COLORADO FOREST RESTORATION INSTITUTE
Colorado State University

Field Data Collection Protocol For Evaluating Forest Restoration and Fire Mitigation Management Effectiveness

2016 Mothership Plot Protocol
CFRI-1604

Sampling Objective:

This protocol is designed by the Colorado Forest Restoration Institute (CFRI) to collect comprehensive data for changes in non-spatial forest structure and composition, fuels and fire potential using the Fuels Characteristic Classification System (within the Fuel and Fire Tools analysis package), and plant species abundance and diversity as a result of management actions in forests and shrublands of Colorado.

Sampling Design and Intensity Recommendations:

The most accurate and straightforward method for quantifying changes in vegetation structure, abundance, and diversity as a result of management actions is to measure at the same location before and after treatment. A more robust study design will include measurements in similar nearby habitats that do not experience management to serve as controls. Establishing control sites is often critical to determine longer term ecological change and effectiveness, but less essential for monitoring short term management outcomes. When conducting pre-post comparisons, permanently marked plot locations are highly desirable and greatly increase ease of finding plot locations and comparability of multiple measurements over time. Sample plots located randomly throughout the area of interest provides a robust study design and is generally, but not always, recommended over a gridded plot system.

How many plots do you need? Appropriate sampling intensity will depend on monitoring objectives and level of confidence needed in results. If you are gathering information to determine standard fuel model for fire behavior modeling, only a few plots of much less intensity than described here may be needed. However, if you want to determine management effectiveness and differences in fire hazard over a large area before and after treatment, much more intensive sampling is required. Exactly how many samples (plots) you need to get a reliable answer depends on local site variability, which cannot be predicted remotely. This protocol is very thorough, but also very labor and time intensive and requires a skilled botanist. Typically CFRI recommends about 6 of these effectiveness plots per stand when ecological change and treatment effectiveness monitoring is desired. However, for more accurate estimate of fuels and forest density, we often combine 6 of these intensive plots with 4 to 10+ additional less intensive rapid assessment plots (not described here) to add accuracy for fuels and forest density estimates in an efficient manner. Typically a crew of 3 trained individuals completes this sampling combination of 6 intensive effectiveness plots and 4-10 additional rapid assessment plots within the managed area in 4-ish full days including travel time. Sampling control sites adds additional days, typically double if the same sampling intensity us used.

Underlying Methods and Data

Where did we come up with all this stuff? This protocol relies heavily on the experience of CFRI staff in conducting combined decades of forest and fire ecology monitoring and research. It is designed to use standard protocols where appropriate so that data is comparable to large monitoring and research efforts in Colorado and throughout the Rocky Mountains. We rely heavily on the Fire Effects Monitoring and Inventory System protocols (FIREMON https://www.frames.gov/partner-sites/firemon/firemon-home/) to remain comparable with national datasets. Much of the sampling protocol was also modified by CFRI staff to facilitate use of the Fuel and Fire Tools modeling platform, which we find useful in evaluating treatment effectiveness and communicating changes in fire potential.

Plot Layout

1. Randomly locate the plot center within the sample area. Use GIS/GPS technology if available, or a random number table with numbers 0-359 can be used to choose a random direction and then a random distance to walk.
    a. If a randomly generated GPS point falls in an area that is not a suitable sample area (e.g. on a road, riparian, treatment boundary, etc.), use the random number table to choose a direction and distance to move the point to a suitable area. If a suitable area cannot be found, use another random point generated in a GIS.
2. From plot center, establish 8 transects in the cardinal (0°, 90°, 180°, 270°) and ordinal directions (45°, 135°, 225°, 315°) using a **declinated** compass (set north to positive 9 degrees for Colorado – 9 degrees to the east). You will use 4 X 100-ft tapes to establish these. To ease calculations, center the 40-ft mark of all 4 tapes over the plot center and extend the tape out to 80-ft. Clip tapes together with a binder clip to ensure they stay in place. Be sure the 0 foot mark is on the south end of the north-south transect (the reel should be on the north end of the transect). Colored tape will be marking the plot center and transect ends, as well as the understory plant and fuels measurement areas on each 100-ft tape. Note that this protocol can be implemented with 50-ft tapes, but care must be taken to ensure measurements happen at the correct locations. This protocol is written under the assumption that 100-ft tapes are used, with the 40 foot marks centered over the plot center.
    a. If 100-ft transect tapes are not marked with colored tape, add a small strip of colored tape around the transect tape at 2.8-ft, 9.5-ft, 34-ft, 40-ft (center), 46-ft, 70.5-ft, and 77.2-ft. Use a different color to mark the 15-ft and 62-ft locations on a designated north-south tape.
    b. Before proceeding, be sure that the edge of the plot is at least 100 feet from a treatment boundary.
3. Each of the three $1m^2$ Sample frames are placed to the left (west) of the north-south transect as depicted below. The frames should be located adjacent to the 15 – 18 foot mark on the tape (25 feet south of the center), at the plot center (40 – 43 foot marks), and adjacent to the 62 – 65 foot marks (22 feet north or center, refer to Figure 1). To avoid trampling vegetation and woody fuels, walk on the right side of the transect as much as possible.

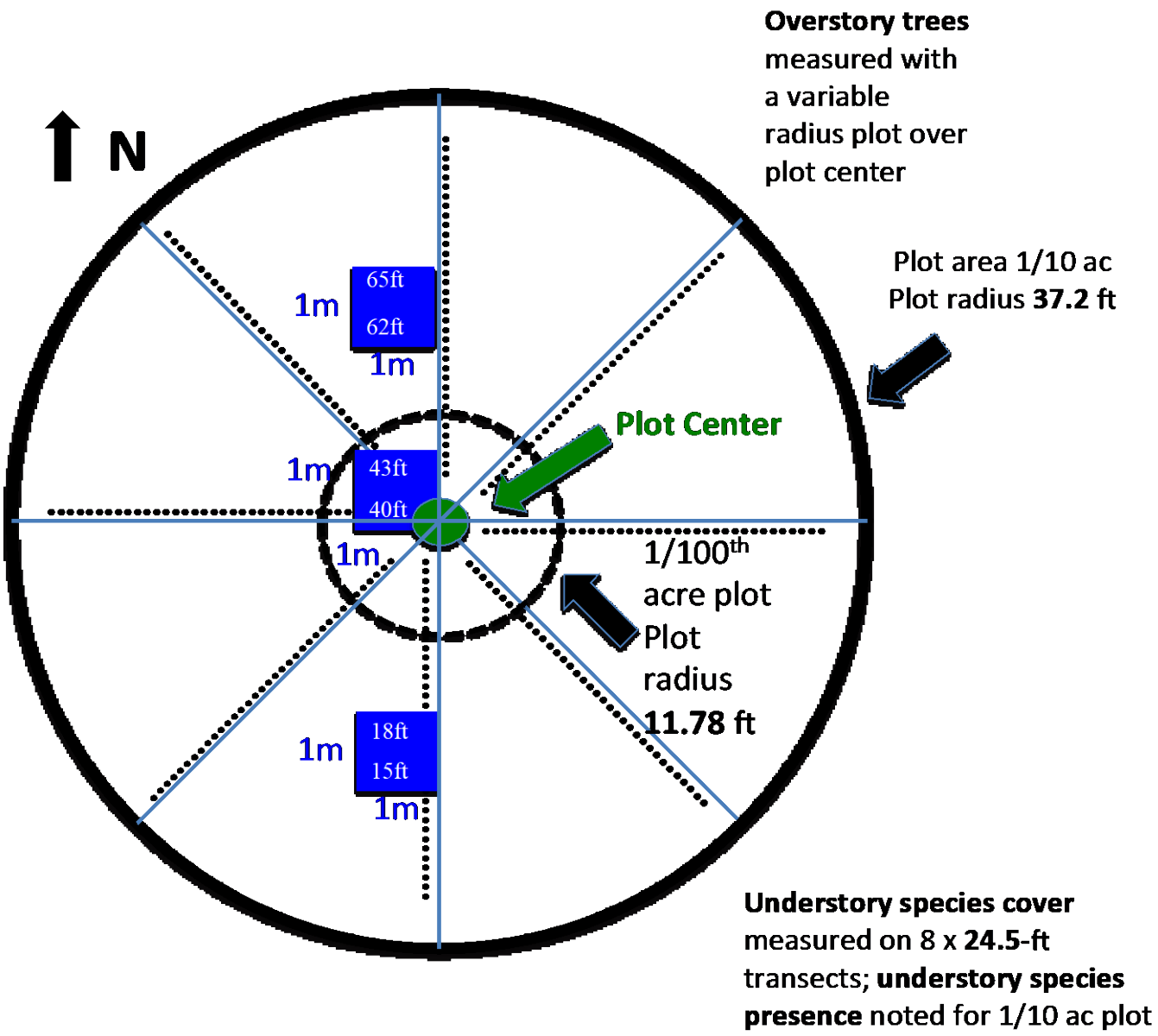

Figure 1. Diagram of the CFRI Forest Restoration and Fire Mitigation Effectiveness Assessment sample plot.

Plot Center

1. **Location**
    a. Using a GPS unit, record the location (UTM's) and elevation at the center point. Use the **NAD83 map datum** for recoding all points.
        1. To locate plots post-treatment, leave three monuments (using a nail and washer painted yellow, silver "CFRI Long-term Monitoring Plot" tag (be sure to mark North, East, or Center and the date on the silver tag with a pen)). Leave the three monuments at the plot center, and at 37.2-ft along both the North and East transects.
        2. Wrap a small piece of pink flagging around the top of each nail. If flagging is missing in post-treatment years, re-flag nails.

b. Using a **declinated** compass, record the hill-slope azimuth in degrees (0-359) within the 1/10th acre plot.

c. Using a clinometer, record the slope to the nearest percent within the 1/10th acre plot. Take slope measurements from plot center both downhill and uphill, and then record the average slope of the two measurements.

d. Take note of any signs of past disturbances (e.g. fire, insect outbreaks, stumps from logging, animal signs/grazing, human disturbance, etc.) and record the start and end time of data collection for each plot.

2. Photos

a. Standing at the plot center, take 4 photos. Photos will be used to describe fuel conditions and to help locate plots post treatment. The standard photo sequence is:
   1. Along the north transect, holding the camera eye level pointed towards the ground and capturing 0-10ft on the transect, including the 1m^2 sampling frame. Rather than stand at the plot center, the photographer should take a few steps back in order to capture the plot center in the photo.
   2. Holding the camera over plot center, along the north transect looking out at eye level.
   3. Holding the camera over plot center, along the north transect looking towards the upper tree canopy.
   4. Holding the camera over plot center, along the south transect looking out at eye level.

3. Tree Overstory

a. Record the basal area prism or angle gauge size and units. Choose a basal area factor prism based on expected tree numbers after harvest in order to capture 6-10 trees *post treatment*.

b. Standing at the plot center, use a basal area prism or angle gauge to record the basal area of the variable radius plot for all live and dead tree's taller than 4.5 ft with a diameter at breast height (DBH) ≥ 5.0 inches. Hold the basal area prism at any convenient distance from the eye, directly over the plot center. The prism should be held vertically (rounded edge on top) and at a right angle to the line of sight (number indicating the basal area factor on the left side). If a tree is a 'hit' and included in the basal area count, mark that tree for further measurement by placing a pin flag at its base. *Tip: Alternate the color of pin flags – makes it easier to remember tree order when measuring heights. Record trees in sequence starting at the north transect moving in a clockwise direction.*

a. For each hit tree included in the basal area count, record:
   1. Tree species.
   2. Live or dead.
   3. Diameter at breast height (to nearest 1/10th in).
   4. Tree height (to the nearest ft).
   5. Lowest height to continuous live foliage vegetation (e.g. crown base height (CBH)) for all live trees and class 1a snags (to the nearest ft).
      a. Tree species, live/dead, and DBH should be done on all trees and are quick easy measurements that are essential for supplementary calculations. Measuring tree height and CBH can be more time intensive. In order to obtain an average tree height and CBH for the plot, measuring height on the first 5 live trees and the first 5 dead trees encountered in

each decay class in the plot rather than measuring every single tree height will typically give reasonable averages for the stand.

b. For standing dead trees taller than DBH (snags) that are included in basal area count, also record decay class on a scale of 1-3.
    1. Decay class 1a *with needles* = recently dead trees, top intact, needles/foliage and fine branches present. NOTE: Record CBH for trees with needles.
    2. Decay class 1b *without needles*= recently dead trees, top intact, fine branches present.
    3. Decay class 2 = snags have coarse branches and bark present, but fine branches and foliage have fallen off.
    4. Decay class 3= snags are rotten, bark not present. Very few if any branches remain.

4. Tree Saplings and Seedlings (1/100th Acre Plot, 11.78 ft radius)

Often variable radius plots measured with a prism or angle gauge are not very effective at capturing smaller trees, or trees with multi-stem branching patterns (e.g. Juniper). However, fuel reduction treatments frequently are aimed specifically at removing these small trees to reduce ladder fuels and crown fire potential.

a. **Tree Saplings** taller than 4.5 ft, but <5 in DBH within the 1/100th acre subplot:
    1. Tree species.
    2. Live or dead.
    3. Diameter at breast height by size class.
        1. Class 1: 0.1-2.4 in.
        2. Class 2: 2.5-4.9 in.
    4. Tree height (to the nearest ft).
    5. Lowest height of continuous live vegetation (e.g. crown base height or CBH) for all live trees and class 1a snags (to the nearest ft).
    6. Decay class from 1-3 if dead.

b. If the number of sapling trees is excessive, an ocular estimate of tree height and CBH for all sapling trees by species and diameter class is typically quicker and sufficient for most monitoring objectives rather than measuring the height of every single sapling tree.

c. **Tree Seedlings** (less than 4.5 ft tall within the 1/100th acre subplot):
    1. Record the species and number of individuals in each height class.
        1. Height Classes: 1 = 0"-4"; 2 = 4.1"-18"; 3 = 18.1"-30"; 4 = 30.1"-54".

d. Note: Typically large shrubs, such as Gambel Oak, are not counted as trees and their abundance is only measured on the 50ft shrub transect. Where Gambel Oak takes on more of a large single stem tree growth form in southwestern Colorado or further south, it may be appropriate to measure this and other tall shrubs as a tree.

1m² Sample Frame

In each of the three 1m^2 sampling frames located at 15-18ft, 40-43ft, and 62-65ft along the north-south transect, measure the following:

1. Fine Woody Fuels

"The Photoload Sampling Technique: Estimating Surface Fuel Loadings From Downward Looking Photographs of Synthetic Fuelbeds." Robert E. Keane and Laura Dickinson. USFS General Technical Report RMRS-GTR-190, pages 15-17. April, 2007. http://www.fs.fed.us/rm/pubs/rmrs_gtr190.pdf

a. Using the Photoload technique, estimate fuel loading for 1 hr, 10 hr, and 100 hr fuels in tons/acre within the 1m^2 sample frame. The photos on pages 15-17 are intended

as guides and not absolute choices. Estimate as close to the picture as possible or chose an intermediate loading between pictures if appropriate. A go-no-go fuels gauge can be used to help classify fuels in the frame.

1. 1 hr fuels (0 to 0.24 inch diameter)
2. 10 hr fuels (0.25 to 0.99 inch diameter)
3. 100 hr fuels (1.00 to 2.99 inches diameter)

a. Double sampling is recommended, but not required, in order to increase the accuracy of fuels measurements. This involves performing the photoload estimates then collecting all woody material in the $1m^2$ sample frame in paper bag with plot, date, initials of photoload estimator, "1hr, 10hr, or 100hr", and the Sample Frame location (15ft, 40ft, or 62ft). When performing double sampling, use one separate paper bag per fuel size class (e.g. 3 bags per plot for 1hr, 10hr, and 100hr). Collect only woody material, not litter or duff (e.g. no needles or cones).

b. All woody material should then be returned to the lab, oven dried to constant mass, weighed to attain dry weight (loading in tons/acre).

ii. Double sampling woody fuels can be time intensive and is not required. Generally a double sample rate of 20% is adequate. **We recommend collecting biomass at only one sample frame (e.g. 40ft) approximately every other plot.**

2. Herbaceous Biomass

a. Clip all herbaceous material at the soil surface (current year's growth and senesced/dead material that is still attached to plants) for each plant *rooted* within the frame.

b. Place in paper bag with plot, date, "HERB", and the sample frame location (15ft, 40ft, or 62ft).

c. All herbaceous material should then be returned to the lab, oven dried to constant mass, and weighed to attain dry weight of herbaceous material (loading in tons/acre).

i. Clipping herbaceous biomass can be time intensive. **We recommend collecting biomass at only one sample frame (e.g. 40ft).**

37.2 ft Transects

Along each of the 8 transects in cardinal and ordinal directions from the plot center:

1. Understory Vegetation

a. Using the line-point intercept method, record any plant present at 25 evenly spaced points (every 1-foot) on all 8 transects. Begin counting at 6-ft from the center and collect data along a 24-ft section of each transect (e.g. understory data should be recorded along the 46 – 70, and 34 – 10 foot marks along each transect tape).

i. A buffer around the center reduces trampling and autocorrelation of counts, and buffering the ends ensures vegetation estimates are within the plot area.

b. Identify plants to the species level using the USDA PLANTS database 4 letter code or the full Latin nomenclature if unsure of code. If unable to identify a plant, give the plant an unknown number and name. Show the plant to everyone on the crew to ensure that consistent unknown names are used. Collect a specimen from outside the plot for later identification in the lab, and place in a paper bag labeled with the appropriate unknown name.

c. If more than one species is visible at a sampling point record them all (i.e. kinnickinnick, mountain mahogany, Douglas-fir). Record the top most vegetation as the top hit, and then other species of shorter stature as bottom hits. This allows calculation of total percent cover as well as relative species cover.

i. Each transect should have no more than 25 top most vegetation counts, i.e. maximum of 1 top hit for every point measured. There is no limit to the amount of bottom hits.

ii. Include ANY vegetation when they are encountered below 4.5ft, e.g. large shrubs, tree branches, and live tree trunks, etc.

2. **Forest Floor Substrate**

a. At each of the 25 points per transect record forest floor substrate as well. Each transect should have exactly 25 substrate counts, i.e. 1 substrate for every point measured.

b. Substrate categories: litter/duff, soil/gravel, rock (>0.5 inch), fine fuels (1/10/100hr), Coarse fuels (1000hr, rotten or sound), moss/lichen, woody basal, and herbaceous vegetation basal.

3. **What about wood suspended off the forest floor?**

a. If a substrate category is encountered suspended higher than ~1 inch above the ground, record that substrate as a species with the notation "in air" and then record a substrate category on the forest floor. For example, if a log is suspended above the ground with a grass growing under it, and pine needles are under the grass, you would record 1000hr in air, Muhlenbergia montana, and then litter as the substrate. Be judicious and only use the "in air" category if you can see potential growing space for plants under the suspended substrate. This measure will be used to estimate woody debris abundance, compare different slash disposal techniques, and estimate potential vegetation growing space.

4. **Heights for Vegetation and Fine Woody Fuels**

a. At the end of each transect estimate the average maximum height of herbaceous and shrub vegetation, as well as 1hr/10hr/100hr wood "in air" that was tallied, in inches to the nearest 1 inch. This is recorded at the bottom of the datasheet for each transect (H=Herbaceous, S=Shrub, W=1hr/10hr/100hr fuels). This is not the height above the ground where the sampling point touches the vegetation, but the average maximum height of the plants that are tallied.

i. Measure heights *where they occur* and do not average in zero values within each transect. If you record a cover of any herbaceous, shrub, or 1hr/10hr/100hr fuels anywhere on a transect, the height must be >0. Therefore, only height values >0 should be calculated into averages. A yard stick is handy to estimate heights.

5. **Litter and Duff Depths**

a. At regularly spaced intervals along the N, E, S, and W transects, measure litter and duff depths to the nearest 0.25-inch. Measurement points are 10-ft, 20-ft, 30-ft, 50-ft, 60-ft, and-70 ft markings along each transect tape (e.g. 10, 20, and 30 feet on either side of the plot center).

i. Following the FIREMON protocol (RMRS-GTR-164-CD) "Litter" is the loose layer made up of needles, dead grasses detached from the plants, recently fallen leaves, twigs not visible from above, and so forth, where the individual pieces are still identifiable and little altered by decomposition. The "duff"

layer lies below the litter layer and above the mineral soil. It is made up of litter material that has decomposed to the point that the individual pieces are no longer identifiable. Pine cones are considered litter or duff, not woody fuel.

6. **Tree Cover**
    a. Using the densitometer scope, at every foot along the North-South transect record cover of any **live** tree taller than 4.5-ft (DBH). Begin counting at the start of the South transect (3ft mark on the tape), and count every 1-ft until you reach 37-ft from plot center on the North transect (77ft mark on the tape) for a total of 75 measurements (37 counts each side of the plot center, plus one count over the plot center). Stand directly over each point along the transect, look straight up through the densitometer scope and record when tree (foliage or trunk) is encountered. For each hit, record the tree species.
        i. If multiple live tree species are encountered at one point, record the tree species lowest in height at that point.
7. **Tree Group Size Transect**

    The goal here is to measure the distances covered by closed-canopy forest areas ("tree clumps") versus openings along a transect.

    a. Walking along the entire length (75 ft) of the North-South transect, record the start and end points of "openings" and "canopy clumps" that are directly overhead the transect. Include as canopy clumps, any canopy overhead the transect produced by trees > 1 in. DBH. Use the densitometer scope to identify the location along the transect at which transitions between canopy and openings occur.
    b. Along with the start and end points for each length of canopy clump, record the number of trees that contribute to the formation of that clump. For example, the tree canopy intersecting the transect may be an individual tree, or it may be part of a small or large clump of trees extending beyond the transect. Record the number of trees forming each canopy clump as classes (0 if open, Class 1= 1 tree, Class 2= 2-4 trees, Class 3= 5-9 trees, Class 4 = 10-15 trees, or Class 5= 16+ trees). If canopies of trees are interlocking or less than 5 ft apart, count them as part of the same canopy clump.

1/10th Acre Plot (37.2 ft radius)

1. **1000 hr fuels** (larger than 3 in diameter)
    a. Measure the end diameters and the length of every log larger than 3 inches diameter within the 1/10th acre plot to the nearest 0.1 inches.
        1. If diameter drops below 3 inches on the log, stop measuring at that point.
        2. When a log travels outside of the 1/10th acre plot boundary, stop measuring the log at the plot boundary.
        3. If the center point of the log is below the duff, stop measuring at that point.
    b. Record if the fuel is rotten or sound. Consider pieces rotten when the piece at the intersection is obviously punky or can be easily kicked apart.
    c. *Tip: occasionally 1000hr fuel is very abundant and can take very long to measure. Consider measuring half, or even a quarter of the plot if this is the case and recording total area measured on the datasheet. Always start from the North transect and work clockwise around the plot. If half a plot is measured the loading will be multiplied by 2, a quarter plot multiplied by 4. Our general rule of thumb is to measure maximum of approximately 30*

logs in a plot, unless 1000hr fuels are a main focus of the monitoring. ***If only measuring a portion of the plot due to abundant 1000 hr fuel, ALWAYS circle "Full," "Half," or Quarter" indicating the portion of the plot measured.***

2. **Understory Vegetation Presence**
   - **a.** Systematically search for and record any additional plant species present in the 0.1-acre plot that were not recorded as cover hits on the 8 transects surveyed for percent cover.
   - **b.** Identify plants to the species level. If unable to identify a plant, give the plant an unknown number and name. Show the plant to everyone on the crew to ensure that consistent unknown names are used. Collect a specimen from outside the plot for later identification in the lab.
   - **c.** If any exotic species of concern are found during this search, estimate their cover in the 0.1-acre plot as rare (>0 – 1%), common (2 – 10%), abundant (11 – 50%), or very abundant (51% +).

Gear List

100 foot tape x4
1m^2 sampling frame x1
Basal area prism or angle gauge x1
Binder clip (to hold tapes together at the plot center) x1
18 inch Calipers (for Fuels) x1-2,
6 inch Calipers (for saplings, optional) x1
Camera and Batteries/charger x1
Chaining pins x10
Clicker counter x1
Clinometer x1
Clipboard/Tatum x1-2
Compass x1-2
Cruising Vest x1 as necessary
Data sheets and unknown plant sheets (regular and rite in the rain)
Densitometer (for tree cover) x1
Diameter tape x1 per person
Duct tape x1
First aid kit, bug spray, sunscreen
Go no go gauge (for woody fuel class size measurement, optional) x1-2
GPS and Batteries x1
Grass clippers/shears and small shovel x1-2
Hammer x1
Hard Hats x1 for each person as appropriate
Hypsometer and Batteries (to estimate tree height, optional) x1-2
Loggers tape x1 per person
Maps of the site (quads and plot maps)
Metal dowel with seedling height class markings x1
Monuments (large nails, whiskers, washers, plot tags, etc.) x3 per plot
Paper bags (medium and large sizes for plant biomass, fuels double sampling, and unknown plant collections)

Densitometer

Pencils, Pens, Sharpie (at least 10 each crew)
Photo load guides for 1hr, 10hr, and 100hr fuels (pages 15-17) x1

"The Photoload Sampling Technique: Estimating Surface Fuel Loadings From Downward Looking Photographs of Synthetic Fuelbeds." By Robert E. Keane and Laura Dickinson. USFS General Technical Report RMRS-GTR-190, pages 15-17. April, 2007.
http://www.fs.fed.us/rm/pubs/rmrs_gtr190.pdf

Photo load for herbaceous fuels
Pin flags x15-20 flags
Pink flagging x1 roll per person
Plant field guides (Ackerfield, Wingate Illustrated keys to grasses of Colorado, etc.)
Plant press x1
Protocol x1
Random number table (0-359)
Road atlas (navigating to study area) x1
Rope (measured out to 11.78ft for sapling and tree regeneration subplots, optional) x1
Ruler for litter/duff depths x1 per person
Species lists x1 per person
Walkie-talkie and batteries/charger
Water cooler
White Board (for photos) and dry erase markers x1
Yard stick for plant heights x1