM) among n number of round coarse woody debris of species s (WD_GENUS, WD_SPECIES) along transect z (TRANSECT_NUM) among k number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM).

Then sum these volumes for medium and large pieces to calculate total volume of round coarse woody debris by species per hectare (V_ROUND):

$$V_ROUND_{mps} = V_ROUND_LARGE_{mps} + V_ROUND_MED_{mps}$$

where s is a unique species (WD_GENUS, WD_SPECIES) within plot p (NFI_PLOT) at measurement m (MEAS_NUM).

2) Assign a variety label (WD_VARIETY) to the woody debris species if the most abundant associated taxon in the large or small tree species composition table (LTP_TREE_SPECIES_COMP; STP_TREE_SPECIES_COMP) defines this level of classification.

3) The cross sectional area of each odd-shaped coarse woody debris and woody debris accumulation is calculated using the product of length (HOR_LENGTH) and depth (VER_DEPTH). Odd-shaped debris and accumulations are then stratified into two size classes according to the round-diameter equivalents (EQ_DIAMETER) to cross sectional areas as defined below: medium ($7.5 < EQ_DIAMETER \leq 30$ cm) and large ($EQ_DIAMETER > 30$ cm):

$$EQ_DIAMETER_{mpzw} = \sqrt{\frac{HOR_LENGTH_{mpzw} * VER_DEPTH_{mpzw} * 4}{\pi}}$$

where w is a unique odd shaped coarse woody debris (WD_PIECE_NUM) along transect z (TRANSECT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) Calculate the volume of odd-shaped coarse woody debris by species for medium (V_ODD_MED) and large (V_ODD_LARGE) pieces using appropriate transect lengths for medium (MCWD_MEASLEN) and large (LCWD_MEASLEN) size classes to calculate per-hectare estimates:

For large odd-shaped coarse woody debris:

$$V_ODD_LARGE_{mps} = \left[\sum_{z=1}^k \sum_{w=1}^n HOR_LENGTH_{mpsw} * VER_DEPTH_{mpsw} \right] * \sum_{z=1}^k \frac{1}{LCWD_MEASLEN_{mpz}}$$

For medium odd-shaped coarse woody debris:

$$V_ODD_MED_{mps} = \left[\sum_{z=1}^k \sum_{w=1}^n HOR_LENGTH_{mpsw} * VER_DEPTH_{mpsw} \right] * \sum_{z=1}^k \frac{1}{MCWD_MEASLEN_{mpz}}$$

where w is a unique odd-shaped coarse woody debris (WD_PIECE_NUM) among n number of odd-shaped coarse woody debris of species s (WD_GENUS, WD_SPECIES) along transect z (TRANSECT_NUM) among k number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM).

Then sum these volumes for medium and large pieces to calculate total volume of odd-shaped coarse woody debris by species per hectare (V_ODD):

$$V_ODD_{mps} = V_ODD_LARGE_{mps} + V_ODD_MED_{mps}$$

where s is a unique species (WD_GENUS, WD_SPECIES) within plot p (NFI_PLOT) at measurement m (MEAS_NUM).

5) Assign a variety label (WD_VARIETY) to the woody debris species if the most abundant associated taxon in the large or small tree species composition table (LTP_TREE_SPECIES_COMP; STP_TREE_SPECIES_COMP) defines this level of classification.

6) Sum the volume of odd-shaped woody debris (V_ODD) with the volume of round woody debris (V_ROUND) by taxon. Select the taxon with the largest combined coarse woody-debris volume (V_CWD) and designate as the leading woody debris species (i.e. WD_GENUS, WD_SPECIES and WD_VARIETY).

$$V_CWD_{mps} = V_ODD_{mps} + V_ROUND_{mps}$$

where s is a unique taxon (WD_GENUS, WD_SPECIES, WD_VARIETY) within plot p (NFI_PLOT) at measurement m (MEAS_NUM).

7) If a plot has small woody debris but no coarse woody debris, select the most common taxon from the large tree plot as the leading woody debris species. This is the species in the large tree species composition table (LTP_TREE_SPECIES_COMP) with the first ranked abundance (species_num = 1).

8) If a plot has small woody debris but no large woody debris or large trees, then select the most common taxon from the small tree plot as the leading woody debris species. This is the species in the small tree species composition table (STP_TREE_SPECIES_COMP) with the first ranked abundance (species_num = 1).

9) If a plot has small woody debris but no large woody debris, no large trees and no small trees, then assign the leading woody debris species as unknown (i.e. WD_GENUS = 'UNKN' and WD_SPECIES = 'SPP').

10) If no coarse or small woody debris were measured, then select the most common taxon from the large tree plot, else the small tree plot, as the leading woody debris species. This is the species in the large or small tree species composition table (LTP_TREE_SPECIES_COMP; STP_TREE_SPECIES_COMP) with the first ranked abundance (species_num = 1).

Output

WD_GENUS, WD_SPECIES, WD_VARIETY

PLOTVOL_SWD, PLOTBIO_SWD

Inputs

TRANSECT_NUM; SWD_DIAM_CLASS; SWD_TALLY; SWD_DECAY_CLASS; SWD_MEASLEN;
PROVINCE

Computations

1) Calculate the per-hectare volume of small woody debris (SWD_VOLUME; $\text{m}^3 \text{ha}^{-1}$) for each diameter class (SWD_DIAM_CLASS), weighted by transect length (SWD_MEASLEN). Small woody debris is assumed parallel with the ground, there is therefore no need to account for the tilt angle where debris intercept with sampling transects.

Woody debris diameter is set to 2 cm if the diameter small woody debris is 1 to 3 cm (SWD_DIAM_CLASS = 1):

$$SWD_VOLUME_{mpc} = \left[\sum_{z=1}^k \frac{\pi^2 * SWD_TALLY_{mpcz} * 2^2}{8} \right] / \sum_{z=1}^k SWD_MEASLEN_{mpz}$$

Woody debris diameter is set to 4 cm if the diameter small woody debris is 3 to 5 cm (SWD_DIAM_CLASS = 2):

$$SWD_VOLUME_{mpc} = \left[\sum_{z=1}^k \frac{\pi^2 * SWD_TALLY_{mpcz} * 4^2}{8} \right] / \sum_{z=1}^k SWD_MEASLEN_{mpz}$$

Woody debris diameter is set to 6.25 cm if the diameter small woody debris is 4 to 7.5 cm (SWD_DIAM_CLASS = 3):

$$SWD_VOLUME_{mpc} = \left[\sum_{z=1}^k \frac{\pi^2 * SWD_TALLY_{mpcz} * 6.25^2}{8} \right] / \sum_{z=1}^k SWD_MEASLEN_{mpz}$$

where c is one of three diameter classes for small woody debris (SWD_DIAM_CLASS) along transect z (TRANSECT_NUM) among k number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Volumes are converted to biomass (SWD_BIOMASS; Mg ha⁻¹) by multiplying volume estimates (SWD_VOLUME) by wood density (DENSITY), which is based on small woody debris decay class (SWD_DECAY_CLASS) and the leading woody debris taxon (WD_GENUS, WD_SPECIES, WD_VARIETY) in the plot, determined by the CWD_LEAD_SPECIES routine documented above.

$$SWD_BIOMASS_{mpc} = SWD_VOLUME_{mpc} * DENSITY_{jsd}$$

where c is one of three diameter classes for small woody debris (SWD_DIAM_CLASS) of taxon s (WD_GENUS, WD_SPECIES, WD_VARIETY) and decay class d (SWD_DECAY_CLASS) within province j (PROVINCE) and plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Sum the volume (SWD_VOLUME) and biomass (SWD_BIOMASS) estimates across diameter classes (SWD_DIAM_CLASS) to get total small woody debris volume (PLOTVOL_SWD) and biomass (PLOTBIO_SWD) per hectare:

$$PLOTVOL_SWD_{mp} = \sum_{c=1}^n SWD_VOLUME_{mpc}$$

$$PLOTBIO_SWD_{mp} = \sum_{c=1}^n SWD_BIOMASS_{mpc}$$

where c is a unique diameter class of small woody debris (SWD_DIAM_CLASS) among n number of diameter classes within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_SWD, PLOTBIO_SWD

PLOTVOL_ODDWD, PLOTBIO_ODDWD

Inputs

TRANSECT_NUM; WD_PIECE_NUM; DENSITY; HOR_LENGTH; VER_DEPTH; MCWD_MEASLEN;
LCWD_MEASLEN

Computations

1) The cross sectional area of each odd shaped coarse woody debris and woody debris accumulation is calculated using the product of length (HOR_LENGTH) and depth (VER_DEPTH). Odd shaped debris and accumulations are then stratified into two size classes according to the round-diameter equivalents (EQ_DIAMETER) to cross sectional areas as defined below: medium (7.5 < EQ_DIAMETER ≤ 30 cm) and large (EQ_DIAMETER > 30 cm):

$$EQ_DIAMETER_{mpzw} = \sqrt{\frac{HOR_LENGTH_{mpzw} * VER_DEPTH_{mpzw} * 4}{\pi}}$$

where w is a unique odd shaped coarse woody debris (WD_PIECE_NUM) along transect z (TRANSECT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate the volume per hectare for each size class of odd shaped coarse woody debris and woody debris accumulations (WD_ODD_MED_VOLUME; WD_ODD_LARGE_VOLUME), using the product of debris length (HOR_LENGTH) and depth (VER_DEPTH) and weighing the sum of cross sectional areas by the total measured transect length for medium (MCWD_MEASLEN) and large (LCWD_MEASLEN) size classes:

$$WD_ODD_MED_VOLUME_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n HOR_LENGTH_{mpzw} * VER_DEPTH_{mpzw} \right] / \sum_{z=1}^k MCWD_MEASLEN_{mpz}$$

$$WD_ODD_LARGE_VOLUME_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n HOR_LENGTH_{mpzw} * VER_DEPTH_{mpzw} \right] / \sum_{z=1}^k LCWD_MEASLEN_{mpz}$$

where w is a unique odd shaped coarse woody debris (WD_PIECE_NUM) among n number of odd woody debris along transect z (TRANSECT_NUM) among k number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Biomass estimates for each size class of odd shaped coarse woody debris and woody debris accumulations (WD_ODD_MED_BIOMASS; WD_ODD_LARGE_BIOMASS) are calculated similarly to volume estimates however account for debris density (DENSITY):

$$WD_ODD_MED_BIOMASS_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n HOR_LENGTH_{mpzw} * VER_DEPTH_{mpzw} * DENSITY_{jsd} \right] / \sum_{z=1}^k MCWD_MEASLEN_{mpz}$$

$$WD_ODD_LARGE_BIOMASS_{mp} = \left[\sum_{z=1}^k \sum_{w=1}^n HOR_LENGTH_{mpzw} * VER_DEPTH_{mpzw} * DENSITY_{jsd} \right] / \sum_{z=1}^k LCWD_MEASLEN_{mpz}$$

where w is a unique odd shaped coarse woody debris (WD_PIECE_NUM) of taxon s (WD_GENUS, WD_SPECIES, WD_VARIETY) and decay class d (SWD_DECAY_CLASS) among n number of odd woody debris along transect z (TRANSECT_NUM) among k number of transects within province j (PROVINCE) and plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) Sum the volumes and biomass estimates across medium and large size classes to calculate total odd shaped coarse woody debris volume (PLOTVOL_ODDWD) and biomass (PLOTBIO_ODDWD) per hectare:

$$PLOTVOL_ODDWD_{mp} = WD_ODD_LARGE_VOLUME_{mp} + WD_ODD_MED_VOLUME_{mp}$$

$$PLOTBIO_ODDWD_{mp} = WD_ODD_LARGE_BIOMASS_{mp} + WD_ODD_MED_BIOMASS_{mp}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_ODDWD, PLOTBIO_ODDWD

PLOTVOL_CWD, PLOTBIO_CWD

Inputs

PLOTVOL_ROUNDWD; PLOTVOL_ODDWD; PLOTBIO_ROUNDWD; PLOTBIO_ODDWD

Computations

Pool the biomass and volume estimates for round (PLOTVOL_ROUNDWD; PLOTBIO_ROUNDWD) and odd shaped (PLOTVOL_ODDWD; PLOTBIO_ODDWD) coarse woody debris to get the total coarse woody debris volume (PLOTVOL_CWD) and biomass (PLOTBIO_CWD) per hectare:

$$PLOTVOL_CWD_{mp} = PLOTVOL_ROUNDWD_{mp} + PLOTVOL_ODDWD_{mp}$$

$$PLOTBIO_CWD_{mp} = PLOTBIO_ROUNDWD_{mp} + PLOTBIO_ODDWD_{mp}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

Output

PLOTVOL_CWD, PLOTBIO_CWD

14. Coarse and Small Woody Debris – Plot-Level Summary by Decay Class

Compiler routines

gp_woody_debris.sas

Output written to

wd_summary

PLOTVOL_ROUNDWD, PLOTBIO_ROUNDWD, PLOTVOL_ODDWD, PLOTBIO_ODDWD, PLOTVOL_WD, PLOTBIO_WD, PLOTVOL_SWD, PLOTBIO_SWD

Inputs

ROUND COARSE WOODY DEBRIS (from woody_debris_round table):

TRANSECT_NUM; WD_PIECE_NUM; WD_GENUS; WD_SPECIES; WD_DIAMETER; DECAY_CLASS;
TILT_ANGLE; MCWD_MEASLEN; LCWD_MEASLEN

SMALL WOODY DEBRIS (from woody_debris_small table):

TRANSECT_NUM; SWD_DIAM_CLASS; SWD_TALLY; SWD_DECAY_CLASS; SWD_MEASLEN

ODD COARSE WOODY DEBRIS (from woody_debris_odd table):

TRANSECT_NUM; WD_PIECE_NUM; WD_GENUS; WD_SPECIES; DECAY_CLASS; HOR_LENGTH;
VER_DEPTH; MCWD_MEASLEN; LCWD_MEASLEN

TOTAL WOODY DEBRIS (from wd_summary table, calculated using attributes above):
PLOTVOL_ROUNDWD; PLOTVOL_ODDWD; PLOTBIO_ROUNDWD; PLOTBIO_ODDWD;
PLOTVOL_SWD; PLOTBIO_SWD

Computations

Essentially, these are a repeat of the previous woody debris calculations but the summaries are calculated by measurement number (MEAS_NUM), plot (NFI_PLOT) and decay class (DECAY_CLASS) rather than only by measurement number and plot. Note that, unlike total coarse woody debris estimates in the site_info table (PLOTVOL_CWD and PLOTBIO_CWD), total woody debris estimates in the wd_summary table (PLOTVOL_WD and PLOTBIO_WD) include the volume and biomass of small woody debris.

Output

PLOTVOL_WD, PLOTBIO_WD, PLOTVOL_SWD, PLOTBIO_SWD, PLOTVOL_ROUNDWD,
PLOTBIO_ROUNDWD, PLOTVOL_ODDWD, PLOTBIO_ODDWD

15. Soil Carbon

Compiler routines

gp_carbon_content.sas
gp_substrate_tally.sas
gp_soil_layer_cc.sas
gp_soil_layer_cc_org_rev.sas
gp_soil_layer_cf_horizons.sas
gp_cwd_lead_species.sas

Output written to

surface_substrate_header
site_info
soil_pit_depth
soil_mineral_sample
soil_org_sample
for_flr_org_sample

**TALLY_SS_BED, TALLY_SS_ROCK, TALLY_SS_MIN, TALLY_SS_WATER,
TALLY_SS_ORG, TALLY_SS_BURIED, TALLY_SS_DECAY, TOTAL_MEAS**

Inputs

TRANSECT_NUM; STATION_NUM; SUBSTRATE_TYPE

Computations

Surface substrate information is collected for computing per-hectare estimates of carbon content in the forest floor, mineral soil layer and organic soil layer.

1) Count the total number of sampling stations (STATION_NUM) along each transect (TOTAL_MEAS):

$$TOTAL_MEAS_{mpz} = n_{mpz}$$

where z is a unique transect (TRANSECT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Count the number of sampling stations (STATION_NUM) with bedrock surface coverage (SUBSTRATE_TYPE = 'BR') along each transect (TALLY_SS_BED):

$$TALLY_SS_BED_{mpz} = n_{mpz}$$

where z is a unique transect (TRANSECT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Tallies of surface coverage for water (TALLY_SS_WATER; SUBSTRATE_TYPE = 'WA'), mineral soil (TALLY_SS_MIN; SUBSTRATE_TYPE = 'MS'), rock (TALLY_SS_ROCK; SUBSTRATE_TYPE = 'RC'), decaying wood (TALLY_SS_DECAY; SUBSTRATE_TYPE = 'DW'), organic matter (TALLY_SS_ORG; SUBSTRATE_TYPE = 'OM') and buried wood (TALLY_SS_BURIED; SUBSTRATE_TYPE = 'BW') substrate types are calculated in the same manner.

3) Calculate the average depth (DEPTH) of organic matter (SUBSTRATE_TYPE = 'OM') at sampling stations for each transect (AVG_ORG_THICK):

$$AVG_ORG_THICK_{mpz} = \sum_{a=1}^n DEPTH_{mpza} / n_{mpz}$$

where z is a unique transect (TRANSECT_NUM) with n number of sampling stations (STATION_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) The average depth (DEPTH) of buried wood (SUBSTRATE_TYPE = 'BW') along each transect is calculated in the same manner (AVG_BURIED_THICK):

$$AVG_BURIED_THICK_{mpz} = \sum_{a=1}^n DEPTH_{mpza} / n_{mpz}$$

where z is a unique transect (TRANSECT_NUM) with n number of sampling stations (STATION_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

5) For each plot, calculate the percent surface coverage of bedrock (PCT_SS_BED) by dividing the total number of surface substrate sampling stations with bedrock cover (TALLY_SS_BED) with the total number of surface substrate sampling stations (TOTAL_MEAS) across transects:

$$PCT_SS_BED_{mp} = 100 * \sum_{z=1}^n TALLY_SS_BED_{mpz} / \sum_{z=1}^n TOTAL_MEAS_{mpz}$$

where z is a unique transect (TRANSECT_NUM) among n number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Percent surface substrate cover for water (PCT_SS_WATER), organic matter (PCT_SS_ORG), decayed wood (PCT_SS_DECAY), buried wood (PCT_SS_BURIED), rock (PCT_SS_ROCK) and mineral soil (PCT_SS_MIN) are all calculated in the same manner. Note that percent surface coverage values are intermediate variables that are not written to the database.

7) For each plot, calculate the average thickness of organic matter (PLOT_AVG_ORG_THICK) and buried wood (PLOT_AVG_BURIED_THICK) by summing average substrate thickness (AVG_ORG_THICK and AVG_BURIED_THICK, respectively) across transects and dividing by the number of transects. Note that

plot-level averages of surface substrates thickness are intermediate variables that are not written to the database:

$$PLOT_AVG_ORG_THICK_{mp} = \sum_{z=1}^n AVG_ORG_THICK_{mpz} / n_{mp}$$

$$PLOT_AVG_BURIED_THICK_{mp} = \sum_{z=1}^n AVG_BURIED_THICK_{mpz} / n_{mp}$$

where z is a unique transect (TRANSECT_NUM) among n number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

TALLY_SS_ORG, AVG_ORG_THICK, TALLY_SS_BURIED, AVG_BURIED_THICK, TALLY_SS_DECAY, TALLY_SS_BED, TALLY_SS_MIN, TALLY_SS_WATER, TALLY_SS_ROCK (surface_substrate_header table)

BULK_DENSITY_2MM, BULK_DENSITY_TOTAL, CF_GRAV, CF_COBB, CF_STONE (mineral soil samples)

Inputs

MASS_DISC_ROCKS; MASS_TOTAL; MASS_ROOT; MASS_COBBLE; MASS_GRAVEL; MASS_2MM; VOLUME; PIT_NUM; SAMPLE_NUM

Computations

Warning: These compiled attributes (or their precursors) were not compiled by the NFI office prior to August 1, 2007 and therefore may not follow the procedures outlined below.

Note: Cobble may be included in rocks discarded from mineral soil samples (MASS_DISC_ROCKS) therefore potentially overestimating actual percent content of stones (CF_STONE) and underestimating percent content of cobble (CF_COBB) in small soil pit samples. Volume occupied by roots (MASS_ROOT) is not accounted for when calculating bulk density of mineral soil fraction less than 2mm (BULK_DENSITY_2MM). The air-dried mass of gravel, cobbles and stones is assumed equal to their oven-dried mass (at 105 °C).

1) For small soil pits in microplots or other locations (PIT_NUM = MP1 –MP8 or PT1 – PT4; note: for measurements prior to August 1, 2007 small soil pits may also have been collected where large pits were dug), calculate coarse fragment content of gravel (CF_GRAV), cobble (CF_COBB) and stones (CF_STONE) by dividing the mass of gravel (MASS_GRAVEL), cobble (MASS_COBBLE), or stones (MASS_DISC_ROCKS) in the sample by the total sample mass (MASS_TOTAL):

$$CF_GRAV_{mpuh} = \frac{MASS_GRAVEL_{mpuh}}{MASS_TOTAL_{mpuh} + MASS_DISC_ROCKS_{mpuh}} * 100$$

$$CF_COBB_{mpuh} = \frac{MASS_COBB_{mpuh}}{MASS_TOTAL_{mpuh} + MASS_DISC_ROCKS_{mpuh}} * 100$$

$$CF_STONE_{mpuh} = \frac{MASS_DISC_ROCKS_{mpuh}}{MASS_TOTAL_{mpuh} + MASS_DISC_ROCKS_{mpuh}} * 100$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

- 2) Calculate total bulk density (BULK_DENSITY_TOTAL) by dividing total sampled mass (MASS_TOTAL + MASS_DISC_ROCKS) adjusted for moisture content in mineral soil fraction less than 2 mm (MASS_2MM * (1 – SOIL_MOISTURE)) by total sampled volume (VOLUME):

$$BULK_DENSITY_TOTAL_{mpuh} = \frac{MASS_TOTAL_{mpuh} - MASS_2MM_{mpuh} + (MASS_2MM_{mpuh} * (1 - SOIL_MOISTURE_{mpuh})) + MASS_DISC_ROCKS_{mpuh}}{VOLUME_{mpuh}}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

- 3) Calculate the bulk density of the mineral soil fraction ≤ 2 mm (BULK_DENSITY_2MM) by dividing the mass of the mineral soil fraction ≤ 2 mm (MASS_2MM) adjusted for moisture content (SOIL_MOISTURE) by the sample volume (VOLUME) adjusted for volume occupied by gravel, cobble and stones (i.e. the mass of coarse mineral fragments [MASS_GRAVEL + MASS_COBBLE + MASS_DISC_ROCKS] divided by the bulk density of quartz [2.65 g cm⁻³]):

$$BULK_DENSITY_2MM_{mpuh} = \frac{MASS_2MM_{mpuh} * (1 - SOIL_MOISTURE_{mpuh})}{VOLUME_{mpuh} - ((MASS_GRAVEL_{mpuh} + MASS_COBBLE_{mpuh} + MASS_DISC_ROCKS_{mpuh}) / 2.65)}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

BULK_DENSITY_2MM, BULK_DENSITY_TOTAL, CF_GRAV, CF_COBB, CF_STONE (soil_mineral_sample table)

LAYER_CC (mineral soil samples)

Inputs

MASS_2MM; VOLUME; CF_GRAV; CF_COBB; CF_STONE; TOC; TC; SAMPLE_UPPER;
SAMPLE_BOTTOM

Computations

Warning: These compiled attributes (or their precursors) were not compiled by the NFI office prior to August 1, 2007 and therefore may not follow the procedures outlined below.

- 1) Calculate the thickness (THICKNESS) of each mineral soil samples as the difference between upper and bottom depths of each sample (SAMPLE_UPPER, SAMPLE_BOTTOM)

$$THICKNESS_{mpuh} = SAMPLE_BOTTOM_{mpuh} - SAMPLE_UPPER_{mpuh}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate effective bulk density of mineral soil ≤ 2 mm (BULK_DENSITY_EFFECTIVE_2MM) and roots (BULK_DENSITY_EFFECTIVE_ROOT) by dividing respective masses (MASS_2MM, MASS_ROOT), when applicable adjusted for moisture content (SOIL_MOISTURE), by sample volume (VOLUME):

$$BULK_DENSITY_EFFECTIVE_2MM_{mpuh} = \frac{MASS_2MM_{mpuh} * (1 - SOIL_MOISTURE_{mpuh})}{VOLUME_{mpuh}}$$

$$BULK_DENSITY_EFFECTIVE_ROOT_{mpuh} = \frac{MASS_ROOT_{mpuh}}{VOLUME_{mpuh}}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Calculate the carbon content of each sampled layer within each soil pit (LAYER_CC) by multiplying effective bulk density of mineral soil ≤ 2 mm (BULK_DENSITY_EFFECTIVE_2MM) or roots (BULK_DENSITY_EFFECTIVE_ROOT) with soil sample thickness (THICKNESS) and organic carbon content of the ≤ 2 mm (TOC) or root (46 g kg⁻¹; Ma et al. 2018) fraction of mineral soil and convert units to kg m⁻² (use total carbon content [TC] if total organic carbon [TOC] is missing):

$$LAYER_CC_{mpuh} = \frac{TOC_{mpuh}}{1000} * BULK_DENSITY_EFFECTIVE_2MM_{mpuh} * THICKNESS_{mpuh} * 10 + \frac{46}{1000} * BULK_DENSITY_EFFECTIVE_ROOT_{mpuh} * THICKNESS_{mpuh} * 10$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

LAYER_CC (soil_mineral_sample table)

CC_MIN0_15, CC_MIN15_35, CC_MIN35_55

Inputs

SAMPLE_UPPER; SAMPLE_BOTTOM; LAYER_CC; PCT_SS_BED; PCT_SS_WATER

Computations

Warning: These compiled attributes (or their precursors) were not compiled by the NFI office prior to August 1, 2007 and therefore may not follow the procedures outlined below.

Note: Carbon content in mineral soil layers was adjusted for coarse fragment occupancy in both small and large (representative) soil pits. Since small soil pits are unlikely to effectively capture cobbles (75 – 250 mm) and stones (> 250 mm), the carbon content of each sampled layer within small soil pits (LAYER_CC) is adjusted to only reflect gravel content (LAYER_CC_GRAVADJ). Therefore, adjustments for coarser soil fragments (i.e. cobbles and stones) rely on percent cobble and percent stone determined by a large representative soil pit. The carbon content of the mineral soil at each depth layer should therefore be considered overestimated if data from a large representative soil pit is not available for a site.

1) Multiply the carbon content of each sampled layer within each soil pit (LAYER_CC) by the ratio of total sample volume (VOLUME) to volume not occupied by cobble (MASS_COBBLE/2.65) and stone (MASS_COBBLE/2.65) coarse fragments assuming these have the bulk density of quartz (2.65 g cm⁻³), to

adjust carbon content of each sampled layer within each soil pit to only reflect gravel content (LAYER_CC_GRAVADJ):

$$LAYER_CC_GRAVADJ_{mpuh} = LAYER_CC_{mpuh} * \frac{VOLUME_{mpuh}}{VOLUME_{mpuh} - ((MASS_COBBLE_{mpuh} + MASS_DISC_ROCKS_{mpuh})/2.65)}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

For reporting, the original mineral soil layers are reapportioned to three standardized layers of 0-15 cm, 15-35 cm and 35-55 cm. The carbon content of the mineral soil is reported to the maximum depth for which all required data are available.

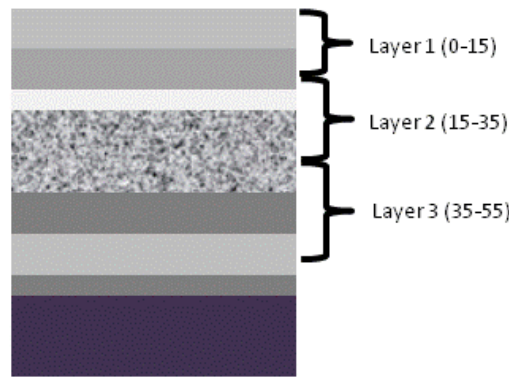


Figure 1. The original soil horizons are reapportioned to three layers of standardized depth.

2) For each standardized layer within a pit, determine the portion (ϵ 0 – 15) of each sample's thickness (SAMPLE_BOTTOM – SAMPLE_UPPER) and carbon content adjusted only for gravel content (LAYER_CC_GRAVADJ) contained within the depth range of a layer, and sum to calculate the total measured thickness (i.e. sampled interval; THICKNESS_0_15) and carbon content (CC0_15) corresponding to each layer. The calculations for the 0-15 cm layer are as follows:

$$THICKNESS_0_15_{mpu} = \sum_{h=1}^n (SAMPLE_BOTTOM_{mpuh} - SAMPLE_UPPER_{mpuh}) * (\epsilon 0 - 15)$$

$$CC0_15_{mpu} = \sum_{h=1}^n LAYER_CC_GRAVADJ_{mpuh} * (\epsilon 0 - 15)$$

where h is a unique sample (SAMPLE_NUM) among n number of samples where the midpoint of the sampled interval lies in the layer range (e.g. 0 – 15 cm) within pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM). The term (ϵ 0 – 15) stands for the proportion of each sample that lies in the designated range of a layer. For example, if the interval sampled runs from 11-21 cm, the midpoint of that interval is 16. Therefore, only the portion of the sample that is in the 15-35 cm layer (15-21 cm) will be used in calculating carbon content in the 15-35 cm layer (CC15_35). The portion that is in the 0-15 cm layer (11-14 cm) will not be used since the midpoint lies outside of the 0-15 cm layer. Exceptions were made for thick soil samples with

midpoints lying outside the range of a soil layer being completely enclosed in the sample. In these cases, the portion of the sample associated with the enclosed soil layer is used to calculate that layer's thickness and carbon content.

3) Calculate the adjusted carbon content (kg m^{-2}) for each standard layer across all soil pits ($CC0_15_ADJ$) and for all layers combined ($PLOT_TOT_CC$) by dividing the carbon content ($CC0_15$) by measured thickness ($THICKNESS_0_15$) in each standardized layer in a pit, then dividing the summed fractions across all pits by the number of pits in a plot and multiplying by the nominal thickness of each layer ($NOM_THICKNESS$):

$$CC0_15_ADJ_{mp} = \left[\left[\sum_{u=1}^n (CC0_15_{mpu} / THICKNESS_0_15_{mpu}) \right] / n \right] * NOM_THICKNESS_{mp}$$

$$PLOT_TOT_CC_{mp} = CC0_15_ADJ_{mp} + CC15_35_ADJ_{mp} + CC35_55_ADJ_{mp}$$

where u is a unique pit (PIT_NUM) among n number of pits within plot p (NFI_PLOT) at measurement m ($MEAS_NUM$) and where the nominal thickness ($NOM_THICKNESS$) of the standardized layer l is 15 cm for the 0-15 cm layer, 20 cm for the 15-35 cm layer and 20 cm for the 35-55 cm layer or, alternatively, the portion of the nominal thickness which corresponds to the maximum depth for which all required data are available for computing carbon content.

4) Calculate total depth of sampled mineral soil ($SAMPLE_DEPTH_MIN$) as the sum of nominal thickness values ($NOM_THICKNESS$) used to calculate adjusted carbon content for each standard layer across all soil pits:

$$SAMPLE_DEPTH_MIN_{mp} = \sum_{l=1}^n NOM_THICKNESS_{mpl}$$

where l is one of three standardized soil layers (0-15 cm, 15-35 cm, 35-55 cm) within plot p (NFI_PLOT) at measurement m ($MEAS_NUM$)

5) For the latest sampled, large representative soil pit within each plot, calculate percent cobble and percent stone for each standardized layer adjusting percent values contributed by each sample according to the proportion of total measured thickness within a layer:

$$CCOBB0_15_{pu} = \left[\sum_{h=1}^n CF_COBB_{puh} * THICKNESS_{puh} * (\epsilon 0 - 15) \right] / \left[\sum_{h=1}^n THICKNESS_{puh} * (\epsilon 0 - 15) \right]$$

$$CSTONE0_15_{pu} = \left[\sum_{h=1}^n CF_STONE_{puh} * THICKNESS_{puh} * (\epsilon 0 - 15) \right] / \left[\sum_{h=1}^n THICKNESS_{puh} * (\epsilon 0 - 15) \right]$$

where h is a unique sample ($SAMPLE_NUM$) among n number of samples with sampled interval lying in the layer range (e.g. 0 – 15 cm) within large representative pit number u ($PIT_NUM = LP0, PT1, PT2, PT3$ or $PT4$) within plot p (NFI_PLOT). The term $(\epsilon 0 - 15)$ stands for the proportion of each sample that lies in the designated range of a layer. For example, if the interval sampled runs from 11-21 cm, only the portion of the sample that is in the 0-15 cm layer (11-14 cm) will be used in calculating percent coarse fragments in the 0-15 cm layer ($CCOBB0_15, CSTONE0_15$). The

portion that is in the 15-35 cm layer (15-21 cm) will be used in calculating percent coarse fragments in the 15-35 cm layer (CCOBB15_35, CSTONE15_35).

6) If the latest measurement of a plot included more than one large representative pit, then take the mean percent cobble (CCOBB0_15) and percent stone (CSTONE0_15) across large representative pits:

$$CCOBB0_{15_p} = \left[\sum_{u=1}^n CCOBB0_{15_{pu}} \right] / n$$

$$CSTONE0_{15_p} = \left[\sum_{u=1}^n CSTONE0_{15_{pu}} \right] / n$$

where u is a unique large representative soil pit (PIT_NUM = LP0, PT1, PT2, PT3 or PT4) among n number of large representative soil pits within plot p (NFI_PLOT).

7) Adjust carbon content in mineral soil layers (CC0_15_ADJ) to account for percent volume occupied by cobble (CCOBB0_15) and stone (CSTONE0_15):

$$CC0_{15_HADJ}_{mp} = CC0_{15_ADJ}_{mp} * (100 - (CCOBB0_{15_p} + CSTONE0_{15_p})) / 100$$

8) Calculate the per hectare carbon content in a mineral soil layer (CC_MIN0_15, CC_MIN15_35, CC_MIN35_55) by multiplying the adjusted carbon content in a layer (CC0_15_HADJ, CC15_35_HADJ, CC35_55_HADJ) with the percent surface substrate not occupied by bedrock (PCT_SS_BED), rock (PCT_SS_ROCK), and water (PCT_SS_WATER) and convert units to Mg C ha⁻¹:

$$CC_MIN0_{15_{mp}} = \frac{CC0_{15_HADJ}_{mp} * [(100 - (PCT_SS_BED_{mp} + PCT_SS_ROCK_{mp} + PCT_SS_WATER_{mp})) / 100] * 10000}{1000}$$

Where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

Output

CC_MIN0_15, CC_MIN15_35, CC_MIN35_55, SAMPLE_DEPTH_MIN (site_info table)

BULK_DENSITY_8MM, BULK_DENSITY_TOTAL (forest floor & organic soil samples)

Inputs

MASS_TOTAL; MASS_LIVE_ROOT; MASS_GRAVEL; MASS_GT8MM; MASS_8MM; VOLUME;
PIT_NUM; SAMPLE_NUM

Computations

Warning: These compiled attributes (or their precursors) were not compiled by the NFI office prior to August 1, 2007 and therefore may not follow the procedures outlined below.

Note: The density of roots and organic fractions > 8 mm is assumed to be the same as organic fractions ≤ 8 mm when calculating the bulk density of organic fractions ≤ 8 mm.

1) Calculate total bulk density (BULK_DENSITY_TOTAL) by dividing total sampled mass (MASS_TOTAL) by total sampled volume (VOLUME):

$$BULK_DENSITY_TOTAL_{mpuh} = \frac{MASS_TOTAL_{mpuh}}{VOLUME_{mpuh}}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate the bulk density of the forest floor or organic soil fraction ≤ 8 mm (BULK_DENSITY_8MM) by dividing the mass of the forest floor or organic soil fraction ≤ 8 mm (MASS_8MM) by the sample volume (VOLUME) adjusted for volume occupied by gravel (i.e. MASS_GRAVEL divided by the bulk density of quartz [2.65 g cm⁻³]) and by live roots and fraction > 8 mm:

$$BULK_DENSITY_8MM_{mpuh} = \frac{MASS_8MM_{mpuh}}{(VOLUME_{mpuh} - (MASS_GRAVEL_{mpuh}/2.65)) * (MASS_8MM_{mpuh}/(MASS_TOTAL_{mpuh} - MASS_GRAVEL_{mpuh}))}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

BULK_DENSITY_8MM, BULK_DENSITY_TOTAL (for_flr_org_sample and soil_org_sample tables)

LAYER_CC_8MM, LAYER_CC_TOTAL (forest floor & organic soil samples)

Inputs

MASS_8MM; MASS_GT8MM; MASS_LIVE_ROOT; VOLUME; SAMPLE_UPPER; SAMPLE_BOTTOM;
TOC_8MM; TOC_GT8MM

Computations

Warning: These compiled attributes (or their precursors) were not compiled by the NFI office prior to August 1, 2007 and therefore may not follow the procedures outlined below.

Note: 'Effective density' values for small pit samples include volumes occupied by gravel and roots, therefore can be integrated with organic depth measurements along transects to calculate carbon content at plot level.

1) Calculate the thickness (THICKNESS) of forest floor or organic soil samples as the difference between upper and bottom depths of each sample (SAMPLE_UPPER, SAMPLE_BOTTOM):

$$THICKNESS_{mpuh} = SAMPLE_BOTTOM_{mpuh} - SAMPLE_UPPER_{mpuh}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Calculate effective bulk density of the forest floor or organic soil fractions > 8 mm (BULK_DENSITY_EFFECTIVE_GT8MM), ≤ 8 mm (BULK_DENSITY_EFFECTIVE_8MM) and/or of live roots (BULK_DENSITY_EFFECTIVE_ROOT) by dividing the mass of the soil fractions > 8 mm, ≤ 8 mm and/or of live roots (i.e. those used to quantify carbon; MASS_8MM, MASS_GT_8MM, MASS_LIVE_ROOT) by total sampled volume:

$$BULK_DENSITY_EFFECTIVE_8MM_{mpuh} = \frac{MASS_8MM_{mpuh}}{VOLUME_{mpuh}}$$

$$BULK_DENSITY_EFFECTIVE_GT8MM_{mpuh} = \frac{MASS_GT8MM_{mpuh}}{VOLUME_{mpuh}}$$

$$BULK_DENSITY_EFFECTIVE_ROOT_{mpuh} = \frac{MASS_LIVE_ROOT_{mpuh}}{VOLUME_{mpuh}}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) Calculate the total carbon content (LAYER_CC_TOTAL) and carbon content from the fraction ≤ 8 mm (LAYER_CC_8MM) in each of the forest floor or organic soil samples by multiplying the effective bulk density of the ≤ 8 mm (BULK_DENSITY_EFFECTIVE_8MM), > 8 mm (BULK_DENSITY_EFFECTIVE_GT8MM) or live roots (BULK_DENSITY_EFFECTIVE_ROOT) fractions with soil sample thickness (THICKNESS) and organic carbon content of the ≤ 8 mm (TOC_8MM), > 8 mm (TOC_GT8MM) or root (46 g kg⁻¹; Ma et al. 2018) fractions of forest floor or organic soil and convert units to kg m⁻². Use total carbon content [TC_8MM, TC_GT8MM] if total organic carbon [TOC_8MM, TOC_GT8MM] is missing. If no values of carbon content are available for the fraction > 8 mm [TC_GT8MM, TOC_GT8MM], then carbon content in the fraction ≤ 8 mm [TC_8MM, TOC_8MM] is used as a substitute. Total carbon content is the sum of carbon content in ≤ 8 mm, > 8 mm and live root fractions:

$$\begin{aligned} LAYER_CC_8MM_{mpuh} &= \frac{TOC_8MM_{mpuh}}{1000} * BULK_DENSITY_EFFECTIVE_8MM_{mpuh} * THICKNESS_{mpuh} \\ &* 10 \end{aligned}$$

$$\begin{aligned} LAYER_CC_TOTAL_{mpuh} &= \left[\frac{TOC_8MM_{mpuh}}{1000} * BULK_DENSITY_EFFECTIVE_8MM_{mpuh} * THICKNESS_{mpuh} \right. \\ &* 10 \left. + \left[\frac{TOC_GT8MM_{mpuh}}{1000} * BULK_DENSITY_EFFECTIVE_GT8MM_{mpuh} \right. \right. \\ &* THICKNESS_{mpuh} * 10 \left. \right] \\ &+ \left[\frac{46}{1000} * BULK_DENSITY_EFFECTIVE_ROOT_{mpuh} * THICKNESS_{mpuh} * 10 \right] \end{aligned}$$

where h is a unique sample (SAMPLE_NUM) of pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

LAYER_CC_8MM, LAYER_CC_TOTAL (for_flr_org_sample and soil_org_sample tables)

**CC_FOR_FLOOR_8MM, CC_FOR_FLOOR_TOTAL,
CC_ORGANIC0_15_8MM, CC_ORGANIC15_35_8MM,**

CC_ORGANIC35_55_8MM, CC_ORGANIC0_15_TOTAL, CC_ORGANIC15_35_TOTAL, CC_ORGANIC35_55_TOTAL

Inputs

BULK_DENSITY_8MM; BULK_DENSITY_TOTAL; TOC_8MM; TOC_GT8MM; THICKNESS;
LAYER_CC_8MM; LAYER_CC_TOTAL; AVG_ORG_THICK; AVG_BURIED_THICK; PCT_SS_ORG;
PCT_SS_DECAY; PCT_SS_BURIED; DENSITY; ORG_CARB_WD

Computations

Warning: These compiled attributes (or their precursors) were not compiled by the NFI office prior to August 1, 2007 and therefore may not follow the procedures outlined below.

For Forest Floor

1) Compute the weighted average organic carbon (AVG_ORG_CARB_PIT) and bulk density (AVG_BULK_DENSITY_PIT) for the < 8 mm fraction in each soil pit (in case there are multiple samples in the pit) by multiplying total organic carbon of the < 8 mm fractions (TOC_8MM) with sample thickness (THICKNESS), summing these products across all samples in a pit and dividing the result by the summed thickness of all samples in a pit:

$$AVG_ORG_CARB_PIT_{mpu} = \sum_{h=1}^n TOC_8MM_{mpuh} * THICKNESS_{mpuh} / \sum_{h=1}^n THICKNESS_{mpuh}$$

$$AVG_BULK_DENSITY_PIT_{mpu} = \sum_{h=1}^n BULK_DENSITY_8MM_{mpuh} * THICKNESS_{mpuh} / \sum_{h=1}^n THICKNESS_{mpuh}$$

where h is a unique sample (SAMPLE_NUM) among n number of samples in pit u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Then calculate the average organic carbon (AVG_ORG_CARB_FF) and bulk density (AVG_BULK_DENSITY_FF) of the < 8mm fraction of forest floor for the plot as a whole, by summing the weighted average organic carbon (AVG_ORG_CARB_PIT) or bulk density (AVG_BULK_DENSITY_PIT) across soil pits and dividing by the number of soil pits in a plot:

$$AVG_ORG_CARB_FF_{mp} = \sum_{u=1}^n AVG_ORG_CARB_PIT_{mpu} / n_{mp}$$

$$AVG_BULK_DENSITY_FF_{mp} = \sum_{u=1}^n AVG_BULK_DENSITY_PIT_{mpu} / n_{mp}$$

where u is a unique pit number (PIT_NUM) among n number of pits within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) For each pit, determine the carbon content per cm depth in the < 8 mm fraction (LAYER_CC_CM_PIT) and total forest floor layer (LAYER_CCTOTAL_CM_PIT) within each pit by dividing the sum of carbon content values in each sample (LAYER_CC_8MM, LAYER_CC_TOTAL) by the sum of forest floor thickness sampled (THICKNESS).

$$LAYER_CC_CM_PIT_{mpu} = \left[\sum_{h=1}^n LAYER_CC_8MM_{mpuh} \right] / \sum_{h=1}^n THICKNESS_{mpuh}$$

$$LAYER_CCTOTAL_CM_PIT_{mpu} = \left[\sum_{h=1}^n LAYER_CC_TOTAL_{mpuh} \right] / \sum_{h=1}^n THICKNESS_{mpuh}$$

where h is a unique sample (SAMPLE_NUM) among n number of samples in pit u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) For each NFI plot, Calculate the average carbon content per cm depth in the < 8 mm fraction (LAYER_CC_CM) and total forest floor layer (LAYER_CCTOTAL_CM) across all small soil pits in the plot:

$$LAYER_CC_CM_{mp} = \left[\sum_{u=1}^n LAYER_CC_CM_{mpu} \right] / n_{mp}$$

$$LAYER_CCTOTAL_CM_{mp} = \left[\sum_{u=1}^n LAYER_CCTOTAL_CM_{mpu} \right] / n_{mp}$$

where u is a unique pit (PIT_NUM) among n number of pits in plot p (NFI_PLOT) at measurement m (MEAS_NUM)

5) Calculate the plot-level average organic (PLOT_AVG_ORG_THICK) and buried wood (PLOT_AVG_BURIED_THICK) thicknesses (cm) determined from surface substrate sampling, by averaging organic (AVG_ORG_THICK) and buried wood (AVG_BURIED_THICK) thicknesses across transects. Then calculate an average layer carbon content (kg m⁻²) in the < 8 mm fraction (AVG_LAYER_CC) and total forest floor layer (AVG_LAYER_CC_TOTAL) using the plot-level average organic thickness determined from surface substrate sampling along transects (PLOT_AVG_ORG_THICK):

$$PLOT_AVG_ORG_THICK_{mp} = \left[\sum_{z=1}^n AVG_ORG_THICK_{mpz} \right] / n_{mp}$$

$$PLOT_AVG_BURIED_THICK_{mp} = \left[\sum_{z=1}^n AVG_BURIED_THICK_{mpz} \right] / n_{mp}$$

$$AVG_LAYER_CC_{mp} = LAYER_CC_CM_{mp} * PLOT_AVG_ORG_THICK_{mp}$$

$$AVG_LAYER_CC_TOTAL_{mp} = LAYER_CCTOTAL_CM_{mp} * PLOT_AVG_ORG_THICK_{mp}$$

where z is a unique transect (TRANSECT_NUM) among n number of transects within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

6) Determine the leading taxon of coarse woody debris in the plot using the same algorithms as in [section 13](#) and use that to determine the wood density (DENSITY; refer to support-data table gpcsd_wood_density) and organic carbon content of the buried wood (ORG_CARB_WD; refer to support-data table gpcsd_cwd_org_carb) tallied during surface substrate sampling (PCT_SS_BURIED), assuming a decay class of 5.

7) Determine the total carbon content per hectare in the forest floor (CCTOTAL_FOR_FLOOR), by multiplying the average layer carbon content (AVG_LAYER_CC) with the fractions of the plot that is covered by organics (PCT_SS_ORG) and decaying wood (PCT_SS_DECAY) and adding the carbon content contained in buried wood (i.e. the fraction of the plot that is covered by buried wood [PCT_SS_BURIED] multiplied by buried wood carbon content [ORG_CARB_WD], density [DENSITY] and thickness [PLOT_AVG_BURIED_THICK]) then converting units to Mg ha⁻¹:

$$\begin{aligned} CCTOTAL_FOR_FLOOR_{mp} &= (AVG_LAYER_CC_TOTAL_{mp} * (PCT_SS_ORG_{mp}/100) * 10000 \\ &+ AVG_LAYER_CC_TOTAL_{mp} * (PCT_SS_DECAY_{mp}/100) * 10000 \\ &+ PLOT_AVG_BURIED_THICK_{mp} * DENSITY_{mp} * (ORG_CARB_WD_{mp}/1000) * 10 \\ &* (PCT_SS_BURIED_{mp}/100) * 10000)/1000 \end{aligned}$$

If the average thickness of organic matter along transects (PLOT_AVG_ORG_THICK) is greater than the average thickness of buried wood along transects (PLOT_AVG_BURIED_THICK), then calculation of total carbon content per hectare in the forest floor (CCTOTAL_FOR_FLOOR) needs to include a term to account for organic content surrounding buried wood using:

$$\begin{aligned} CCTOTAL_FOR_FLOOR_{mp} &= (AVG_LAYER_CC_TOTAL_{mp} * (PCT_SS_ORG_{mp}/100) * 10000 \\ &+ AVG_LAYER_CC_TOTAL_{mp} * (PCT_SS_DECAY_{mp}/100) * 10000 \\ &+ PLOT_AVG_BURIED_THICK_{mp} * DENSITY_{mp} * (ORG_CARB_WD_{mp}/1000) * 10 \\ &* (PCT_SS_BURIED_{mp}/100) * 10000 + (PLOT_AVG_ORG_THICK_{mp} \\ &- PLOT_AVG_BURIED_THICK_{mp})/PLOT_AVG_ORG_THICK_{mp} \\ &* AVG_LAYER_CC_TOTAL_{mp} * (PCT_SS_BURIED_{mp}/100) * 10000)/1000 \end{aligned}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

8) Determine the carbon content per hectare in the < 8 mm fraction of the forest floor (CC_FOR_FLOOR), by multiplying the average layer carbon content (AVG_LAYER_CC) with the fractions of the plot that is covered by organics (PCT_SS_ORG) then converting units to Mg ha⁻¹:

$$CC_FOR_FLOOR_{mp} = (AVG_LAYER_CC_{mp} * (PCT_SS_ORG_{mp}/100) * 10000)/1000$$

If the average thickness of organic matter along transects (PLOT_AVG_ORG_THICK) is greater than the average thickness of buried wood along transects (PLOT_AVG_BURIED_THICK), then calculation of total carbon content per hectare in the < 8 mm fraction of the forest floor (CC_FOR_FLOOR) needs to include a term to account for organic content surrounding buried wood using:

$$\begin{aligned} CC_FOR_FLOOR_{mp} &= (AVG_LAYER_CC_{mp} * (PCT_SS_ORG_{mp}/100) * 10000 \\ &+ (PLOT_AVG_ORG_THICK_{mp} \\ &- PLOT_AVG_BURIED_THICK_{mp})/PLOT_AVG_ORG_THICK_{mp} * AVG_LAYER_CC_{mp} \\ &* (PCT_SS_BURIED_{mp}/100) * 10000)/1000 \end{aligned}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

9) If forest floor and organic soil samples are taken from the same NFI plot, then the forest floor is only considered as a surface litter layer. Therefore, the carbon content in the total forest floor or fraction < 8 mm is determined by multiplying the carbon content per cm of depth (LAYER_CCTOTAL_CM or LAYER_CC_CM, respectively), the average depth of the forest floor sample pits (TOT_THICKNESS) and the fraction of the plot that is covered by organic matter (PCT_SS_ORG), then converting units to Mg ha⁻¹:

First calculate the total thickness of each plot (TOT_THICKNESS) by summing the thickness (THICKNESS) of all samples in a pit:

$$TOT_THICKNESS_{mpu} = \left[\sum_{h=1}^n THICKNESS_{mpuh} \right]$$

where h is a unique sample (SAMPLE_NUM) among n number of samples in pit u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Then calculate the carbon content in the forest floor layer using the average depth of forest sample pits:

$$\begin{aligned} CCTOTAL_FOR_FLOOR_LITTER_{mp} \\ = (LAYER_CCTOTAL_CM_{mp} * \left[\sum_{u=1}^n TOT_THICKNESS_{mpu} \right] / n_{mp} \\ * (PCT_SS_ORG_{mp}/100) * 10000) / 1000 \end{aligned}$$

$$\begin{aligned} CC_FOR_FLOOR_LITTER_{mp} \\ = (LAYER_CC_CM_{mp} * \left[\sum_{u=1}^n TOT_THICKNESS_{mpu} \right] / n_{mp} * (PCT_SS_ORG_{mp}/100) \\ * 10000) / 1000 \end{aligned}$$

where u is a unique pit (PIT_NUM) among n number of pits within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

For Organic Soil

1) Compute the weighted average organic carbon (AVG_ORG_CARB_PIT) and bulk density (AVG_BULK_DENSITY_PIT) for the < 8 mm fraction in each soil pit (in case there are multiple samples in the pit) by multiplying total organic carbon of the < 8 mm fractions (TOC_8MM) with sample thickness (THICKNESS), summing these products across all samples in a pit and dividing the result by the summed thickness of all samples in a pit:

$$AVG_ORG_CARB_PIT_{mpu} = \sum_{h=1}^n TOC_8MM_{mpuh} * THICKNESS_{mpuh} / \sum_{h=1}^n THICKNESS_{mpuh}$$

$$\begin{aligned} AVG_BULK_DENSITY_PIT_{mpu} \\ = \sum_{h=1}^n BULK_DENSITY_8MM_{mpuh} * THICKNESS_{mpuh} / \sum_{h=1}^n THICKNESS_{mpuh} \end{aligned}$$

where h is a unique sample (SAMPLE_NUM) among n number of samples in pit u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) Then calculate the average organic carbon (AVG_ORG_CARB_OS) and bulk density (AVG_BULK_DENSITY_OS) of the < 8 mm fraction of organic soils for the plot as a whole, by summing the weighted average organic carbon (AVG_ORG_CARB_PIT) or bulk density (AVG_BULK_DENSITY_PIT) across soil pits and dividing by the number of soil pits in a plot:

$$AVG_ORG_CARB_OS_{mp} = \sum_{u=1}^n AVG_ORG_CARB_PIT_{mpu} / n_{mp}$$

$$AVG_BULK_DENSITY_OS_{mp} = \sum_{u=1}^n AVG_BULK_DENSITY_PIT_{mpu} / n_{mp}$$

where u is a unique pit number (PIT_NUM) among n number of pits within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) For reporting, the original organic soil layers are reapportioned to three standardized layers of 0-15 cm, 15-35 cm and 35-55 cm. The carbon content of the organic soil is reported to the maximum depth for which all required data are available, up to a depth of 55 cm. For each standardized layer within a pit, determine the portion (ϵ 0 – 15) of each sample's thickness (SAMPLE_BOTTOM – SAMPLE_UPPER) and carbon content (LAYER_CCTOTAL for the entire organic soil, LAYER_CC for the < 8mm fraction) contained within the depth range of a layer, and sum to calculate the total measured thickness (i.e. sampled interval; THICKNESS_0_15) and carbon content in the entire organic soil (CCTOTAL_15) and the < 8 mm fraction (CC0_15) corresponding to each layer. The calculations for the 0-15 cm layer are as follows:

$$THICKNESS_0_15_{mpu} = \sum_{h=1}^n (SAMPLE_BOTTOM_{mpuh} - SAMPLE_UPPER_{mpuh}) * (\epsilon 0 - 15)$$

$$CCTOTAL0_15_{mpu} = \sum_{h=1}^n LAYER_CCTOTAL_{mpuh} * (\epsilon 0 - 15)$$

$$CC0_15_{mpu} = \sum_{h=1}^n LAYER_CC_{mpuh} * (\epsilon 0 - 15)$$

where h is a unique sample (SAMPLE_NUM) among n number of samples where the midpoint of the sampled interval lies in the layer range (e.g. 0 – 15 cm) within pit number u (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM). The term (ϵ 0 – 15) stands for the proportion of each sample that lies in the designated range of a layer. For example, if the interval sampled runs from 11-21 cm, the midpoint of that interval is 16. Therefore, only the portion of the sample that is in the 15-35 cm layer (15-21 cm) will be used in calculating carbon content in the 15-35 cm layer (CC15_35). The portion that is in the 0-15 cm layer (11-14 cm) will not be used since the midpoint lies outside of the 0-15 cm layer. The midpoint constraint is ignored in cases where all samples spanning a higher layer's standardized depth have midpoints in lower layers. For example, in the case where the first sampled horizon ranged from 0-40 cm, the portion that is in the 0-15 cm layer will be used to calculate that layer's carbon content, while the 15-35 cm portion will be used to calculate the second standardized layer's carbon content (where the midpoint lies) and the 35-40 cm portion will not be used.

4) Calculate the adjusted carbon content (kg m^{-2}) for each standard layer across all soil pits (CCTOTAL0_15_ADJ and CC0_15_ADJ for the entire and < 8 mm fraction of organic soil, respectively) and for all layers combined (PLOT_TOT_CC_TOTAL and PLOT_TOT_CC for the entire and < 8 mm fraction of organic soil, respectively) by dividing the carbon content (CCTOTAL0_15 and CC0_15 for the entire and < 8 mm fraction of organic soil, respectively) by the measured thickness (THICKNESS_0_15) in standardized layers for each pit, then dividing the summed fractions across pits by the number of pits in a plot and multiplying by the nominal thickness of each layer (NOM_THICKNESS):

$$CCTOTAL0_15_ADJ_{mp} = \left[\left[\sum_{u=1}^n (CCTOTAL0_15_{mpu} / THICKNESS_0_15_{mpu}) \right] / n \right] * NOM_THICKNESS_{mp}$$

$$CC0_15_ADJ_{mp} = \left[\left[\sum_{u=1}^n (CC0_15_{mpu} / THICKNESS_0_15_{mpu}) \right] / n \right] * NOM_THICKNESS_{mp}$$

$$PLOT_TOT_CC_TOTAL_{mp} = CCTOTAL0_15_ADJ_{mp} + CCTOTAL15_35_ADJ_{mp} + CCTOTAL35_55_ADJ_{mp}$$

$$PLOT_TOT_CC_{mp} = CC0_15_ADJ_{mp} + CC15_35_ADJ_{mp} + CC35_55_ADJ_{mp}$$

where u is a unique pit (PIT_NUM) among n number of pits within plot p (NFI_PLOT) at measurement m (MEAS_NUM) and where the nominal thickness (NOM_THICKNESS) of the standardized layer l is 15 cm for the 0-15 cm layer, 20 cm for the 15-35 cm layer and 20 cm for the 35-55 cm layer or, alternatively, the portion of the nominal thickness which corresponds to the maximum depth for which all required data are available for computing carbon content.

Note: The average thickness of organic matter along transects (PLOT_AVG_ORG_THICK) and the maximum depth sampled (the maximum value of SAMPLE_BOTTOM among samples used to calculate carbon content in a standardized layer [LAYER_CC]) in a plot govern the nominal thickness applied to the calculation of the adjusted carbon content of standardized layers.

If the average thickness of organic matter along transects is 40 cm or more, then the nominal thickness of the third layer is 20 – (55 – maximum depth) when the maximum depth sampled is 35-55cm, otherwise the nominal thickness of the third layer is 20 cm when the maximum depth sampled is 55 cm or more.

Where the average thickness of organic matter along transects is less than 40 cm, the midpoint of the layer is either the middle of the standardized layer thickness (e.g. $[15 + 35] / 2 = 25$ for the second layer) or the middle of the interval in which the average thickness of organic matter along transects lies within the standardized layer, whichever is less. For example, if the average thickness of organic matter along transects is 32, then the middle of the interval running from 15 to 32 in the second standardized layer is 23.5 ($[15 + 32] / 2$) whereas the middle of the layer itself is 25. The midpoint chosen is therefore 23.5. The maximum depth is then used to determine the nominal thickness of the second layer. If the maximum depth is less than 35 cm but higher than the midpoint and the average thickness of organic matter along transects is more than 35 cm, then the nominal thickness of the second layer is 20, otherwise it is only as thick as the depth allowed by the average thickness of organic matter along transects (i.e., $20 - [35 - \text{plot average organic thickness}]$). If the maximum depth is less than the midpoint, then the maximum depth dictates the nominal thickness of the second layer (i.e., $20 - [35 - \text{maximum depth}]$). If the maximum depth is 35 cm or more, then the average thickness of organic matter along transects determines the nominal thickness of the second layer. If it is 35 cm or more, then the nominal thickness of the second layer is 20, otherwise it is constrained by the average thickness of organic matter along transects.

5) Calculate total depth of sampled organic soil (SAMPLE_DEPTH_ORG) as the sum of nominal thickness values (NOM_THICKNESS) used to calculate adjusted carbon content for each standard layer across all soil pits:

$$SAMPLE_DEPTH_ORG_{mp} = \sum_{l=1}^n NOM_THICKNESS_{mpl}$$

where l is one of three standardized soil layers (0-15 cm, 15-35 cm, 35-55 cm) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

6) Determine the leading taxon of coarse woody debris in the plot using the same algorithms as in [section 13](#) and use that to determine the wood density (DENSITY; refer to support-data table gpcsd_wood_density) and organic carbon content of the buried wood (ORG_CARB_WD; refer to support-data table gpcsd_cwd_org_carb) tallied during surface substrate sampling (PCT_SS_BURIED), assuming a decay class of 5.

7) The sum of the nominal thicknesses of the first, second and third standardized layers (SAMPLE_DEPTH_ORG) is reapportioned to each of three standardized layers: ORG_SOIL_THICK0-15, ORG_SOIL_THICK15-35 and ORG_SOIL_THICK35-55. The plot average buried thickness (PLOT_AVG_BURIED_THICK) is similarly reapportioned to three standardized layers: PLOT_AVG_BURIED_THICK0_15, PLOT_AVG_BURIED_THICK15_35 and PLOT_AVG_BURIED_THICK35_55.

8) For each of the standardized layer, determine the total carbon content per hectare in the organic soil (CCTOTAL_ORGANIC0_15) by multiplying the adjusted carbon content in a layer (CCTOTAL0_15_ADJ) with the fractions of the plot that is covered by organics (PCT_SS_ORG) and decaying wood (PCT_SS_DECAY), adding the carbon content contained in buried wood in the layer (i.e. the fraction of the plot that is covered by buried wood [PCT_SS_BURIED] multiplied by buried wood carbon content [ORG_CARB_WD], density [DENSITY] and thickness [PLOT_AVG_BURIED_THICK0_15]) and including a term to account for organic content surrounding buried wood if the average thickness of organic matter along transects (ORG_SOIL_THICK0_15) is greater than the average thickness of buried wood along transects (PLOT_AVG_BURIED_THICK0_15) within a layer. Units are then converted to Mg ha⁻¹:

$$\begin{aligned} CCTOTAL_ORGANIC0_15_{mp} &= (CCTOTAL0_15_ADJ_{mp} * (PCT_SS_ORG_{mp}/100) * 10000 + CCTOTAL0_15_ADJ_{mp} \\ &* (PCT_SS_DECAY_{mp}/100) * 10000 + PLOT_AVG_BURIED_THICK0_15_{mp} \\ &* DENSITY_{mp} * (ORG_CARB_WD_{mp}/1000) * 10 * (PCT_SS_BURIED_{mp}/100) \\ &* 10000 + ((ORG_SOIL_THICK0_15_{mp} \\ &- PLOT_AVG_BURIED_THICK0_15_{mp})/ORG_SOIL_THICK0_15_{mp}) \\ &* CCTOTAL0_15_ADJ_{mp} * (PCT_SS_BURIED_{mp}/100) * 10000)/1000 \end{aligned}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

9) For each of the standardized layer, determine the carbon content per hectare in the < 8 mm fraction of organic soil (CC_ORGANIC0_15) by multiplying the adjusted carbon content in a layer (CC0_15_ADJ) with the fractions of the plot that is covered by organics (PCT_SS_ORG) and including a term to account for organic content surrounding buried wood if the average thickness of organic matter along transects (ORG_SOIL_THICK0_15) is greater than the average thickness of buried wood along transects (PLOT_AVG_BURIED_THICK0_15) within a layer. Units are then converted to Mg ha⁻¹:

$$\begin{aligned} CC_ORGANIC0_15_{mp} &= (CC0_15_ADJ_{mp} * (PCT_SS_ORG_{mp}/100) * 10000 + ((ORG_SOIL_THICK0_15_{mp} \\ &- PLOT_AVG_BURIED_THICK0_15_{mp})/ORG_SOIL_THICK0_15_{mp}) * C0_15_ADJ_{mp} \\ &* (PCT_SS_BURIED_{mp}/100) * 10000)/1000 \end{aligned}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

10) For organic soil, calculate the products of the total depth of sampled organic soil standardized to 55 cm (SAMPLE_DEPTH_ORG; i.e. sum of nominal thickness of standardized layers) with the average organic

carbon (AVG_ORG_CARB_OS) and the average bulk density (AVG_BULK_DENSITY_OS) in the < 8 mm fraction:

$$WT_AVG_ORG_CARB_OS_{mp} = AVG_ORG_CARB_OS_{mp} * SAMPLE_DEPTH_ORG_{mp}$$

$$WT_AVG_BULK_DENSITY_OS_{mp} = AVG_BULK_DENSITY_OS_{mp} * SAMPLE_DEPTH_ORG_{mp}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

For forest floor, calculate the products of the average thickness of organic matter along transects (PLOT_AVG_ORG_THICK) with the average organic carbon (AVG_ORG_CARB_FF) and the average bulk density (AVG_BULK_DENSITY_FF) in the < 8 mm fraction:

$$WT_AVG_ORG_CARB_FF_{mp} = AVG_ORG_CARB_FF_{mp} * PLOT_AVG_ORG_THICK_{mp}$$

$$WT_AVG_BULK_DENSITY_FF_{mp} = AVG_BULK_DENSITY_FF_{mp} * PLOT_AVG_ORG_THICK_{mp}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

11) Calculate the weighted average organic carbon (AVG_ORG_CARB; g kg⁻¹) and weighted average bulk density (AVG_BULK_DENSITY; g cm⁻³) for the joint forest floor and organic soil components using the average thickness of organic matter along transects (for forest floor overlying mineral soil; PLOT_AVG_ORG_THICK) and organic soil thickness standardized to 55 cm (for organic soils; SAMPLE_DEPTH_ORG).

$$AVG_ORG_CARB_{mp} = \frac{(WT_AVG_ORG_CARB_FF_{mp} + WT_AVG_ORG_CARB_OS_{mp})}{(PLOT_AVG_ORG_THICK_{mp} + ORG_SOIL_THICK_{mp})}$$

$$AVG_BULK_DENSITY_ORG_{mp} = \frac{(WT_AVG_BULK_DENSITY_FF_{mp} + WT_AVG_BULK_DENSITY_OS_{mp})}{(PLOT_AVG_ORG_THICK_{mp} + ORG_SOIL_THICK_{mp})}$$

where p is a unique plot (NFI_PLOT) at measurement m (MEAS_NUM)

Note: Values for the weighted average organic carbon (AVG_ORG_CARB) and weighted average bulk density (AVG_BULK_DENSITY) are equivalent to plot-level average organic carbon and average bulk density in only forest floors or only organic soils when the other soil type is absent.

Output

CC_FOR_FLOOR_8MM, CC_FOR_FLOOR_TOTAL, CC_ORGANIC0_15_8MM, CC_ORGANIC15_35_8MM, CC_ORGANIC35_55_8MM, CC_ORGANIC0_15_TOTAL, CC_ORGANIC15_35_TOTAL, CC_ORGANIC35_55_TOTAL, AVG_ORG_CARB, AVG_BULK_DENSITY_ORG, SAMPLE_DEPTH_ORG (site_info table)

DEPTH_ORG, DEPTH_MIN

Inputs

SAMPLE_BOTTOM

Computations

1) For forest floor, the depth of the organic layer (DEPTH_ORG_FLOOR) is the maximum bottom-depth value (SAMPLE_BOTTOM) among forest floor samples collected in the pit:

$$DEPTH_ORG_FLOOR_{mpu} = MAX(SAMPLE_BOTTOM_{mpu})$$

where u is a unique pit number (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

2) For organic soil, the depth of the organic layer (DEPTH_ORG_FLOOR) is the maximum bottom-depth value (SAMPLE_BOTTOM) among organic soil samples collected in the pit:

$$DEPTH_ORG_ORGANIC_{mpu} = MAX(SAMPLE_BOTTOM_{mpu})$$

where u is a unique pit number (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

3) For mineral soil, the depth of the mineral layer (DEPTH_MIN) is the maximum bottom-depth value (SAMPLE_BOTTOM) among mineral soil samples collected in the pit:

$$DEPTH_MIN_{mpu} = MAX(SAMPLE_BOTTOM_{mpu})$$

where u is a unique pit number (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

4) The organic soil depth (DEPTH_ORG) is the sum of the depths of the forest floor (DEPTH_ORG_FLOOR) and organic soil (DEPTH_ORG_ORGANIC) in the pit:

$$DEPTH_ORG_{mpu} = DEPTH_ORG_FLOOR_{mpu} + DEPTH_ORG_ORGANIC_{mpu}$$

where u is a unique pit number (PIT_NUM) within plot p (NFI_PLOT) at measurement m (MEAS_NUM)

Output

DEPTH_ORG, DEPTH_MIN (soil_pit_depth table)

16. Computational References for Tree Volume

Tree volume equations and systems were requested from the provinces and territories to be used for compilation of tree volumes within their respective jurisdictions. In some cases these compilation procedures were modified by the NFI office to accommodate the unique format and structure of the NFI ground plot program. The following includes a listing by province/territory of the tree volume equations and systems that are used by the NFI, along with jurisdictional contacts. Volume and taper coefficients used by the NFI compiler are available upon request.

Height estimation for broken top trees

Some trees have broken tops or have missing height values, in which cases total tree heights are projected (HT_PRJ). The projected height (HT_PRJ) of broken top trees is used to adjust quantification of volume and biomass. Total projected heights are calculated using Chapman-Richard's model for tree height prediction (Huang et al. 2009; gp_ht_dbh_prj.sas).

Coefficients for height projection equations are parameterized by plot, measurement and species using only measured (or unspecified) tree heights (MEAS_EST_HEIGHT = 'M' or 'S'). The minimum sample size for calibrating the equation is three trees. If the sample size requirement is not met, curves are generated by plot, measurement and vegetation type (hardwood vs. softwood). If the sample size requirement is still not met, equations are fit (within jurisdiction) by ecozone and species. If the sample size requirement is still not met, equations are fit (within jurisdiction) by ecozone and vegetation type (hardwood vs. softwood).

$$HT_{PRJ} = 1.3 + a * (1 - e^{-b*DBH})^c$$

where $a > 0$

If a projected tree height (HT_PRJ) is less or equal to 1.3 m, then that projected tree height is set to missing. If a projected tree height is less than the measured tree height, then that projected height is set equal to the measured height. Projected height for small trees (i.e. trees with diameter at breast height less than 9 cm) is set to missing when greater than 20 m.

Merchantability limits

The merchantable volume is the inside bark stem wood volume excluding the stump and top, unless otherwise stated.

Table 24. The merchantability limits used, when necessary, in calculations of total volume.

| Province/territory | Stump height (m) | Top diameter (cm) | Additional requirement |
|-------------------------|------------------|--------------------------------|---|
| Alberta | 0.3 | 10.0 | stump diameter ≥ 15 cm |
| British Columbia | 0.3 | 10.0 | DBH ≥ 17.5 cm for CWH and CDF BEC zones DBH ≥ 12.5 cm otherwise |
| Manitoba | 0.3 | 7.62 | DBH > 9.0 cm |
| Newfoundland & Labrador | 0.15 | 7.6 | DBH > 9.0 cm |
| New Brunswick | 0.15 | 6.6 hardwoods 6.7 softwoods | DBH ≥ 9.1 cm |
| Northwest Territory | 0.3 | 7.0 | DBH > 10.1 cm |
| Nova Scotia | 0.15 | 7.0 | DBH ≥ 9.0 cm |
| Ontario | 0.3 | 7.0 | DBH ≥ 9.0 cm |
| Prince Edward Island | 0.2 | 8.0 | DBH ≥ 9.0 cm |
| Quebec | 0.15 | 9.0 | DBH ≥ 9.0 cm |
| Saskatchewan | 0.3 | 8.01 | DBH ≥ 7.0 cm |
| Yukon Territory | 0.3 | 7.5 | |

Alberta

Kozak's variable-exponent taper equation (Kozak 1988) was tested and proven to be appropriate for major tree species in Alberta (Huang 1994, Huang et al. 2000). Tree volumes in Alberta are calculated using Kozak's taper function (equation 1) and the following calculations.

1. Calculate the diameter inside bark (DIB) at stump height (0.3 m).
2. Calculate the merchantable height (height at which the top diameter is 10.0 cm).
3. Calculate the volume for stump (assumed to be a cylinder with diameter equal to the stump diameter) and top (assumed to be a cone).
4. Split the merchantable length (between stump and merchantable height) into 20 segments and calculate the top diameters for each segment.
5. Calculate the volume for each log using Newton's formula.

$$(1) \quad d_i = a_0 D^{a_1} a_2^D X_i^{b_1 z_i^2 + b_2 \ln(z_i + 0.001) + b_3 \sqrt{z_i} + b_4 e^{z_i} + b_5 (D/H)} + \varepsilon_i$$

where d_i is the diameter inside bark (cm) at h_i , h_i is the height (m) above ground ($0 < h_i < H$), H is the total tree height (m), D is the breast height diameter outside bark (cm), p is the relative height constraint (input as a parameter), $e = 2.718282$, $a_0 - a_2$ and $b_1 - b_5$ are taxon-specific input

parameters, ε_i is the error term, $X_i = \frac{1 - \sqrt{h_i/H}}{1 - \sqrt{p}}$, and $z_i = h_i/H$.

References

- Huang, S. 1994. Ecologically based Individual Tree Volume Estimation for Major Alberta Tree Species: Report #1 Methods of Formulation and Statistical Functions. Alberta Environmental Protection, Land and Forest Service, Forest Mngmt. Division. Tech. Rep. Pub. No. T/288. 80 p.
- Huang, S., D. Price, D. Morgan, and K. Peck. 2000. Kozak's variable-exponent taper equation regionalized for white spruce in Alberta. W. J. App. For. 15: 75-85.
- Kozak, A. 1988. A variable-exponent taper equation. Can. J. For. Res. 18: 1363-1368.

Alberta Contact:

Dr. Shongming Huang
Email: Shongming.Huang@gov.ab.ca

British Columbia

Kozak's variable-exponent taper equation (Kozak 1997; equation 2) is used in BC. The procedure is as follows.

1. Calculate the diameter inside bark (DIB) at stump height (0.3 m).
2. Calculate the merchantable height (height at which the top diameter is 10.0 cm).
3. Calculate the volume for stump (assumed to be a cylinder with diameter equal to the stump diameter).
4. Split the merchantable length (between stump and merchantable height) into 10 cm slices and calculate the top diameters for each slice.
5. Calculate the volume for each slice using Smalian's formula.
6. The top volume is calculated using 10 cm slices and Smalian's formula.

Merchantable volume is the stem wood volume between the stump and the top diameter for trees with DBH ≥ 17.5 cm for CWH and CDF BEC zones, else the minimum DBH is 12.5 cm.

$$(2) \quad d_i = e^{\frac{err}{2}} \cdot b_1 D b h^{b_2} b_3^{Dbh} X^{b_4 + b_5 z_i^{0.25} + b_6 \cdot z_i^{1/3} + b_7 \sqrt{z_i} + b_8 \cdot \arcsin(1 - \sqrt{z_i}) + b_9 \cdot (z_i + Dbh / height)^{-1} + b_{10} \cdot height} + \varepsilon_i$$

$$\text{where } X_i = \frac{1 - \sqrt{h_i/H}}{1 - \sqrt{p}}, p = 0.01 \text{ and } z_i = h_i/H$$

References

- Kozak, A. 1997. Effects of multicollinearity and autocorrelation on the variable-exponent taper functions. Can. J. For. Res. 27:619-629.

Manitoba

Kozak's variable-exponent tape equation (Kozak 1988) was tested for Manitoba (Klos et al. 2007). Taxon-specific coefficients parameterized for Manitoba are used when available, with the exception of Balsam poplar (Klos et al. 2007), else those for Saskatchewan (Gal and Bella 1994) and Alberta (Huang 1994; Huang et al. 2000) are used. The procedure is as follows.

1. Calculate the diameter inside bark (DIB) at stump height (0.3 m).
2. Calculate the merchantable height (height at which the top diameter is 7.62 cm).
3. Calculate the volume for stump (assumed to be a cylinder with diameter equal to the stump diameter) and top (assumed to be a cone).
4. Split the merchantable length (between stump and merchantable height) into 20 segments and calculate the top diameters for each segment (equation 1).
5. Calculate the volume for each log using Newton's formula.

Merchantable volume is the stem wood volume between the stump and the top diameter for trees with DBH > 9.0 cm.

References

- Huang, S. 1994. Ecologically based individual tree volume estimation for major Alberta tree species. Report #1, Individual tree volume estimation procedures for Alberta: methods of formulation and statistical foundations. Alberta Environmental Protection, Land and Forest Services, Forest Management Division. Edmonton Alberta.
- Huang, S., D. Price, D. Morgan, and K. Peck. 2000. Kozak's variable-exponent taper equation regionalized for white spruce in Alberta. W. J. App. For. 15: 75-85.
- Kozak, A. 1988. A variable-exponent taper equation. Can. J. For. Res. 18: 1363-1368.
- Klos, R.J., G.G. Wang, Q.-L. Dang, and E.W. East. 2007. Taper equations for five major commercial tree species in Manitoba, Canada. West. J. Appl. For. 22(3): 163-170.
- Gal, J. and I.E. Bella. 1994. New stem taper function for 12 Saskatchewan timber species. CFS Northwest Region, Information Report NOR-X-338.

Manitoba Contact:

Wenli Xu
Forest Resource Analyst
Forest Inventory and Resource Analysis
Manitoba Conservation, Forestry Branch
Box 70, 200 Saulteaux Crescent,
Winnipeg, Manitoba, R3J 3W3
Tel:(204) 945-7995
Fax:(204)948-2671

Newfoundland & Labrador

Total and merchantable tree volume calculations use species- and district-specific coefficients when these are available for Balsam fir and black spruce (Warren and Meades 1986; equations 3 and 5), else species-specific coefficients from Ker (1974; equations 4 and 5). Customized equations and coefficients were used for merchantable volume of Balsam fir and black spruce in Labrador (i.e. district ≥ 19; equation 6).

Merchantable volume calculations use a stump height of 0.15 m ($Height_{stump}$) and a top diameter of 7.6 cm ($Diameter_{merch}$) for trees with DBH > 9.0 cm.

1. Plots within district 50 (federal lands) were assign equations from district 2 when these lie in Terra Nova National Park and district 16 when in Gros Morne National Park
2. Assign coefficients based on tree genus and species as well as the district where the plot lies
3. Calculate total and merchantable volumes using respective equations according to tree taxon and the district where the plot lies (i.e. Balsam fir and black spruce are treated differently).

$$(3) \text{ volume}_{total} = 0.00439 * (DBH)^2 * \left(\frac{(1-0.04365*f)^2}{a+0.3048*b/HEIGHT} \right)$$

$$(4) \text{ volume}_{total} = \frac{(DBH)^2}{(a+b/HEIGHT)}$$

if Balsam fir or black spruce in district other than 1 or 3

$$(5) \text{ volume}_{\text{merch}} = \text{volume}_{\text{total}} * (c + x * (d + e * x))$$

$$(6) \text{ volume}_{\text{merch}} = \text{volume}_{\text{total}} * (d + x * (c + e * x))$$

if Balsam fir or black spruce in district greater or equal to 19

where

$$x = \left(\frac{\text{Diameter}_{\text{merch}}}{\text{DBH}} \right)^2 * \left(1 + \frac{\text{Height}_{\text{stump}}}{\text{HEIGHT}} \right) * (1 - 0.04365 * f)^{-2}$$

$$x = \left(\frac{\text{Diameter}_{\text{merch}}}{\text{DBH}} \right)^2 * \left(1 + \frac{\text{Height}_{\text{stump}}}{\text{HEIGHT}} \right)$$

if Balsam fir or black spruce in district other than 1 or 3

References

Ker, M.F. 1974. Metric tree volume tables for Newfoundland. CFS Report N-X-122,
Warren, G.R. and J. P. Meades. 1986. Wood defect and density studies II. Total and net volume equations
for Newfoundland forest management units. CFS Report N-X-242.

Newfoundland & Labrador Contact:

Ken Parsons
Mensurationist, Forest Ecosystem Management
Department of Fisheries and Land Resources
P.O. Box 2006, Fortis Building
Corner Brook, NL, Canada, A2H 6J8
kenparsons@gov.nl.ca
Phone 709-637-2600

New Brunswick

Kozak's variable-exponent taper equation (equation 7; Kozak 2004, model 02) is used when taxon-specific coefficients are available for NB, else Honer *et al.* (1983) model and coefficients are used. Coefficients for inside-bark taper models are used for most softwood species (Li et al. 2012, Hennigar 2019), while coefficients for outside bark taper models (Li et al. 2012, Hennigar 2019) combined with bark thickness models (equation 8; Li and Weiskittel 2011, Hennigar 2019) are used for eastern hemlock and tamarack. Most hardwood species use coefficients for outside-bark taper models combined with bark thickness models (equation 8; Weiskittel and Li 2011, Hennigar 2019). When taxon-specific or applicable taper coefficients are not available (e.g. rarer/non-commercial softwoods and hardwoods), Honer et al. (1983) equations for lodgepole pine (equation 9; total volume) and softwoods (equation 10; merchantable volume) or for maple (equation 11; total volume) and hardwoods (equation 12; merchantable volumes) are used.

Taper equations (equation 7) were implemented as follows.

1. Calculate the volume of stump (from ground to 0.15 m) by dividing stump into 10 cm slices, calculate the top and bottom diameters inside bark for each slice, and calculate the volume of each slice using Smalian's formula
2. Calculate the merchantable height (height at which the top diameter is 6.7 cm for softwoods and 6.6 for hardwoods).
3. Split the merchantable length (between stump and merchantable height) into 10 cm slices, calculate the top and bottom diameters for each slice, and calculate the volume for each slice using Smalian's formula.

4. The volume above merchantable height is calculated using 10 cm slices, calculate the top and bottom diameters for each slice, and calculate the volume for each slice using Smalian's formula. Merchantable volume is the stem wood volume between the stump and the top diameter for trees with DBH ≥ 9.1 cm.

$$(7) \text{ dib or dob} = a_0 * DBH^{a_1} * HEIGHT^{a_2} * x^{((b_1 * z^4) + (b_2 * (1/e^{DBH/HEIGHT})) + (b_3 * x^{0.1}) + (b_4 * (1/DBH)) + (b_5 * HEIGHT^Q) + (b_6 * x))}$$

where dib = diameter inside bark at h_i height from the ground (cm), dob = diameter outside bark at h_i height from the ground (cm), h_i = height of the slice from the ground (cm)

$$p = \frac{1.3}{HEIGHT}$$

$$z = \frac{h_i}{HEIGHT}$$

$$x = \frac{1 - z^{1/3}}{1 - p^{1/3}}$$

$$Q = 1 - z^{1/3}$$

$$(8) \text{ dib} = c_0 * \text{dob}^{c_1}$$

When taper coefficients are not available for a given taxon, equations from Honer *et al.* (1983) were implemented as follows. For softwood total volume, the equation for lodgepole pine (Honer *et al.* 1983, Table 3) is used (equation 9).

$$(9) \text{ Volume}_{total} = 0.0043891 * DBH^2 * \frac{(1 - 0.04365 * 0.118)^2}{0.694 + 0.3048 * 343.896 / HEIGHT}$$

For softwood merchantable volume, the equation parameterized for softwoods is used (Honer *et al.* 1983, Table 6), where top diameter (Diameter_{merch}) is set to 6.7 cm and stump height (Height_{stump}) is set to 0.15 cm (equation 10).

$$(10) \text{ Volume}_{merch} = \text{Volume}_{total} * (0.9645 - 0.1616 * x - 0.7945 * x^2)$$

where

$$x = \left(\frac{\text{Diameter}_{merch}}{DBH} \right)^2 * \left(1 + \frac{\text{Height}_{stump}}{HEIGHT} \right) * (1 - 0.04365 * 0.155)^{-2}$$

For hardwood total volume, the equation parameterized for maple (Honer *et al.* 1983, Table 3) is used (equation 11).

$$(11) \text{ Volume}_{total} = 0.0043891 * DBH^2 * \frac{(1 - 0.04365 * 0.145)^2}{1.046 + 0.3048 * 383.972 / HEIGHT}$$

For hardwood merchantable volume, the equation parameterized for hardwoods is used (Honer *et al.* 1983, Table 6), where top diameter (Diameter_{merch}) is set to 6.6 cm and stump height (Height_{stump}) is set to 0.15 cm (equation 12).

$$(12) \text{ Volume}_{merch} = \text{Volume}_{total} * (0.9057 - 0.0708 * x - 0.8375 * x^2)$$

where

$$x = \left(\frac{\text{Diameter}_{merch}}{DBH} \right)^2 * \left(1 + \frac{\text{Height}_{stump}}{HEIGHT} \right) * (1 - 0.04365 * 0.145)^{-2}$$

References:

- Honer, T.G., M.F. Ker, and I.S. Alemdag. 1983. Metric Timber Tables for the Commercial Tree Species of Central and Eastern Canada. Canadian Forestry Service, Inf. Rep. M-X-140. 139p.
- Li, R., A.R. Weiskittel, J.A. Kershaw Jr, A. Dick, and R.S. Seymour. 2012. Regional stem taper equations for eleven conifer species in the Acadian Region of North America: Development and assessment. North. J. Appl. For. 29, 5-14.
- Li, R. and A.R. Weiskittel. 2011. Estimating and predicting bark thickness for seven conifer species in the Acadian Region of North America using a mixed-effects modeling approach: Comparison of model forms and subsampling strategies. Eur. J. For. Res. 130, 219-233.
- Weiskittel, A. and R. Li. 2011. Development of regional taper and volume equations: hardwood species. In: Roth, B.E. (ed.). Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine. Orono, ME. pp. 76-84.

New Brunswick Contact:

Rob White
Forestry and Lands Division
Department of Natural Resources and Energy Development
P.O. Box 6000, Hugh John Flemming Forestry Centre
Fredericton, NB, Canada, E3B 5H1
rob.white@gnb.ca

Northwest Territories

The Alberta volume coefficients are used for the Northwest Territories. The Alberta Northern Mixedwood sub-region is used for the Northwest Territories.

Ontario, Quebec and Nova Scotia

For Ontario, Quebec and Nova Scotia, Honer *et al.*'s (1983) volume equations are used (equation 13).

$$(13) \text{ Volume}_{total} = \frac{0.0043891 * DBH^2 * (1 - 0.04365 * b_2)^2}{c_1 + 0.3048 * c_2 / HEIGHT}$$

Merchantable volume is estimated for trees larger than the merchantable DBH limit using merchantable model form from Honer *et al.* (1983; equation 14).

For Ontario, the stump height is 0.30m, the top diameter (diameter_{merch}) is 7.0 cm.

For Quebec, the stump height is 0.15m, the top diameter (diameter_{merch}) is 9.0 cm.

For Nova Scotia, the stump height is 0.15m, the top diameter (diameter_{merch}) is 7.0 cm.

The merchantable DBH for Ontario, Quebec and Nova Scotia is 9 cm.

$$(14) \text{ Volume}_{merch} = \text{Volume}_{total} * (a + b * x + c * x^2)$$

Where

$$x = \left(1 + \frac{\text{Height}_{stump}}{HEIGHT}\right) * \left(\frac{\text{Diameter}_{merch}^2}{DBH^2}\right) * (1 - 0.04365 * b_2)^{-2}$$

References:

- Honer, T.G., M.F. Ker, and I.S. Alemdag. 1983. Metric Timber Tables for the Commercial Tree Species of Central and Eastern Canada. Canadian Forestry Service, Inf. Rep. M-X-140. 139p.
- OMNRF. 2020. Scaling Manual, Toronto; Queen's Printer: Ontario, Queen's Printer for Ontario. 169 pp.

Ontario Contact:

Kris Sawula
ON Ministry of Natural Resources and Forestry
e-mail kris.sawula@ontario.ca

Nova Scotia Contact:

Peter Townsend, RPF
NS DNR Forest Inventory
Office 902-893-5689
e-mail pgtownse@gov.ns.ca

Prince Edward Island

The Schumacher total volume equations for PEI (equation 15) are taken from Hutchinson (1986) for all species except white pine, which is from Hutchinson (1992). Honer et al's (1983) volume equations for Central and Eastern Canada (equation 13) are used when taxon-specific coefficients for Schumacher total volume equations for PEI are not available.

$$(15) \text{ Volume}_{total} = e^a * DBH^b * HEIGHT^c$$

Merchantable volume is estimated for trees larger than the merchantable DBH limit using merchantable model form from Honer *et al.* (1983; Hutchinson 1986; equation 16). The stump height is 0.2m; the top diameter (diameter_{merch}) is 8.0 cm. The merchantable DBH is 9 cm.

$$(16) \text{ Volume}_{merch} = \text{Volume}_{total} * (a + b * x + c * x^2)$$

Where

$$x = \left(1 + \frac{\text{Height}_{stump}}{HEIGHT}\right) * \left(\frac{\text{Diameter}_{merch}^2}{DBH^2}\right)$$

References

- Honer, T.G., M.F. Ker, and I.S. Alemdag. 1983. Metric Timber Tables for the Commercial Tree Species of Central and Eastern Canada. Canadian Forestry Service, Inf. Rep. M-X-140. 139p.
- Hutchinson, P.J. 1986. The Prince Edward Island forest site classification and capability system: an interim report. PEI department of energy and forestry, Forestry Branch, Silviculture development section.
- Hutchinson, P.J. 1982. Local volume tables, total volume, merchantable volume and tree biomass, for the commercial tree species of Prince Edward Island. PEI department of energy and forestry, Forestry Branch, Silviculture development section.
- Hutchinson, P.J. 1992. Development of white pine biometrical relationships for Prince Edward Island. PEI department of energy and forestry, Forestry Branch, Silviculture development section. FRDA SD-007.

Prince Edward Island contact:

Matt Angus
Forest Inventory Analyst - Resource Inventory & Modelling Section
Forests, Fish and Wildlife Division
Dept. of Environment, Water & Climate Change
J. Frank Gaudet Tree Nursery
Box 2000 183 Upton Rd.
Charlottetown, PE C1A 7N8
Telephone: (902) 569-7598
Facsimile: (902) 368 4713

Email: mangus@gov.pe.ca

Saskatchewan:

Volumes are estimated using Kozak's taper function (equation 1) calibrated for Saskatchewan by Gal and Bella (1994).

1. Calculate the diameter inside bark (DIB) at stump height (0.3 m).
2. Calculate the merchantable height (height at which the top diameter is 8.01 cm).
3. Calculate the volume for stump (assumed to be a cylinder with diameter equal to the stump diameter) and top.
4. Calculate the top diameters for each log (log length = 2.6 m).
5. Calculate the volume for each log using Newton's formula.

References:

Gal, J. and I.E. Bella. 1994. New stem taper function for 12 Saskatchewan timber species. CFS Northwest Region, Information Report NOR-X-338.
Kozak, A. 1988. A variable-exponent taper equation. Can. J. For. Res. 18: 1363-1368.

Saskatchewan Contact:

Xilin Fang
Inventory Forester
Forest Ecosystems Branch, SE
(306)953-2452

Or

Phil Loseth
Forest Mensurationist
Forest Ecosystems Branch, SE
(306) 953-3567
ploseth@serm.gov.sk.ca

Yukon Territory

Bonnor and Boudewyn's (1990) calibration of Kozak's (1988) taper model is used to estimate tree volumes in the Yukon.

1. Calculate the diameter inside bark (DIB) at stump height (0.3 m).
2. Calculate the merchantable height (height at which the top diameter is 7.5 cm).
3. Calculate the volume for stump (assumed to be a cylinder with diameter *equal* to the stump diameter) and top (assumed to be a cone).
4. Split the merchantable length (between stump and merchantable height) into 20 segments and calculate the top diameters for each segment.
5. Calculate the volume for each log using Newton's formula.
6. Merchantable volume is the stem wood volume between the stump and the top diameter.

There is no provision yet in the volume estimation routine for estimating the virtual height of broken top trees. The taper model assumes total height is being input. If the height to the break is supplied, this will lead to an underestimate of total and merchantable volume.

References:

Bonnor, G.M. and Boudewyn, P. 1990. Taper-volume equations for major tree species of the Yukon Territory. Forestry Canada, Pacific and Yukon Region, Pacific Forestry Centre.

Yukon Contact:

Kirk Price (Forest Inventory Analyst)
Forest Management Branch
Box 2703 K-918
Whitehorse, Yukon Y1A 2C6
tel: (867) 633-7914
fax: (867) 667-3138
email: kirk.price@gov.yk.ca

17. Computational References for Biomass

There are three sets of equations for estimating biomass. All deal with aboveground biomass only.

1. National equations were calibrated from the ENFOR data for all provinces and ecozones combined (Lambert et al. 2005 and Ung et al. 2008).
2. Regional equations were calibrated using the same data but by species and ecozone. These are not published.
3. Preferred equations were taken from literature and generally calibrated at the provincial or territorial scale.

The biomass components (stem wood, stem bark, branches, foliage) for the national and regional equations were fit simultaneously ensuring the components sum to the total biomass. As well, the national and regional equations have a standard equation form and predict biomass in kg using inputs of DBH in cm and height (if used) in m. The preferred equations are a mix of model forms, units (metric and imperial), and were not necessarily fit considering the correlation between components or even including all the components.

In general, the regional equations are recommended followed by the national equations and then the preferred equations.

References:

- Lambert, M.-C., C.-H. Ung and F. Raulier. 2005. Canadian national tree aboveground biomass equations. *Can. J. For. Res.* 35:1996-2018.
- Ung, C.-H., P. Bernier and X.-J. Guo. 2009. Canadian national biomass equations: new parameter estimates that include British Columbia data. *Can. J. For. Res.* 38:1123-1132.

18. Wood Density

This section describes the procedures followed for the development of a wood density support table for use in the compilation of NFI ground plot attributes (support-data table name: gpcsd_wood_density).

Wood density data used to generate our support table included: 1- density of undecayed 'green' wood (i.e. harvested live wood; e.g. Alden 1997, Alden 1995, Alemdag 1984, Gonzalez 1990, Mullins and McKnight 1981) and density of woody debris based on decay classes (all of which following the standard by Sollins [1981; e.g. Adams and Owens 2001, Dauthieu 2003, Harmon and Serton 1996, Harmon et al. 1995, Harmon et al. 2000, Harmon et al 2011, Liu et al. 2006, Renninger et al. 2014, Preston et al. 2006, Seedre et al. 2013], or harmonized to this standard [Harmon et al 2008]). References such as Harmon et al. (2008) have separated undecayed 'green' wood density from densities by decay class in their reports. Advantages of separating 'decay class 1' from undecayed 'green' wood include ensuring that starting (time 0) density values for modelling (i.e. undecayed 'green' wood) do not risk being swayed by the subjective bias of field workers and processes taking place while the wood still appears intact and hard. Therefore, decay class 1 may include undecayed 'green' wood but the reverse is not true.

The mean wood densities per decay class (including undecayed 'green' wood) per taxon per publication were compiled and separated into wood from Canadian and foreign (e.g. USA, boreal Russia) sources. We only selected densities based on oven-dried weight and volume not corrected for moisture content (i.e. green volume basis). Care was taken to remove values previously computed or estimated by publications' authors from our compiled list.

Undecayed 'green' wood density was assigned to each taxon in the NFI tree species list for each jurisdiction. Values were first assigned on a taxon-specific basis using province/territory-specific values when these were available, else the mean of Canadian-sourced values when these are available, else the mean of foreign-sourced values when these are available. If taxon-specific values of undecayed 'green' wood are not available, then these were assigned respective genus-level means from Canadian sources when available, else from foreign sources. If genus-specific values of undecayed 'green' wood are not available, then these were assigned respective vegetation-type-level (hardwood versus softwood) means from Canadian sources. Undecayed 'green' wood density for unknown taxa were assigned the mean of the hardwood and softwood means from Canadian sources, in order not to weight the overall mean by the number of available values for hardwood and softwood species.

Exponential, sigmoidal and polynomial model structures were tested using non-linear mixed effect modeling with species as a random effect (R package nlme v3.1-140) and the best fit model structure was selected based on log-likelihood, AIC and BIC. Thus, missing wood density values for each taxon in each province/territory were modeled using a sigmoidal model structure that can account for possible lag in decay at the onset of decay and later reduction in decay rates (Preston et al. 2012):

$$WOOD_DENSITY = a * e^{-(b*DECAY_CLASS)^2}$$

where a and b are constants; and a DECAY_CLASS of zero is equivalent to wood density for undecayed 'green' wood, such that the constant a will be equal to undecayed 'green' wood density.

Taxon-specific model parameterization and computation of missing wood densities for particular decay classes were done for each province/territorial-specific, Canadian or foreign data sources when wood densities were available for at least 3 decay classes (including undecayed 'green' wood) in a taxon's decay trajectory. Otherwise, models were parameterized by genus or vegetation type (hardwood versus softwood) from province/territorial-specific data or from all data sources combined when wood densities were available for at least 3 decay classes in a decay trajectory. These parameters were then used to compute missing wood densities for a particular taxon using its associated undecayed 'green' wood density.

In summary, assigning the best wood density values per decay class for each taxon prioritized 1- published values and associated 'gap-filled' wood densities calculated using taxon-specific parameterized decay trajectories (from province/territorial-specific data sources when available, else from Canadian sources when these are available, else from foreign sources), 2- wood density values predicted from the best available undecayed 'green' wood density and decay trajectories parameterized from province/territorial-specific data sources (using data sharing the taxon's genus if available, else its vegetation type), 3- wood density values predicted from the best available undecayed 'green' wood density and decay trajectories parameterized from all data sources combined (using data sharing the taxon's genus when available, else its vegetation type).

References:

- Adams, M.B. and Owens, D.R. 2001. Specific gravity of coarse woody debris for some central Appalachian hardwood forest species. U.S. Department of Agriculture, Forest Service Northeastern Research Station. Research Paper NE-716.
- Alemdag, I.S. 1984. Wood density variation of 28 tree species from Ontario. Agriculture Canada. Canadian Forest Service. PNFI Information Report PI-X-45.
- Alden, Harry A. 1997. Softwoods of North America. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Madison, WI. General Technical Report FPL-GTR-102.
- Alden, Harry A. 1995. Hardwoods of North America. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. Madison, WI. General Technical Report FPL-GTR-83.
- Dauthieu, M.M. 2003. Variabilité du stock de carbone dans la biomasse. Rapport de Stage de Maîtrise, Faculté des Sciences et Technologies, Université Paris XII – Val de Marne.
- Forest Products Laboratory. 1999. Wood handbook – Wood as an engineering material. U.S. Department of Agriculture, Forest Service. General Technical Report FPL-GTR-113.
- Gonzalez, J.S. 1990. Wood density of Canadian tree species. For. Can., Northwest Region, North Forestry Centre. Edmonton, Alberta. Information Report NOR-X-315.
- Harmon, M.E., Krankina, O.N. and Sexton, J. 2000. Decomposition vectors: a new approach to estimating woody detritus decomposition dynamics. Canadian Journal of Forest Research. 30: 76-84.
- Harmon, M. E., Woodall, C.W., Fasth, B. and Sexton, J. 2008. Woody detritus density and density reduction factors for tree species in the United States: a synthesis. U.S. Department of Agriculture, Forest Service. Northern Research Station. General Technical Report NRS-29.
- Harmon, M. E., Woodall, C.W., Fasth, B., Sexton, J. and Yatkov, M. 2011. Differences between standing and downed dead tree wood density reduction factors: a comparison across decay classes and tree species. U.S. Department of Agriculture, Forest Service. Northern Research Station. General Technical Report NRS-15.
- Kennedy, E.I., Jessome, A.P. and Petro, F.J. 1968. Specific gravity survey of eastern Canadian woods. Government of Canada, Department of Forestry and Rural Development. Departmental publication (Canada. Forestry Branch) no. 1221.
- Liu, W.H., Bryant, D.M., Hutrya, L.R., Saleska, S.R., Hammond-Pyle, E., Curran, D. and Wofsy, S.C. 2006. Woody debris contribution to the carbon budget of selectively logged and maturing mid-latitude forests. *Oecologia*. 148:108 – 117.
- Mertz, M. 2016. Wood and traditional woodworking in Japan. Second edition. Kaiseisha press. Otsu City, Japan. 219 pp.
- Miles, P.D. and Smith, W.B. 2009. Specific gravity and other properties of wood and bark for 156 tree species found in North America. U.S. Department of Agriculture, Forest Service. Northern Research Station. Research Note NRS-38.
- Mullins, E.J. and McKnight, T.S. 1981. Canadian woods, their properties and uses. Ottawa, Canada: University of Toronto Press in cooperation with the Canadian Forest Service, Environment Canada and the Canadian Government Publishing Center, Supply and Services Canada.

Preston, C.M., Trofymow, J.A. and Flanagan, L.B. 2006. Decomposition, $\Delta^{13}\text{C}$, and the “lignin paradox”. *Canadian Journal of Soil Science*. 86(2): 235 – 245.

Preston, C.M., Trofymow, J.A. and Nault, J.R. 2012. Decomposition and change in N and organic composition of small-diameter Douglas-fir woody debris over 23 years. *Canadian Journal of Forest Research*. 42: 1153 – 1167.

Renninger, H.J., Carlo, N. Clark, K.L. and Schäfer, K.V.R. 2014. Modeling respiration from snags and coarse woody debris before and after an invasive gypsy moth disturbance. *Journal of Geophysical Research: Biogeosciences*. 119: 630 – 644.

Seedre, M., Taylor, A.R., Chen, Y.H. and Jogiste, K. 2013. Deadwood density of five boreal tree species in relation to field-assigned decay class. *Forest Science*. 59(3): 261 –266.

Sollins, P. 1981. Input and decay of coarse woody debris in coniferous stands in western Oregon and Washington. *Canadian Journal Forest Research*. 12: 18 – 28.

Ter-Mikaelian, M.T., Colombo, S.J. and Chen, J. 2008. Amount of downed woody debris and its prediction using stand characteristics in boreal and mixedwood forests of Ontario, Canada. *Canadian Journal of Forest Research*. 38: 2189 –2197.

Wiemann, M.C. 1990. Wood specific gravity gradients in tropical trees. LSU Historical Dissertations and Theses. 5025. https://digitalcommons.lsu.edu/gradschool_disstheses/5025