NORTHERN ARIZONA UNIVERSITY | Ecological Restoration Institute
Monitoring Report

Four Forest Restoration Initiative (4FRI)
Rapid Plot Pre-Treatment Monitoring Report 2019

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Prepared for:
Four Forest Restoration Initiative
Stakeholder Group

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Introduction

The Four Forest Restoration Initiative (4FRI) Multi-Party Monitoring Board (MPMB) is tasked with monitoring the effectiveness of 4FRI treatments and providing technical recommendations to the 4FRI Stakeholder Group regarding adaptive management. Adaptive management is a key aspect of the 4FRI monitoring plan, which outlines a process that plans for and identifies uncertainties, collects data and tests assumptions, analyzes and evaluates data, and incorporates adaptive management.

The Ecological Restoration Institute has been a member and leader of the 4FRI MPMB since its inception in 2014. In addition to the monitoring plan development, ERI staff have contributed to monitoring protocol development, training, and data collection across the 4FRI footprint. To address a gap in data compilation, error-checking, and pre-treatment assessment for the ground-based, rapid plot data, the ERI was asked to build on work for the Kaibab National Forest from 2017 to incorporate 4FRI monitoring data into an Access database, and develop summaries for the pre-treatment data collected as of 2018. The rapid plot protocol addressed 4FRI monitoring questions regarding forest structure, composition, and condition. A table of the monitoring questions addressed by the rapid plot monitoring methodology can be found in the appendices of this report.

Rapid plot pre-treatment data collection has been ongoing since 2015, and due to challenges initiating a large-landscape monitoring program, has had changes in protocol and inconsistent data storage in the last four years. This report includes analysis of three years of data collected on 4FRI task orders, and summaries relative to 4FRI desired conditions and monitoring questions. We also discuss the challenges and opportunities provided by the rapid plot approach, and in collaborative data management for and by federal land management agencies.

Methods

The 4FRI used a rapid plot protocol adapted from the rapid forest assessment method (Davis et al. 2016) and originally piloted for the Kaibab National Forest by the Lab of Landscape Ecology and Conservation Biology at Northern Arizona University (NAU) in 2012 (Ray et al. 2012). The protocol is designed to address 4FRI project-level monitoring questions as well as Kaibab and Coconino national forest plan monitoring questions. Data was collected annually starting in 2015 in 4FRI projects selected by the 4FRI MPMB and the 4FRI Monitoring Coordinator. Projects that were understood to be most likely treated first were prioritized for measurement. The 2015 data was collected in NEPA shelf stock acres that were within the 4FRI footprint and closely aligned with 4FRI collaborative goals and objectives.

The Nature Conservancy coordinated the 2015 field season (Woolley 2016), and following seasons were coordinated by the Landscape Conservation Initiative at NAU. The 2015 plots were randomly selected from a potential plot network grid, with a sample density of one plot per 50 acres (Woolley 2016). Plot locations in subsequent years (2016 onward) were generated using an oversample created by Conservation Science Partners (CSP) for monitoring across the 4FRI, which creates a spatially balanced sample within selected treatment units. Based on the power analysis completed by CSP (Gray 2017), recommended sample intensity to detect significant changes in total basal area and mean diameter at breast height was 1 plot per 50 acres. The total sample by project can be found in Table 1.

Table 1. Sample by project

Project	Year Collected	Number of Plots
Chimney	2017	40
Clints Well	2015	128
Cloverdog	2017	79
Cougar	2017	10
Coyote	2017	15
Ft. Valley	2016	18
Ham	2017	16
Hart	2015	63
Hochderffer	2015	42
Johnnys	2016	14
Moonset	2017	30
Willard	2016	12
Wing Mountain East	2015	54

A protocol and data forms can be found in Appendix B. The protocol borrows heavily from Ray et al. 2012 and Davis et al. 2016, and the 4FRI-adapted version is below. In general, plots were 0.2-acre, fixed-radius plots for overstory measurements and assessing wildlife and invasive presence/absence. Smaller sample units were used for tree regeneration densities, fuels estimates, and grass, forb, shrub and substrate frequency.

Key variables in rapid plot monitoring tier directly to the 4FRI Monitoring Plan. Plot variables include:

- Overstory structure and composition
    - Estimated overstory presettlement structure and composition (ERI)
- Forest floor substrate frequency
- Grass, forb, and shrub frequency
- Fine and woody fuels
- Invasive herbaceous presence
- Disturbance and wildlife indicators: log density, small mammal evidence

Plot Layout

The plot was a 105.33-ft diameter circle (0.2 acres). Once the center of the plot was determined, two transects (100-ft tapes) were laid out perpendicularly in the cardinal directions through the center. For more precise remeasurement, plot centers were monumented in the field using plot stakes and tags, and two reference trees were tagged, with dbh, distance, and azimuth to plot center recorded. Overall plot condition was documented using two photos; one taken from the northern endpoint of the north-south transect and one taken from the eastern endpoint of the east-west transect.

Overstory – Trees

Within the entire plot, we measured all live and dead trees taller than breast height (i.e., 4.5 ft) and greater than 4 inches dbh to the nearest tenth centimeter using a diameter tape. A hypsometer or an extra tape measure was used to determine whether trees near the circle boundary were within the plot. The following data were recorded: species, dbh, and condition (i.e., live or dead). The height of three co-dominant trees (which represented the average height of the trees within plot) were recorded and those trees were tagged. The three lowest canopy base heights were recorded.

Understory – Tree Regeneration and Shrubs, Grasses, and Forbs

Seedlings and saplings were counted by species within four, 6-foot-by-45-foot transects along the directional transect tapes (0.025 acres). Trees shorter than breast height (4.5 ft) were considered seedlings. Trees taller than breast height and smaller than 4 inches dbh were considered saplings.

Forest floor substrate cover and vegetative frequency by functional group and were recorded using the point-line intercept method (Elzinga et al. 2001, Herrick et al. 2009) along the north and east transects. Starting at the end of a transect, a pointer (e.g., pin flag or chaining pin) was lowered every 2 feet along the transect to record all vegetation hits below 19.7 inches, stopping at the first layer of ground cover (i.e., litter, grass, forb, bare soil, shrub, tree, woody debris, rock, and moss/lichen). Substrate cover was calculated using only the final substrate hit, and substrate cover totals 100 percent. The intercepted vegetation above substrate was also tallied as a frequency, totals can exceed 100 percent as each point may have multiple interceptions. The percent cover for substrate and frequency of vegetative types were calculated for the plot based on the total of 46 points. These data characterize forest floor conditions, including exposed mineral soils, amount of litter, and frequency of plant functional types.

Fine and Woody Fuels

To quantify fine woody fuels (1-, 10-, and 100-hour fuels), we used the Photoload sampling technique developed by Keane and Dickinson (2007) based on known fuel loads within the Rocky Mountains. Three feet from the end of each transect, we placed a 10.76-ft^2 square frame (e.g., polyvinyl chloride piping) on the ground and compared the dead woody fuels with those in existing photos of known fuel quantities from Keane and Dickinson (2007). For each fuel size class, the values are binned further into five classes (0, 0–1.8, 1.8–4.5, 4.5–9.0, and 9.0 tons/acre).

An estimate of woody fuels across the stand was estimated also estimated using the photoload sampling technique, comparing field conditions to photos of known fuel quantities from Keane and Dickinson (2007) and from Scott and Burgan (2005).

Invasive Herbaceous Presence, Disturbance, and Wildlife Indicators

Field crews recorded presence and absence data for erosion and compaction as indicators of soil disturbance, evidence of recent (with one year) fire, and evidence of grazing (cow pies). The number of plot quadrants (i.e., 1–4) with the presence of disturbance.

The number of plot quadrants with invasive herbaceous species presence was also recorded. Field crews were instructed to look for 11 invasive species identified by the Kaibab National Forest as most noxious and likely to be present. These species were Russian thistle, other invasive thistle species (bull thistle, Canada thistle, musk thistle, scotch thistle, and yellow starthistle) cheatgrass, knapweed species (Russian, spotted, and diffuse knapweeds), dalmatian toadflax, and “other” species (leafy spurge).

The number of logs over 12 inches in diameter and 8 feet long that are within the plot were tallied. The presence and absence of squirrel sign (stripped cones and twigs, and/or clippings) and/or vole runways was recorded at the plot level.

Changes to Plot Protocol

Lessons learned in the initial 2015 field season and data collection led to updates to the protocol in 2016. Those changes are summarized in this section and in Table 2.

In 2015, data was collected on a .18-acre plot, and seedling and sapling data was collected on two transects totaling .011 acres. In 2016, this was changed to a .20-acre plot, with seedling and sapling data collected on four transects totaling 0.025 acres.

The 2015 protocol required field crews estimate a fuel model that characterized the stand. Crews were provided with pictures for guidance, but had difficulty making confident estimates. After discussions with the 4FRI Fire Ecologist, it was determined that an estimated fuel model would not be helpful in fire modeling. In 2016, the protocol was updated to include the Photoload approach, which meets forest plan monitoring goals.

The protocol for the presence of small mammal sign also changed over time. The 2015 protocol called for selecting bins for the presence or absence of categories of squirrel sign—twigs and clips (none, 1-30, or >30), cones (none, 1-10, or >10), and digs (none or >1) to estimate the presence of squirrels as a closed canopy species. Vole presence as an open canopy species was evaluated with the presence or absence of two types of vole sign—runways and clippings/droppings. In 2016, this was simplified to a single presence or absence observation of squirrel sign (cone, twigs, or clips) and a single presence or absence observation of vole sign (runways, grass clippings, or droppings).

The 2015 protocol called for the fuel model to be estimated for the plot based on pictures provided, and for the fuel loading to be estimated as either less than three tons per acre, 3-10 tons per acre, or more than 10 tons per acre, also using pictures as a guide. In 2016, the fuel model component was removed from the protocol, the Photoload method of fine fuel estimation was added, as was a tally of logs over 12 inches in diameter and over 8 feet long within the plot.

Table 2. Differences between 2014 and 2017 rapid plot protocols

	2015 Protocol	2016–2019 Protocol
Plot size	0.18 acres	.2 acres
Reference tree	One reference tree	Two reference trees
Overstory - Live trees	All trees over 4 in measured to 1/10 of an inch	
Overstory - Snags		
Regeneration	Seedlings (<4" dbh and <4.5' height) and saplings (<4" dbh and >4.5' height) tallied in two belt transects (6’x40’, .011 acre)	Seedlings (<4" dbh and <4.5' height) and saplings (<4" dbh and >4.5' height) tallied in four belt transects (6'x45', .025 acre)
Understory	Point-intercept transect with multiple observations per point - one substrate cover observation and potential for multiple vegetation cover observations	
Woody debris	Fuel model estimated for stand	Photoload, estimated in the field. Logs >12” in diameter and >8’ long counted per plot
Disturbance	Tallied quadrants of presence of evidence of grazing, fire, soil erosion, soil compaction	Tallied quadrants of presence of evidence of grazing, fire, soil erosion, soil compaction
Invasive species	Same data collection protocol	
Small mammal	Presence/absence of categories of squirrel sign—cones, twigs/clips, and digs. Presence/absence of vole sign— runways and clippings/droppings.	Presence/absence of any squirrel sign and presence/absence of any vole sign

Data Collection and Management

Field data was collected on paper data sheets in 2015 and 2016 and entered into the FS Veg database and an Excel spreadsheet at a later time. The FS Veg database stores overstory, regeneration, ground cover and vegetation cover, reference tree, and location data. All additional plot components—fuels, log counts, small mammal sign, disturbance, invasive species, were stored in an Excel spreadsheet because there was not an appropriate place to store these variables in the corporate database. In 2017, field crews started collecting data into the FS Veg database and the Excel spreadsheet in the field using Trimble GPS units. Paper was also used as a worksheet and as a backup in case of technical problems. Data was collected on paper forms and starting in 2017, electronically on Trimble GPS units with Microsoft Excel and the USFS ExamsPC program.

In the pilot year (2015) we attempted to use a character string in a user field in FS Veg to link the auxiliary data to the FS Veg records, this was determined to be untenable for the purposes of data entry and data analysis.

Data Inconsistencies and Missing Data

Due to data extraction issues with FS Veg, there is missing data for 2015 disturbance, invasive species, and small mammal data, and a portion of the 2016 and 2017 seedling and sapling data was also unavailable at the time of this report. The 2018 data was not available at the time of this report due to an unknown issue with data entry (Dan Kipervaser, personal communication); paper records of the data are available and will be reentered to a partner database currently underway.

Analysis

For this project, all data in FS Veg databases and in Excel were extracted and imported into an Access databases. Data needed to be reconstructed to raw numbers for some variables, as the FS Veg database used automated conversion and summation processes prior to storage. Particular care was taken with the two different plot sizes, which required two different conversions to per acre summaries. Changing protocols were sometimes able to be addressed, and data was converted to compare equivalently with data collected under other protocols. For some plots collected in 2015-16, no data were available for later-developed protocols.

Data were error-checked, errors were recorded, and the rectification and use of any assumptions captured in the Access Plot Info table. Access queries were used to summarize data by plots within task orders, and then exported to SAS Jmp for data summaries (averages and standard errors) presented here.

Results

A total of 533 plots were collected from 4FRI task orders, all occurring in the ponderosa pine plant vegetation types from the US Forest Service Ecological Response Units (Gray 2017). The results of this report are summarized by project or task order.

Overstory — Trees (Structure and Composition)

Tree species observed across the 4FRI projects are listed in Table 3. A few additional species were observed; however, only tree species that accounted for more than 5 percent of overall tree density or basal area were included in our overstory structure summary.

Table 3. 4FRI Tree Species

Common name	Scientific name	Species code
Rocky mountain alpine fir	*Abies lasiocarpa*	ABBI
White fir	*Abies concolor*	ABCO
Alligator juniper	*Juniperus deppeana*	JUDE
Alligator juniper	*Juniperus deppeana*	JUDE2
One seed juniper	*Juniperus monosperma*	JUMO
Utah juniper	*Juniperus osteosperma*	JUOS
Pinyon pine	*Pinus edulis*	PIED
Engelmann spruce	*Picea engelmannii*	PIEN
Ponderosa pine	*Pinus ponderosa*	PIPO
Quaking aspen	*Populus tremuloides*	POTR
Douglas fir	*Pseudotsuga menziesii*	PSME
Oak species	*Quercus spp.*	QUERC
Gambel oak	*Quercus gambelii*	QUGA

Overstory structure summaries are provided in Table 4 (trees per acre (TPA) and Table 5 (BA). All projects were dominated by ponderosa pine. Gambel oak, alligator juniper, and aspen were the next most abundant tree species, with small numbers of other fir, juniper, spruce, pine, and oak species occurring. Overall TPA ranged from a low of 124.5 TPA in the Cougar project area to 227.9 TPA in the Willard project area. Overall basal area ranged from 97.31 ft^2/acre in the Cougar project area to 142.76 ft^2/acre in the Hart Prairie project area. Very small numbers of white fir, one seed juniper, rocky mountain juniper, pinyon pine, southwestern pine, Douglas fir, and New Mexico locust were found across the project areas. Four plots in the Cloverdog project area had no living trees.

Table 4. Tree Density: TPA (standard error)

Project	Total TPA	JUDE2	PIPO	POTR	QUGA
Chimney	129.5 (12.82)	-	129.1 (12.81)	-	-
Clints Well	184.5 (9.23)	2.5 (0.60)	162.8 (9.23)	-	17.6 (1.70)
Cloverdog	141.6 (9.14)	-	124.2 (8.76)	-	11.3 (1.45)
Cougar	124.5 (34.4)	9.5 (7.17)	91.0 (25.58)	-	24.0 (11.27)
Coyote	194.0 (23.09)	9.3 (2.48)	137.3 (14.71)	-	46 (17.46)
Ft. Valley	155.0 (24.34)	-	154.7 (24.27)	-	-
Ham	148.8 (19.00)	1.3 (0.56)	107.8 (12.34)	-	39.7 (15.19)
Hart	178.6 (12.21)	-	162.3 (12.34)	12.5 (3.60)	-
Hochderffer	166.3 (14.17)	-	152.1 (13.37)	13.9 (8.89)	-
Johnnys	177.9 (26.59)	-	158.6 (21.27)	-	19.3 (9.51)
Moonset	143.8 (14.38)	7.3 (4.27)	116.7 (10.25)	-	19.8 (9.22)
Willard	227.9 (18.77)	2.1 (1.14)	190.0 (19.78)	-	35.8 (8.48)
Wing Mountain East	159.3 (10.32)	-	154.9 (10.07)	0.6 (0.65)	-

Table 5. Tree Density: BA (standard error)

Project	BA Per Acre	JUDE2	PIPO	POTR	QUGA
Chimney	126.43 (5.31)	-	126.09 (5.30)	-	-
Clints Well	116.20 (5.78)	1.59 (0.58)	103.91 (5.78)	-	10.07 (1.01)
Cloverdog	126.45 (6.00)	-	101.74 (6.14)	-	12.82 (1.93)
Cougar	97.31 (15.03)	3.26 (2.67)	84.07(10.75)	-	9.99 (4.32)
Coyote	126.33 (13.70)	9.53 (3.96)	99.86 (9.77)	-	15.24 (5.49)
Ft. Valley	116.28 (11.73)	-	116.18 (11.73)	-	-
Ham	124.65 (9.85)	0.32 (0.19)	108.80 (11.83)	-	15.53 (5.41)
Hart	142.76 (9.77)	-	133.48 (10.26)	6.93 (2.08)	-
Hochderffer	134.20 (8.10)	-	127.91 (8.69)	6.10 (2.87)	-
Johnnys	136.50 (11.30)	-	129.12 (9.91)	-	7.38 (3.57)
Moonset	116.74 (6.77)	3.35 (1.71)	107.76 (6.80)	-	5.64 (2.83)
Willard	135.89 (9.56)	0.74 (0.46)	120.35 (11.11)	-	14.80 (3.60)
Wing Mountain East	124.39 (5.90)	-	121.06 (5.96)	0.73 (0.73)	-

Diameter distributions by species, in 4-inch diameter classes, are presented in Figure 1 for trees across all 4FRI task orders. As expected, ponderosa pine makes up the largest proportion of all tree density. The distributions of living trees show that 40 percent of trees are less than 16 inches (14-inch midpoint) in diameter. Across all sites, only 0.01 percent of TPA were found having a greater than 50-inch dbh confirming these large trees are rare on the landscape.

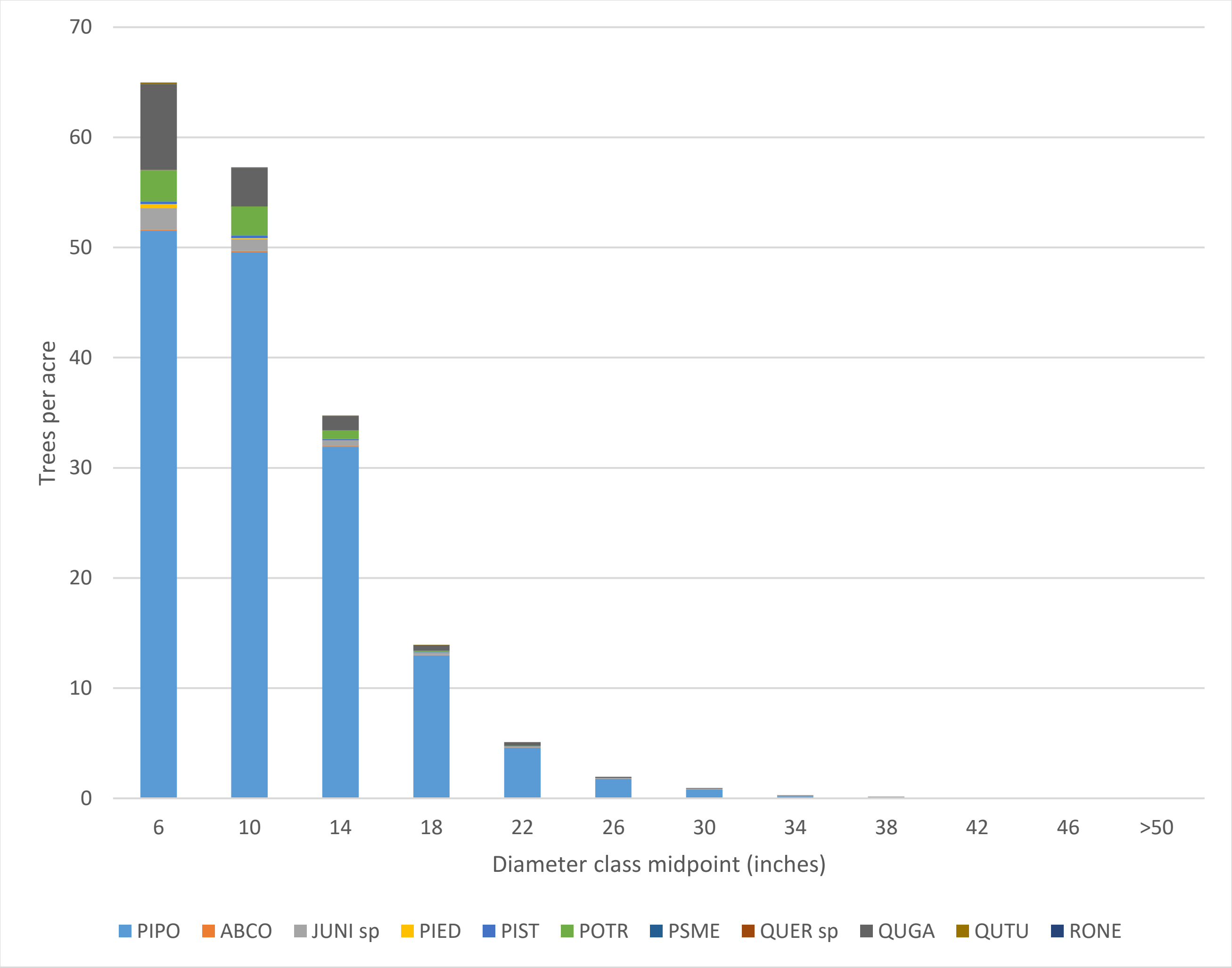

Figure 1. Diameter distribution (diameter in inches).

Tree Regeneration

Seedling density is summarized in Table 6 and sapling density is summarized in Table 7. Due to an error in FS Veg data extraction, the following project areas show no recorded seedlings or saplings: Chimney Springs, Cloverdog, Ft. Valley, Johnnys, and Willard. This data was collected and is in the FS Veg database, but was not available in time for this report.

The lowest number of seedlings per acre was 158.7 in Hart Prairie; the highest seedling density was in Coyote with 2461.3 per acre. Data results show only 41 out of 63 Hart Prairie plots had observed seedlings; remeasurement will confirm is data sampling errors occurred. The lowest number of saplings per acre was 1 in Hart Prairie, the highest was Coyote with 195 per acre. Gamble oak had the highest seedling densities in the projects it was found, but was not as dominant among saplings. Ponderosa pine was either the most abundant or second most abundant species among seedlings across all project areas, and was the dominant species among saplings. Hart Prairie, Hochderffer, and Wing Mountain had no Gamble oak seedlings or saplings.

Table 6: Seedling density (Standard error)

Project	TPA	JUDE2	PIPO	PIST3	POTR	QUGA	RONE
Chimney	No data	No data	No data	No data	No data	No data	No data
Clints Well	996.9 (244.1)	9.1 (3.5)	64.7 (14.5)	-	-	885.3 (241.5)	37.2 (22.2)
Cloverdog	No data	No data	No data	No data	No data	No data	No data
Cougar	908.0 (471.6)	32.0 (27.8)	80.0 (26.7)	-	-	796.0 (429.8)	-
Coyote	2461.3 (448.2)	26.7 (16.4)	850.7 (363.7)	-	-	1584.0 (337.5)	-
Ft. Valley	No data	No data	No data	No data	No data	No data	No data
Ham	1907.5 (460.6)	-	315.0 (135.5)	-	-	1317.5 (263.4)	275.0 (199.5)
Hart	158.7 (32.3)	-	63.5 (18.4)	10.8 (7.1)	84.4 (27.5)	-	-
Hochderffer	664.8 (298.8)	-	595.2 (297.7)	67.6 (48.0)	1.9 (1.3)	-	-
Johnnys	No data	No data	No data	No data	No data	No data	No data
Moonset	1042.7 (300.1)	30.7 (15.5)	181.3 (83.3)	-	-	830.7 (284.5)	-
Willard	No data	No data	No data	No data	No data	No data	No data
Wing Mountain East	328.1 (77.0)	-	323.7 (77.2)	-	1.5 (1.5)	-	-

Table 7: Sapling density (standard error)

Project	TPA	JUDE2	PIPO	PIST3	QUGA
Chimney	No data	No data	No data	No data	No data
Clints Well	56.3 (12.7)	5.3 (2.6)	43.1 (12.2)	-	4.7 (2.1)
Cloverdog	No data	No data	No data	No data	No data
Cougar	52.0 (29.2)	-	44.0 (24.2)	-	8.0 (8.0)
Coyote	194.7 (62.7)	26.7 (4.4)	61.3 (24.0)	-	106.7 (55.7)
Ft. Valley	No data	No data	No data	No data	No data
Ham	25.0 (17.8)	2.5 (2.5)	17.5 (15.0)	-	5.0 (5.0)
Hart	0.6 (0.6)	-	0.6 (0.6)	-	-
Hochderffer	11.4 (7.0)	-	11.4 (7.0)	-	-
Johnnys	No data	No data	No data	No data	No data
Moonset	94.7 (27.8)	5.3 (3.2)	53.3 (15.4)	-	36.0 (23.5)
Willard	No data	No data	No data	No data	No data
Wing Mountain East	11.1 (3.9)	-	8.9 (3.3)	1.5 (1.5)	-

Forest Floor Substrate Cover

Substrate cover along the herbaceous transects is summarized in Table 8. Non-vegetated cover (bare ground, litter, rock, or wood) accounted for the majority of substrate cover. Litter was the dominant cover in most task orders. Cougar has the highest vegetative ground cover at 11 percent, and Ham had the lowest at just over 1 percent. Grass accounted for most of the vegetative cover in all project areas except in Cloverdog, where moss and lichen was the most abundant vegetative cover.

Litter was the most frequent substrate cover, ranging from an average of 85 percent in Clints Well to 57 percent in Cougar. Cougar also had the highest average bare ground, at 11 percent. All other projects had average bare soil of 8 percent or less.

Table 8. Average percent substrate cover by type and project (standard error)

Project	Forb	Grass	Bare	Shrub	Tree	Moss/Lichen	Litter	Rock	Wood
Chimney	0.05% (0.05)	2.08% (0.48)	3.70% (0.92)	-	-	0.05% (0.05)	80.88% (1.66)	6.80% (1.03)	6.45% (0.9)
Clints Well	1.05% (0.20)	1.80% (0.25)	3.82% (0.66)	0.02% (0.02)	0.31% (0.08)	0.31% (0.11)	85.10% (1.03)	4.66% (0.47)	2.93% (0.35)
Cloverdog	-	0.75% (0.44)	2.5% (1.21)	-	-	2.13% (0.82)	74.25% (3.13)	8.38% (1.79)	12.0% (1.2))
Cougar	3.30% (1.60)	7.90% (3.14)	11.10% (5.6)	-	0.2% (0.2)	-	56.7% (8.78)	11.90% (5.48)	8.90% (2.96)
Coyote	-	3.11% (2.65)	4.67% (1.67)	-	-	-	67.33% (6.93)	18.33% (4.25)	6.563% (0.91)
Ft. Valley	0.11% (0.11)	4.83% (1.71)	3.72% (1.59)	-	0.22% (0.15)	0.67% (0.32)	71.0% (3.19)	10.72% (2.81)	8.72% (2.18)
Ham	0.38% (0.20)	0.75% (0.25)	8.44% (2.16)	-	0.13% (0.13)	-	70.44% (4.39)	15.19% (4.03)	4.69% (1.05)
Hart	0.36% (0.14)	5.67% (1.15)	3.69% (1.19)	-	0.40% (0.12)	0.08% (0.06)	82.58% (2.15)	2.62% (0.57)	4.60% (0.66)
Hochderffer	1.43% (0.4)	5.36% (0.75)	2.74% (0.79)	-	0.36% (0.14)	0.18% (0.1)	82.26% (1.7)	3.93% (0.77)	3.75% (0.73)
Johnnys	0.43% (0.23)	9.29% (1.8)	0.79% (0.65)	-	0.57% (0.25)	0.14% (0.14)	68.57% (2.35)	16.29% (2.13)	3.93% (0.96)
Moonset	0.23% (0.16)	2.78% (0.71)	4.6% (1.28)	0.87% (0.87)	-	0.27% (0.16)	67.65% (4.01)	12.11% (1.7)	6.33% (0.97)
Willard	0.33% (0.22)	1.92% (1.22)	1.58% (0.67)	-	0.50% (0.26)	0.17% (0.17)	74.00% (2.92)	14.83% (2.11)	6.67% (1.69)
Wing Mountain East	0.59% (0.22)	5.16% (1.01)	4.68% (2.17)	-	0.37% (0.17)	0.16% (0.12)	75.96% (2.87)	6.12% (0.9)	6.97% (2.19)

Grass, Forb, and Shrub Frequency

Vegetative understory is summarized in Table 9. Grass was the dominant functional group across projects, and forbs were the second most abundant functional group across projects. Hochderffer had the highest vegetative cover, with an average of 54 percent cover across plots. Willard had the lowest average vegetative cover at 16 percent.

Table 9. Average percent vegetation cover by type and project (standard error)

Project	Forb	Grass	Shrub	Tree
Chimney	2.85 (0.55)	17.88 (2.14)	0.28 (0.23)	1.23 (0.60)
Clints Well	5.01 (0.56)	18.91 (1.24)	0.92 (0.42)	3.48 (0.48)
Cloverdog	1.67 (0.36)	14.47 (1.49)	0.27 (0.11)	4.58 (1.02)
Cougar	17.60 (5.52)	25.40 (4.55)	0.90 (0.71)	1.50 (0.75)
Coyote	2.60 (1.01)	7.73 (2.48)	0.73 (0.52)	2.00 (0.97)
Ft. Valley	7.06 (1.84)	27.56 (4.79)	-	4.50 (2.74)
Ham	11.13 (5.28)	16.81 (3.74)	-	-
Hart	4.33 (0.74)	40.59 (3.50)	-	1.87 (0.42)
Hochderffer	8.79 (1.96)	44.00 (4.70)	-	0.83 (0.26)
Johnnys	2.43 (0.99)	26.36 (2.48)	-	1.71 (0.79)
Moonset	5.53 (1.36)	21.13 (2.39)	0.47 (0.21)	0.37 (0.31)
Willard	3.67(1.02)	10.42(1.62)	-	1.83 (0.52)
Wing Mountain East	3.20 (0.91)	23.72 (3.56)	0.06 (0.06)	1.39 (0.56)

Fine and Woody Fuels

Fine fuel data were not collected during the 2015 field season. Instead, field crews estimated a fuel model for each plot. This data is not comparable to the fuel estimates collected in other years. Fuel loadings from 2016 and 2017 are summarized in Table 10. Duff and litter were not included in this assessment; this may contribute to an underestimate of fuel loading.

Table 10. Average estimated tons of fine fuels (standard error)

Project	1 hour fuels	10 hour fuels	100 hour fuels
Chimney	0.18 (0.02)	0.31 (0.06)	0.42 (0.07)
Clints Well	No data	No data	No data
Cloverdog	0.46 (0.05)	0.69 (0.07)	0.68 (0.06)
Cougar	0.14 (0.03)	0.23 (0.08)	0.31 (0.17)
Coyote	0.22 (0.06)	0.31 (0.10)	0.20 (0.08)
Ft. Valley	0.10 (0.02)	0.37 (0.09)	1.45 (0.58)
Ham	0.13 (0.02)	0.17 (0.02)	0.35 (0.09)
Hart	No data	No data	No data
Hochderffer	No data	No data	No data
Johnnys	0.14 (0.03)	0.31 (0.07)	1.02 (0.57)
Moonset	0.13 (0.01)	0.27 (0.05)	0.39 (0.13)
Willard	0.18 (0.03)	0.58 (0.12)	3.85 (1.12)
Wing Mountain East	No data	No data	No data

Invasive Herbaceous Presence

Project plots collected in 2015 had zero observations of invasive species. There may have been a low detection rate for invasive species in 2015 due to lack of crew training in species identification. Field crews across field seasons also had difficulty discerning between native and non-native thistle species, which may have led to a high rate of false identification of invasive thistle species. Cheatgrass, thistle species, and other invasive species (e.g., knapweed) were the most commonly detected invasive species within project areas.

Table 11. Percent of plots with invasive species present, by project

Project	Russian Thistle	Other Thistle Spp	Cheatgrass	Knapweed Spp	Dalmatian Toadflax	Other weed species
Chimney	0%	30%	0%	0%	38%	30%
Clints Well	0%	0%	0%	0%	0%	0%
Cloverdog	0%	71%	43%	1%	16%	3%
Cougar	0%	0%	40%	0%	0%	0%
Coyote	0%	0%	7%	0%	0%	0%
Ft. Valley	0%	44%	0%	0%	56%	56%
Ham	0%	0%	13%	0%	0%	6%
Hart	0%	0%	0%	0%	0%	0%
Hochderffer	0%	0%	0%	0%	0%	0%
Johnnys	0%	50%	21%	0%	0%	57%
Moonset	0%	3%	0%	0%	3%	3%
Willard	0%	17%	17%	0%	25%	67%
Wing Mountain East	0%	0%	0%	0%	0%	0%

Disturbance Indicators

Evidence of disturbance is summarized in Table 12. No data was available for Hart, Hochderffer, and Wing Mountain East projects due to a data extraction issue. Compaction was the most frequently observed disturbance across project areas. The Coconino National Forest is heavily roaded, and it is likely that most of the compaction observed is from roads as this data is all pre-treatment. Evidence of grazing and fire were also observed but were concentrated in only a subset of projects. Erosion was the least commonly observed disturbance.

Table 12. Percent of plots with disturbance indicators present, by type of disturbance and project

Project	Erosion	Compaction	Fire	Grazing
Chimney	0%	10%	0%	0%
Clints Well	6%	6%	0%	63%
Cloverdog	5%	15%	0%	5%
Cougar	0%	0%	10%	0%
Coyote	20%	13%	27%	0%
Ft. Valley	6%	11%	0%	0%
Ham	0%	31%	81%	13%
Hart	No data	No data	No data	No data
Hochderffer	No data	No data	No data	No data
Johnnys	7%	14%	0%	7%
Moonset	7%	3%	0%	63%
Willard	0%	17%	0%	42%
Wing Mountain East	No data	No data	No data	No data

Wildlife Indicators: Log Density, Small Mammal Evidence

Signs of recent squirrel activity was observed on most plots (Table 13). No data was available for Hart, Hochderffer, and Wing Mountain East projects due to a data extraction issue. Data for Ft. Valley, Johnnys, and Williard task orders are missing. Chimney Springs and Clints Well were the only projects that did not have squirrel activity on all plots. There was no evidence of voles on any plots.

Table 13. Percent of plots with observed squirrel sign by project

Project	Pct plots
Chimney Springs	98%
Clints Well	86%
Cloverdog	100%
Cougar	100%
Coyote	100%
Ft. Valley	No data
Ham	100%
Hart	No data
Hochderffer	No data
Johnnys	No data
Moonset	100%
Willard	No data
Wing Mountain East	No data

Data for coarse woody debris is summarized in Table 14. The highest log density per acre was in Ham, at 17.5 per acre. The lowest was in Ft. Valley, with 3.06 per acre. This portion of the protocol was not instituted until 2016, so there are no data for Hart, Hochderffer, and Wing Mountain East. For many of the project areas there were only a few observations of downed logs, leading to high standard errors.

Table 14. Logs > 12 inches diameter, > 8 feet length per acre by project (standard error)

Project	Avg logs/acre
Chimney Springs	8.25 (1.75)
Clints Well	3.59 (0.52)
Cloverdog	7.91 (1.18)
Cougar	10.0 (3.65)
Coyote	15.67 (4.25)
Ft. Valley	3.06 (1.57)
Ham	17.5 (5.57)
Hart	No data
Hochderffer	No data
Johnnys	8.21 (4.34)
Moonset	10.67 (2.74)
Willard	3.75 (1.75)
Wing Mountain East	No data

Discussion

The intent of the 4FRI monitoring ground plots is to evaluate change due to restoration treatments in the 4FRI footprint and measure against the collaborative desired conditions developed for the landscape project. This report summarizes the pre-treatment data across 13 projects. These data are important to summarize now. The first post-treatment data were collected in 2019, and data will be entered into the database and available for analysis winter of 2019–2020.

Pretreatment data confirms that tree densities across all projects were in a higher range than the range of natural variability. 4FRI pretreatment densities were 124 to 228 trees per acre while historical reconstructions estimate the natural range of variability for southwestern ponderosa pine was between 12 to 124 trees per acre (Reynolds et al. 2013). The lowest densities found today are over ten times as high as the lowest densities historically, and highest densities found today are almost twice the historical high density. Site-specific research consistently shows current tree densities are higher than site-based natural range of variability. To sustain a ponderosa pine forest within its natural range of tree densities, about 0.10 to 8.9 seedlings per acre per decade need to successfully establish (Mast et al. 1999). The observed ponderosa pine seedling density and sapling density for all 4FRI projects is well above this density, except for the Hart Prairie project. Regeneration rates are shown to increase following thinning treatments.

This suggests there may be future management needed to control ponderosa pine regeneration through time.

Many projects showed a lack of size class distribution. The 4FRI project seeks to reach an uneven aged, structurally diverse forest. When pre-treatment conditions are particularly homogenous, the structural diversity may not be achieved for decades. For future post-treatment data collection and analysis, the evaluation of restoration success will be with respect to the project-specific pre-treatment assessment.

Pre-treatment invasive species assessments were challenged by changing protocols and lack of trained crew members (see below). Invasive species have been shown to increase following the disturbance associated with forest restoration treatments. Tracking these populations appropriately may require a different sampling strategy, with investment in botanist skills for post-treatment assessments. To meet these needs, a separate invasive species monitoring effort is underway, looking specifically at project roads and landings.

Integrated plot sampling is designed to collect data important to all aspects of forest management. In addition to the forest structure, fuel loading information, especially after mechanical thinning and before fire, can inform burn plans; invasive observations can inform potential pre-treatment control measures; and wildlife observations may inform future monitoring and research opportunities.

Lessons Learned

We evaluated lessons learned and recommendations for data management, including data entry, collection and storage, between the Forest Service and their non-agency partners.

Protocol

We documented lessons learned for the current protocol, including an assessment of protocol implementation, and efficacy of methodology to meet the question.

The efficacy of the methods was low in particular for plot-level variables meant to meet multiple resource needs. The protocol asks for a count of quadrats where the variable of interest was observed, for disturbance factors (erosion, compaction, fire, and grazing) and for invasive species. However, this method does not account for frequency or extent within each quadrant of the plot (e.g., one individual of an invasive species in a single quadrant of the plot gets a count of 1, and 1,000 individuals over the entire extent of the quadrant also gets a count of 1). Changes to the presence/absence plot level data collection may improve protocol efficacy.

For protocol implementation, protocol modifications have been necessary over time as we learned what did and did not work, and as we compromise as a collaborative group. However, consistency is important for dataset integrity, for training field staff, for data analysis and management, and especially when data nuances, or meta-data, are not comprehensively captured.

These protocol changes have caused significant confusion in the field and in data management. For instance, the 2015 protocol asked field staff to estimate fuel model based on pictures provided, but field staff felt this was too subjective and had difficulty making confident estimates. In 2016, the protocol was changed to integrate estimates of fine fuels using the Photoload method (Keane 2007), but due to communication issues, data on only one quadrat instead of four quadrats was collected. The four quadrat approach was implemented in 2017. In 2018, field crews failed to record nulls when there were no fine fuels and instead recorded the lowest non-zero number instead. As a result, the fuel estimates from that year will over-estimate fuel loads. As a result of protocol changes and resulting confusion, no one fuel estimation protocol was used across more than one year.

Monitoring Expertise, Management, and Training

The rapid plot protocol was designed to be easy to learn across experience levels. 4FRI field crews have had a range of experience and those with field experience and a background in biophysical sciences required less training, completed plots more quickly, and had fewer data errors than those without experience. While most protocol components do not require specific expertise beyond identifying plant functional groups, it is necessary to identify trees at the seedling, sapling, and mature stage. Therefore, it is helpful to have crew members with knowledge and training in identifying local tree species.

Training and supervision of the field crews was inconsistent, and these tasks were shared across Forest Service staff and collaborative partners from 2015–2018. Consistency is also challenged by contracting with different organizations through the years. There was insufficient capacity among Forest Service and partners for adequate training and quality control; basic persistent errors can be caught when capacity exists to review field work and data.

Data Collection, Entry, and Management

Initially, the 4FRI MPMB planned to store the 4FRI collaborative monitoring data in the Forest Service database to maximize institutionalization of data within the Forest Service for adaptive management. As partners, we hoped storing data with the managing agency would support and encourage agency use of partner-collected monitoring data. Our experience with the 2015–2017 4FRI monitoring data indicates that there are a number of barriers to accomplishing effective storage, management, use, and sharing of this data when held in Forest Service databases.

Data Collection: As highlighted earlier in the report, not all data can be easily collected by existing Forest Service software, and Excel was used for some data collection. However, only the ExamsPC software is designed to be directly imported into the Forest Service corporate database, FS Veg. Data collected in Excel are disparate from the rest of the data, and we had no way to formally link the two, and no way to store the excel data in a way that could be used broader by future Forest Service staff.

The electronic data collection using ExamsPC and Excel and subsequent data entry had technical and data management barriers. Initial use of electronic data collectors in the field had a tiered approach: the tree list and forest structural data were recorded directly into Exams PC, and the remaining data were recorded on paper and transferred into either ExamsPC or Excel. The ExamsPC software was difficult to learn and had unpredictable errors in the field that resulted in a need to restart, with potential loss of data. Using two separate programs (Excel and Exams PC) for entering data led to data entry errors. Paper data collection was needed for tabulating ground and vegetation cover data prior to electronic entry (calculation of percentage cover is required for ExamsPC), and to increase efficiency in crews. However, it created an additional step in data entry, which led to errors. Despite errors, the paper worksheets proved essential for providing a back-up data recording method when software or electronic hardware failed. Due to difficulty using electronic data entry methods and the Exams PC software, 2017 field data was only inconsistently entered in the field, and in the case of the 2018 field season, all data will need to be reentered from paper forms.

Data management: The biggest barrier to the use of Forest Service corporate databases is that partners do not have access to the data. In large collaborative restoration projects, partners external to the Forest Service may have the largest capacity and available skill sets for long-term monitoring needs. The ExamsPC software allowed partners to create electronic records of field data for upload into FS Veg. Partners were then reliant on the Forest Service to load the ExamsPC data into FS Veg, and to share the data back with partners in an accessible format (such as an Excel file or Access database). A key lesson learned was that the forest personnel did not always have the capacity or training to extract this data in the format needed for partner analysis. Forest-level staff can and did request these services from regional-level and Washington-level database analysts. While these resources were accommodating, the two degrees of separation between partners analyzing the data (ERI) and the Forest Service staff who can write specialized queries to export the data created difficulty in communication and getting the complete dataset in a usable format. This is very restricting, and the expected timeline for data transfer was delayed months at a time, delaying analysis and the scope of this report.

Moving data to an external, partner-developed database allowed all data to be in one database. This helped identify errors and missing data, as well as provided meta-data storage for plot-level attributes applicable to all variables collected and analyzed. However, this database is not designed to be shared via server for multiple partners and Forest Service staff. Storing data outside of the Forest Service corporate database also means that data is not as readily available for planning and analysis processes, or initiatives like broader-scale monitoring, where data will be aggregated across forests. Also, a level of database management will be required to maintain and update this database with future data collected. This ownership has not been explicitly determined at the time of this report.

Conclusion

Pre-treatment data summary and evaluation is important in any land management project. However, the analysis at this time was also critical to better understand the barriers and potential solutions to large, multi-stakeholder monitoring programs on federal landscapes. This summary and evaluation is intended to inform the post-treatment monitoring, with lessons learned to ensure that future data summaries have reduced error and analysis can be assessed efficiently.

There is significant pressure within federal agencies to increase monitoring efficiencies across resource areas. However, with consistently scarce resources for monitoring, it is difficult to invest sufficient human resources to meet monitoring guidelines and timelines at leadership levels, as well as to vet protocols and approaches at the technical level to meet these efficiency needs. This report highlights the difficulties of storing data and analyzing trend analysis across multiple years with changing protocols, changing sub-contractors, and variable error-checking processes. Leadership intent and support for early investment in monitoring programs, with dedicated staff and engagement of technical expertise, could significantly increase effectiveness of incorporating monitoring data into adaptive management recommendations.

Recommendations and Next Steps

Data Accessibility: Data for forest plan and collaborative project monitoring are best utilized when data is stored in one easily accessible and shareable database. Collaborative partners and Forest Service staff working on the 4FRI monitoring have identified that maintaining monitoring data in the Forest Service corporate databases has a number of barriers to accomplishing effective storage, management, use, and sharing of this data (Waltz et al. 2018). Due to the extensive issues with ExamsPC and retrieving data from the FS Veg database, the 4FRI monitoring board has decided to collect data on paper data sheets for the near future. The board is in the process of creating an Access database for data entry and management that tiers to the database designed for this reporting effort. It is the hope of the MPMB that this database will provide a short-term solution by making ground plot data easily entered, easily imported into the multi-year database, with existing summary queries that match pre-treatment summaries. Additionally, the MPMB hopes these data to be accessible to both partners and the Forest Service. As the MPMB is responsible for providing adaptive management recommendations to the 4FRI Stakeholder Group and Forest Service partners, it is essential for the MPMB partners to have access to collaboratively collected monitoring data.

Partnerships: Partnerships have been integral in this monitoring program. The ERI has played a primary role in data collection, management, and analysis. The Nature Conservancy ran the first year of data collection, and LCI currently runs the data collection and provided the sampling methodology. Some of these contributions are in-kind and some are funded through agreements with the Forest Service. The Forest Service is able to do more with less when the agency invests in partner relationships.

Sampling: Both the Kaibab and Coconino national forests have collected rapid plot data outside of project areas to support forest plan monitoring. The work done in 2012–2015 by LCI/CSP both for the Kaibab NF and the 4FRI monitoring did create a sampling algorithm for 4FRI that included densification with the hopes that task order data collection could inform both task order and forest plan monitoring goals. However, there were analyses issues with tiering the data up for forest plan analyses that are beyond the scope of this project. The forest-level questions and the need for resampling should be examined for future data collection.

Monitoring Capacity and Methodology Consistencies: There is significant pressure within federal agencies to increase monitoring efficiencies across resource areas. However, with consistently scarce resources for monitoring, it is difficult to invest sufficient human resources to meet monitoring guidelines and timelines at leadership levels, as well as to vet protocols and approaches at the technical level to meet these efficiency needs. Forest plan monitoring is a commitment to long-term trend analysis, with engagement from Forest Service resources for data collection and incorporation into planning areas. It additionally requires the use of consistent sampling protocol to measure indicators through time. This report highlights the difficulties of analyzing trend analysis across multiple years with changing protocols, changing sub-contractors, and variable error-checking processes. Leadership intent and support for early investment in monitoring programs, with dedicated staff and engagement of technical expertise, could significantly increase effectiveness of incorporating monitoring data into adaptive management recommendations.

Forest plan monitoring with the rapid plot protocol has had mixed results. Changes in protocols have been necessary as the approach to rapid plot monitoring has been adjusted and improved. In addition, the 2012 Planning Rule allows for adaptive management, particularly if monitoring questions and/or indicators are found to be inappropriate for the resource being monitored. However, changes have significantly impacted the ease with which these data can be stored and analyzed. Federal land managers need to invest in the technical capacity to manage any monitoring protocol changes for only the most strategic reasons, while accommodating the cost to data management.

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Appendix A. 4FRI rapid plot monitoring questions, indicators, metrics, and triggers

Indicator #	Desired Condition	Monitoring Question	Indicator	Indicator Metric	Trigger	Adaptive Management
3	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Following mechanical treatments, are invasive plant species occurrences increasing in number or extent at landings/roads? Are efforts to control invasive species at these locations succeeding? (Broad scale, long-term) Are populations of invasive plant species expanding in treated acres?	Invasive Plants	Species cover	Identification of new or existing “watch list” or “high risk” invasive species populations	If inventories, surveys and map checks indicate presence of 'high risk' or 'watch list' species (see narrative), evaluate all BMPs, especially for cleaning equipment moving from infested sites to clean sites. Consider aggressive treatments leading to population eradication. If treatments do not reduce the cover of “watch list” species by 90% in one year or “high risk” species by 50% in 2 years, consider new approaches to eradication.
4	There is reduced potential for introduction, establishment, and spread of invasive species. Additionally, efforts are made to reduce existing infestations.	Following mechanical treatments are invasive plant species occurrences increasing in number or extent at landings/roads? Are efforts to control invasive species at these locations succeeding?	Invasive Plants	Species cover	Identification of new or existing “watch list” or “high risk” invasive species populations	If inventories, surveys and map checks indicate presence of 'medium risk' species (see narrative), consider controlling these species on individual basis especially when high value areas or habitats are at risk. If treatments do not reduce the cover of “medium risk” species by 20% in 5 years, consider new approaches to weed management.
7	Understory vegetation composition and abundance are consistent with the natural range of variability.	Does plant functional group frequency change through time?	Abundance	Substrate and plant functional group frequency	Within 5 years of mechanical treatment, the cover should increase 20% +/- 5% (15-25%) above controls	If this threshold is not reached, then re-evaluate treatment for management change, taking into account soils and burn treatment, (e.g. reduce overstory basal area).
8	Understory vegetation composition and abundance are consistent with the natural range of variability.	Does plant cover & substrate change through time?	Functional group Diversity (understory communities)	Substrate & plant cover	Within 5 years of treatment (mechanical and/or fire), bare soil should comprise less than 20% of area affected by treatment.	If bare soil exceeds 20% of area within plots, re-evaluate restoration treatment for modification.
9	Understory vegetation composition and abundance are consistent with the natural range of variability.	What is the rate of regeneration through time?	Regeneration		Within 10 years of treatment, seedling and sapling density should be within 0.4 to 3.6 plants/hectare/decade on basalt soils.	If seedlings and saplings fall below this range across sub-units where regeneration is a desired condition, then evaluate implementation of BMPs to increase probability of successful

						regeneration. If regeneration falls above this range, then more aggressive prescribed burning may be necessary to reduce plant density.
12	Sensitive soils are protected through use of appropriate timber harvesting equipment and techniques to reduce erosion and sedimentation that could otherwise damage aquatic life, increase flooding, reduce reservoir capacity, and increase costs of maintaining infrastructure in the vicinity of waterways.	No question developed	Soils	Sensitive soil protection	Fine Scale- Increasing bulk density trend; Decreasing infiltration rate trend Broad Scale- Soil disturbance is > 15% of the treated area	Evaluate treatment methods and/or BMPs, and consider making adjustments or implementing additional mitigation measures
13	Sensitive soils are protected through use of appropriate timber harvesting equipment and techniques to reduce erosion and sedimentation that could otherwise damage aquatic life, increase flooding, reduce reservoir capacity, and increase costs of maintaining infrastructure in the vicinity of waterways.	No question developed	Soils	Soil productivity	C:N ratios increasing from 12-14 toward 30, indicating a reduction in nitrogen availability that would impact plant productivity	Evaluate treatments in light of soil processes and make adjustments in treatment methods and forest pattern.
24	Ponderosa pine ecosystems are composed of all age and size classes within the analysis area and are distributed in patterns more consistent with reference conditions.	Is the removal of mechanically thinned trees promoting a diameter distribution that favors uneven-aged forest structure? When large trees were removed, were they removed in accordance with the LTRS/LTIP?	Diameter Distributions	Tree diameters, density	*TBD*	*TBD*
25	Protect old-growth forest structure during planned and unplanned fires.	No question developed	Old Trees	Old tree density, conditions	*Any loss old tree that is cut outside of those identified as allowed in the OTIP*	*TBD; however, when an old tree is cut, the cause or rationale will be reviewed by the MPMB*
27	Rare and ecologically valuable habitat components such as Gambel oak, aspen, springs and wet meadows are protected and enhanced through appropriate restoration treatments where needed.	No question developed	Rare/ Unique Habitats	Percent cover	*TBD*	*TBD*
30	Ponderosa pine ecosystems are composed of all age and size classes within the analysis area and are distributed in patterns more consistent with reference conditions.	No question developed	Snags	Snag sizes, density, conditions	*TBD*	*TBD*

31	Protect old-growth forest structure during planned and unplanned fires.	No question developed	Tree Mortality	Stand Density, basal area, and species composition. Canopy cover, number of pathogen-affected patches, size of dead patches and percent of mortality on landscape	*TBD*	*TBD*
32	A majority of the ponderosa pine ecosystems supports frequent, low-intensity fire.	Are fuel loading metrics (eg cbd, dbh, fuel model and canopy cover) trending down towards ranges that support surface fire?	Fuel Hazard	Crown bulk density, crown base height, and surface fuels	*TBD*	*TBD*

Appendix B. Protocol and Data Sheets

Plot #: Crew: 4FRI rapid plot worksheet

Date: 5/17/19

Lat: Long: Photo # N: E:

Checklist	
○ Tag & GPS point plot center	
○ Plot photos – white board with plot #, unit, date. Record photo #s	
○ Ref trees (2) – Dist, azimuth, DBH, tag @ stump height	
○ Tree heights (3, tag at BH), CBH (3)	
○ Measure trees	
○ Seedling/sapling transects	
○ Vegetation & ground cover transects	
○ Estimate fuels (quadrats (4), woody fuel tonnage)	
○ Log count	
○ Invasives	
Species	Quadrants
Russian Thistle	
Other Thistle	
Cheatgrass	
Knapweed Spp	
Dalmation Toadflax	
Other	
○ Soil disturbance	
Erosion	
Compaction	
○ Grazing	
○ Recent fire	
○ Small mammal	
Squirrel	
Vole	

Woody Fuels

	1 hr	10 hr	100 hr	stand
N				< 3
E				3-10
S				> 10
W				

Seedlings (< DBH)

Sp.	**Total Live**

Saplings (Up to 4" DBH)

Sp.	**Total Live**

N-S Vegetation Transect

Pt	**Vegetation**				**Grnd**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

E-W Vegetation Transect

Pt	**Vegetation**				**Grnd**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

G = graminoid; F = forb; S = shrub; T = tree; B = bare soil; W = woody debris; R = rock; M = moss/lichen; L = litter

Ref tree 1		Ref tree 2	
Dist:	Spp:	Dist:	Spp:
Azi:	DBH:	Azi:	DBH:

Plot #:

Date:

Tree Data (Live and dead trees > 4" DBH)

Tree #	Species	DBH (in.)	Status (L/D)	Height (ft)	CBH (ft)
1					▨
2					▨
3					▨
4				▨	
5				▨	
6				▨	
7				▨	▨
8				▨	▨
9				▨	▨
10				▨	▨
11				▨	▨
12				▨	▨
13				▨	▨
14				▨	▨
15				▨	▨
16				▨	▨
17				▨	▨
18				▨	▨
19				▨	▨
20				▨	▨
21				▨	▨
22				▨	▨
23				▨	▨
24				▨	▨
25				▨	▨
26				▨	▨
27				▨	▨
28				▨	▨
29				▨	▨
30				▨	▨
31				▨	▨
32				▨	▨
33				▨	▨
34				▨	▨
35				▨	▨
36				▨	▨
37				▨	▨
38				▨	▨
39				▨	▨
40				▨	▨

Status: L = live (at least one green leaf persists), D = dead (no green leaves remain)

Plot #:			Date:

Tree Data (Live trees > 4" DBH, Dead Trees > 16" DBH)

Tree #	**Species**	**DBH (in.)**	**Status (L/D)**
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
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59			
60			
61			
62			
63			
64			
65			
66			
67			
68			
69			
70			
71			
72			
73			
74			
75			
76			
77			
78			
79			
80			

Status: L = live (at least one green leaf persists), D = dead (no green leaves remain)

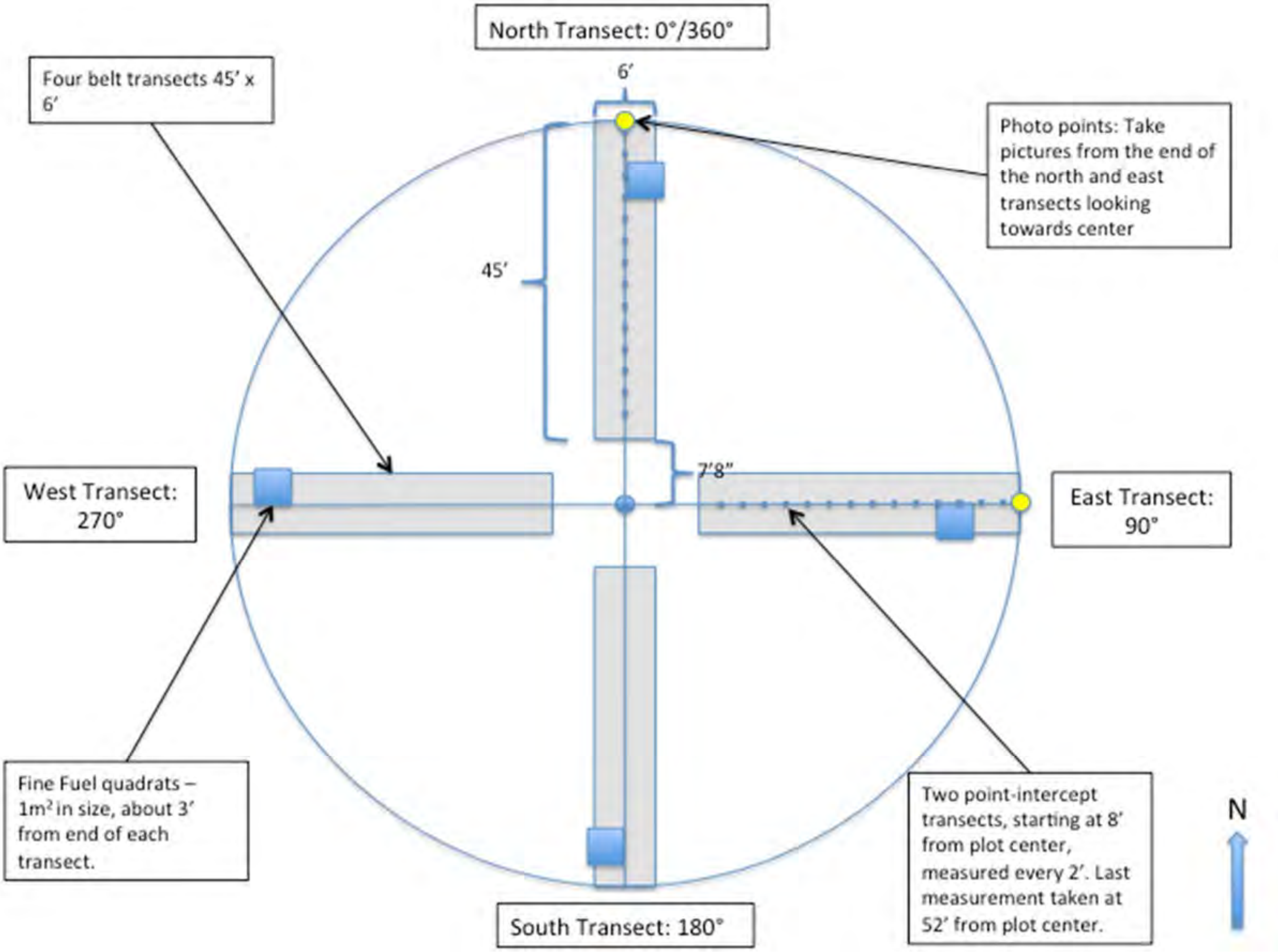
Updated 5/17/19

Rapid Plot Quick Guide

Equipment List:

- GPS Unit
- Compass
- Rebar/plot stake
- Hammer
- Tags
- Nails (aluminum)
- DBH tape(s) (English units)
- 3 transect tapes (200 ft.) (one can be shorter)
- Laser rangefinder
- Camera
- Clipboard and datasheets
- Chaining pins (6) and flagging
- 1m^2 PVC quadrat (4 1m sections and four elbows)
- White erase board & marker

Plot Diagram



Four belt transects 45' x 6'

Photo points: Take pictures from the end of the north and east transects looking towards center

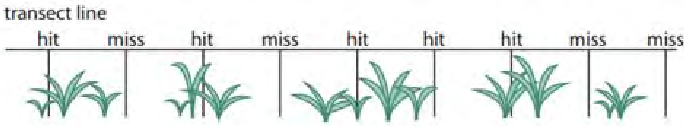
Fine Fuel quadrats – $1m^2$ in size, about 3' from end of each transect.

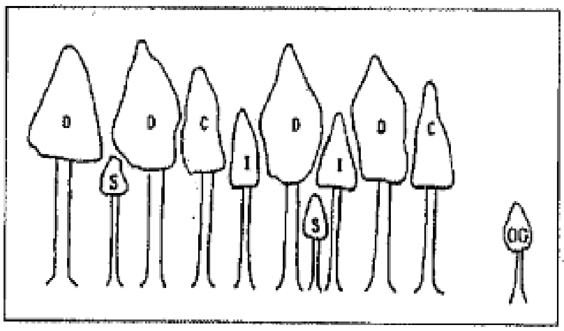
Two point-intercept transects, starting at 8' from plot center, measured every 2'. Last measurement taken at 52' from plot center.

1. Set up plot (52’8” radius circle, .2 acre)
    a. Lay out two tapes to 105’4”, one N-S, one E-W (tapes cross at plot center at the 52’8” mark). Set “0” end of the tape on the North end and East end of the transects. Pay attention to style of tape measure as it may be divided into 10ths/
2. Fill out top of data sheet
    a. Note start time
    b. Date, crew initials, plot #
    c. Latitude & Longitude - use Trimble GPS. Open Rover file and create point with plot number. Place GPS at plot center and collect at least 200 points (latitude and longitude -- degrees, minutes, seconds).
        i. Datum: NAD83, Do not change
    d. Reference tree – pick the two (2) largest, closest trees to plot center
        i. Record species, DBH in inches, distance in feet & azimuth from tree to plot center on data sheet
        ii. Record plot #, distance in feet & azimuth from tree to plot center on tree tags
        iii. Tag tree at stump height
    e. Rebar or wire stake at plot center with tag with plot #
3. Take pictures – North to plot center, East to plot center, photos should show ground and plot. Use white board to record plot number, unit, date and direction (N to center or E to center) in pictures. Record photo numbers on data sheet.
4. Tree Sampling
    a. Use loggers tape to measure DBH of every tree >4” DBH. Record species, DBH, and live/dead. Start in NE quadrant.
        i. Measure height of 3 co-dominant trees (average large trees). Tag trees at breast height, labeled 1,2,3.
        ii. Measure CBH of 3 trees with lowest canopy height >4” DBH. CBH is at the lowest piece of live vegetation on the lowest branch. (these trees are NOT tagged)
        iii. Trees on plot edge are ‘in’ if the center of the tree is 52’8” from plot center.
        iv. If a tree forks below BH, measure and record DBH as two separate trees. If forks above BH, measure as one tree.
    b. Count number of all live seedlings (<4.5’ tall) and saplings (>4.5’ and <4”DBH) in four 6’ x 45’ transects.
        i. If seedlings of a species are too numerous to count in an efficient way (>50 in a small area), stop counting individually and estimate the total number in the plot to the nearest 50.
        ii. If transect is blocked, move clockwise, and clearly indicate which transects are sampled.
5. Ground cover sampling – two transects, one NS and one EW. Transects start at the end of the tape 1 foot mark and proceed to the 45 foot mark (total of 23 points on each transect).
    a. Record functional group/life form every 2 ft, starting from tallest to shortest.

   b. Record understory canopy cover measurements and ground cover measurements separately. Don't double count functional groups within the canopy cover measurements, even if there are two of the same type at one point. Presence-absence only.

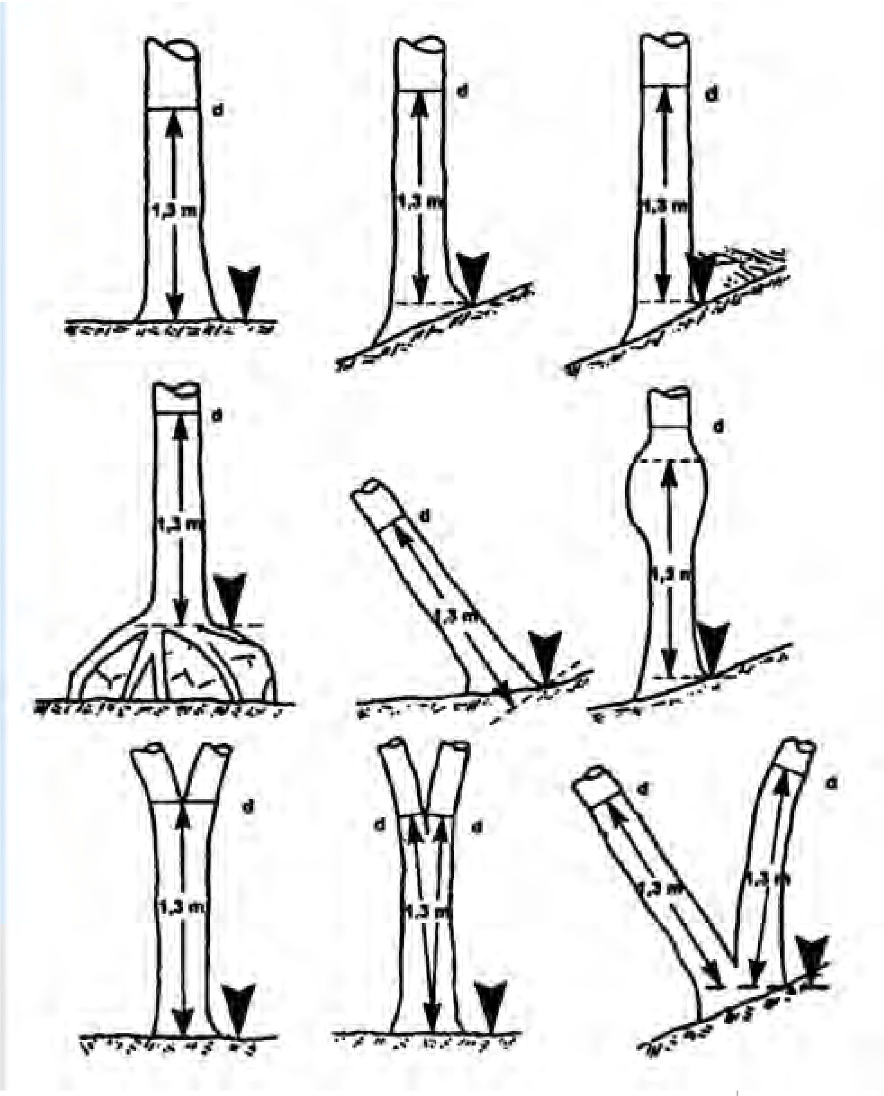
6. Fuels – woody fuel tonnage, fine fuels, and log tally
   a. Estimate fine woody fuels (1hr, 10hr, and 100hr) in each 1m^2 quadrats 3 feet from the end of each transect using the provided picture guides. Identify the fuel load that matches the picture for each size class and record the value. (Pine needles and pine cones are litter, not woody fuel.)
   b. Estimate coarse woody fuel tonnage using the provided pictures. Consider downed woody debris both inside and outside the plot (all that you can see, selection should characterize the stand). Indicate one of three woody fuel categories of tons/acre.
   c. Tally all large logs in the plot. At least 8' of the log must lie in the plot, and midpoint of the portion of the log lying in the plot must be greater than 12" in diameter.
7. Disturbance sampling
   a. Record presence/absence of:
      i. Invasive species (see most wanted list, record species and # of quadrants)
      ii. Soil disturbance (erosion, or compaction (trails, roads, bare areas > 1ft^2), record type and # of quadrants)
      iii. Grazing (cow pies) (record # of quadrants)
      iv. Recent fire (do not note evidence of old fire, such as old fire scars; record # of quadrants)
8. Small mammal sampling
   a. Vole sign (runways, grass clippings, or droppings) – yes or no
   b. Squirrel sign (eaten cones, bud clippings, or stripped twigs) – yes or no
9. Record end time, coordinates of averaged waypoint.

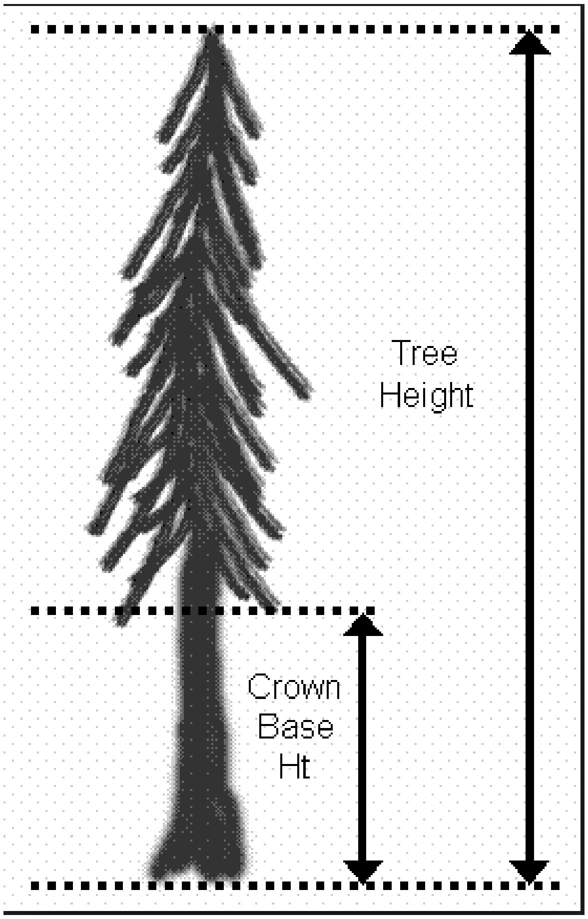




Crown Position Classes: D = dominant, C = codominant, I = intermediate, S = suppressed, OG = open–grown.

The dominance of a tree refers to the position of its crown relative to other trees in the canopy. Dominant trees have relatively large crowns and are taller than most other trees in the stand. Co-dominant trees make up the general canopy level.





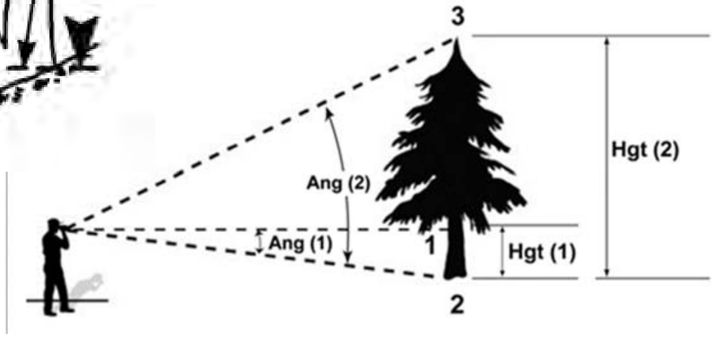
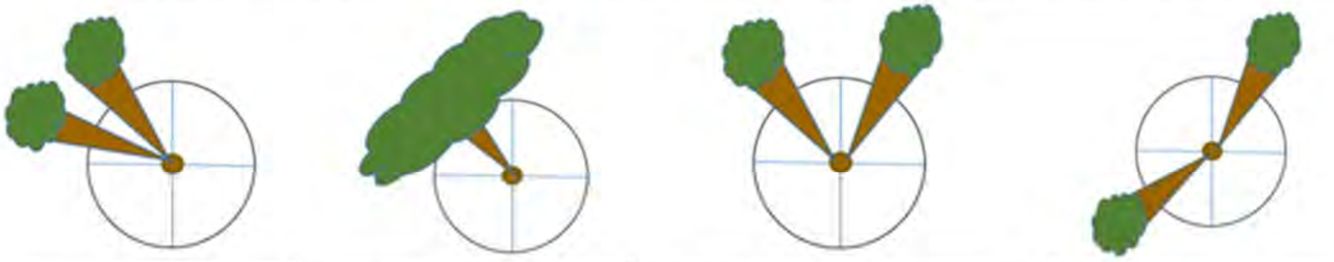


Figure 1. CBH diagram. Solid brown circles represent tree trunks, and areas delineated by black circles and blue lines represent four 90° quadrants around tree trunks. Imagine looking straight down from a tree top to where the lowest branches come off of the trunk.



1a. If lowest branch(es) and foliage don't span more than 90° around the trunk, they **do not** represent CBH.

1b. If lowest branch(es) and foliage span more than 90° around the trunk, they **do** represent CBH.

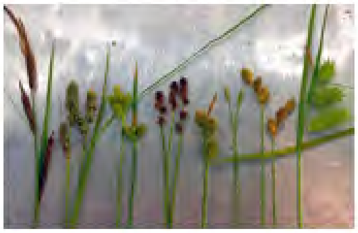
1c. If lowest branches extend from two separate, adjacent quadrants, they **do** represent CBH.

1c. If lowest branches extend from two separate, opposite quadrants, they **do** represent CBH.

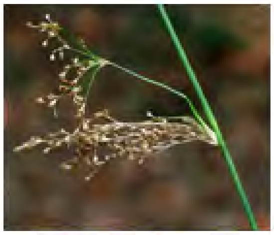
Graminoids

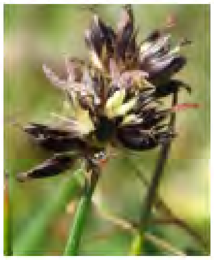
Grasses

Sedges

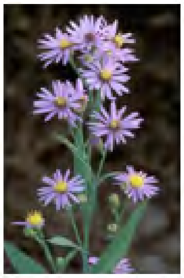


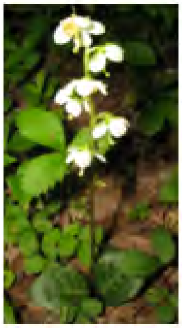
Rushes



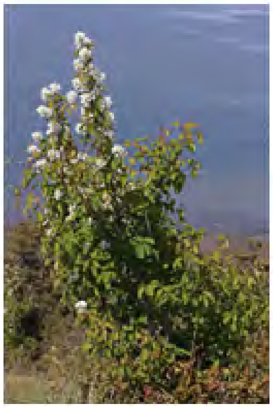


Forbs

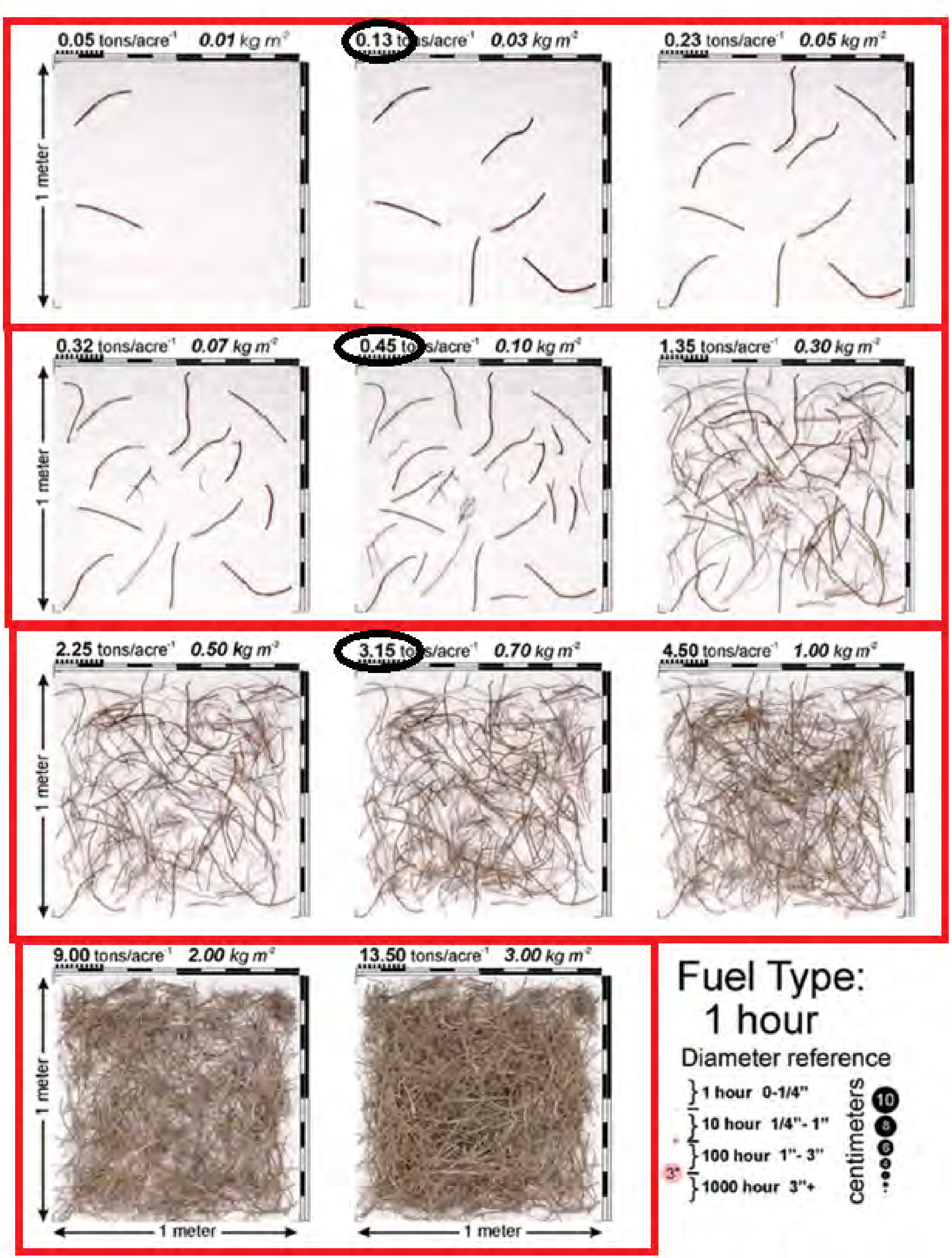




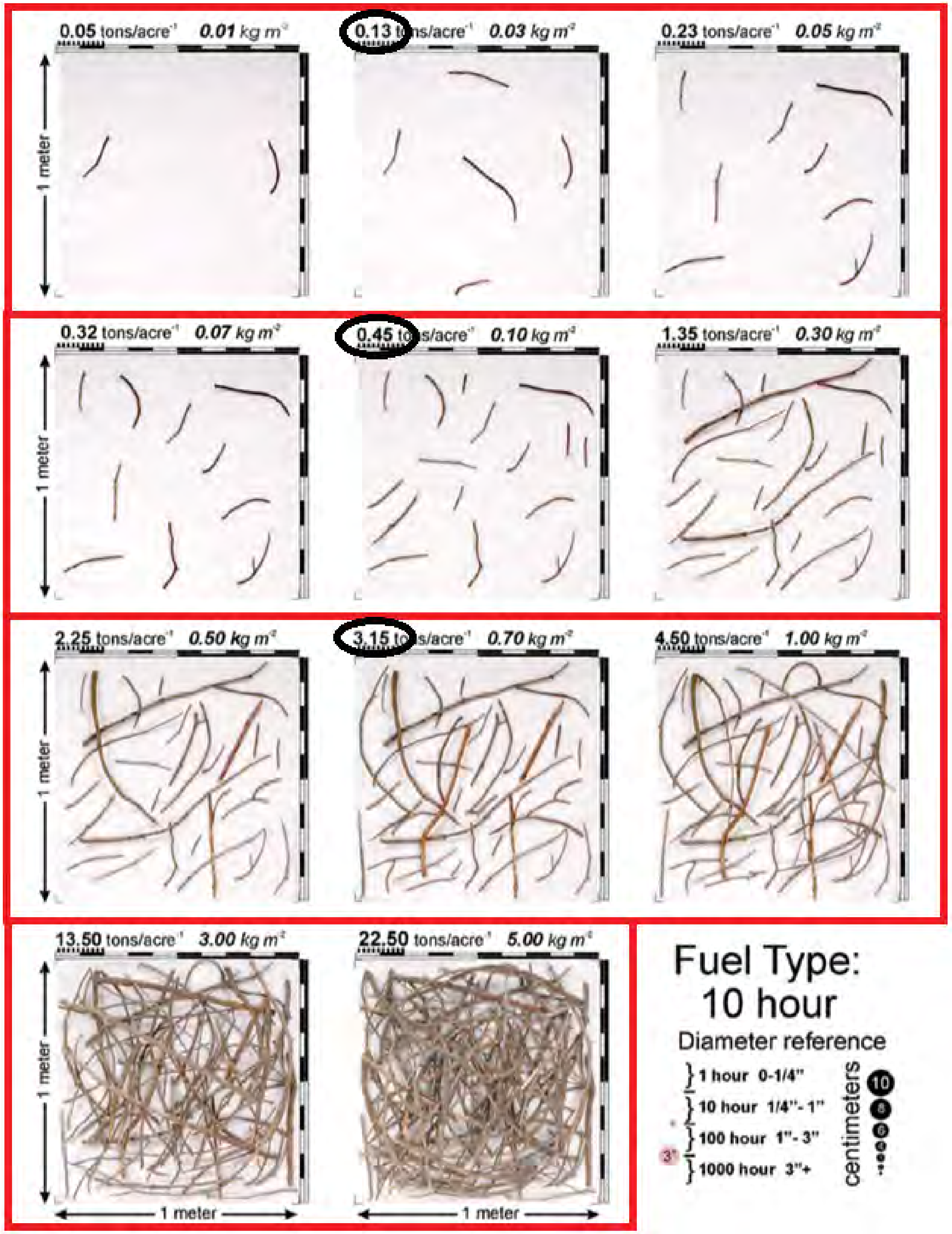
Shrubs



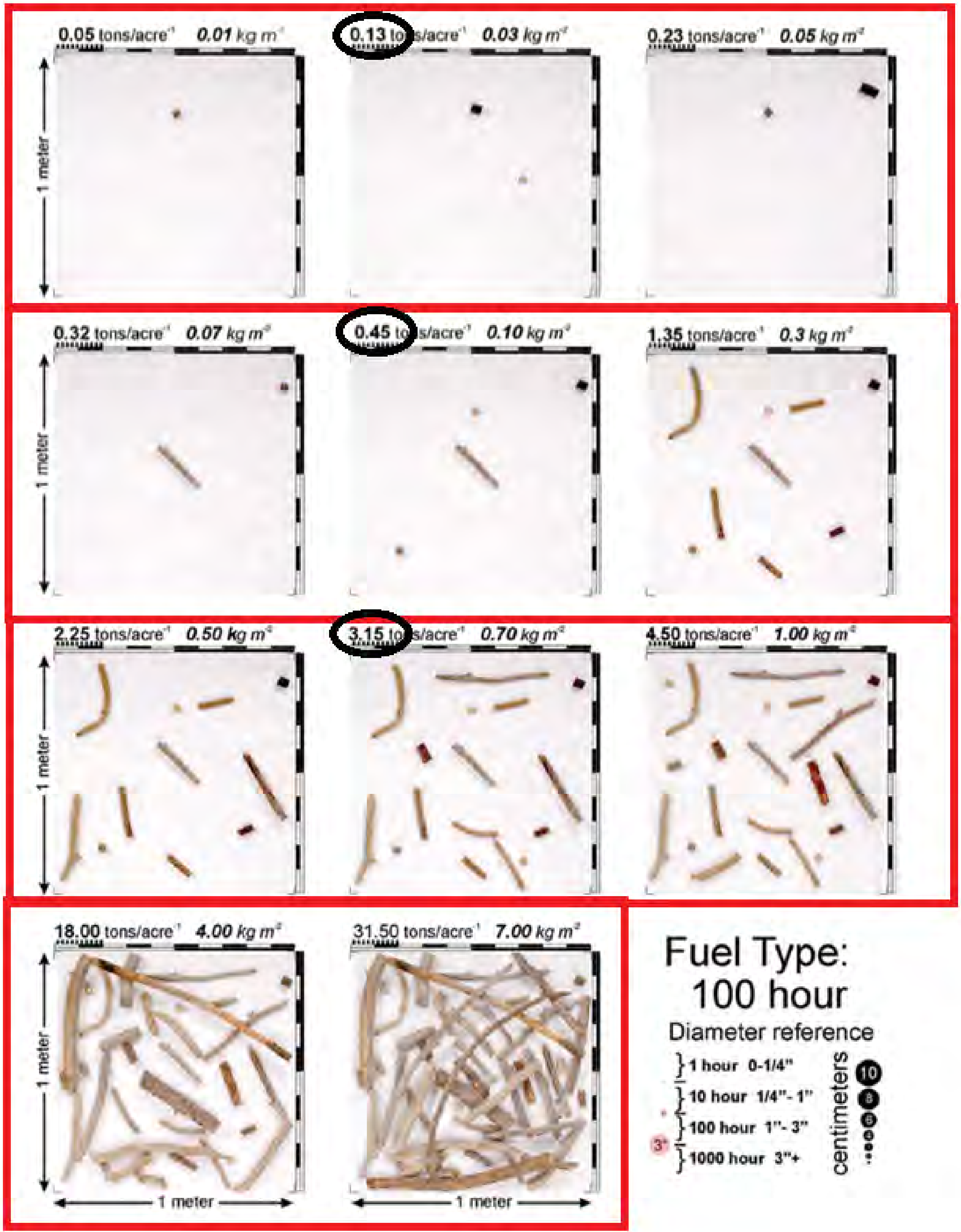
Trees



11.25 tons/acre


0.05 tons/acre^{-1} 0.01 kg m^{-2}
0.13 t ns/acre^{-1} 0.03 kg m^{-2}
0.23 tons/acre^{-1} 0.05 kg m^{-2}
0.32 tons/acre^{-1} 0.07 kg m^{-2}
0.45 to s/acre^{-1} 0.10 kg m^{-2}
1.35 tons/acre^{-1} 0.30 kg m^{-2}
2.25 tons/acre^{-1} 0.50 kg m^{-2}
3.15 to s/acre^{-1} 0.70 kg m^{-2}
4.50 tons/acre^{-1} 1.00 kg m^{-2}
13.50 tons/acre^{-1} 3.00 kg m^{-2}
22.50 tons/acre^{-1} 5.00 kg m^{-2}
1 meter
1 meter
1 meter
1 meter
1 meter
1 meter
Fuel Type:
10 hour
Diameter reference
1 hour 0-1/4"
10 hour 1/4"- 1"
100 hour 1"- 3"
1000 hour 3"+
3"
centimeters
10
8
6

18 tons/acre



24.75 tons/acre

< 3 Tons/ Acre

1.80 tons acre^{-1} ***0.40*** *kg m*$^{-2}$ Total log length: 18 feet

1.80 tons acre^{-1} ***0.40*** *kg m*$^{-2}$ Total log length: 6 ft

>10 Tons/ Acre

11.25 tons acre^{-1} ***2.50*** *kg m*$^{-2}$ Total log length: 110 ft

11.25 tons acre^{-1} ***2.50*** *kg m*$^{-2}$ Total log length: 40 ft

3 – 10 Tons/ Acre

6.75 tons acre^{-1} ***1.50*** *kg m*$^{-2}$ Total log length: 66 ft

6.75 tons acre^{-1} ***1.50*** *kg m*$^{-2}$ Total log length: 24 ft