FIRE BEHAVIOR ASSESSMENT TEAM (FBAT)

Measurement Protocols

2023

Contents

OVERVIEW

Document Purpose

The protocols describe what kinds of monitoring FBAT does and how to collect the data. The Operations Guide includes some logistical information that is relevant to getting the monitoring done (such as packing lists for plot kits). The reports are examples of how the data come together. See the new FBAT website on FRAMES for the Operations Guide, Protocols, reports, and other materials (https://www.frames.gov/fbat/home).

Program Objectives

In collaboration with land managers and interested research groups, the primary FBAT goals are to:

1. Build an archive of coordinated fuels, vegetation, fire behavior, and fire effects measurements useful for understanding the effects of past fires and fuel treatments and for comparing and calibrating consumption, emissions, fire behavior, and fire effects against modeled outputs.
2. Support incidents through information delivery and supply data and video useful for improving firefighter safety and public outreach.
3. Support wildfire research and application through collaborative projects.

During the 2021 season, a specific objective is to advance ecological risk mapping by prioritizing plot installation in areas or times of the year most likely to capture fire behavior which causes moderate to high levels of tree mortality and that captures conditions that lead to the transition between surface and crown fires.

Fire Selection

We focus on fires that are expected to last at least a few days in duration after our arrival time and include areas with fuel treatments or recent wildfires that are expected to burn. Ideal situation is to be ordered to, and arrive at, a fire that is still emerging in its growth and spread patterns.

For each fire event, we will: 1) rapidly obtain vegetation management history information (from WFDSS as necessary, which is linked to FACTS); 2) maintain LCES and communication with Division Supervisor for the areas we are working when we are working on the fire (not in camp) ; 3) collect pre-fire fuels and vegetation condition data ahead of the fire; 4) record fire behavior through sites where we have collected pre-burn data; and 5) measure immediate post-fire effects and indirect measures of fire behavior. We will capture and record all weather, fire behavior, topography, fuels, fire suppression actions and other pertinent information providing an overall context for the fire's behavior in the sampling area.

Plot Selection

After safety risks are mitigated, our plan is to sample 10 locations (plots) on average on each fire. Sample more plots if possible. Consider your objectives and try to choose plots that can help you tell a coherent story after the fire is over and you are writing the report. For instance, if you have the opportunity to assess the effectiveness of fuel treatments, sample plots that have either been treated or are untreated. The story that you can tell on a given fire will depend on opportunity and local concerns and objectives. You may not be able to collect a statistically robust sample on a given fire, but the plots accumulated over years will help answer questions about relationships among fuels, vegetation, fire behavior, and fire effects. Coordination with fire and land management staff or other stakeholders prior to fire season can help with planning during the plot selection phase.

In coordination with incident management personnel, sites are placed opportunistically ahead of the fire, accounting for current and expected fire behavior, safe access, and fire management tactics. Fire behavior monitoring equipment that is heat resistant will be deployed and left on-site through the fire and fuel inventories.

Choose a plot location that is within as large an area of consistent vegetation as possible. That way, any remote sensing data will be most readily related to fuels, vegetation, fire behavior, and fire effects.

GIS Information

Make sure FBAT iPads are loaded with software and information useful in meeting objectives on an incident (see the Operations Guide). We currently do not use any GIS-based apps for data collection (e.g., Survey123).

Materials for Data Collection, Entry, and Analysis

Each season, an updated set of printable PowerPoint and Excel spreadsheets for data collection and data entry and analysis will be available on Pinyon (for those with access):

All Files > FireBehaviorAssessmentTeam-External > 2023_Season > MaterialsForAssignment

Folders: DataCollectionSheets, DataEntrySheets&Folders, Software, SupplementaryProtocols&Info

The data collection sheets are printed prior to assignment:

- FBAT_DataCollection_Fuels_Vege_DATE.xlsx
- PlotLayout-Narrative-Camera&FBP-ROS-TLS_DATE.pptx

Data entry and analysis spreadsheets are contained within subfolders within DataEntrySheets&Folders. Final spreadsheets for generating information for the report are at the root and include:

- FBAT_DataEntry_FireName_FTA_Fuels_EnglishUnits_REV_2021.01.13.xlsx
- FBAT_DataEntry_FireName_Plot#_ROS%Direction_REV_2020.xlsx
- FBAT_DataEntry_FireName_Trees_Data_FVS_REV_2020.01.03.xlsx
- FBAT_DataEntry_FireName_Veg_Canopy-BR_severity_moose_REV_2021.01.13.xlsx
- FBAT_DataEntry_FireName_Video_REV_2021.07.02.xlsx

The data entry tracker is used to make sure all tasks are completed:

- FBAT_DataEntry_FireName_DataTracker_REV_2020.08.17.xlsx

Often, FBAT will also collect fire weather, fuels, and fire behavior and effects information for delivery to incident staff. FEMO/FOBS datasheets are printed prior to assignment.

PLOT ESTABLISHMENT

Sketch Map

On the appropriate data entry template, sketch general map of location of plot in relation to all sides of the project area, such as key roads, landings, streams, roads you took to get there, etc.

General Measurements

Four general types of data are collected on each plot (see Figure 1).

1. Fuels (crown/trees, small trees, surface fuels, understory vegetation)

2. Fire Behavior (video camera, Fire Behavior Package [FBP], autonomous rate of spread sensors, and anemometer for eye-level winds)

3. Fire Effects (soil heating and effects, char heights, scorch and torch heights and percentages, severity)

4. GIS Data (stand, topography, post-severity imagery when available, and forest roads and streams)

See Appendix A for a list of measurements and related details. The main reference for measurement methods is FIREMON (https://www.frames.gov/firemon/home). Also refer to DOI Fire Monitoring Handbook (http://www.nps.gov/orgs/1965/upload/fire-effects-monitoring-hanbook.pdf), e.g., for snag classes. Units are Imperial (inches, feet) and GPS in decimal degrees (see Variables in Appendix A) using WGS84 datum. Where possible, instructions and reminders are written into the data collection and entry sheets.

Gear Management

Measurement materials, tools, and instruments will be packed into a vehicle at the beginning of an assignment. Gear will be packed into kits and all those kits will be labeled with what they contain. When kits are being rehabilitated during an assignment or after a fire, the contents of kits and the label should match. Currently, FBAT carries the following kits: a Fuel Kit (with gear needed to sample surface and understory fuels), a Tree Kit (with gear needed to do the variable-radius plot tree sampling), 8-10 Fire Behavior Kits (with video cameras, FBPs, ROS sensors, anemometers, and associated gear), FOBS kits, rehab kits, MadgeTech datalogger kits, and tool kits. The FBAT Lead list includes various items including electronics (iPads, hard drive, etc.) and datasheets. Kit inventories and labels are found in the Operations Guide.

Plot Layout

An ideal plot layout follows (See Figure 1). The intersection of the 3 fuels transects form plot center. The center of the variable-radius pole- and canopy-sized tree plot is located 10 ft south of the center of the fuel transects (adjust as needed). The camera is positioned to maximize the likelihood that the fire will spread across the plot perpendicular (right to left or left to right) to the camera's field of view. The center of the ROS sensor layout is 10 ft east of plot center. The Fire Behavior Package (FBP) is located between the camera and fuel transect center. The FBP looks (i.e., the incident heat flux sensor points) directly at the fire inside each fire behavior equipment plot. For expected backing fire, orient FBP towards receding fire. The FBP is positioned to the side of the camera's field of view so as to allow the fire to spread in front of the camera before it impacts the FBP. For instance, if the fire is expected to spread from right to left, the FBP should be on the left side of the camera's field of view.

Transects

1. Mark center point of plot: with rebar and GPS (WGS 84 datum set on GPS)
2. Lay out 3 line-intercept transects 50 feet in length and oriented North (0 degrees), 120 degrees, and 240 degrees.
3. Adjust azimuth to avoid rocky areas with no fuels. % cover of rocky areas (where there is no fuel) will be noted for the plot and total fuel loading adjusted later.
4. Mark ending point of transect with rebar
5. Record slope and azimuth of each transect

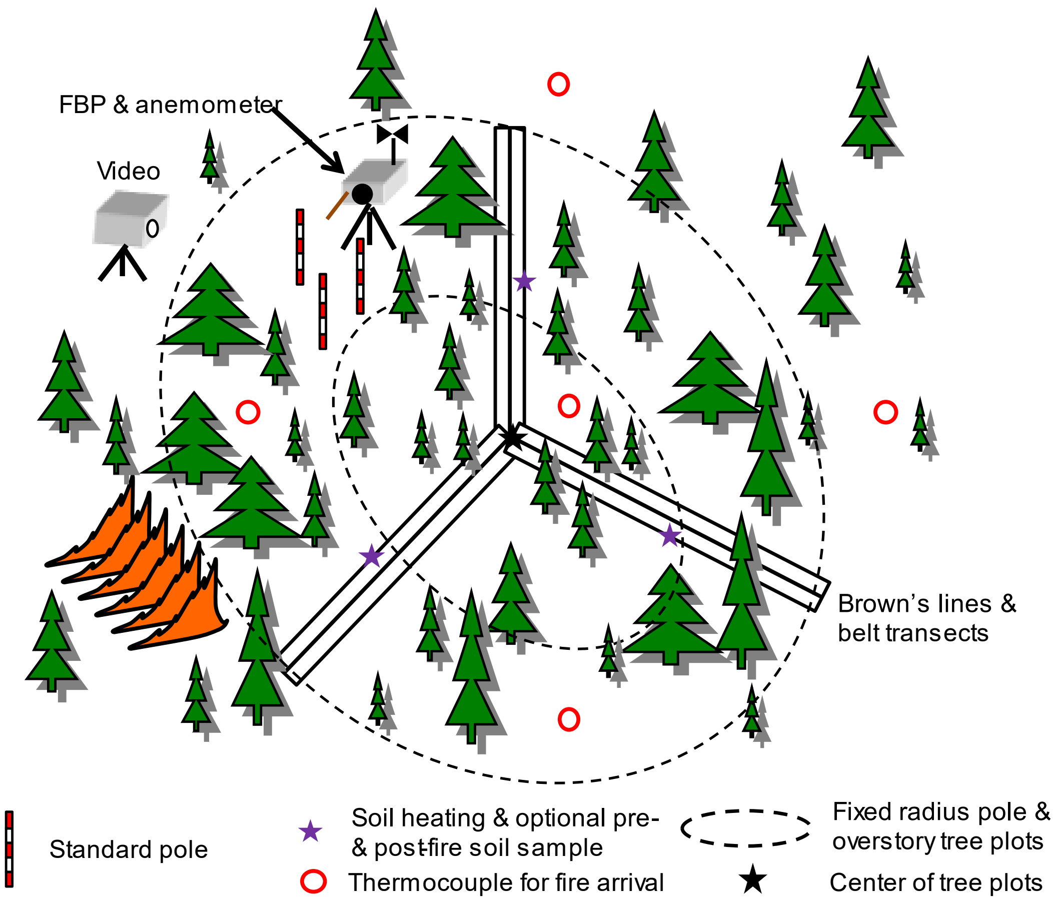


Figure 1. General plot layout with variable radius overstory and pole tree plots, fuel transects, ROS sensor array, soil heating and sampling locations, and desired orientation of camera relative to fire spread. The tree variable radius plots (poles and overstory) have no fixed size or shape and so are represented as non-circular. As a rule, the location of the center of the tree plots and ROS sensor array are fixed relative to the center of the fuel transects (where they meet) as shown.

Terrestrial Laser Scanning

In the works for 2022 season. If part of data collection, include layout relative to other measurements.

PRE-FIRE INSTALLATION AND DATA COLLECTION

The layout of measurements is shown in Figure 2.

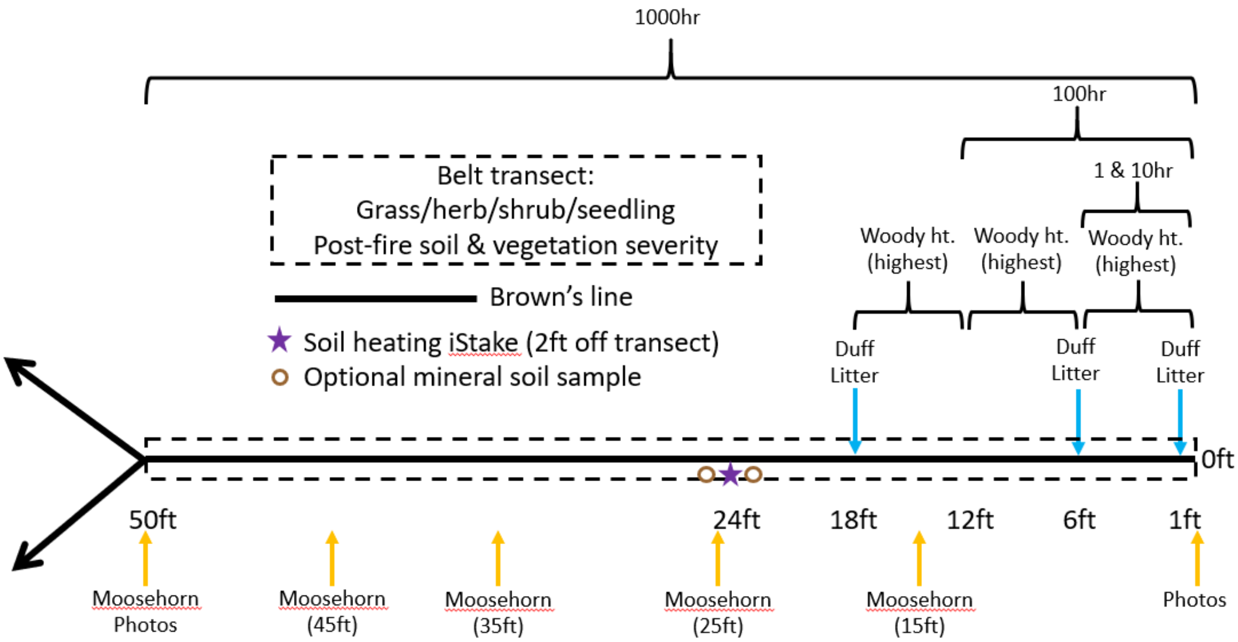


Figure 2. Photos, moosehorn canopy cover, modified Brown's lines, understory vegetation and severity transect, and soil heating and sampling layout. Soil sample collection will not be done in 2021.

Photos

Take photos along transects from both the outside in and from the plot center out and one wide-angle photo of the canopy from the plot center. There will be 7 total pre-fire. Center the tape at the bottom of photo while including as much of the canopy as possible (Figure 3). On the "Plot Information & Fuels Data" collection sheet, note photo number for each transect and orientation. Tip: put pre-fire photos on the iPad or on a separate iPhone to duplicate framing. See examples of pre- and post-fire images in reports. (Note: hemispherical photos using clip-on lens are low quality, consider a purpose-built camera)

Figure 3. Pre- and post-fire photos. Note photo orientation, position of center rebar, and similar framing.

Plot Information

The FBAT plot re-measurement project showed that we could only re-locate about 50% of the FBAT plots. In 2022, we will add a few new procedures to improve the success rate. First, in the plot narrative, record a GPS position of the parking location (or other appropriate landmark) and sketch out plot access. When near the plot, use reflective GeoCaching tacks to mark the approach. Third, mark each tree in the plot with forestry crayons. Fourth, leave four (4 rebar).

Make sure to let the fuels-transect center GPS position stabilize ("lock") before recording. Do position averaging.

Using the moosehorn (a device for estimating canopy cover based on the fraction of a set of vertical point measurements that intersect with live canopy) note whether the crosshairs intersected with canopy at each point along the transects (Figure 2). Exclude understory vegetation from counts, include all intersections with midstory and canopy trees. The goal is to make the measurement as compatible as possible with a canopy cover estimate derived from tree basal area.

Modified Brown's Lines

Collect fuels data along each of the three transects (Figure 1 and 2), from the outside of the plot (0 ft) working towards the center (50ft, the center rebar is 50 ft on all transects). Enter data on the "Plot information & Fuels data" collection sheet. The layout of the measurements on each transect is shown in Figure 2. Note that fuel bed depth (highest woody fuel particle in sections of the transect) measurements, location of duff samples, and length of transects over which fuel size classes are sampled differ from Brown's original method (https://www.fs.usda.gov/treesearch/pubs/28647). In addition, we've added litter depth measurements that are not in Brown.

Litter and Duff Depths

Take 3 readings at 1, 6, and 16 ft. Measure to nearest half inch. Definitions of litter and duff are pictured in Figure 4.

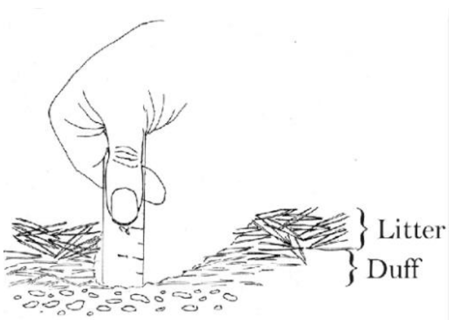


Figure 4. Separation of litter (fresh material on top) and duff (partially to heavily decomposed material below litter and above mineral soil.

Litter: The top layer of forest floor (AKA, L-Layer), composed of dead, fresh and minimally decomposed, loose plant litter (recently fallen leaves, needles, pine cones, bark, etc.) that is detached from the parent stem.

Duff: The "duff" layer lies below the litter layer and above the mineral soil. Duff is both the partly decomposed material under the litter (AKA fermentation, F-layer) and the highly decomposed material for which you typically can't recognize origin (AKA humus, H-layer).

Fuel Depth

Height from bottom of litter layer to tallest woody fuel particle intersecting transect between intervals: 0-6 ft, 6-12 ft, 12-18 ft. Measure to nearest half inch. Note: fuel bed height required for Rothermel or BEHAVE runs will be a weighted average of all surface fuels, including understory vegetation.

Coarse woody debris (CWD)

Large (1000 hr+) dead and down fuels (>3 in on go-no go gauge): collect from 0-50 ft (Figure 2). Rules demonstrated in Figure 5. If rooted, considered dead and down if angle of repose is <45 degree from vertical at transect. Considered duff if >50% of diameter is within the duff. Write on datasheet:

1. Diameter and species of each log (measured in inches)
2. Status of each log: rotten or sound
3. Whether piece fell onto the transect after the fire

Figure FL-6. All of the pieces crossing through the sampling plane in this illustration would be considered "down".

Figure 5. FIREMON definition of downed, dead CWD (<45 degree from vertical whether rooted or not).

Fine woody debris (FWD)

Intercept counts for dead and down only. Dead and down means piece not attached to a rooted plant unless it's a dead tree that is <45 degree from vertical. Treat the transect as an infinitely thin sheet of glass that extends from the ground upwards along the edge of the tape (Figure 6). Max height of 6 ft (from JK Brown), unless in heavy slash, then go to top of fuel bed. Use "go-no go" gauge tool to determine time-lag class:

1. 1 hour fuels (0-0.25 in.): collect from 0-6 ft.
2. 10 hour fuels (0.25-1 in): collect from 0-6 ft.
3. 100 hour fuels (1-3 in): collect from 0-12 ft.

Avoid "growing fuels". Don't count FWD that fell onto the transect after the fire (though this is noted for 1000 hr, see above). You should feel through the litter layer pre- and post-fire to count particles that are within the litter, but don't count particles that are within the duff. .

From FIREMON: "Do not tally needles, grass blades, pine cones, cone scales, bark pieces, etc., as they are not 'woody' in nature. This material is considered litter and is measured as part of the duff/litter profile."

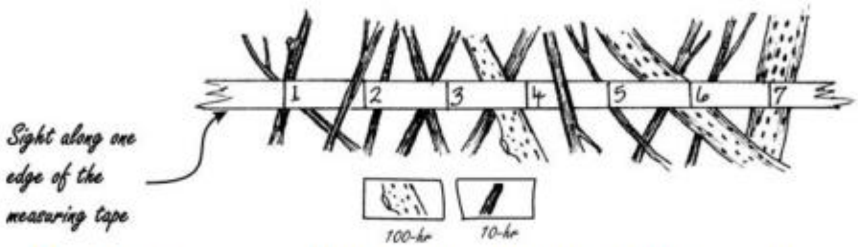


Figure FL-9. Tally pieces that intercept the sampling plane both above and below the measuring tape. Focus on one edge of the tape to make counting easier. Be sure to note any lower fuels that are hidden by pieces above. In this illustration there are 11 1-hour and 3 10-hour fuels.

Figure 6. From FIREMON fuel load field guide.

Understory Vegetation Belt Transect

Consists of grasses/herbs and shrubs/seedlings. Write data on the "Herb/Grass/Shrub/Seedling" collection sheet. Primary objective is characteristics by type and density class. Secondary objective is a species list, but don't sweat it if you don't know the species. Make sure there's an entry for each herb/grass/shrub/seedling category for each transect, even if its zero because that's what's needed when you enter the data and update the pivot table. Treat shrub species as shrubs whether they have a small tree growth form or a shrubby growth form. Don't include them in the tree plot.

1. Collect data within 3ft x 50ft belt plot along each transect, imaginary belt centered on tape. Record data for all rooted vegetation above the belt regardless of whether rooted in plot.
2. Grasses by class: % cover, type 1-4 (see photo series), density class 1-6 (see photo series), average height, % alive (curing level).
3. Herbs by class: % cover, type 1-4, density class 1-6, average height, and % alive (curing level). Categorize herbs as closest grass type and density.
4. Shrub by class: % cover, type 1-5, density class 1-6, average height, % alive.
5. Seedling by class: % cover, type 1-5, density class 1-6, average height, % alive. Treat seedlings as closest shrub class/density.

Grass and shrub type and density classes, used in calculation spreadsheet to estimate loading, are from Burgan and Rothermel's BEHAVE Fuel subsystem (https://www.fs.usda.gov/treesearch/pubs/29616). Photo series are available in FBAT clipboards and copied into Appendix B. Seedlings and herbs aren't categories in Burgan and Rothermel. Seedlings are treated as shrubs. Herbs are a special case: if herb has leathery or big leaves & stems=shrub; if fine foliage & stems=grass.

For percent cover, use the clip-board guide on the datasheet to estimate (i.e., 2 clipboards = 1% of transect area). Figure 7 can help estimate cover within small areas occupied by individual plants. If percent cover is less than 0.5%, then note 0.1 for trace.

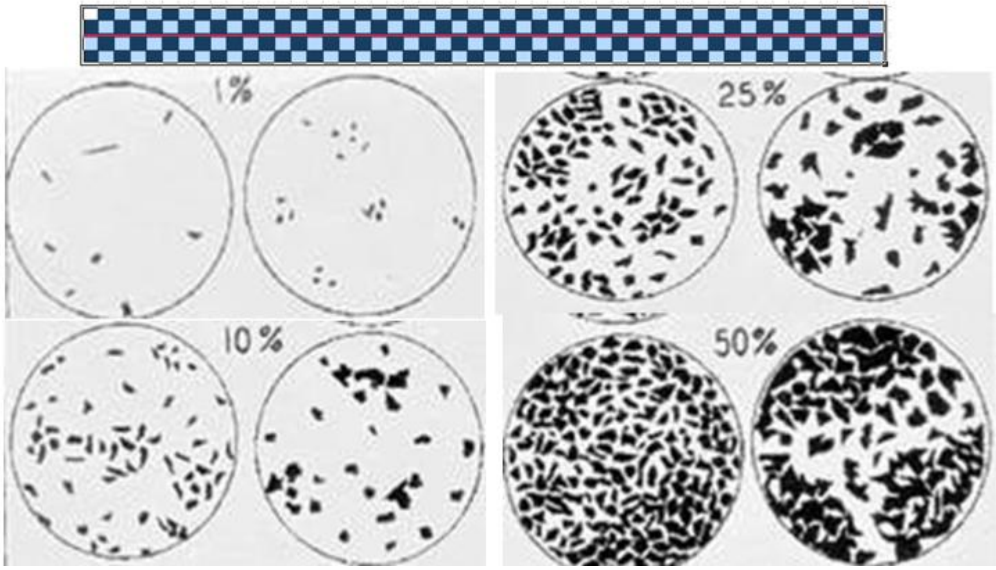


Figure 7. Percent cover at belt transect (top) and plant scales (bottom) for use as guides. Each rectangle on the checkerboard is one clipboard and 2 clipboards are 1% of the belt transect. The transects are 3 ft x 50 ft and centered on tape.

Pole and Overstory Trees

In 2022, we converted from variable radius plots based on a slope-adjusted prism (Relaskop) to fixed area plots for poles and overstory trees. The benefit is primarily to support plot re-measurement in future years.

1. Tree plot center is coincident with the fuel transect center. Work to limit trampling in the center where 1000 hr fuels are inventoried. Standard radii should be 30 ft for poles and 50 ft for overstory. Adjust if needed to sample 10-15 trees but note adjustment on datasheet. Try to stick with standard radii. Situations where you might deviate include if there are an unrepresentative number of trees within the plot (e.g., you miss a patch of poles) or a slightly larger plot will provide a better representation of the overstory.

2. Always start with the tree closest to the north and go clockwise (note on datasheet if you don't do that). Note bearing and distance for each tree so that they can be re-located and mapped. Try to use a can on a pole as an infrared target and get the distance from the tree to center.

3. Use the TruePulse 200 laser/hypsometer to obtain heights, and distances. Cheatsheet in Appendix C.

4. If possible, mark each overstory tree with forestry paint for ease of re-location in later years.

5. Do not include shrub species in the tree plots even if they have a small-tree growth form. We are accounting for them in the shrub layer.

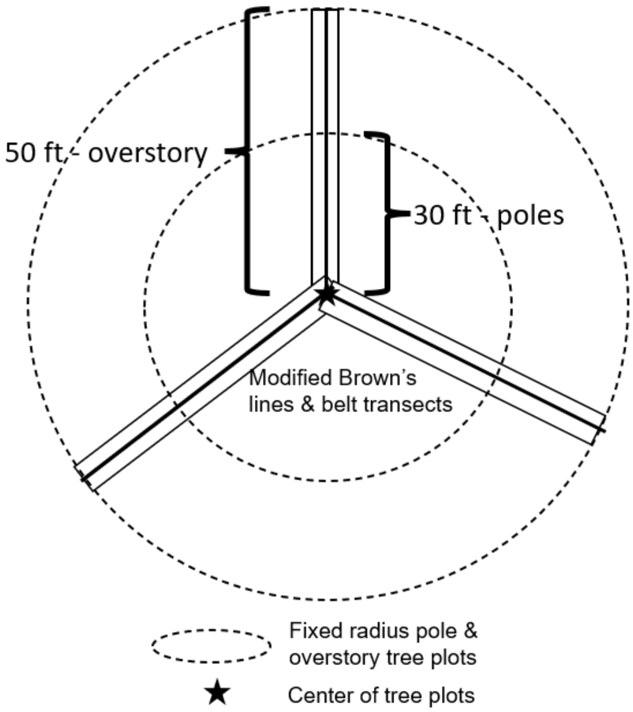


Figure 8. Fixed area plots for poles and overstory trees. Radii should sample about 10 trees based on past FBAT data and field experience.

Pole trees defined by DBH size: DBH > 1 in (2.54 cm) and < 5.9 in (14.99cm)

Overstory trees defined by DBH size: DBH > 6 in (15.24 cm).

A range of information is noted for each tree before fire, much of it from the NPS Fire Monitoring Handbook (https://www.nps.gov/orgs/1965/upload/fire-effects-monitoring-handbook.pdf). For each tree collect:

- FIA species code (search here for FIA species codes).
- Dead or alive.
- Live crown position: NPS codes 1-5 codes where 1 = dominant, 2 = co-dominant, 3 = Intermediate, 4 = subcanopy, 5 = open growth/isolated.
- Mortality phase: G = green/live, Y = yellow needles/recently dead, R = red needles, G = grey phase.
- Snag condition and top diameter: Codes 1-5, which is equivalent to the NPS 6-10 codes (see NPS Fire Monitoring Handbook linked above). Snag class: 1=recent snag (gray phase), 2=loose bark snag, 3=clean snag, 4=broken > BH (breast height), 5=broken <BH. Estimate top diameter to improve accuracy of biomass estimates.
- DBH using logger's tape (graduated in inches and 1/10ths of inches).
- Total Tree Height (feet) – re-measure post-fire if warranted.

- Height to Live Crown: Use laser to measure height to lowest living crown vegetation that is at least a 30º wedge of 360º circumference and continuous with rest of canopy (i.e. not an isolated epicormic branch). See Figure 9 for definition. Record in feet.
- Basal duff depth for overstory trees – average of min and max depth.
- Use Appendix D (NPS tree damage codes) to code pre-fire tree conditions. Put these codes in the comments section for each tree.

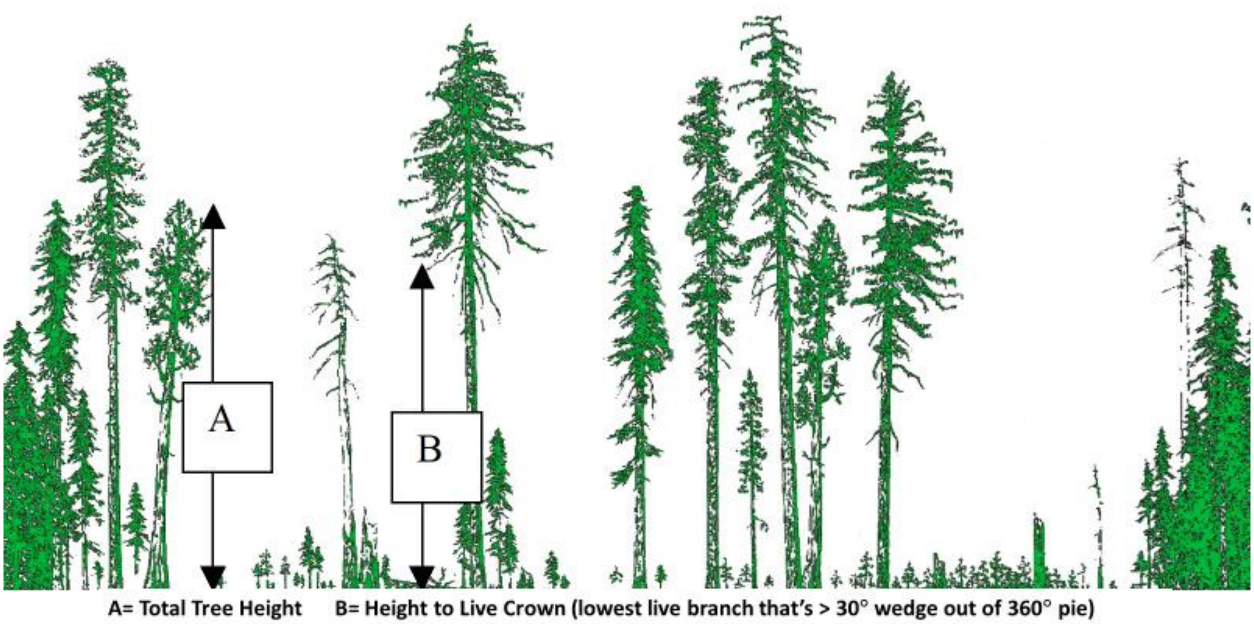


Figure 9. Height to live crown defined. Drawing by Robert Van Pelt (see Aber et al. 2000).

Infrequently, you will have a multi-stemmed or a leaning tree. For a leaning tree, determine breast height by measuring along the leaning trunk. You will need a DBH for each stem where there are multiple stems (Figure 10). If there is a coppice-like growth form with many stems arising from ground level, you may choose to measure one representative stem and note number of stems for entering as separate stems later.

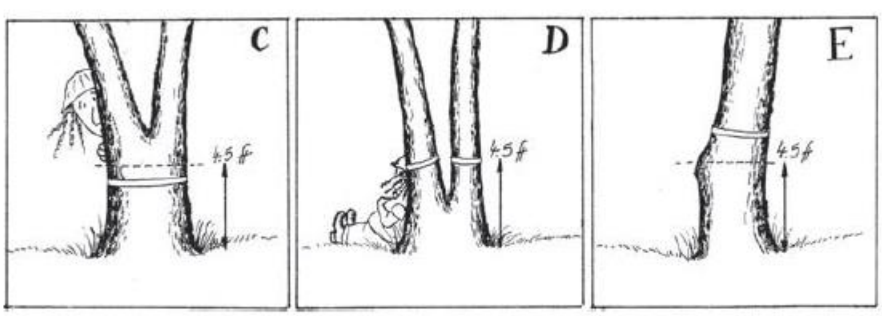


Figure 10. DBH measurements from FIREMON guide (RMRS-GTR-164, 2006). C. If the tree splits above breast height measure tree diameter below any swell caused by the separation. D. If the tree splits below breast height measure as two trees (or however many). E. Measure the most representative diameter above or below any deformity.

ACTIVE FIRE MEASUREMENTS

Note: I include optional soil sampling in this section because it is associated with soil heating measurements.

Rate of Spread

Launch Madgetech thermocouple loggers evening before plot setup (see Appendix E).

1. Set laptop time to UTC so that FBP, camera, and ROS fire-arrival data are consistent.
2. Use newest MadgeTech loggers because they store more data (1,000,000 which will give you 23 days at 2 second logging interval). Old ones are TC110's while new ones are TC101A's.
3. Follow launching procedures detailed in Appendix E.
4. Put Madgie in canister, record canister and logger #, and put canister at least 6'' below soil.

Set out thermocouples in a "baseball diamond" pattern. Mark locations with rebar or chaining pins. Tree plot re-bar offset from fuel transect center rebar 10 ft at 60 degree azimuth (ENE). Adjust as needed. Central thermocouple with four other ones each in a cardinal direction at 50 feet from the center. Minimum measurement is azimuth and distance from center. If possible, measure distances among outer thermocouples. Record on datasheet. Be cautious of fuel trampling. Retrieving MadgeTechs in field, downloading data back at camp:

1. Follow stopping (battery saving) and downloading instructions in Appendix E.
2. Re-launch if appropriate

Video

The FBAT camera (Figure 11) consists of an outer hard (aluminum) box and internal sub-box containing a video recorder and a trigger circuit for activating the camera (other triggering methods are possible). In heavy fuels, use the insulation cover composed of two layers of fire shelter material and one layer of insulation. In all cases, use an outer layer of highly reflective food-service grade aluminum foil as a solar radiation shield and sacrificial layer. Use wire to secure as needed. The camera remains in standby mode until a wire circuit is broken. The camera will record for about 6-8 hours on a fully charged battery, depending on the ambient temperature.

Figure 11. Camera on tripod with trigger wire.

Prepping the camera

1. Formatting the SD Card: Do not use "Quick Format" - un-check the Quick Format box (Figure 12). Choose FAT32 (Default) and 8192 allocation unit (block) size. Card should not be larger than 32 GB. You can choose a volume label if you know the camera the SD card is going be used in. Formatting takes ~25 min to format.
2. Remove the top plate and insulation.
3. Switch to the charging position (righthand switch down as viewed in Figure 13).
4. Find the white charging connector and connect one of the supplied chargers to it. The red light on the charger should light up, and it will go off when charging is complete.
5. The SD card (full size) is inserted in the recorder where shown in Figure 13. Make sure the card is empty or newly formatted as the images take up a lot of space.
6. Testing camera: if running for less than 15 min, press "Stop" on DVR so the data get written to SD card. Otherwise, you will think the camera isn't working.

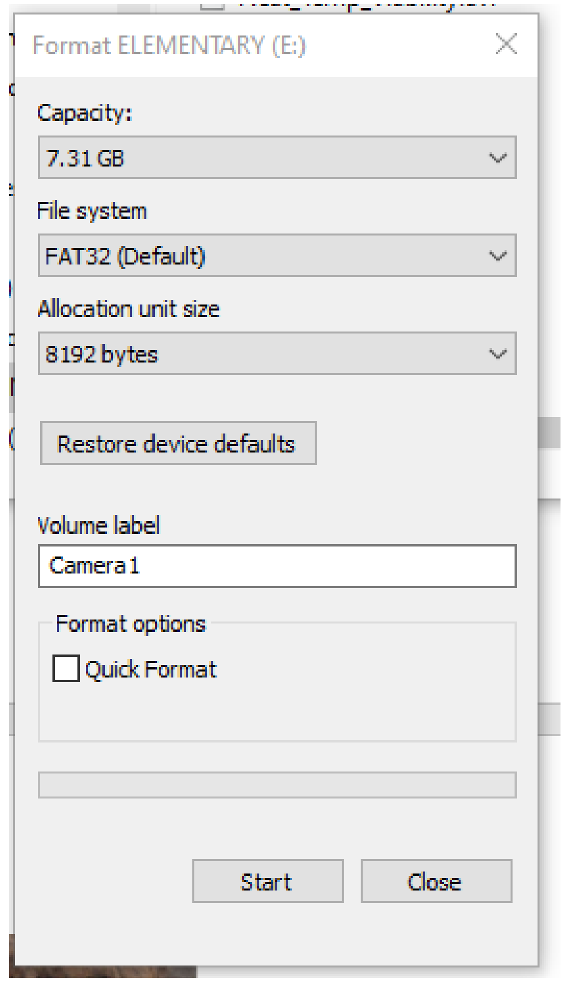


Figure 12. Formatting options that appear when you right click on the SD card's icon in Windows File Explorer and choose "Format…".

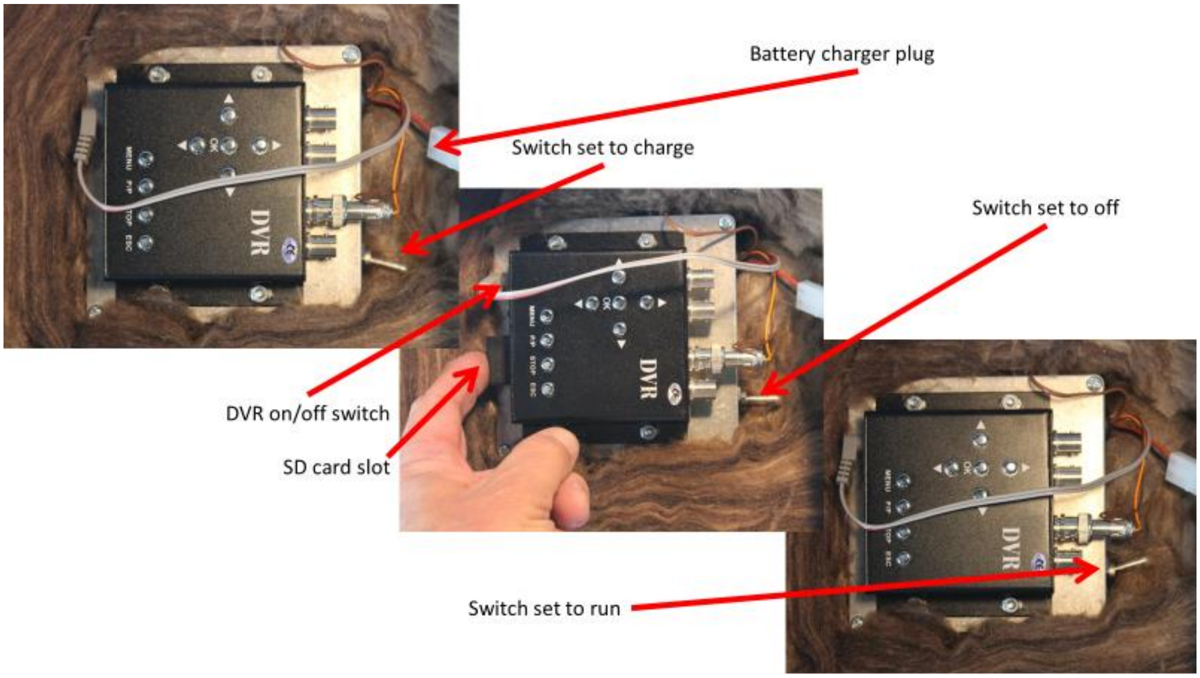


Figure 13. Top left – Run/Off/Charge switch set to charge; middle – inserting SD card and making sure DVR on/off switch is set to "on"; bottom right – Run/Off/Charge switch set to run ready for launch.

Setting up the camera

1. Fill out all information about the camera on the datasheet (camera number, view azimuth, distance to standards, etc.).

2. Set video camera on the margin of the plot so that the it looks out over the center of the fuel transects (Figure 1). Place the video camera to maximize the likelihood that the fire will spread through the plot in a direction perpendicular to the camera's orientation; this simplifies rate of spread and flame length/height estimates. See Figure 1 for general layout.

3. IMPORTANT: camera is a surveillance camera with low resolution. The standards and anything else you want at high resolution needs to be close to the camera. Standards should be no more than ~20 ft from camera.

4. Ring the plot with the circuit wire, a thermistor placed at the junction of the beginning and ends of wire rolls. Connect the ends of the circuit to the ceramic plug that connects to the front of the box. The leads coming out of the plug should be fire-hardened so the wire doesn't fuse to the box shielding.

5. Open the box and remove the insulation on the switch side (see Figure 13). Put the switch into the 'Run' position.

6. You should hear the following: 10 short beeps indicating that the trigger circuitry and battery are OK.

7. If you hear long beeps repeated, it means the wire is broken already and needs to be repaired. Turn the unit off (either of the other two switch positions) and check the wire and repeat #3.

8. When the circuit is broken, by fire or for some other reason, the unit will beep twice a second to indicate that it is recording.

After the fire

Raw video is stored on the SD card which is housed inside the camera. The first step is to remove the SD card from the camera, and backup these raw video files in a safe place (at least 2 locations).

The camera is set up to save video to 15 minute long ASF files (Windows Media Audio/Video format). Depending on the length of the video for a given plot, there may be 1 to 2 dozen 15 minute long segments. Archival videos (full length and shorts) need to be created and information extracted (see the DATA ENTRY, ANALYSIS, AND ARCHIVING section, below).

A Brinno time-lapse camera may sometimes be used instead of or in addition to a video camera. The Brinno's can be protected in the last-generation camera boxes that have a large window. See the instructions on use at http://brinno.com/time-lapse-camera/TLC200Pro.

Fire Behavior Package

The Fire Behavior Package (FBP) consists of a fireproof stainless-steel enclosure and enough thermal insulation to prevent damage to the electronic components during fire exposure. The FBP contains sensors, signal conditioning, and recording electronics for monitoring the following fire parameters: incident radiant and total (radiant + convective) heat flux, vertical and horizontal flow velocity, gas temperature (used to estimate flow velocity).

Prepping the FBP

1. The small circuit boards in the 'parts' kit have a USB connector on one side and a socket for the battery plug on the other side. These are the LiPo battery chargers. Plug (up to 12) chargers into the USB power supply and insert the battery connector into the connector on the charging circuit board. The chargers are fully automatic and will charge the battery in a few hours.

2. Formatting the SD Card: FAT32, default allocation size, card should not be larger than 32 GB

Setting up the FBP on the plot

1. Set up the FBP on the tripod so that it faces towards the expected oncoming fire and is to the far side of the camera's field of view relative to the oncoming fire. Set the FBP up horizontally, not following the slope (e.g., pointed downslope) by adjusting leg lengths.

2. Remove the external cover plate by removing the thumb screws and remove the block of insulation.

3. Plug a battery into the battery extension and tuck it between the inner box and the insulation.

4. Insert a formatted microSD card into the extension that's attached to the lid of the inner box.

5. Plug in the GPS (after making sure it's been turned on long enough to "lock" onto its position). Have to plug in the GPS before inserting the start plug. Garmin GPS 73 works.

6. Insert the 'start up' plug from the parts kit into the other jack. You should hear one of the following:

    a. Good: One short beep if the battery is charged and the micro SD card is inserted in the unit, formatted and not corrupt. Then, six short beeps if the GPS is connected, locked and detected. The unit will have the position recorded and the time will be synched to the GPS clock (using UTC). Finally, after a pause, the unit will beep once a second each time a data sample is collected.

    b. Bad: Two long beeps if the GPS is not connected or not found. Make sure the GPS is on. Five long beeps if the GPS is connected but not locked. Wait a while and reinsert the start-up plug.

7. Once you hear good sounds in 6, unplug the GPS and reinstall the insulation and the cover plate.
8. Cover the FBP with the insulation wrap(s) as for the camera.
9. Install the two flow probes by sliding the tubing into the holes on the front of the box and sliding the silicone tubes over both the probe tube and the tube beneath into which the probe is inserted. Make sure that the upper tubes (horizontal flow) are about 1 inch behind the end of the lower tubes (vertical flow) to avoid interference. See Figure 14.
10. Install the Type K thermocouple probe and position the tip near the ends of the flow probes. CRITICAL: be careful of the thermocouple, the junction at the end where temperature is sensed is fine and delicate.

After fire

1. The microSD card will record for several years without overfilling. Each time the unit is started a new record is kept of the GPS position and starting time. These data are added to the one file on the micro SD card, DATALOG.CSV, so there is no need to download data if the unit is going to be redeployed, unless the data are needed immediately. To download the data, just copy DATALOG.CSV to another storage device. It is advisable to rename this file as all the files on all the FBPs are named DATALOG.CSV.
2. Recharge the battery and reformat the micro SD card

A supplied spreadsheet will be used to reduce the data – not currently available.

Wind

The FBP's and cameras are set up to receive an anemometer (Figure 14).

Launch the MadgeTech Pulse datalogger the evening before plot setup. Logger model is Pulse101A (latest model with same memory as TC101A, the new TC logger). A magnet opens a circuit and if the magnet stops over the gap, the circuit stays open until it moves again, this tends to suck power. You cannot do anything about this issue except to make sure that the battery level is not "low" when you launch. See Appendix E for launching loggers, process is similar for thermocouple (ROS) and pulse (wind) loggers. Set the time step to 2 seconds to give 24 days of logging. Make sure your computer time is set to UTC (Greenwich Mean Time).

Screw the anemometer to the box by the top middle screw on the box cover. The bottom hole on the anemometer arm fits over the dimple on the box. Stuff the MadgeTech logger between the side of the inner box and the insulation so it doesn't move. Protect the cable as needed. The anemometer leads should have been shortened from factory length and fitted with a green plug (a MadgeTech plug) that fits into the logger.

Figure 14. FBP with pressure tubes and anemometer installed. The plug on the front that's visible is where the thermocouple probe is plugged in. The bubble wrap protects the face of the incident heat flux sensor (remove the bubble wrap).

If time allows and RAWS data aren't expected to be accurate, set up the Onset Weather Station near plots. Requires installation of drivers that required CHD support, see notes in PlotSamplingMaterials -> SamplingProtocols&Info -> OnsetWeatherStation.

Once you have plot wind data, convert the data file to excel. Calculate the average wind speed and maximum over a 20-minute period leading up to fire arrival at anemometer. Fire arrival is often determined by melting of the anemometer which results in wind=0 thereafter. Otherwise, use fire arrival at ROS sensors to approximate fire arrival time at the anemometer. Anemometers are attached to camera boxes but cameras do not record useable timestamps. Camera time can be "calibrated" by reference to fire arrival at ROS sensors visible in the video. Use calibrated time to determine fire arrival time at camera.

Soil Heating and Associated Soil Sampling

Soil heating is now a standard FBAT measurement. Whether we sample soils will depend on staffing. The protocols for soil sampling are in Appendix H because they are not done for every fire.

Launch the iButtons and set up the iStakes as described in Appendix G.

iStake installation

Install three iStakes (iButtons set in a wooden stake, Figure 15) each 2 ft in a perpendicular and clockwise (from overhead perspective) direction from the 24 ft mark on the tape (Figure 2). This will provide co-located litter/duff consumption for each iStake in case soil samples are not collected.

The fire-shelter flagging and wire help re-locate the stakes after fire, but they may disintegrate during intense fires or under deep duff layers. Take care to install the stakes at their standard locations and take careful notes if the location needs to be shifted in case of a rock or log.

For information on assembling iStakes and working with iButtons, See Appendix G - Setting Up iStakes and Launching and Downloading Data from iButtons.

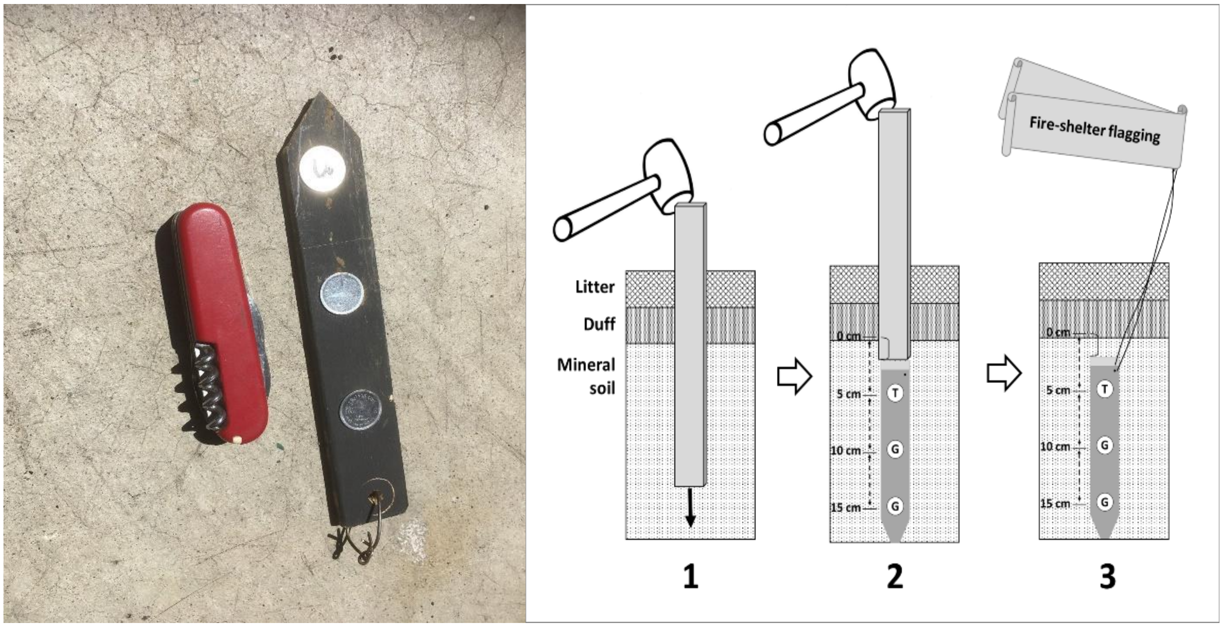


Figure 15. iStake design and installation method.

Install the iStakes:

1. Use the rubber mallet and steel insertion bar to make a pilot hole to 15 cm into the mineral soil.
2. Remove the steel bar and insert a pre-loaded iButton stake into the pilot hole until the top of the stake is 2 cm below the mineral soil surface. This places the iButton positions at 5 cm, 10 cm, and 15 cm into the mineral soil. If needed, use the steel bar and mallet to gently tap in the stake. Use caution here or the stake will break.
3. Smooth over the mineral soil surface and replace any disturbed duff and litter. Make sure the wire and flagging are well-exposed and visible.

Optional soil sampling

If soils are collected, pre- and post-fire samples will be located on either side of the iStakes. Because we won't be doing it every year, the soil sampling protocol is in Appendix H.

POST-FIRE DATA COLLECTION

Retrieve and back-up stored data on the MadgeTech loggers (ROS) and camera and FBP SD cards. See above for instructions.

Photos

Take pictures from both ends of the 50-foot transects (center tape at bottom of photo) both outwards from the center and inwards towards the center. Use pre-fire photos to guide framing so that the photos match up (Figure 16). Place the center of the plot closer to the bottom of the photos than shown in Figure 15 while imaging the transect and as much of the canopy as possible. Take a photo vertically from the center with the clip-on hemispherical lens.

Figure 16. Pre- and post-fire photos from center outward along transect.

Modified Brown's Lines

Repeat data collection along transect, from the outside of the plot (0 ft) working towards the center (50ft, the center rebar is 50 ft on all transects). Refer to 1000 hr pre-fire data to make sure measurements capture unconsumed fuel particles and don't result in added fuel.

Leave four (4) rebar because it helps with plot re-sampling. Only 50% of old FBAT plots were re-located in a recent re-sampling effort. This will help increase the success rate. Drive rebar into soil far enough to ensure that the rebar stays in place. Mark with flagging. Note on datasheet that you left 4 rebar.

Understory Vegetation

Repeat measurements on grasses/herbs and seedlings and sapling that were sampled pre-fire. Post-fire average height and % total coverage are measured to determine post-fire fuels that are used to determine consumption. See notes on pre-fire sample and on the datasheet for guidance as needed.

Soil/Substrate and Vegetation Severity

Record data on bottom of "Fuels & plot info" sheet that also includes the Brown's lines. Assessments of severity (in 6 classes ordered from unburnable to high severity) are made for each transect and for the plot area roughly defined by the extent of the fuels transects. Use the definitions found in Appendix F - Soil/Substrate and Vegetation Severity Coding Matrix. Classes are from the NPS Fire Monitoring

Handbook (http://www.nps.gov/orgs/1965/upload/fire-effects-monitoring-handbook.pdf). In training, compare your values with an experienced assessor to gain consistency.

Pole and Overstory Trees

Use pre-fire datasheets to locate poles and overstory trees. Repeat basal duff depth measurement for overstory trees. Use laser rangefinder/hypsometer to re-measure total height (if it has changed) and other heights. The total height would change if the tree was snapped off or if the top of the bole consumed (most common for snags). Record minimum and maximum height of bole char from the fire. Maximum bole char height is usually in the upslope position, and minimum bole char height in the downslope position, but not always.

Definitions of scorch and torch heights and percentages have created confusion in the past. We define affected heights and percentages as including both scorch (brown or otherwise injured) and torch (consumption). Estimate (using laser) average height of affected canopy and the percentage of the original canopy volume affected by fire. Then, estimate average height of torched canopy (again, using the laser) and the percentage of the original canopy that was torched. Percent scorched = % affected minus % torched. Since the objective of scorch height is to approximate the likely flame length that produced the >140 degree needle-killing heat, if you have a really odd scorch pattern (e.g., if only one side of the tree is affected), it might not really lend itself to estimating an average. In that case, code as NA.

See Appendix D for post-fire coding of tree condition.

Re-mark trees with forestry crayon if needed. Remember to leave GeoCaching tacks along the approach to the plot. These steps are intended to help increase the success rate of re-finding FBAT plots.

Soil Sampling

Use pre-fire datasheets to locate the iStakes. The location identity of each stake (position in the plot) and each iButton (depth measurement) is important for relating the temperature data to fuel consumption and other measurements. Put each removed stake into a small Ziploc-type bag, and label the bag with plot number, transect ID, and position on the transect.

If the stake is intact, grasp the sides of the stake and pull it carefully out of the ground. Make sure all iButtons are present. If any iButtons are loose or likely to fall out of the stake, use more ziploc bags or tape to keep the buttons separate and identified by depth (top = 5 cm, middle = 10 cm, bottom = 15 cm).

If the top of the stake is damaged (charred or broken), use a trowel to gently excavate around the stake and lever it up. Make sure to retrieve all three iButtons. Identify them via labeled bags as above. If you're unable to determine the iButton position, make a note of it on the bag(s) – if the plot burned, we will likely be able to identify the iButton depth when we download the data, by the temperatures they recorded.

Follow the same procedure even when plots did not burn. Data from unburned plots provide information about ambient soil temperatures and diurnal temperature fluctuations that can help us interpret data from burned plots.

DATA ENTRY, ANALYSIS, AND ARCHIVING

Use the data entry sheets from the last fire (or the last update) to make sure you have the most up-to-date structure and equations. Each kind of data has its own sheet. Update pivot tables to summarize data. Using a the "Data Entry Tracker" (an Excel file), the data squad boss maintains a list of datasets and whether data have been entered and quality checked and by whom. Intermediate and final datasets are kept by the data squad boss and backed up on the external harddrive. When available, back up on the FBAT BOX site for the appropriate year and fire (https://usfs.box.com/s/7l3tfcxye0r7yszok8r2enftierph4es).

Data analysis procedures are either encoded in the data entry sheets or are available in ancillary files. Most data summaries by plot are done by pivot tables in Excel that FBAT On-Callers should learn how to use. Not included in this document are a couple of lengthy how-to-analyze documents that are included with data entry sheets and other materials on the FBAT external harddrive and thumbdrives.

IAPs & Operations Maps

Because the NIFC FTP site is not intended to be an archive, the FTP site is purged periodically. Keep all IAPs and Operations Maps from the assignment and save with other FBAT data in the designated folder.

Rate of Spread

To calculate rate of spread, you must first determine fire arrival time at each thermocouple location. The most straightforward method is to use the time at peak temperature. If there is no obvious peak, use the time where the rate of temperature rise is highest, indicating flame arrival. Fire arrival time is also used in extracting information from videos and anemometers.

Rate of spread is calculated in the data entry spreadsheet ("ROS_Distances_5Sensors*.xlxs") that also contains guidance. You will need Julian day (number of days since January 1st). See: https://landweb.modaps.eosdis.nasa.gov/browse/calendar.html

Wind

Determine fire arrival time at the anemometer. If the fire was intense, it will be when the anemometer melted, an event followed by zero wind. Otherwise, check the fire arrival times at the anemometers and make a best guess as to when the fire arrived at the camera (often, that will be close to the time at which fire arrived at the nearest thermocouple. You may see a peak in wind speed when fire spreads by the camera. If not, use your best guess as to fire arrival time. Calculate the average wind speed for 20 minutes preceding fire arrival and the maximum during that interval. The calibration for wind speed (using Inspeed anemometers) is as follows:

$$Wind\ speed\ (MPH) = 2.5\left(\frac{Pulses}{Timestep}\right)$$

where each pulse (rotation of the cup anemometer) is 2.5 MPH and the timestep is usually 2 seconds (see Appendix E). Apply this equation in Excel as shown in the example spreadsheet. Enter summary into the appropriate spreadsheet.

Plot Photos

Download and name according to the file naming convention. File name will have this info: fire name, plot and transect number, direction, and pre- or post- fire. For instance: Summer_P1T1_0-50_POST. Copy photos into the table in the report's Appendix.

Soil Temperature

Download and name files according to the file naming convention described in Appendix G. Estimate peak temperature and background (pre-fire) temperature. Background will be the temperature just before the first sign of fire heating. Determine temperature rise as the difference between peak and background.

Creating Videos for Archiving and Analysis

Use the video (for plots where it is available) to describe general and specific fire information and create short videos for archiving on the FBAT website. A person with FEMO/FOBS/FBAN experience is best suited for this task or for training others on the task. Objectives: create one long video encompassing the fire's duration on the plot, create 1 or more video shorts, extract and record information from the videos. Create videos using a video editing package capable of converting and saving video to MP4 format (eg. Microsoft Video Editor, see Software Center on USFS machine)

Creating videos

The camera is set up to save video to 15 minute long .ASF files (Windows Media Audio/Video format). Depending on the length of the video for a given plot, there may be 1 to 2 dozen 15 minute long segments which need to be stitched together to create a single video file (MP4 format) containing the full length of video of the active fire as it burns through the plot, beginning when fire enters the plot, and ending as the flaming front exits the plot.

In addition, create 1 or more short (~30s) videos that capture general fire behavior on the plot and any notable fire phenomena that will help understand what happened on the plot. Typically, there are 3 clips of 30 seconds created for each plot, however the number of clips and the length of the clips can vary according to needs. For example if fire behavior is homogenous, then only one short clip might be necessary. If fire intensity varies significantly as fire burns through the plot, or if unique events occur (such as transition of fire type, or variation due to fuels or wind speed), then the videos can be made longer (1 to 2 minutes), or the number of short clips can be increased. Use the "VideoShorts" tab to record descriptive information about each video short, including a short narrative. You can see example video shorts here: https://www.fs.fed.us/adaptivemanagement/amset_videos.php.

As show in Figure 17, each video has text inserted to describe the following:

1) Fire Name
2) Plot Number, and clip identification (Full Video, Clip 1, Clip2, etc)
3) Start time (local) of that particular video clip in format: HH:MM:SS Timezone, Date

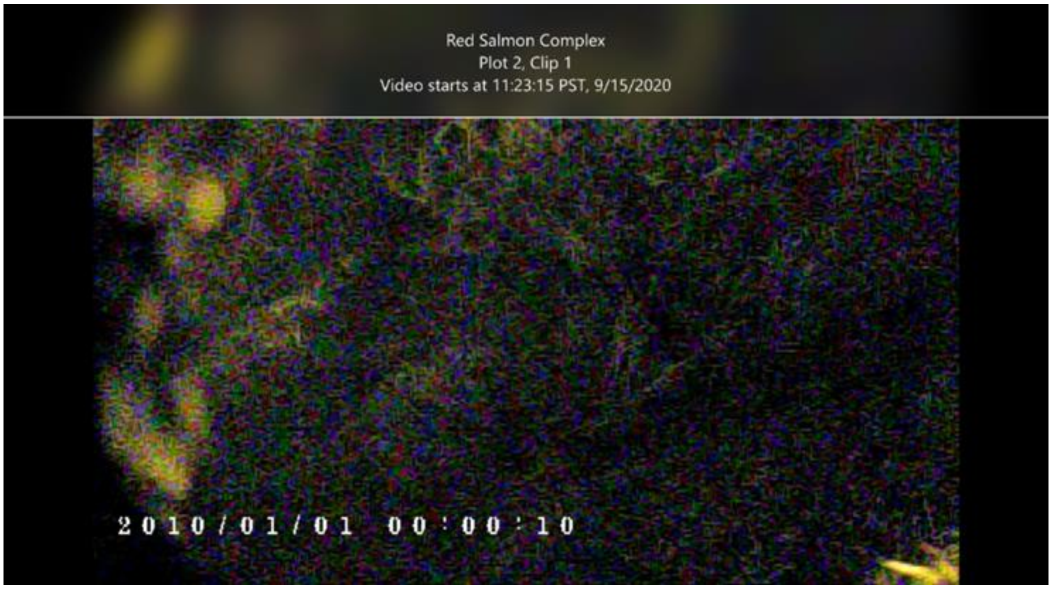


Figure 17. Video information inserted in text box.

Tips for adding text to video files:

1) Keep the font simple and professional (avoid animation)
2) Make the text large enough to read (including on a mobile device).
3) If possible, utilize a text box style which places a solid or opaque background behind the text so that text doesn't blend into the background (the text must be legible).
4) Display the text for the first 10 seconds of the video, then have it drop out so that it doesn't obscure the view of fire behavior.
5) To avoid text obscuring the video, consider adjusting the start time of the video, or the location of the text in the viewing frame.

Video analysis

Use the video (for plots where it is available) to describe general and specific fire-behavior related information. Use the spreadsheet "FBAT_VideoObsDATA_*.xlsx" to guide analysis of the videos (the file is found in the "MarterialsForAssignment" folder). Each plot will have a row in the VideoObsData tab in the spreadsheet. Detailed descriptions for each of the video observation variables can be found under the tab "VideoObsMetadata". Please review this metadata prior to video analysis. The data are used in analyses and to create tags that allow a user to search the video archive.

In addition to determining specifics on targeted variables, write a short descriptive narrative that explains fire behavior captured in the video. The narrative field can be used to help tell the story about the plot such as fire history, fuel treatments applied, and nuances about the weather, topography, and fuel type which might be difficult to capture with single word descriptors. Use narrative in the "plot narrative" portion of the report. The lack of an accurate video timestamp is a known problem. When referring to time, make the translation between video time (a relative time) and real time based on arrival at key locations (the time fire entered the plot, FBP, center, iStakes, etc.). Use local time for this purpose. For reference, the video records 1 frame per second. Note that times from fire arrival sensors (for rate of spread determination) and the soil iStakes are UTC.

Stand Characteristics

With a fixed-radius plot, tree density and basal area per unit area are calculated in the tree data entry spreadsheet. Average crown base heights are estimated in the pivot table. When we used variable-radius plots, we used FVS to estimate stand characteristics. Not having to use FVS simplifies data summary.

APPENDICES

A - Variables

Data Category	Metric/ Measure	Definition	Method	Units of Measure	Codes/Notes
Time	UTC	Time to GPS time (AKA UTC or GMT)			Set clock on laptops used to launch MadgeTech loggers
Plot Center	GPS point	Lat/Lon	Best GPS available	Decimal deg.	WGS84
Surface fuel	Slope & azimuth	Slope & azimuth of overall plot & fuel transects	clinometer & compass	% & deg.	
	1000 hr species	FIA code for each coarse woody debris particle (CWD) >3”			FIA Species Codes
	1000 hr status	Rotten or sound		R=rotten, S=sound	
	1000 hr size	Diameter		Inches	Count 0-50 ft of line
	1-hour fuels	Count of all 0-1/4 in fine woody debris (FWD)(search in litter!)	Go, no-go gauge	Count	Count 0-6 ft of line
	10-hour fuels	Count of all ¼-1 in FWD (search in litter!)	Go, no-go gauge	Count	Count 0-6 ft of line
	100-hour fuels	Count of all 1-3 in FWD	Go, no-go gauge	Count	Count 0-12 ft of line
	Duff depth	Reading at 1 & 6 ft	Ruler/tape	Nearest 0.5 in	Duff is F + H-layer (partly to highly decomposed material)
	Litter depth	Reading at 1 & 6 ft	Ruler/tape	Nearest 0.5 in	Litter is L-layer (fresh)
	Fuel depth	Highest particle intersecting vertical plane along tape	Ruler/tape	Nearest 1 in	Intervals: 0-6’, 6-12’, 12-18’

Variables, continued.

Data Category	Metric/ Measure	Definition	Method	Units of Measure	Codes/Notes
Surface fuels, cont.	Photos	6 total photos from 0 & 50 ft & 50 to 0 ft along each transect and one wide angle looking up	Imaging device		Tape end at center-bottom of photo, use pre-fire photo as guide for post-fire
Herb	% cover & alive & avg. height in 1 yd x 50 ft transect	Cover by qualitative class (e.g., all herbs, groundcover, tall herbs)	See % cover guide in Figure 7. Visually estimate average height	Height in inches	Don't go to species. Choose reasonable classes.
Grass	% cover & alive & avg. height in 1 yd x 50 ft trans.	Assign grasses to one or more Types & Density Classes	See % cover guide in Figure 7	Height in inches	See "Grass & Shrub Type & Density Classes" in Appendix B
Seedlings	% seedling cover & alive & avg. height in 1 yd x 50 ft trans.	Assign seedlings to one or more Shrub Types & Density Classes	See % cover guide in Figure 7	Height in inches	See "Grass & Shrub Type & Density Classes" in Appendix B
Shrub	% shrub cover & alive & avg. height in 1 yd x 50 ft transect	One row per species. Assign species a Shrub Type & Density Class	See % cover guide in Figure 7	Height in inches	See "Grass & Shrub Type & Density Classes" in Appendix B
Trees (poles & overstory)	Basal Area Factor (BAF) from prism	Fit 5-10 trees only	Relaskop	5, 10, 20, 40	Poles typically 5 factor, trees >=10 factor
	Species				FIA Species Codes
	Distance & azimuth	Measure or estimate as time allows			For tree re-location & mapping
	Height	Total tree height, see Figure 9	Hypsometer	Feet	To nearest ft
	Height to live crown	To first branch with >30º wedge of 360º pie, see Figure 9	Hypsometer	Feet	To nearest ft

Variables, continued

Data Category	Metric/ Measure	Definition	Method	Units of Measure	Codes/Notes
Trees, cont.	DBH	Diameter at 4.5'	Foresters tape or Biltmore stick	Inches	
	Alive/Dead	Judge by foliage color			
	Beetle sign	Yes or no			
	Mortality phase	G = green/live, Y = yellow needles/recently dead, R = red needles, G = grey phase			Used for FBAT work during 2012-2016 Sierra Nevada drought
	Condition class	1=G, 2=loose bark, 3=clean, 4=broken > BH, 5=broken <BH			From DOI Fire Monitoring Handbook, Figure 50 and Table 18.

B - Grass and Shrub Type and Density Classes

From Burgan and Rothermel (https://www.fs.usda.gov/treesearch/pubs/29616) and available in the FBAT clipboards.

APPENDIX A: GRASS AND SHRUB FUEL TYPES

The photos in this appendix are meant to illustrate the general morphology for broadly different types of grasses and shrubs. That is, any set (page) of grass or shrub photos represents a **large** variety of grass or shrub species. One must select the photo that best fits the actual conditions at hand.

To help you visualize the general plant morphology each grass and shrub type is meant to represent, the specific species photographed are listed below:

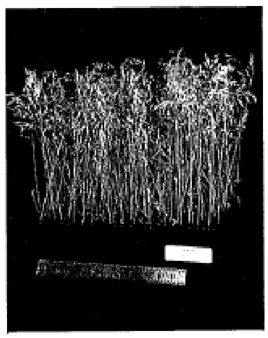
Photo page	Species photographed	Morphology represented
Grass Type 1	Cheatgrass *Bromus tectorum*	Fine grasses
Grass Type 2	Rough fescue *Festuca scabrella*	Medium coarse grasses
Grass Type 3	Fountaingrass *Pennisetum ruppeli*	Coarse grasses
Grass Type 4	Sawgrass *Mariscus* spp.	Very coarse grasses
Shrub Type 1	Huckleberry *Vaccinium* spp.	Fine stems, thin leaves
Shrub Type 2	Ninebark *Physocarpus* spp.	Medium stems, thin leaves
Shrub Type 3	Ceanothus *Ceanothus* spp.	Medium stems, thick leaves
Shrub Type 4	Chamise *Adenostoma* spp.	Very dense, fine stems and leaves
Shrub Type 5	Manzanita *Arctostaphylos* spp.	Thick stems and leaves

GRASS TYPE 1

DENSITY 1

DENSITY 2

DENSITY 3



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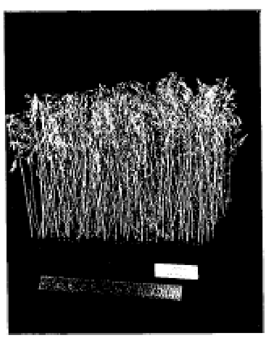

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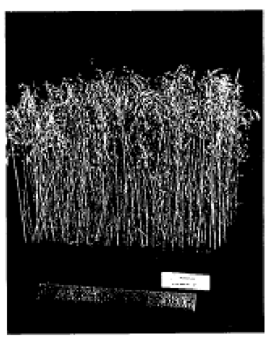
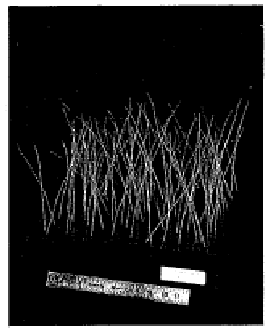


DENSITY 6

GRASS TYPE 2



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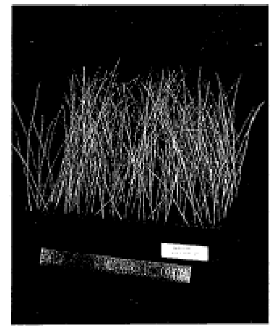

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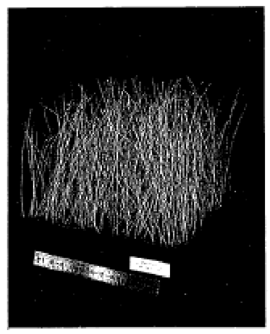

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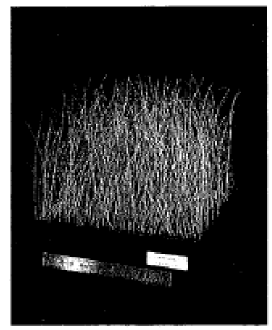

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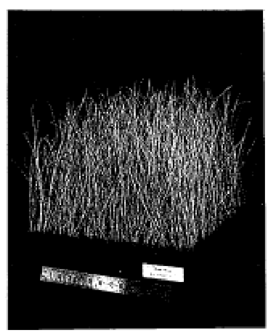

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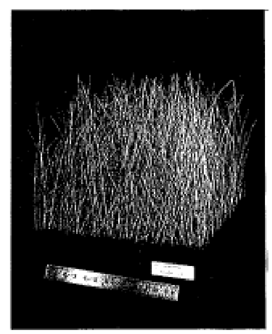
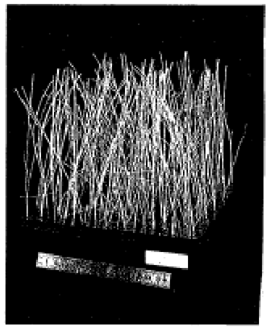


DENSITY 6

GRASS TYPE 3


DENSITY 1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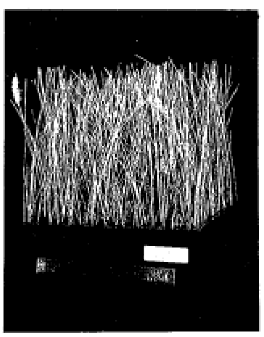
DENSITY 3


DENSITY 4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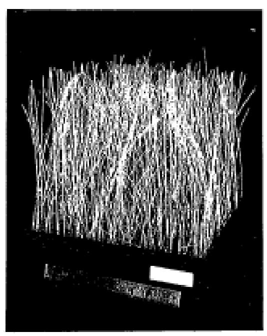
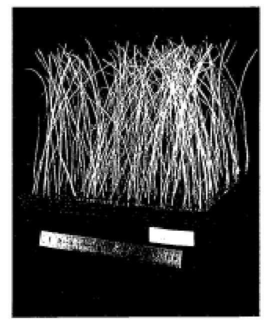

DENSITY 6

GRASS TYPE 4


DENSITY 1


DENSITY 2


DENSITY 3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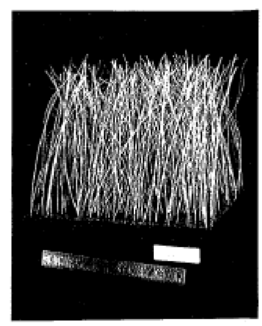
DENSITY 5

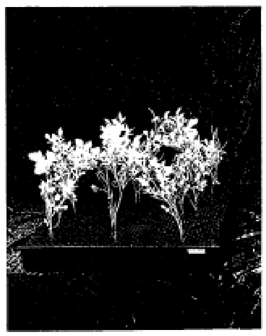

DENSITY 6

SHRUB TYPE 1

DENSITY 1

DENSITY 2

DENSITY 3

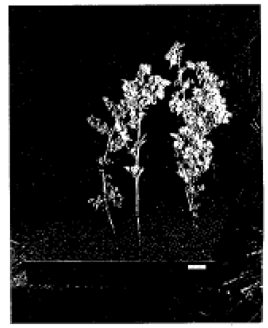


DENSITY 4

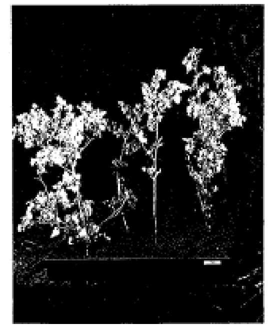
DENSITY 5

DENSITY 6

SHRUB TYPE 2



DENSITY 1



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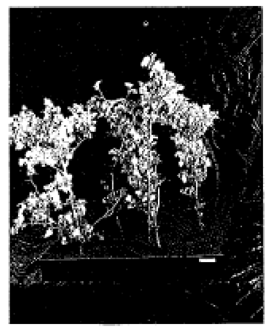

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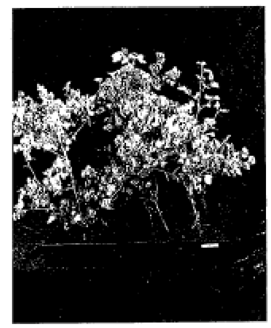

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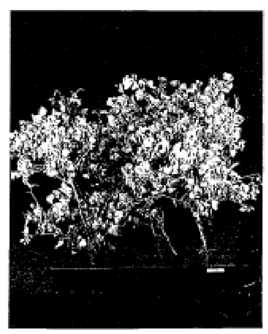

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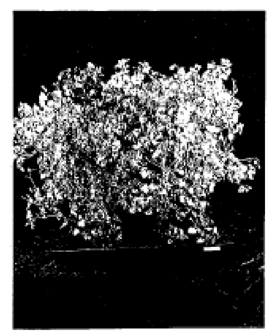

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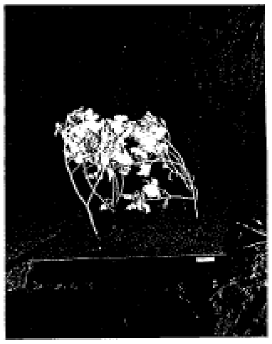
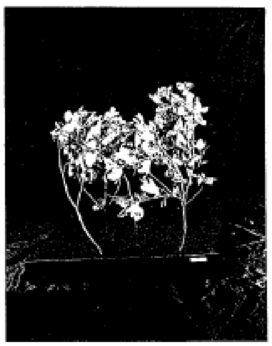


DENSITY 1

DENSITY 2



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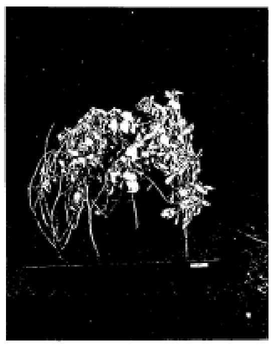

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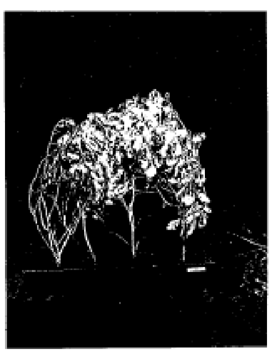

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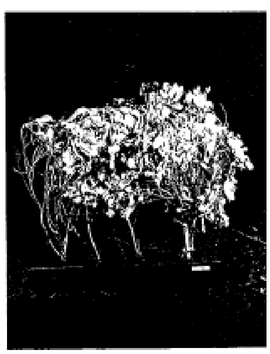

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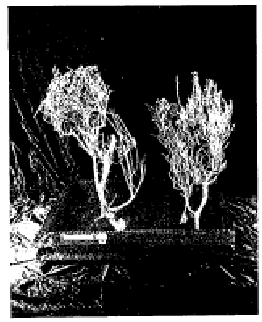
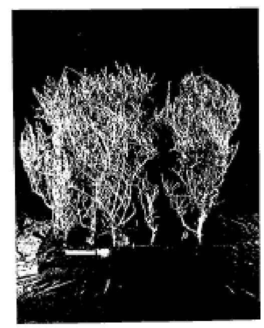
SHRUB TYPE 4



DENSITY 1

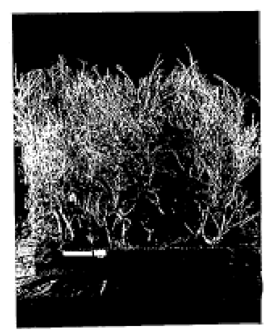
DENSITY 2

DENSITY 3



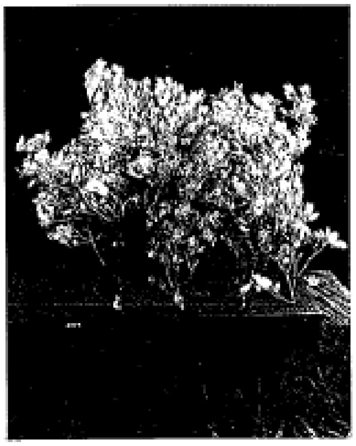
DENSITY 4

DENSITY 5

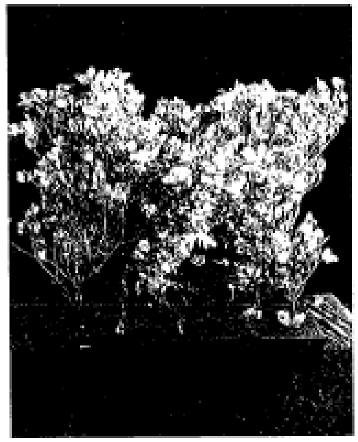


DENSITY 6

SHRUB TYPE 5



DENSITY 1



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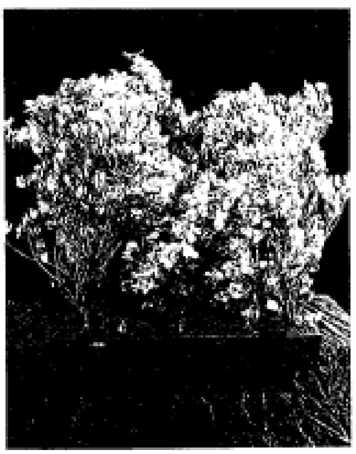
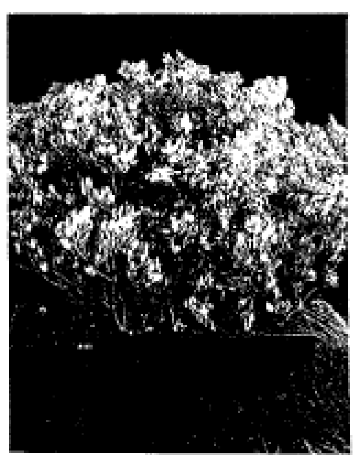


DENSITY 3

DENSITY 4

DENSITY 5



DENSITY 6

C – TruePulse Laser/Hypsometer Cheat Sheet

TruePulse Laser Cheat Sheet

For reference- there are 3 buttons, the On/Fire is located on top and is used to Turn the Laser on and also to Fire the Laser for you measurement. The other 2 buttons are located on the left side and are used to scroll through the advanced setting.

1. Turn the Laser on: Push the On/Fire button.
2. HD (blinking) and HT should be on lower screen, if not, use scroll buttons to find this setting.
3. Take the HD (horizontal distance) measurement by aiming at the bole of the target tree at eye level and holding down the On/Fire button. This distance will be given in meters. This measurement is the only one that needs a **clear** view of the bole of the tree. Branches and brush in the way will shorten the reading distance causing the final tree height to be inaccurate.
4. For the Angle 1 measurement, aim at either the Top or Bottom of the tree (Angle 1 is displayed at top of screen as Ang_1 and INC will be blinking). Hold down the On/Fire button. This will be measured in Degrees.
5. For Angle 2, repeat step 4 but aim at opposite end of tree as in previous step. (Angle 2 is displayed at top of screen as Ang_2 and INC will be blinking).
6. The Height of the Tree (HT) will be displayed at the top in meters when HT is visible at the lower right of screen.
7. The Laser can be turned off by holding down both scroll buttons or after 1 minute of inactivity.

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7. The Laser can be turned off by holding down both scroll buttons or after 1 minute of inactivity.

D – Tree Damage Codes

Tree damage codes are used for the pre- and post-fire pole and overstory tree sample. Pre-fire codes are the NPS codes from Table 19 (pp 96-97) in the Fire Monitoring Handbook, found at: https://www.nps.gov/orgs/1965/upload/fire-effects-monitoring-handbook.pdf. NPS Snag class and tree position codes are also entered, see the notes on the tree data collection spreadsheet for guidance. Note that snag codes are re-ordered for FBAT. Several post-fire codes from the Yosemite Forest Dynamics Plot mortality survey are provided for use when applicable. Make notes if no category fits or for other unique types of damage.

PRE-FIRE

ABGR: Abnormal growth pattern for the species of concern. This category would include a range of physical deformities not included in the remainder of the damage codes.

BIRD: Bird damage such as woodpecker or sapsucker holes.

BLIG: Blight is generally defined as any plant disease or injury that results in general withering and death of the plant without rotting. Blight can result from a wide variety of needle, cone, and stem rusts, as well as canker diseases, and is often species- or genus-specific. Consultation with local plant pathologists may assist in identifying specific blight conditions.

BROK: Broken top of the tree.

BROM: Witches' broom diseases are characterized by an abnormal cluster of small branches or twigs on a tree as a result of attack by fungi, viruses, dwarf mistletoes, or insects. Brooms caused by dwarf mistletoe and from yellow witches' broom disease are common in the west.

BURL: A hard, woody, often rounded outgrowth on a tree. This occurs naturally in some tree and shrub species and is a sign of an infection or disease in other species.

CONK: The knobby fruiting body of a tree fungal infection visible on a tree bole, such as a shelf fungus.

CROK: Crooked or twisted bole for species in which this is uncharacteristic.

DTOP: Dead top.

EPIC: Epicormic sprouting, adventitious shoots arising from suppressed buds on the stem; often found on trees following thinning or partial girdling.

EPIP: Epiphytes present.

FIRE: Fire scar or cambial damage due to fire.

FORK: Forked top of a tree or multiple primary leaders in a tree crown for species in which this is uncharacteristic. Forks assume vertical growth and should be distinguished from branches, which assume horizontal growth.

FRST: Frost crack or other frost damage.

GALL: Galls found on stems, leaves or roots. Galls are formed by infection of the plant by bacteria or fungi, or by an attack by certain mites, nematodes, or insects, most notably wasps.

HOLW: Hollowed-out trees. Repeated hot fires can burn through the bark and the tree's core may then rot out, especially in trees with tough bark, but soft heartwood, e.g., sequoia, coast redwood. These hollowed-out trees are sometimes called "goose pens" because early settlers kept poultry in them.

INSE: Visible insects in the tree bole or the canopy, or their sign, such as frass, pitch tubes or bark beetle galleries.

LEAN: Tree is leaning significantly. If on a slope, tree deviates considerably from plumb.

LICH: Lichens present.

LIGT: Lightning scar or other damage to the tree caused by lightning.

MAMM: Damage caused by mammals, such as bear claw marks, porcupine or beaver chewings, and deer or elk rubbings.
MISL: Mistletoe is visible in the tree (as opposed to signs of mistletoe, such as broom, without visible mistletoe).
MOSS: Moss present.
OZON: Ozone damage. Ozone injury is often seen in the form of stippling or speckling on the leaves or needles of trees. This discoloration varies among species and ranges in color from red or purple to yellow or brown. Susceptible species often drop their leaves prematurely.
ROOT: Large exposed roots.
ROTT: A rot of fungus other than a conk, often associated with a wound or crack in a tree.
SPAR: Unusually sparse foliage for that species and size of tree.
SPRT Basal sprouting; new shoots arising from the root collar or burl.
TWIN A tree that forks below BH and has two or more boles. Use this code for tree species that typically have single boles.
UMAN: Human-caused damage such as axe marks, embedded nails or fence wire, or vandalism.
WOND: A wound to a tree that cannot be identified by one of the other damage codes, including wounds or cracks of unknown cause.

POST-FIRE
Physical causes
UPRT: uproot (note cause)
BSTEM: broken stem (note cause)
CDAM: crown damage (note cause)
Fire causes
BCOM: bole/stem combustion (small trees)
FMEC: roots/base/stem burned out by fire causing mechanical/structural failure

E - Setting up and Downloading MadgeTech Dataloggers for ROS and Wind

Obtain MadgeTech 4 Standard software from the "Materials for Assignment Folder" or download from: https://www.madgetech.com/software/madgetech-4-software/

NOTE - MadgeTech 4 software has been technically approved by USFS CHD: Reference number: CRQ000004044115

Once you have launched the temperature (thermocouple) and wind (pulse) loggers, place 5 thermocouple (model TC101A) and 1 wind logger (Pulse101A) in a single ziplock bag for use on each plot. [Do not use the TC110 loggers unless you have to, they don't hold enough data. If you have to use them, set the reading interval to 5 seconds.]

Thermocouple logger setup

STEP 1. Set laptop clock to UTC (also known as GMT). This way, the times for FBPs, cameras, and MadgeTech's will be synchronized.

STEP 2. Use USB Datalogger Interface cable to connect the MadgeTech datalogger to the computer. Open the MadgeTech 4 program.

STEP 3. Check battery level (green and yellow are OK, red is not). Batteries should last for multiple fires. If red, open up datalogger with Philips screwdriver. Do not strip the screws. If there are four connecter wires on battery: find the pair of connectors that are more widely spaced and break this pair off. Shorten the remaining pair of connectors and insert battery in datalogger, then light should blink once.

STEP 4. Under the Device tab in the data connection window the datalogger should appear and be labeled with correct serial number. Check the serial #.

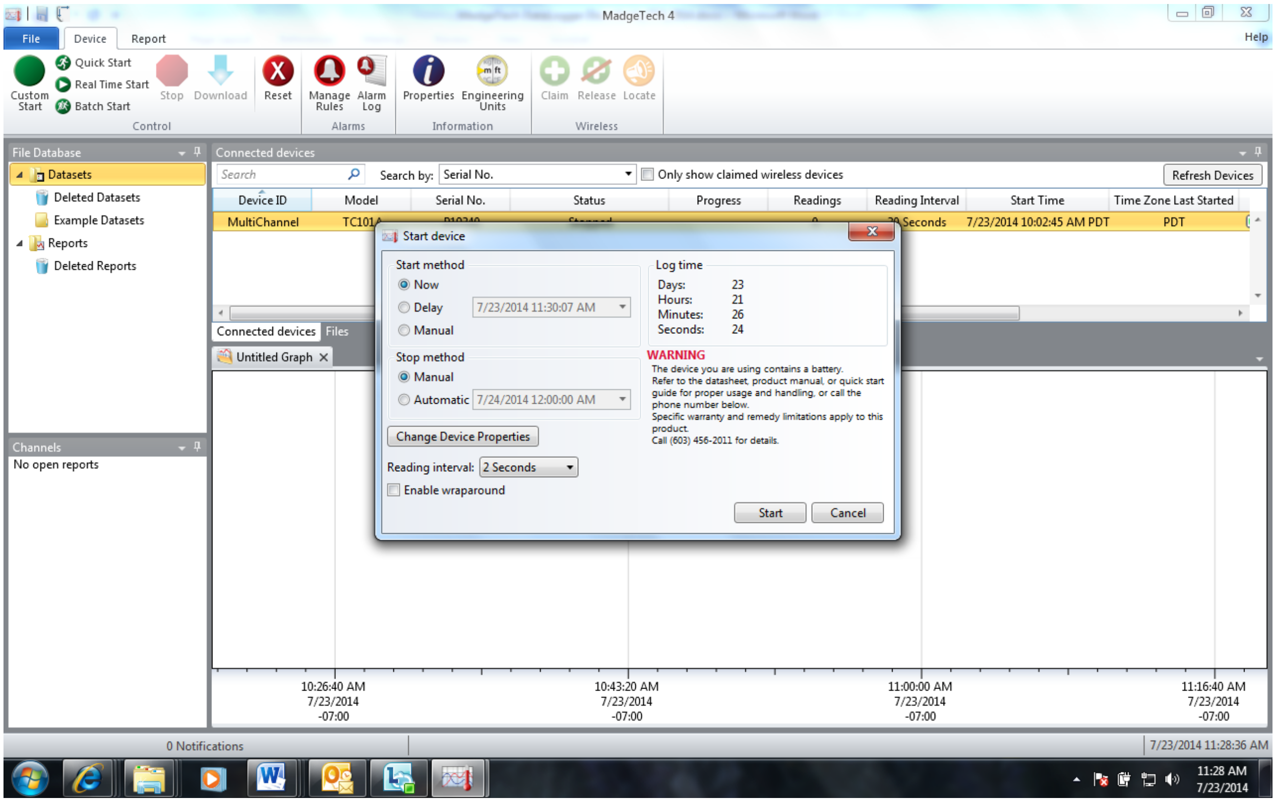
Troubleshooting connection issues.

1. Unplug and replug the madgetech.
2. Unplug and replug the USB connection.
3. Close MadgeTech program and reopen.

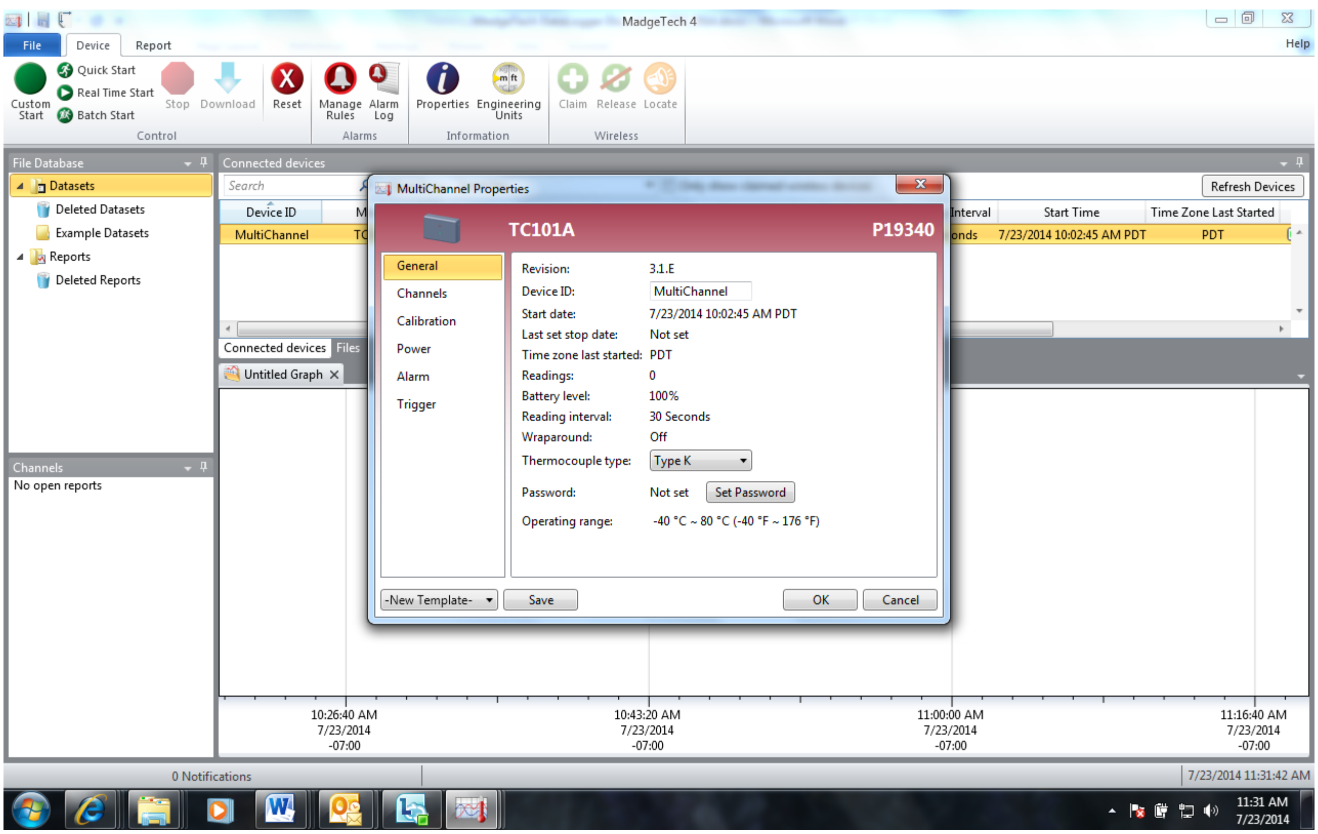
STEP 5. Select device and go to the Custom Start button on top left of Device tab.

STEP 6. Start method = Now or Delay if not deploying for several hours. Stop method = manual. Reading interval= 2 seconds.

STEP 7. Click the Change Device Properties. Make sure "enable wraparound" is unchecked so data aren't overwritten.



STEP 8. Be sure that the thermocouple type is set to Type K. Select Okay then Start.



STEP 9: When the device status is running unplug the datalogger.

STEP 10. Record Madgie serial #'s on data form, at the correct spot/base on the form.

STEP 11. Ideally you put the burnable duff/litter/sticks in a pile on a trash bag or in a bucket to save separate, so it's not filled with dirt when digging the hole. Put Madgie in canister and put canister at least 6'' below soil (deeper if thick duff will burn).

STEP 12. Position thermocouple so that flames will make contact. Add fuels around thermocouple if needed. Make sure that the fuels around the thermocouple are continuous with surrounding fuels.

Anemometer (pulse) logger setup

Step 1. UTC time

Step 2. Two (2) second logging to give ~24 days logging time

Step 3. Make sure "enable wraparound" is unchecked so data aren't overwritten.

STEP 4. When the download is complete a window will pop up to name the report. Use the serial number as a file name. A graph will load with the data. Make sure that both the ambient temp and thermocoupler data boxes are checked under the channels window at lower left. At this point it is easy to see where the spike in temperature may have occurred. Use the zoom tool under the reports tab if necessary to see the date and time of the temperature spike of the thermocoupler. Write this down.

STEP 5. In upper right corner go to Report Options and choose Export to Excel option. When the Excel file opens save the data as Plot#_Fire_Serial Number and as an excel file .xls.

STEP 6. In upper left corner of MadgeTech 4 go to file and choose save. Save under a folder labeled by fire name.

STEP 7. Check battery level. Replace battery if its low.

STEP 8. Relaunch if appropriate, otherwise unplug MadgeTech datalogger.

Downloading (both thermocouple and anemometer loggers)

STEP 1. Open MadeTech. Make sure you are under the Device tab at top of page. Device should automatically connect and appear under the connected devices window.

STEP 2. When MadgeTech connects the device will appear in the connected devices window and be labeled with the serial number. Make sure the serial number matches up with what the label. Choose the device in the window and then hit the Download button. A download progress should be indicated in the device window.

STEP 3. Click the "Reset" button to fully stop the logger (the red light should no longer blink).

F - Soil/Substrate and Vegetation Severity Coding Matrix

Modified from NPS Fire Monitoring Handbook (Table 28) – note that the scale is 0 (unburned) to 5 (heavily burned), the reverse of the NPS scale.

	Forests		Shrublands		Grasslands	
	Substrate (S)	**Vegetation (V)**	**Substrate (S)**	**Vegetation (V)**	**Substrate (S)**	**Vegetation (V)**
Unburned (0)	not burned	not burned	not burned	not burned	not burned	not burned
Scorched (1)	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; wood/ leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; leaf structures unchanged	foliage scorched
Lightly burned (3)	litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned; logs are scorched or blackened but not charred; rotten wood is scorched to partially burned	foliage and smaller twigs partially to completely consumed; branches mostly intact	litter charred to partially consumed, some leaf structure undamaged; surface is predominately black; some gray ash may be present immediately postburn; charring may extend slightly into soil surface where litter is sparse, otherwise soil is not altered	foliage and smaller twigs partially to completely consumed; branches mostly intact; less than 60% of the shrub canopy is commonly consumed	litter charred to partially consumed, but some plant parts are still discernible; charring may extend slightly into soil surface, but soil is not visibly altered; surface appears black (this soon becomes inconspicuous); burns may be spotty to uniform depending on the grass continuity	grasses with approximately two inches of stubble; foliage and smaller twigs of associated species partially to completely consumed; some plant parts may still be standing; bases of plants are not deeply burned and are still recognizable
Moderately burned (4)	litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches still present	leaf litter consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches (>.6–1 cm in diameter) (0.25–0.50 in) still present; 40–80% of the shrub canopy is commonly consumed.	leaf litter consumed, leaving coarse, light gray or white colored ash immediately after the burn; ash soon disappears leaving bare mineral soil; charring may extend slightly into soil surface	unburned grass stubble usually less than two inches tall, and mostly confined to an outer ring; for other species, foliage completely consumed, plant bases are burned to ground level and obscured in ash immediately after burning; burns tend to be uniform
Heavily burned (5)	litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred, and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas	all plant parts consumed, leaving some or no major stems or trunks; any left are deeply charred	leaf litter completely consumed, leaving a fluffy fine white ash; all organic material is consumed in mineral soil to a depth of 1–2.5 cm (0.5–1 in), this is underlain by a zone of black organic material; colloidal structure of the surface mineral soil may be altered	all plant parts consumed leaving only stubs greater than 1 cm (0.5 in) in diameter	leaf litter completely consumed, leaving a fluffy fine white ash, this soon disappears leaving bare mineral soil; charring extends to a depth of 1 cm (0.5 in) into the soil; this severity class is usually limited to situations where heavy fuel load on mesic sites has burned under dry conditions and low wind	no unburned grasses above the root crown; for other species, all plant parts consumed leaving some or no major stems or trunks, any left are deeply charred; this severity class is uncommon due to the short burnout time of grasses
NA	inorganic preburn	none present preburn	inorganic preburn	none present preburn	inorganic preburn	none present preburn

G - Setting Up iStakes and Launching and Downloading Data from iButtons

Overview

We have two types of iButton loggers. The two types are designed for different temperature ranges.

- High temperature i-Button (0°C to +125°C): https://www.ibuttonlink.com/products/ds1922t
- Low temperature i-Button (-40°C to +85°C): https://www.ibuttonlink.com/products/ds1921g
- The comm cable (iButton reader) and USB adapter: https://www.ibuttonlink.com/products/expressthermo-package

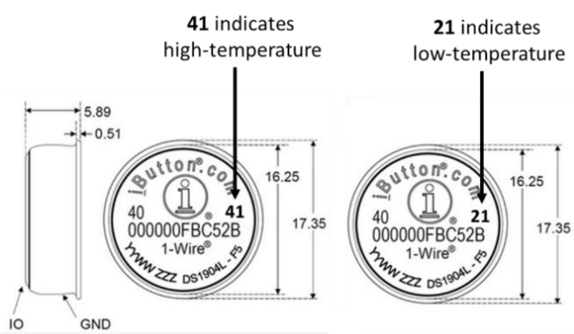
The FBAT temperature profile stakes (iStakes) use a high temperature (type T) iButton at 5 cm and a low temperature (type G) iButton at each of the 10 and 15 cm holes. The letters are part of the model ID but for FBAT you can think of them as indicating TOP (T) or GROUND (G) positions in temperature stakes. Buttons are marked with T or G with permanent marker. Refresh the marking when it starts to wear off.

You will need all of the parts below & to the right:

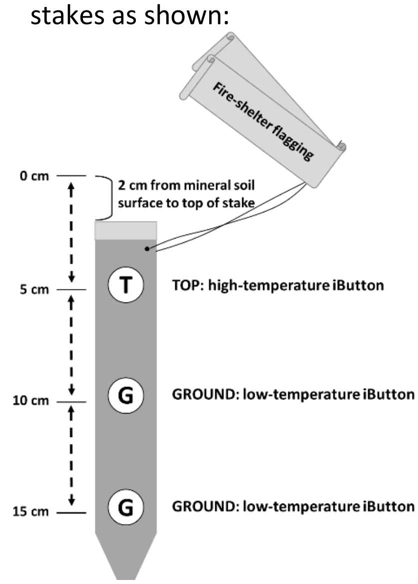
iButtons are easy to pop into the reader, but these clips are necessary to get them out. Make sure several are available because they stop working as their edges wear down.

You can differentiate between high- and low-temperature buttons by the number on the back:

- 41 = high-temperature (T)
- 21 = low-temperature (G)



Each button is fitted into holes in temperature stakes as shown:



Setting up the iStakes

Once you have launched the iButtons (see below):

- Prepare enough complete iStakes for each plot you expect to install each day. Fit one T and two G iButtons into each stake and bundle the total number of stakes needed for one plot into a ziploc bag (one bag per plot). Bring extra empty stakes as backups in case any break.
- Refer to the field installation instructions in the main text for pre-fire plot measurements.

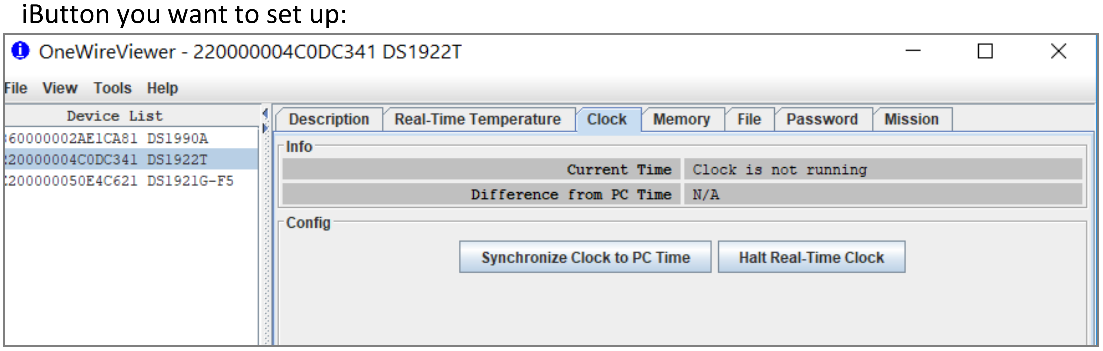
Installing software to set up logger missions

Starting and stopping logger "missions" is done through a software interface.

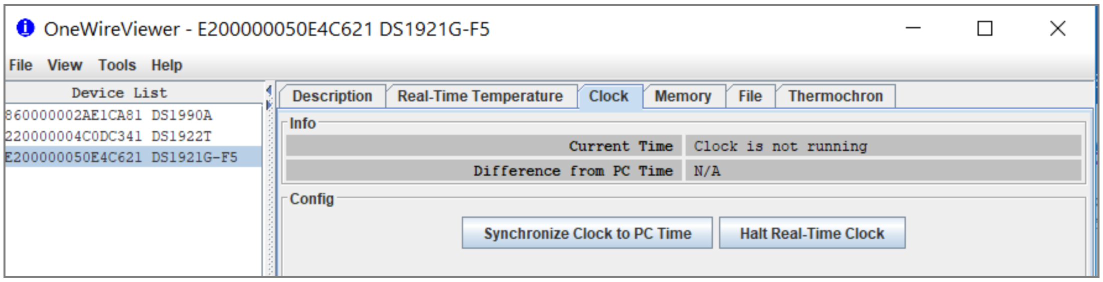
- The Maxim "OneWireViewer.jar" software is available as a free download here: https://www.ibuttonlink.com/products/maxim-1-wire-viewer
- The download provides a bundled viewer and drivers to install on your laptop.
- Note: if you are Federal, tell the computer support folks they are just drivers and that should circumvent the technical approval process
- You have to choose your operating system (e.g., Windows 10) and whether your machine is 32 or 64-bit (64-bit is standard for most USFS laptops).
- You have to have active version of Java on your machine
- Quick Start Guide: https://www.maximintegrated.com/en/app-notes/index.mvp/id/4373
- Be sure to have the drivers and software installed *before* you connect the USB adapter & iButton reader (otherwise the software will not get linked correctly to the USB adapter).
- Then plug in the USB adapter and follow the device installation wizard prompts.

Once you install the drivers, open the 1-Wire Viewer software:

- On Windows 10, 64-bit machine, go to the Windows start menu and click on the folder "1-Wire Drivers x64"
- Then double-click on "OneWireViewer.jar" to open software. The software requires Java to run. If it OneWireViewer.jar doesn't open (or if you're prompted to select a program to open it), make sure you have Java installed and that it is up-to-date, then try opening it again.
- Here's some useful information on communicating with the loggers and other information:
- https://www.embeddeddatasystems.com/Getting-Started-with-Thermochrons-and-Hygrochrons-using-1-Wire-Viewer_df_18.html
- Here's what the viewer looks like when open. Note that this shows two iButtons in the reader: one DS1922T (high temp) and one DS1921G-F5 (low temp). In the Device List panel, click on the iButton you want to set up:



- Notice that the high-temp iButton will show Password and Mission tabs (above) whereas the low-temp iButtons may only show a Thermochron tab (below):



Starting and stopping logger missions

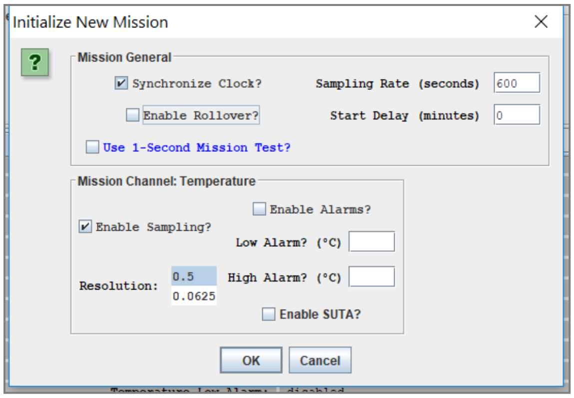
<u>>> Make sure your computer is set to UTC time so it is synchronized with all other FBAT gear!! <<</u>

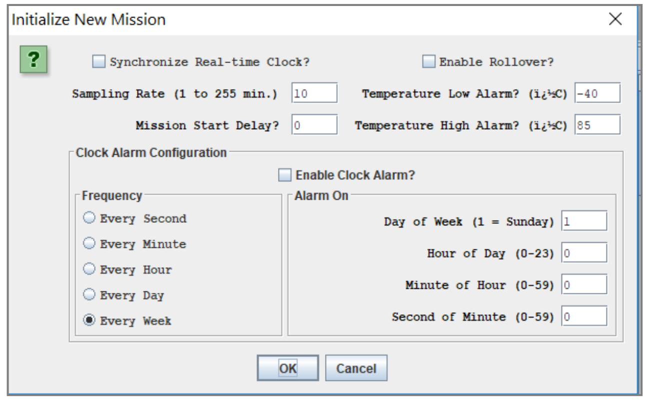
Each iButton can be missioned many times. The internal memory is overwritten when a new mission is setup, so make sure any needed data have been downloaded to avoid loss.

<u>To start a logger mission:</u>

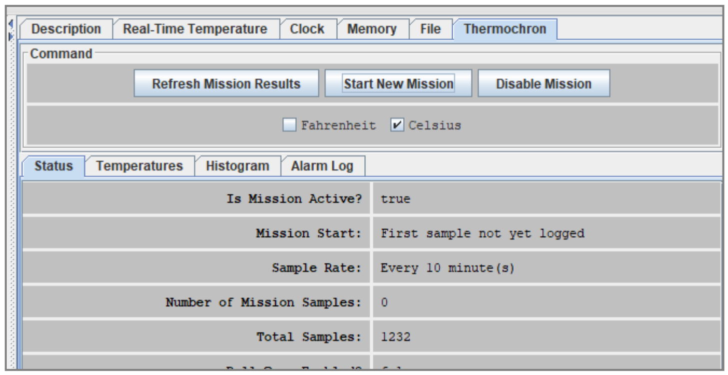
- Go to the Clock tab (see images above) and click "Synchronize Clock to PC Time." This turns on the iButton clock and will assign a time-stamp to each temperature logged. The current time (in UTC) will show up when you have successfully turned on the iButton clock.
- Go to the Mission tab (if T iButton) or to the Thermochron (if G iButton)
    - Make sure "Celsius" is selected, then click "Start New Mission." A dialog box will appear.
    - Unclick the "Enable Rollover" box to prevent data from being overwritten if the mission is long-term.
    - Mission start delay can be set to 0. This means the iButton will begin logging temperature immediately. Otherwise, set mission delay time in minutes (e.g., 24 hrs x 60 min/hr = 1440 min). Although not indicated on low-temp (G) iButtons, mission start delay is in units of minutes just like the high-temp (T) iButtons.
    - Unclick the "Enable Alarm" box.
    - What sample rate should you use? Let's allow for at least 14 days of logging and stick with the same logging interval for different depths. A 10 minute logging rate (600 seconds) will be OK for soils at ≥5 cm depth.
        - The high-temp iButton (DS1922T) can store 8192 measurements in a single mission. At a 10 min sampling rate, this provides up to 57 days of measurement.
        - The low-temp iButton DS1921G can record 2048 samples in one mission. At a 10 min sampling rate, this provides about 14 days of measurement.
    - Temperature resolution (only available for high-temp):
        - For the high-temp iButton (DS1922T), select 0.5 degrees C (this is the low-resolution option and increases the number of measurements we can take).
    - Do NOT click "Enable SUTA" or "Enable Alarms." SUTA means Start Upon Temperature Alarm, no.

<u>High-temperature iButtons:</u> *<u>Low-temperature iButtons (delay is in minutes):</u>*





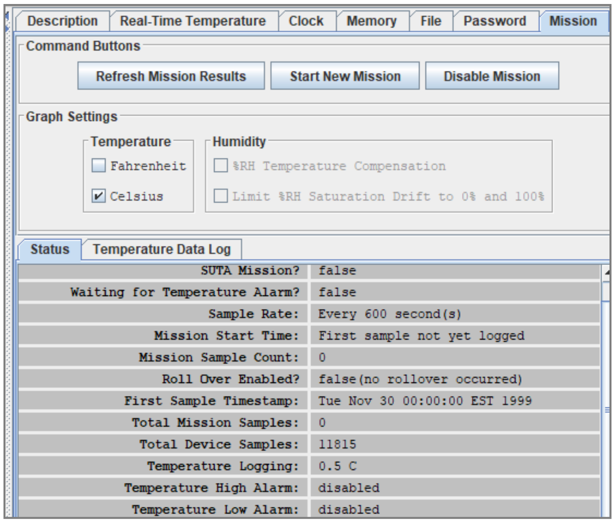
- Finally, click "OK." The dialog box will close. Check the Status tab to make sure "Is Mission Active" = true. This means the iButton mission has now been launched!

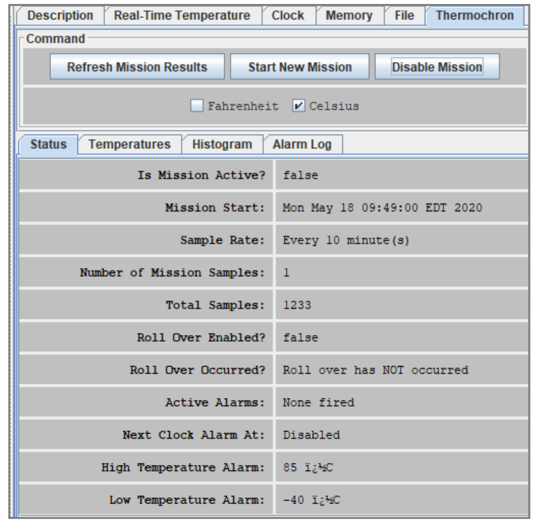


To end a logger mission

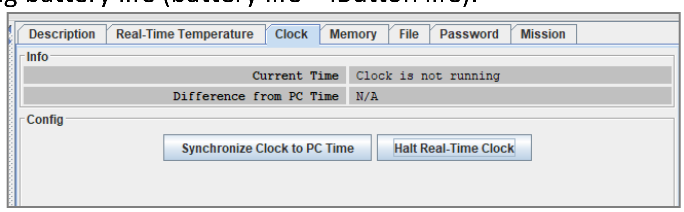
- After you successfully launch and have used the iButton in the field, pop the iButton into the reader. The iButton identifier number will show up in the menu on the left side of the window. Select the iButton you want to download.
- Go to the "Mission" tab (for high-temp iButtons), or to the "Thermochron" tab (for low-temp iButtons). Here you will see whether or not the mission is still active (true / false).
- Go to the "Status" tab and click "disable mission" to turn the logger off. The screenshot below shows the status after the mission has been disabled ("mission in progress" = false):

High-temp iButtons: *Low-temp iButtons:*





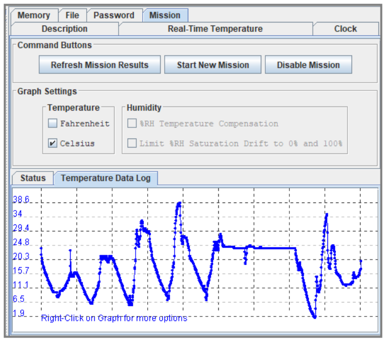
- **Remember to also go to the Clock tab and click "Halt Real-Time Clock."** Stopping the clock and disabling the mission are important for saving battery life (battery life = iButton life).
    - The "Current Time" will show "Clock is not running" when you have successfully stopped the clock:

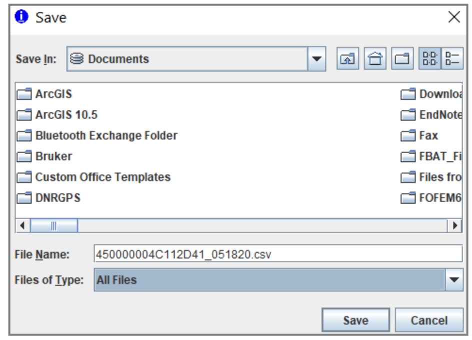


To download data

- After you have ended the iButton mission and halted the clock, then click on the "Temperature Data Log" (or "Temperatures") tab to see the graph. This tab will be inactive until the mission is disabled. You can right-click to rescale the graph in the viewer window.
- To download the data, right-click on the graph and choose "Save data to *.csv file".
- The CSV files must be named to retain their field location & soil depth identity. Use the following file naming format: **Plot#_Location_StakePosition&Type_iButtonSerialNumber_MMDDYY.csv**
    - Where **Location** = direction of corner at which the stake was installed (NE, SE, etc.).
        - (If stakes pulled from unburned plots are not separated by their installation location, indicate an unknown stake location at time of data download as X1, X2, X3, etc.)
    - **StakePosition&Type** = vertical position of the iButton in the stake (1 = top; 2 = middle; 3 = bottom) + iButton type (T = top; G = ground). Top = 5 cm below mineral soil surface; Middle = 10 cm below mineral soil surface; Bottom = 15 cm below mineral soil surface.
    - **iButtonSerialNumber** = the serial number automatically appears for the CSV data file name. It is important to retain this in case an iButton stops functioning so we can identify a faulty iButton to remove it from the supply cache.
    - **MMDDYY** = the data download date. It appears automatically in the CSV file name.
    - <u>*Example:*</u> Plot8_NE_2G_XXXXXX_0911819.csv is the middle G iButton from the NE corner of plot 8.

- If FBAT is detailed to more than one fire, save iButton data into separate folders named for each fire.





- Should you download data from iButtons installed in plots that did not burn? YES.
  - These data provide important information on diurnal ambient temperature fluctuations.
  - All iButtons need to have their missions disabled & clocks stopped, regardless of whether they were in burned or unburned plots.
  - Keep mission-disabled buttons separate from mission-enabled buttons.
  - At the end of an FBAT detail, double-check that all iButtons have been disabled and clocks stopped to preserve iButton life.

- How long will these iButtons last? iButton life = battery life.
  - The iButtons can be used until their internal battery is consumed. The battery is not rechargeable or replaceable, so turn the real-time clock off between “missions” to save battery life. Do this by “Halt Real-Time Clock” on the Clock tab (above). Turn the clock back on when launching “Synchronize Clock to PC Time”.
  - Total samples can help you determine if the logger is near finished. On the Mission (or Thermochron) tab, click the Status tab to get total samples info. We will need to use the spec sheets to ballpark when we should stop using an iButton. *Note: one of the DS1921G (low-temp) loggers had not been stopped and accumulated 536285 samples and was still running. All the rest were <10,000 samples.*

H –Collecting Mineral Soil Samples

Collecting physical samples of the organic (forest floor: litter + duff) and/or mineral soil is not a standard part of FBAT protocols and will be done only in partnership with researchers. Confirm details on measurements, sampling, and how to handle samples after collection with the research partner. Past soil sampling has been done in cooperation with Jessica Miesel (Michigan State University) and Erin Hanan (University of Nevada-Reno). Research partners will be responsible for providing the necessary sampling gear and supplies.

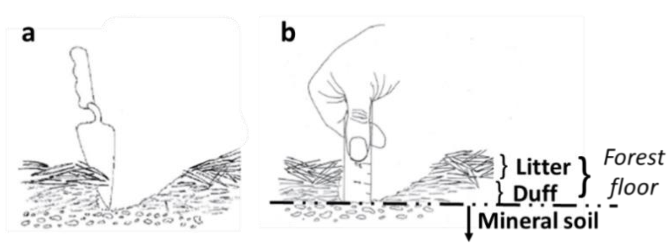
Soil Sampling Protocol

Background: Wildfire changes the amounts of carbon and nutrients in the soil. Soil burn severity level provides a rough index of the overall impact to forest soils. Forest soils are composed of forest floor (i.e., litter and duff) and mineral horizons. Because the forest floor is often consumed in wildfire, pre- and postfire samples will focus on the mineral horizon. Samples of the mineral soil helps us understand how much change the fire caused.

Definitions (following FFI and FBAT practice)

- **Forest floor:** this includes the litter + duff layers (see Figure G1). In soil science terms it is also called the soil "organic (O) horizon." It is derived from dead plant material. It is all the material on top of the mineral soil. *We remove woody material >0.25 in diameter. Do not include animal scat.* We use the FBAT definition of litter and duff:
  - ***Litter:*** The top layer of forest floor (AKA, L-Layer), composed of dead, fresh and minimally decomposed loose plant litter (recently fallen leaves, needles, pine cones, bark, etc.) that is detached from the parent stem.
  - ***Duff:*** The "duff" layer lies below the litter layer and above the mineral soil. Duff is both the partly decomposed material under the litter (AKA fermentation, F-layer) and the highly decomposed material for which you typically can't recognize origin (AKA humus, H-layer). The lower part of the duff often feels smooth or spongy and can be crumbly.
- **Mineral soil:** The mineral soil layer is formed from the weathering of rocks and/or deposition of mineral material by wind or water. It is a mixture of clay, sand, and silt. Mineral soils will typically feel gritty and are usually lighter in color than the duff layer (see Figure G1). The effects of fire decrease with depth into the mineral soil, so we are typically interested only in the top few inches of the mineral soil.

Figure H1. Use a trowel at a location <u>outside</u> the plot to familiarize yourself with how the texture and color changes between the duff layer and the mineral soil. This will help you know how to identify the boundary between the forest floor and mineral soil when you collect samples.



LOGISTICS

1. Avoid walking on the areas you plan to sample to avoid compressing the forest floor layer (compressing the forest floor will influence fire behavior).

2. Establish soil sample locations as close as possible to soil temperature sensors (iStakes). The goal is to relate soil heating to changes in soil characteristics which requires that the pre-fire sample have limited effect on iStake heating (see below).

3. Pre-fill the datasheet as much as possible before you start sampling, and make sure it is complete before you leave the plot. This is important for: re-locating locations post-fire, connecting soil samples to plots and soil temperature data, and interpreting ecosystem response to fire.

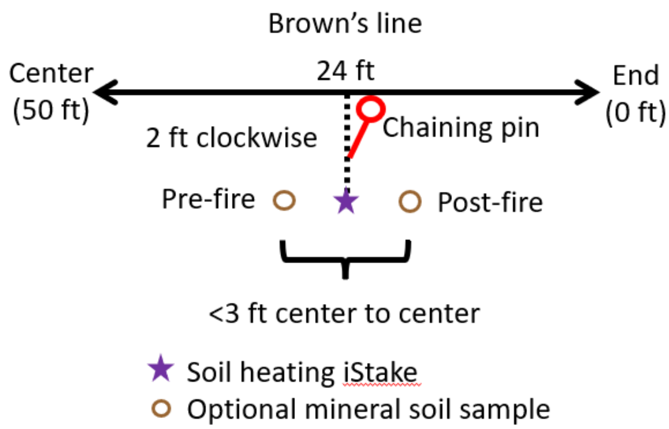


Figure H2. Layout of soil heating iStake and optional mineral soil sample. Repeated for each transect. Clockwise is relative to the center. Pre- and post-fire locations should have similar pre-fire characteristics.

Materials and supplies needed

1. Backpack for carrying all gear & samples to/from plots: keep everything below organized to avoid losing small tools
2. Compass
3. Tatum/clipboard
4. Datasheets
5. Mechanical pencils (several)
6. Black sharpie permanent markers (several)
7. Camera
8. Soil corer (note the core diameter and number of cores per subplot needed by the research partner)
9. Rubber mallet
10. Chaining pins (3) to mark the iStake location with fire shelter flag (will be in gun case, see Ops Guide)
11. Pin flags (3 per plot to leave in place post-fire)
12. Sampling bags (6 per plot, plus extras):
    - Ziploc-type storage bags for mineral soil samples (1-quart size, storage or freezer type)
    - Brown card stock or paper bags for plot label for photo
13. iStakes (Temperature devices), 1 set per transect

- *Depends on objectives or resources: iButton stakes, vs Madgetech dataloggers & thermocouples*

14. Soil screen (1/4” mesh) & trowel if needed for finding iButtons after fire
15. Small/Medium stuff sacks for keeping sampling tools together
16. Large stuff sacks for bundling all samples
17. Large bin, box, or heavy-duty garbage sack for securing samples in the vehicle

Where to sample

1. Plan to sample forest floor & mineral soil at three locations per FBAT plot. The locations are on either side of the iStake at 24 ft on each fuel transect (see Figures 2 and H2).
2. At each sampling location, the goal is to collect the pre-fire and post-fire samples in as close proximity to the iStake as possible (within 1.5 ft or closer) without having fuel disturbance affect fire behavior at the iStake and post-fire soil sample location and in locations representative of each other
3. Take detailed notes and diagram if the sample location(s) need to be shifted (e.g. if a rock or log is in the way).
4. Fill the datasheet completely for the whole plot, and for each subplot sample location
5. Provide a diagram with reference to Figure XX in main text. Note distance from the iStake to the pre- and post-fire sample centerpoints and their orientation relative to the transect and plot center. *Clear diagrams & notes make post-fire sampling more efficient.*

Collecting PRE-FIRE samples

1. Before you enter the plot, pre-label all sample bags for all subplot locations with:
   a. Fire name & plot#
   b. Transect number
   c. PRE
   d. Date
   e. *Tip: Group the empty labeled Ziploc bags by plot to avoid mixing up or losing bags*
2. At each soil sample location, identify a pre-fire and post-fire sampling location within <0.5 m of each other, with similar pre-fire characteristics.
   a. Use a chaining pin or metal pin flag to mark the iStake location to facilitate re-location and prevent trampling. Locate pin 1 ft from iStake towards transect (H2).
   b. Avoid disturbing the post-fire location while collecting the pre-fire sample. Measure depths of litter and duff, record in the datasheet.
3. Remove the organic horizon (a.k.a. the forest floor layer, or litter + duff):
   a. In an approximate 3 ft diameter area where soil cores will be collected, take a straight-down photo of the location (with forest floor in-tact), using a labeled paper bag or brown cardstock as the photo label (writing on plastic bags doesn’t show up well). *Try to avoid shadows: we use photos to estimate vegetation cover.*
   b. Clip away any rooted vegetation
   c. Remove the forest floor layer taking care to avoid any forest floor material being integrated into the soil core
4. Collect a mineral soil sample, to a depth of 2 in. In general, mineral soil analysis requires ~ 1 baking cup of soil volume.
   a. Record the type or diameter of the soil corer on the datasheet (corer dimensions are important for calculating soil bulk density later).

   b. Use the rubber mallet to tap the soil corer 2 in into the ground (2 in-depth will be marked on the outside of the corer with sharpie and may need to be remarked periodically). Avoid collecting soil deeper than 2 in deep.
   c. Carefully twist & pull or tip the corer + soil out of the ground to prevent losing the soil.
   d. Put the mouth of the core into the Ziploc & gently tap with the mallet to release the soil.
   e. Record the number of cores you collected inside the sampling area.

Where to sample

Pre-fire and post-fire soil sample locations will be on either side of the iStake (see Soil Heating and Associated Soil Sampling, above, and Figure 2 in main text and Figure H2, above). The goal is to co-locate temperature readings with the forest floor & mineral soil samples. This helps identify relationships between temperature and fire effects on the soil.

Collecting post-fire samples

5. Wait until soil cooling has finished to collect soils, then follow the same steps listed above for pre-fire sampling:
6. Take a post-fire photo of the residual forest floor layer surface, with sample bag as label
   a. If ash or char is present, it is the residue of combusted forest floor: consider the top of the ash/char layer as the new top of the post-fire forest floor.
   b. If no forest floor material remains after fire, record “0.0 in” as the forest floor depth.
7. After removing the ash/residual forest floor layer, collect a mineral soil sample, to a depth of 5 cm as above
   a. Record the type or diameter of the soil corer on the datasheet (corer dimensions are important for calculating soil bulk density later).
   b. Use the rubber mallet to tap the soil corer 2 in into the ground. Avoid collecting soil deeper than 2 in.
   c. Carefully twist & pull or tip the corer + soil out of the ground to prevent losing the soil.
   d. Put the mouth of the core into the Ziploc & gently tap with the mallet to release the soil.
   e. Record the number of cores you collected inside the sampling area.
   f. Leave a pin flag in the center of the pre-fire sample area for subsequent seasonal sampling that will be carried out by collaborators
8. How samples need to be stored depends on the analyses that will be done. Instructions will be given at the start of the season and/or each FBAT detail.