Field Guide: Sampling Fuels in the Context of the Next-Generation Canadian Forest Fire Danger Rating System (NG-CFFDRS)

Field Sampling Protocol and List of Attributes for Field Crews (2023)

The Fire Danger Group of the Canadian Forest Service of Natural Resources Canada
Boucher, J., Cotton-Gagnon, A., Dagnault, S., Zerb, J., Smiley, B., Russo, G., and Nolan, M. (June 2023)

Abstract

This document presents a field sampling protocol draft that aims at giving guidance on how to measure, estimate, calculate or model each of the fuel attributes that are currently envisioned to be needed in the Next Generation of the Canadian Forest Fire Danger Rating System (NG-CFFDRS; Fire Danger Group, 2021). The full updated list of fuel attributes is presented in Table 1.

We are hoping that this protocol becomes the national standard for NG-CFFDRS Fuel Attributes sampling, where sampled plots using this protocol could become part of a national database that can be used to improve mapping and modelling. The underlying equations of the NG-CFFDRS are still under development, and there are still some uncertainties around what stand level statistics (mean, SD, quadratic mean, quartile, etc.) will be used to best describe individual fuel attributes. With this in mind, we suggest that all raw data taken during field sampling be kept. If this cannot be achieved, plot level mean and standard deviation are minimums. The level of details in the different measurements is dependant on the objectives sought (e.g., detailed sampling for experimental burning studies versus quick estimation for a fire behaviour specialist on an incident).

This protocol draft proposes a plot layout (Figure 1), as well as fuel attributes measurements with related sampling methods and instruments. More detailed information about down dead wood sampling transects is also provided on Figure 2. Field forms supporting the proposed fuel sampling can be available upon request. The protocol is intended to be used for any forest fuels complexes, including post-disturbances, such as insect outbreaks. The development of this protocol was greatly influenced by the National Forest Inventory field sampling protocol (NFI Task Force 2008) and existing fuel sampling protocols (e.g., McRae et al. 1979, Alexander et al. 2004, and Lavoie et al. 2010). In this June 2023 version of the protocol, we propose slight changes from the 2021 and 2022 versions, aiming at reducing the amount of time spent measuring and to ensure better compatibility with the National Forest Inventory (NFI) ground plots protocol but also with the NFI compilation system and databases. This last consideration is motivated by the new Canadian Forest Service 5 year program (with some ongoing hires and infrastructure) called the Northern Forest fuels Mapping program[1], which aims at mapping fuels, both current Fire Behaviour Prediction (FBP) (Hirsch, 1996) and NG-CFFDRS Fuel Attributes.

[1] Previously referred to the Forest Mapping for Wildfire Resilience (FM4WR) Program.

Table of Contents

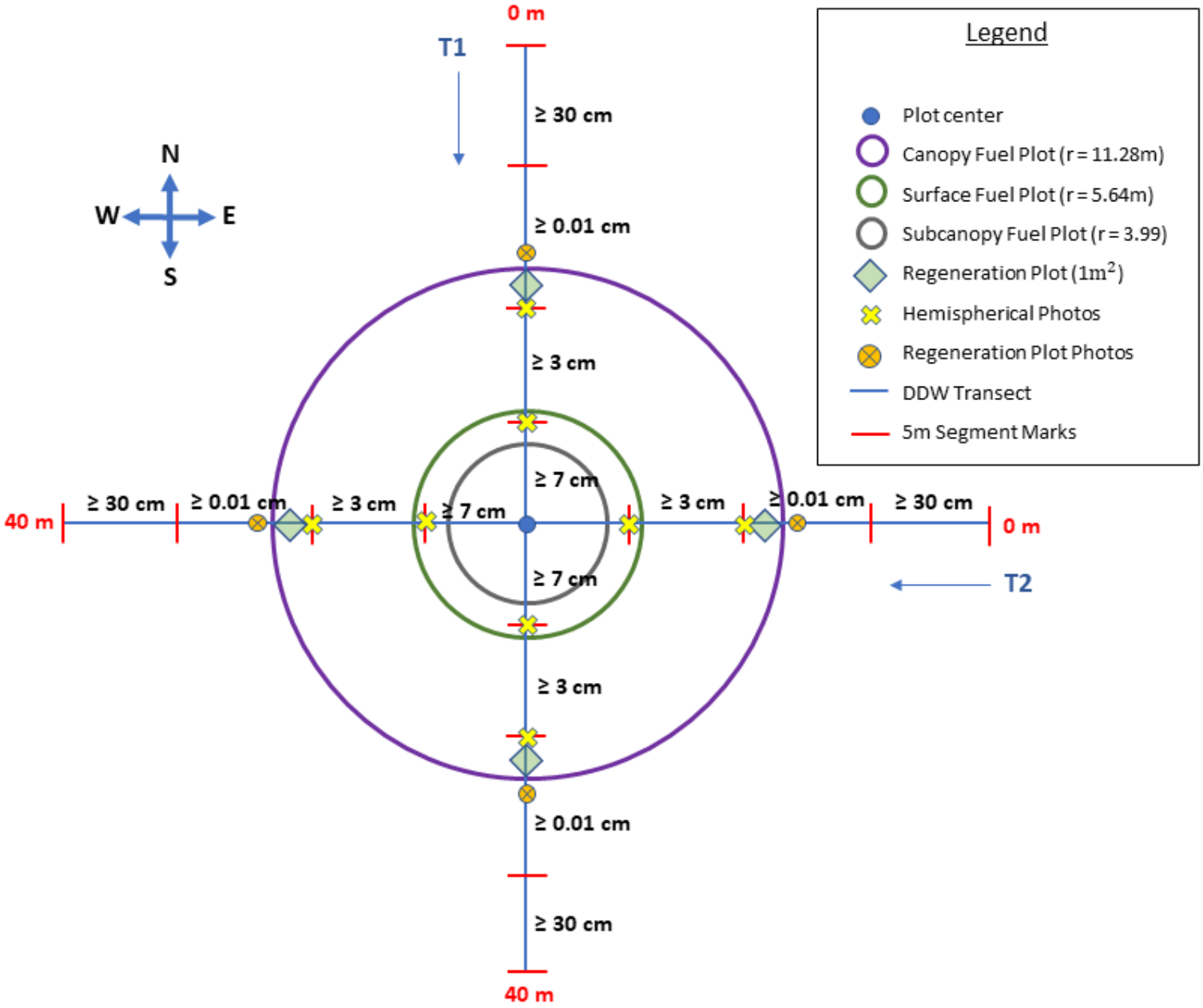
Table of Attributes

Stratum	*Fuel attribute*	*Description*	*Units*	*Use in CFFDRS-2025*
Canopy fuels (or overstory fuels)	Plant area index (PAI) • Leaf area index (LAI): needed for better estimate of PAI for leafless conditions and disturbed stands • Wood (branch and stem) area index (WAI): semi-fixed part of PAI • Canopy closure (CC): maybe an alternate method to estimate PAI/LAI (guidance can be provided)	Plant area index for all vegetation with DBH > 0.1 cm (PAI = WAI+LAI) Leaf area index will be adjusted as a function of Proportion of tree species and Conifer conditions to account for seasonal and health related changes in the leaf/no-leaf states.	unitless	FBP/FMS: In-stand wind model, and solar radiation
	Canopy bulk density (CBD) • Canopy fuel load (CFL) (kg·m-2): needed to calculate CBD. • Stand overstory height (H) (m): needed to calculate CBD • Stand overstory trees diameter at breast height (cm): expected to be needed to estimate CBD from allometric equations • Stand density (stems·ha-1): expected to be needed to estimate CBD from allometric equations	CBD: Density of total live biomass dry weight (branchwood < 1.0 cm and foliage) canopy of conifers with DBH ≥ 3.0 cm (CBD = CFL/(H-CBH)) CFL: Total live biomass dry weight (branchwood < 1.0 cm and foliage) of conifers with DBH ≥ 3.0 cm. H: Height of overstory conifer trees (DBH ≥ 3.0 cm)	$kg \cdot m^{-3}$	FBP: Directly in crown fire intensity (CFL), spread, and consumption models. To determine type of crown fire (passive versus active) FMS/FBP: CFL maybe used for in-stand wind, surface fuel moisture modification
	Proportion of tree species in the canopy	It is the stand level proportion of basal area of overstory trees (i.e, trees with DBH ≥ 3cm) by tree species. Deciduous (or hardwood) species may be group as one species, in some situations it may be useful to separate the aspen genus from other deciduous. Coniferous species will need to be separated by species, or minimally by groups of species (e.g., tamarack, temperate pines, boreal pines, fir/spruces).	%	FBP/FMS: In-stand wind model FBP: Crown fire behaviour in mixedwood FMS: Solar radiation and surface fuel moisture adjustment

	Condition of conifer trees	Stand level percentage of coniferous trees (i.e, trees with DBH ≥ 3.0 cm) per health condition (i.e., tree state) categories: 1. Live 2. Dead with needles (red state) 3. Dead without needles (grey state) 4. Other standing dead tree Other information on trees state may be pertinent to note, such as bark state (no loose bark, some/half loose bark, or no bark at all), and crown state (broken or not)	%	FBP/FMS: In-stand wind model FBP: Crown fire behaviour FBP: Crown fire consumption FMS: Surface fuel moisture
Ladder fuels	Stand effective canopy base height (eCBH) of coniferous species • Crown base height (CBH): needed for eCBH estimation • Subcanopy trees height (STH): needed for eCBH estimation	eCBH: distance between the top of the subcanopy conifer trees (DBH > 0.1 cm and <9.0 cm) and the lowest live branch of the overstory crowns (eCBH = CBH-STH) CBH: is the live crown base height (LCBH) of overstory conifer trees (DBH ≥ 9cm): height of the first verticil where three-quarters of the branches have needles (red or green), if continuity is present, whereas dead crown base height (DCBH): height of the first verticil where three-quarters the branches are dead but still baring twigs STH: is the height of subcanopy conifer trees (DBH > 0.1 cm and < 9.0 cm).	m	FBP: Directly in crown initiation and crown models
	Basal area of subcanopy trees species	It is the basal area of subcanopy trees (DBH > 0.1 cm and < 9.0 cm) by tree species. Deciduous (or hardwood) species maybe group as one species, in some situations it may be useful to separate the aspen genus from other deciduous. Coniferous species will need to be separated by species, or minimally be groups of species (e.g., tamarack, temperate pines, boreal pines, fir/spruces).	stems·ha^{-1}	FBP/FMS: In-stand wind model FBP: Crown fire initiation in mixedwood FMS: Solar radiation and surface fuel moisture adjustment
Ground and surface fuels	Tree seedling density per height classes (deciduous vs coniferous)	Tree seedling density per height classes (< 15 cm, 15.0-59.9 cm, and 60.0-129.9 cm), for deciduous and coniferous separately	stems·ha^{-1}	FMS: Litter moisture adjustment FBP: Sustained flaming model FBP: Surface fire spread models

	Surface vegetation	Surface vegetation cover per height classes (< 15 cm, 15.0-59.9 cm, and 60.0-129.9 cm) and by species	%	FMS: Litter moisture adjustment FBP: Sustained flaming model FBP: Surface fire spread models
	Downed woody debris load	Load by species, diameter, decomposition stage (rotten or sound), and position (touching the ground or elevated) for pieces ≥ 3.0 cm only. Stratified by diameter classes (1.0-2.99 cm, 3.0-6.99 cm, 7.0-29.9 cm, ≥ 30.0 cm).	$kg \cdot m^{-3}$	FBP: Fuel consumption models
	Forest floor cover type	Forest floor cover per type: 1. Lichen 2. Grass 3. Sphagnum 4. Feathermoss 5. General Litter (e.g. bark, cones) 6. Needle Litter 7. Leaf Litter 8. Mixed (unidentified needle/leaf mix) 9. Other (e.g. rock)	%	FMS: Litter moisture adjustment FBP: Sustained flaming model FBP: Surface fire spread models
	Litter load	Weight of ground litter	$kg \cdot m^{-3}$	FBP: Fuel consumption models
	Organic layer depth	Depth of the ground organic layers (F and H)	cm	FBP: Forest floor consumption models
	Organic layer fuel load (bulk density)	Weight of the organic layers (F and H)	$kg \cdot m^{-3}$	FBP: Forest floor consumption models

Figure 1: Plot Diagram



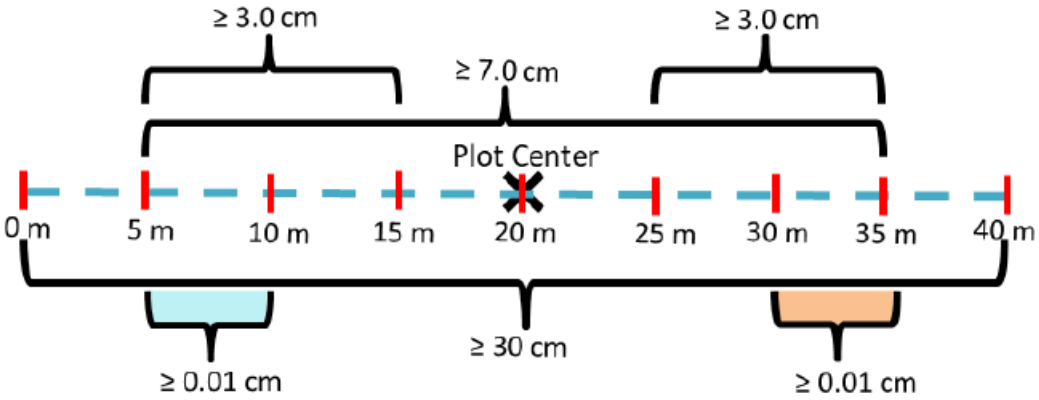


Figure 2. *Details of the down dead wood classes measurements along the 40m DDW transects.*

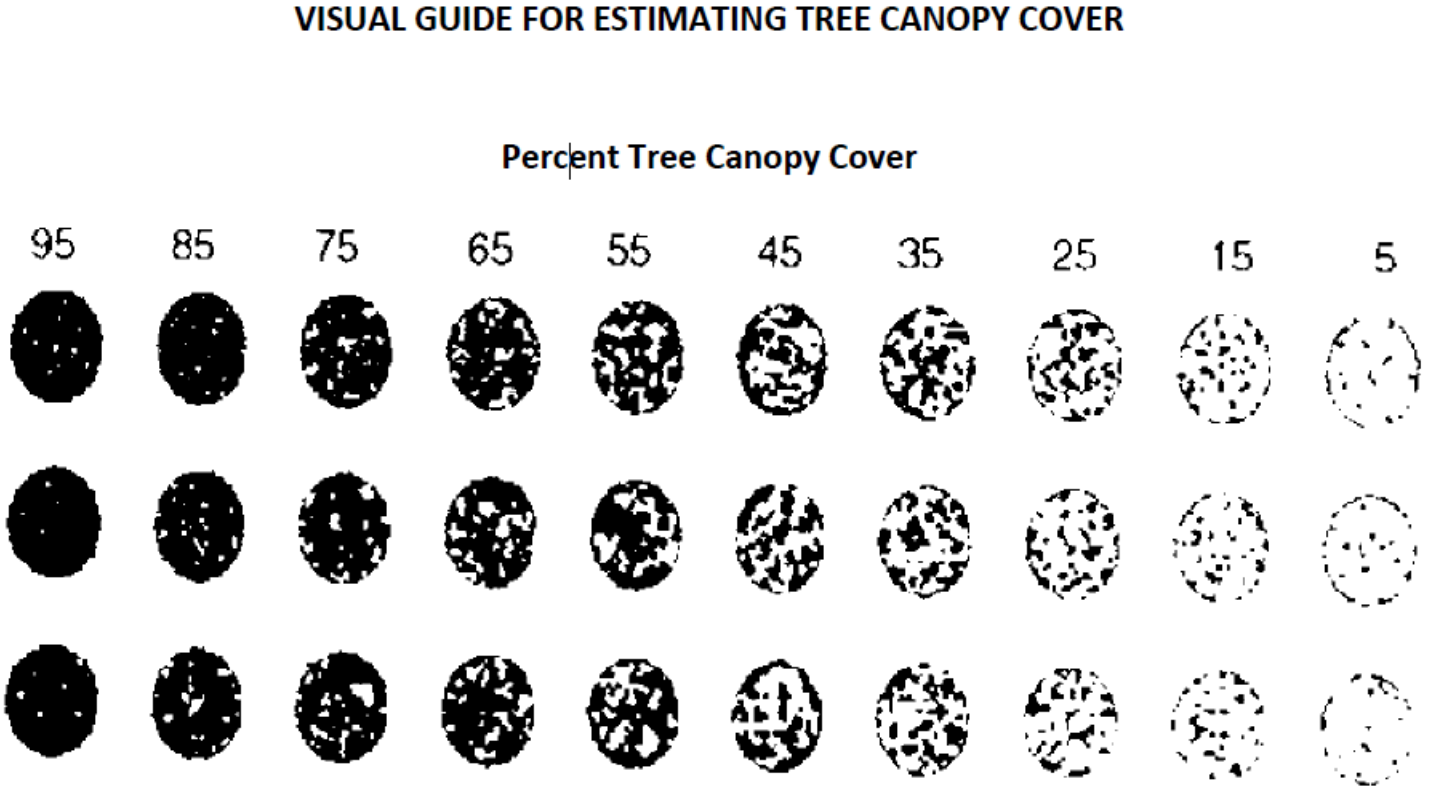


Figure 3: *Visual guide of percent cover (Source: USDA FS FIA Field Manual Version 3.0).*

1. Site Information

1.1 Introduction

A site assessment is required for each ground plot to provide a record of conditions at NG-CFFDRS ground plot locations including characteristics of the stand and information on site disturbance.

1.2 Objectives

- To collect site features information.

1.3 Procedure

1. Measure and record site features for the sample plot.
2. Identify and record position on the slope, relief, % slope, rear slope length, and slope direction.
3. Provide percent cover estimates by species of the upper canopy, lower canopy, and the shrub layer.
4. Draw a diagram of disturbances and their extent as they affect the overall plot. This may include obstructions to plot measurements (e.g. cliff, large rock, etc.)

1.4 Considerations

1. The site information can be completed as the last field card at the plot. This gives crew member the chance to familiarize themselves with the environment and forest stand.

Field Cards for Plot Center:

- Form 7

2. Plot Center

2.1 Introduction

The plot center is placed in the stand, or fuel complex, of interest. It is the reference point from which all other elements of the plot layout are positioned. The needed level of precision of its geographic location is driven by the expected usage of the measurements.

2.2 Objectives

- To record the geographic coordinates of the plot center.

2.3 Instruments

- Metal post
- Flagging tape
- Differential GPS unit
- Compass
- x2 50m measuring tapes

2.4 Procedure

1. Navigate to within 1 meter of the pre-determined plot location using a handheld GPS unit.
2. Place the plot center pin as close as possible to this point.
3. Use a survey grade differential GPS to record the geographic location at plot center.
    a) Optional: Place the vertex transponder at plot center and trace out the 11.28m and 3.99m plot contours using spray paint.
4. Extend two 40m transect tapes in the N-S and W-E directions using a compass. Make sure the intersection of the two tapes aligns perfectly at plot center.

2.5 Conditions

1. A buffer of 1 meter may be used to avoid placing plot center on or by an obstruction.

Field Cards for Plot Center:

- Form 7

3. Canopy Fuel Plot

3.1 Introduction

The canopy fuel plot is where we directly measure or record measurements to estimate the fuel attributes of the canopy fuel strata as well as the CBH, CBD, and CFL of canopy trees. This is done using allometric equations and/or models. A round plot with a radius of 11.28 m which covers an area of 400 m² was selected for its simplicity of establishment and compatibility with other protocols (e.g., NFI).

3.2 Objectives

- To collect detailed information for canopy/large trees (≥ 9.0 cm at diameter breast height).

3.3 Instruments

- Caliper
- Diametric tape
- Vertex (or clinometer)
- Telescopic measuring ruler
- DBH measuring stick

3.4 Measurements

1. Diameter at breast height (DBH), measured for all trees ≥ 9.0 cm
2. Stand density of trees ≥ 9.0 cm
3. Species identification for each tree ≥ 9.0 cm
4. Tree, stem, and bark conditions for all conifers ≥ 9.0 cm (hardwood species may be classified as either live or dead only)
5. Tree heights measured for a minimum of 12 trees to ensure height measurements for all stand layers. Select 12 trees, based on an accurate representation of canopy height classes (across the range of diameters observed), and measure heights. Record whether the height was measured (M) or estimated (E).
6. Live (LCBH) and dead (DCBH) crown base heights for all coniferous stems with DBH ≥ 9.0 cm. The goal is to determine the end of crown continuity. If these are obviously not an effective definition, then use your judgment to determine the LCBH and DCBH:
    a) LCBH: height of the first whorl (at the base of the stem) where three-quarters of the branches have needles (red or green)
    b) DCBH: height of the first whorl (at the base of the stem, except where the dead branches touch the ground) where three-quarters the branches are dead but still baring twigs.

3.5 Procedure

1. Standing at plot center, looking towards the outside of the plot just to the right (east) of Transect 1 (i.e. 0 degrees north magnetic) begin measuring trees closest to plot center along bearing and then scanning clockwise (east).
2. With a caliper (tail towards the center of the plot), or a diametric tape, measure the DBH at 1.30 m for the highest side of the ground.
3. The number of trees ≥ 9.0 cm in the plot is counted while measuring DBH. Paint the tree number using spray paint (in areas this is permitted).
4. Identify species while measuring DBH.
5. Tree condition visually classified as:
    1. Live
    2. Dead with red needles (red stage)
    3. Dead without needles (grey stage), but still baring small twig branches (i.e., <1cm)
    4. Snag (other standing dead state)

    Stem condition visually classified as:
    a) Intact
    b) Broken (if broken, estimate height at break point)

    Bark condition visually classified as:
    a) Intact
    b) Peeling off on more than 30% of the stem (more than 30% peeling)
    c) Completely gone

6. Using the vertex (or clinometer), place the 1.3m height pole on the high side of the tree and place the transponder on the face of the tree (toward plot center). Record height of tree. Do this for a minimum of 12 trees that represent the stand.
7. Telescopic measuring ruler, vertex, or clinometer.
    a) For LCBH: use the telescopic ruler to measure the height of the first whorl (at the base of the stem) where three-quarters of the branches have needles (red or green).
    b) For DCBH: using the telescopic ruler to measure the height of the first whorl (at the base of the stem, except where the dead branches touch the ground) where three-quarters the branches are dead but still baring twigs.

3.6 Conditions

- For height measurements, make sure to number the trees using spray paint. However, if this is not permitted in certain areas, you may use chalk or green spray paint (double check with park authority).
- When dead branches touch the ground, this means the DCBH is measured at zero.
- When live branches touch the ground, this means the LCBH is measured at zero.

Field Cards for Canopy Fuel Plot:

- Form 2

4. Subcanopy Fuel Plot

4.1 Introduction

The subcanopy fuel plot is where we directly measure or record measurements that serve to estimate the fuel attributes of some of the ladder fuel strata (subcanopy tree height and basal area). A round plot with a radius of 3.99 m and thus covering an area of 50 m² was selected for its simplicity of establishment and compatibility with other protocols (e.g., NFI).

4.2 Objectives

- To collect detailed information for subcanopy stems (DBH < 9.0 cm and height ≥ 1.3m).
- To collect detailed information for trees with DBH < 9.0 cm and height ≥ 1.3m
- To collect detailed information for shrubs of height ≥ 1.3m.

4.3 Instruments

- Vertex (or clinometer)
- Telescopic measuring ruler
- Caliper
- DBH measuring stick

4.4 Measurements

For Trees:

1. Tree height for all stems with DBH < 9.0 cm and height ≥ 1.3m.
2. DBH for all stems with DBH < 9.0 cm and height ≥ 1.3m.
3. Species identification for each tree with DBH < 9.0 cm and height ≥ 1.3m.
4. Tree, stem, and bark conditions for all conifers with DBH < 9.0 cm and height ≥ 1.3m (deciduous species may be classified as either live or dead only)
5. Live (LCBH) and dead (DCBH) crown base height for all coniferous trees with DBH < 9.0 cm and height ≥ 1.3m. The goal is to determine the end of crown continuity. If these are obviously not an effective definition, then use your judgment to determine the LCBH and DCBH:
    a. LCBH: height of the first whorl (at the base of the stem) where three-quarters of the branches have needles (red or green)
    b. DCBH: height of the first whorl (at the base of the stem, except where the dead branches touch the ground) where three-quarters the branches are dead but still baring twigs.

For Shrubs:

1. Basal diameter (cm) for all shrubs of height ≥ 1.3m.
2. Species identification for all shrubs of height ≥ 1.3m.
3. Condition for height ≥ 1.3m (classified as either live or dead only)

4.5 Procedure

For Trees:

1. Telescopic measuring ruler, vertex, or clinometer
2. Caliper (tail towards the center of the plot)
3. Identify species
4. Tree condition visually classified as:
    a) Live
    b) Dead with red needles (red stage)
    c) Dead without needles (grey stage), but still baring small twig branches (i.e., <1cm)
    d) Snag (other standing dead state)

    Stem condition visually classified as:
    a) Intact
    b) Broken (if broken, estimate height at break point)

    Bark condition visually classified as:
    a) Intact
    b) Peeling off on more than 30% of the stem
    c) Completely gone

5. Telescopic measuring ruler, vertex, or clinometer
    a) For LCBH: use the telescopic ruler to measure the height of the first whorl (at the base of the stem) where three-quarters of the branches have needles (red or green)
    b) For DCBH: using the telescopic ruler to measure the height of the first whorl (at the base of the stem, except where the dead branches touch the ground) where three-quarters the branches are dead but still baring twigs.

For Shrubs:

1. Basal Diameter: Record the basal diameter of each shrub. Basal diameter is measured at the ground line or just above the root collar, whichever is higher.
2. Shrub Species: Record the species of each shrub using the first three letters of the scientific species name or the NFI code.

4.6 Conditions

- When measuring LCBH or DCBH on trees with blocked growth (from an obstruction or adjacent tree), measure as though the unobstructed whorls cover 100% of the stem.
- When measuring shrubs, suckering species may be difficult to accurately measure the basal diameter. Instead, collect the DBH for all stems of the shrub.

Field Cards for Subcanopy Fuel Plot:

- Form 3

5. Regeneration Plots

5.1 Introduction

These are 1 m² square plots. There are four regeneration plots placed along the DDW transects, the inner corner of the square being positioned at 10 m from the plot center, placing two facing corners in the transect axis.

5.2 Objectives

- To collect detailed information for tree seedlings.
- Collect images of the regeneration plot and from the regeneration plot towards plot center.

5.3 Instruments

- $1m^2$ quadrat (with PVC)
- PVC stick with height classes (< 15 cm; 15-59.9 cm; 60-129.9 cm)
- Measuring tape

5.4 Measurements

1. Tree seedling density per species per height classes (< 15 cm; 15-60 cm; 60-130 cm)

5.5 Procedure

1. Establish four 1 m^2 quadrats at the ends of the line transects used for woody debris. Place opposing corners of the quadrat at the 10-11m mark and the 30-31m mark along each transect length.
2. Take a top-down picture of the regeneration plot at breast height at the 10m and 31m mark along the transect (just outside of the regeneration plot).
    1. Label each image immediately after capture in device and mark the timestamp.
    2. Use the naming convention: Regen - Plot # - Transect # - Length along transect
3. Take a picture towards plot center at the 10m and 31m mark along the transect.
    1. Label each image immediately after capture in device and mark the timestamp.
    2. Use the naming convention: PC - Plot # - Transect # - Length along transect
4. Count tree seedlings contained in $1m^2$ quadrat (defined by a PVC frame) by height class and species using a PVC stick with pre-identified height classes (< 15 cm; 15-59.9 cm; 60-129.9 cm).

Field Cards for Subcanopy Fuel Plot:

- Form 4

6. Litter Plots

6.1 Introduction

Litter plots are used to determine biomass of leaf, needle, cone, and bark litter. In addition, samples of the litter are collected from the litter plots and analyzed to determine bulk density.

6.2 Objectives

- To provide estimates of litter biomass and bulk density.

6.3 Instruments

- $1m^2$ quadrat (with PVC)
- Square frame (20 cm x 20 cm)
- Bread knife
- Pruning shears
- Square metal plates (optional)
- Ruler
- Ziplock bags (large freezer bags)
- Pigtails

6.4 Measurements

1. Average depth of the litter layer
2. Relevant comments about disturbances to the volume

6.5 Collected Samples

1. Collect the litter layer from the 20 cm x 20 cm frame.

6.6 Procedure

1. Remove all live vegetations from the regeneration (quadrat) plot area.
2. Use the pigtails to probe the ground in the regeneration plot to find a viable frame placement for the litter plot (avoid rocks and roots).
3. Place the 20 × 20 cm (inside dimensions) aluminum or wood sampling frame over the sampling point, taking care not to compact the sample. Place the 20cm x 20cm on a sampling area that is most representative of the litter within $1m^2$ quadrat.
4. Using clippers, remove the living layer from inside the 20 X 20 cm frame and discard.
5. Remove the FWD from inside the 20 X 20 cm frame.
6. Collect and bag the litter from inside the 20 X 20 cm frame.
7. Complete the pre-printed label with a waterproof marker, and affix to the outside of the sample bag. You may have to double bag samples or use a plastic overbag to prevent tearing and loss of sample material. Make sure each bag is clearly labeled.
    a) In some areas, more than one bag might be required to hold the sample. If so, label the bags with identical information, and then add “1 of 2”, “2 of 2”, etc., respectively. If no sample is taken, label an empty bag for the soil plot.

8. Measure the distance from the top of the litter layer (0 cm) to the F-H layer interface at four different locations within the excavation (e.g., at the four corners of the sample). Record the average depth to the nearest 0.1 cm. This measurement will be used to calculate the volume of the excavation, and in turn, the bulk density of the litter layer.

6.7 Condition

3. If you hit root or rock that cannot be collected, estimate the volume and subtract this from the sample collected.

Field Cards for Soil Plot:

- Form 6

7. Surface Fuel Plot

7.1 Introduction

The surface fuel plot is where we directly measure or record measurements that serve to estimate the fuel attributes of some of the surface fuel strata (surface vegetation and forest floor cover type). A round plot of a 5.64-m fixed-radius plot and thus covering an area of 100 m² was selected for its simplicity of establishment and compatibility with other protocols (e.g., NFI).

- Low shrubs: Are defined as woody perennial plants shorter than 1.30 m, having multiple stems that branch from the base without a well-defined main stem.
- Herbs: All herbaceous species, including forbs (including ferns and fern allies), grasses, sedges, and rushes.
- Bryoids: Mosses, sphagnum, liverworts, hornworts, and non-crustose lichens.
- Litter: Leaf and needle litter layers on top of the bryoid layer.

7.2 Objectives

- To collect percent cover estimates of vegetation within the low shrub, herb, litter and bryoid layers.

7.3 Measurements

1. Percent cover estimates by genus for all categories (shrubs shorter than 1.30 m, herbs, bryoids, leaves litter, needles litter, and general litter).
2. Species may be determined if field crew members are confident.

7.4 Procedure

1. For measurement of live vegetation within the low shrub, herb, litter and bryoid layers, establish a 5.64-m fixed-radius plot, centered at ground plot center. All genus should be recorded. Species may be recorded except for epiphytes. For example, bryoid species growing on the sides of trees or on overhanging branches should not be recorded. For vegetation species of very low coverage, an exhaustive list is not expected. Given the seasonal variation in flowering and vegetative production, species of very low coverage (< 0.01%) can easily be missed. Concentrate on species having > 0.01% coverage. By percent cover we mean the percent of the ground surface covered by the vertical projection of the crown of the plant onto the ground surface. Cover values for individual plant species in each vegetation layer will be estimated. Within each layer, overlapping crowns are not additive for the same genus or species; consequently, a given genus of species cannot have coverage > 100% in a single layer. Assessing cover by layer will sometimes result in total coverages > 100%.

7.5 Conditions/Notes

a. Use the quadrat (1m x 1m frame) as a reference of 1% of ground covering.
b. One walk of the plot to identify genus or species, second walk of the plot to determine percent covers.
c. From 1-10% range, make 1% adjustments.
d. From 10-25% range, make 5% adjustments.
e. From 25-100% range, make 10% adjustments.

Field Cards for Surface Fuel Plot:

- Form 5

8. Down Dead Wood Transects

8.1 Introduction

Down dead wood pieces are sampled along two 40 m transects centered on the plot center and oriented N-S and W-E (Figure 1).

8.2 Objectives

To collect load by species, diameter, decomposition stage (rotten or sound), and position (touching the ground or elevated) for pieces ≥ 3.0 cm only. Stratified by diameter classes (1.0-2.99 cm, 3.0-6.99 cm, 7.0-29.9 cm, ≥ 30.0 cm).

8.3 Instruments

- Caliper
- Go-no-go gauge
- Measuring tape
- Clinometer

8.4 Measurements

1. Quantify down dead wood (DDW) by size classes (0.01-0.99cm, 1-2.99cm)
2. Quantify down dead wood by size classes (3-6.99cm, 7-29.9cm, ≥ 30cm), species, exact diameter, decomposition stage (rotten or sound), tilt angle, and position (touching the ground or elevated/raised) for pieces ≥ 3.0 cm only.

8.5 Procedure

1. For the 5 m to 10 m and 30 m to 35 m segments, dot tally separately the DDW ≥ 0.01 cm and < 0.99 cm (fine woody debris) from the ≥ 1.0 cm < 3.0 cm (small woody debris) when they are crossing the line (a 10 mm wrench might be useful to determine which DDW are < 1.0 cm). A detailed view of transects is presented in Figure 2. If the dot tally reaches 250 pieces in the fine and small woody debris segment, stop counting. Record the length of the segment measured.
2. For all the segments of the transects, measure DDW pieces diameter (using a caliper) and note the species, decomposition stage (rotten or sound) and position (touching ground or elevated) of each DDW ≥ 30.0 cm crossing the line. For the 5 m to 35 m segments, measure the diameter and note the species, decomposition stage, tilt angle, and position of each DDW ≥ 7.0 cm crossing the line. For the 5 m to 15 m and 25m to 35 m segments, measure the diameter and note the species, decomposition stage, tilt angle, and position of each DDW ≥ 3.0 cm crossing the line.

a) Decay Classes (NFI codes):
   1. Intact, hard
   2. Intact, hard to partly decaying
   3. Hard, large pieces, partly decaying
   4. Small, blocky pieces
   5. Many small pieces, soft portions

	Decay class				
	1	**2**	**3**	**4**	**5**
Wood texture	**intact, hard**	**intact, hard to partly decaying**	**hard, large pieces, partly decaying**	**small, blocky pieces**	**many small pieces, soft portions**
Portion on ground	elevated on support points	elevated but sagging slightly	sagging near ground, or broken	all of log on ground, sinking	all of log on ground, partly sunken
Twigs < 3 cm (if originally present)	twigs present	no twigs	no twigs	no twigs	no twigs
Bark	bark intact	intact or partly missing	trace bark	no bark	no bark
Shape	round	round	round	round to oval	oval
Invading roots	none	none	in sapwood	in heartwood	in heartwood

Note: Sound vs rotten: “Consider pieces rotten when the piece is obviously not solid and can be kicked apart easily” (McRae et al. 1979).

8.6 Conditions

a) In the event of

<u>Measured woody debris includes the following:</u>

• fallen or suspended (not self-supporting) dead tree boles, with or without roots attached;
• fallen trees with green foliage (no longer rooted to the ground);
• fallen trees broken into wood pieces or pieces of bark on the ground surface;
• fallen branches and fallen, broken tree tops that are horizontal or leaning;
• recently cut logs (may include bucked logs or log decks);
• woody debris is above the forest floor at the transect; and
• uprooted (not self-supporting) stumps and any exposed dead roots on the stump.

<u>The following are ***not*** considered woody debris and are not measured:</u>

• live or dead trees that are self-supporting (still rooted);
• live fallen trees;
• exposed roots of self-supporting live or dead trees;

• dead branches still connected to standing trees;
• self-supporting stumps or their exposed roots;
• wood that has decomposed to the point where it could be described as forest floor humus (< 50% above forest floor);
• decaying wood covered by accumulations of organic matter ≥ 1 cm thick;
• buried wood: woody debris below the surrounding surface; and
• if an organic layer has developed over the wood, the woody debris must have > 50% of its thickness above the surrounding surface. Woody debris is considered no longer above the soil when it is entirely buried beneath a layer of surface organic matter (forest floor) > 1 cm thick or mineral soil.

Field Cards for Down Dead Wood Transects:

- Form 1

9. Hemispherical Photos

9.1 Introduction

Hemispherical photos (HP) can be used to estimate Plant Area Index (PAI) in the plot. Refer to figure 3.

9.2 Objectives

- To collect 8 hemispherical photos in each plot along the DDW transect lines (at 10m, 15m, 25m, and 30m).

9.3 Instruments

- Fish eye lens
- iPhone or iPad (12 megapixel camera)
- Microfiber cloth

9.4 Measurements

1. Hemispherical photo along each of the DDW transects at 10m, 15m, 25m, and 30m points from plot center (a total of 8 HPs) between peak daylight hours of 9:00 and 16:30.

9.5 Procedure

1. Along each of the DDW transects, locate 10m, 15m, 25m, and 30m points from plot center.
2. Place the device over the 10m, 15m, 25m, and 30m mark along the two transects.
3. Bring the device to a height of 180cm above the ground using a monopod/height pole. Capture image, ensuring that face/head is not in the image.
4. Label each HP immediately after capture in device.
    1. Naming convention: HP - Plot # - Transect direction - Length along transect

9.6 Conditions

1. Avoid direct sunlight (30cm allowance from transect to avoid direct sunlight)
2. Ensure the lens is clean

Field Cards for Plot Center:

- Form 7

References

Alexander, M.E., Stefner, C.N., Mason, J.A., Stocks, B.J., Hartley, G. R., Maffey, M.E., Wotton, B.M., Taylor, S.W., Lavoie, N., Dalrymple, G.N., 2004. Characterizing the jack pine – black spruce fuel complex of the International Crown Fire Modelling Experiment (ICFME). Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-393. (https://cfs.nrcan.gc.ca/publications?id=24913)

Cameron, H.A., Díaz, G.M. and Beverly, J.L., 2021. Estimating canopy fuel load with hemispherical photographs: A rapid method for opportunistic fuel documentation with smartphones. *Methods in Ecology and Evolution*, *12*(11), pp.2101-2108.

Fire Danger Group, 2021. An overview of the next generation of the Canadian Forest Fire Danger Rating System. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario. Inf. Rep. GLC-X-26. (https://cfs.nrcan.gc.ca/publications?id=40474)

Hirsch, K.G. 1996. Canadian Forest Fire Behavior Prediction (FBP) System: user's guide. 1996. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. Special Report 7. 122 p.

Lavoie, N., Alexander, M. E., & Macdonald, S. E., 2010. Photo guide for quantitatively assessing the characteristics of forest fuels in a jack pine–black spruce chronosequence in the Northwest Territories. Nat. Resour. Can., Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-419. (https://cfs.nrcan.gc.ca/publications?id=31785)

McRae, D.J., Alexander, M.E., Stocks, B.J., 1979. Measurement and description of fuels and fire behavior on prescribed burns: a handbook. Environ. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario. Inf. Rep. O-X-287. (https://cfs.nrcan.gc.ca/publications?id=8963)

NFI Task Force, 2008. Canada's National Forest Inventory Ground Sampling Guidelines : specifications for ongoing measurement. Version 5.0. Library and Archives Canada. Nat. Resour. Can., Can. For. Serv., Pacific For. Cent., Victoria,

British Columbia. ISBN 978-1-100-11329-6. Cat. no.: Fo144-6/2008E. (https://cfs.nrcan.gc.ca/publications?id=29402)