Collaborative monitoring of the impacts of forest restoration treatments on ponderosa pine ecosystems in the Front Range, Colorado

A pilot study in the Front Range Roundtable's Collaborative Forest Landscape Restoration (CFLR) monitoring program, funded by the Southern Rockies Landscape Conservation Cooperative (SRLCC), the US Geological Survey, and the Rocky Mountain Research Station

Report for the Front Range Roundtable Science and Monitoring Team, 2/2/2012

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SUMMARY OF PROJECT BACKGROUND AND OBJECTIVES

In 2010, Colorado Front Range National Forests were awarded a Collaborative Forest Landscape Restoration (CFLR) grant to facilitate the implementation of restoration treatments across 32,000 acres of ponderosa pine-dominated forests. Collaborative, multi-party monitoring of the impacts of restoration was a required component of the grant; however, the budget for this work was limited. A monitoring plan was developed in 2010-11 by the Front Range Roundtable, an interagency collaborative with representation from 50+ stakeholder groups, which had worked with the Pike-San Isabel National Forest (PSI) and Arapaho-Roosevelt National Forest (AR) to prepare the successful CFLR grant proposal. To supplement the limited CFLR monitoring budget, a team of Roundtable members successfully applied for additional funding from the Southern Rockies Landscape Conservation Cooperative in May 2011. We are using this funding to expand the scope of the CFLR monitoring effort in 5 key ways: (1) to conduct monitoring in restoration treatments implemented by partner agencies as well as on National Forest lands; (2) to conduct monitoring in adjacent areas not planned for treatment (controls); (3) to evaluate changes in within-stand structural heterogeneity due to treatments; (4) to measure the use of treated areas by a diverse suite of wildlife species; and (5) to investigate the effects of treatments on understory plant communities. Our supplemental monitoring effort builds on the baseline Common Stand Exam (CSE) forest inventories conducted by the two National Forests before and after treatments on their lands. The methods we used in the initial field season, 2011, are described below. We hope to integrate our additional data to help quantify restoration impacts on diverse components of the ecosystem, to help develop a long-term (10+ years) monitoring strategy for CFLR work, and to help inform the adaptive management process in Front Range forests threatened by increasingly severe and frequent disturbances.

METHODS

Study sites

Data were collected between July and October 2011, on a total of 79 plots divided among 8 "restoration treatment" units (pre-treatment) and 8 untreated "control" areas at the following sites:

A. Pike-San Isabel National Forest (PSI), Phantom Creek area. 2 units were sampled: Phantom 1 Unit 2 (approx. 150 acres) and Phantom 2 Unit 3 (approx. 350 acres). These sites were thinned in July 2011 and September 2011, respectively.
B. Boulder County Parks and Open Space (BCPOS), Hall Ranch. One unit, a 66 acre prescribed fire, was sampled. The fire occurred on October 5, 2011.
C. BCPOS, Heil Valley Ranch. 2 units of approx. 100 acres each were sampled. The units are scheduled to be thinned Winter-Spring 2012.

D. Arapaho-Roosevelt National Forest, Estes Valley area. 3 units were sampled: EV13 (approximately 75 acres; EV34 (approximately 150 acres) and EV28 (approximately 250 acres). All are scheduled to be thinned Winter-Spring 2012.

Plot selection

Sampling density ranged from 1 plot per 10 to 50 acres, approximately. On each of the 8 treatment units, we established between 3 and 10 plots per unit. In the nearby control areas, we established between 3 and 8 plots per unit.

For almost 50% of the plots on treatment units, we found existing Common Stand Exam (CSE) plot locations, where CSE data had recently been recorded by USFS crews or contractors funded by CFLRP, and we collected our additional data there as described below. For the other treatment unit plots, and all control plots, we established new plots.

Plot locations were chosen using a combination of random and targeted selection strategies. On treatment units, in general, we initially visited either a randomly chosen subset of the existing CSE plots, or all CSE plots. The CSE plot locations had been determined by US Forest Service (USFS) silviculturalists using a randomized method in GIS. CSE data had been collected at most plots in June-July 2011 (some in the previous summer). When we visited an existing CSE plot, we assessed whether it contained at least 5 trees (using a Basal Area Factor (BAF) of 10), and had at least 1 sapling/mature ponderosa pine. If so, we used it as a "treatment plot" in this study. If neither of these criteria were met, or if the plot contained unusual conditions such as a high proportion of lodgepole pine, spruce, juniper, or beetle-killed ponderosa pine, we moved on to the next CSE plot. If none or very few of the existing CSE plots in a treatment unit contained ponderosa pine or conditions where ponderosa would be expected to grow, we established new plots within ponderosa pine stands in those treatment units.

To determine the location of control plots, we generated random coordinates (in GIS) for plot locations in areas within approx. 1 mile of treatment units that met 2 criteria: 1) the area appeared to have similar species composition to the treatment units, and 2) the area was not scheduled for treatment in the next few years. We visited each random point in the field and evaluated whether the conditions there (i.e. overstory/understory species composition) approximately matched the conditions in one of the treatment plots. If so, we used that location as a control plot. If not, we either continued to the next random point or selected a new site nearby which matched a treatment plot more closely. Overall, we attempted to select a set of control plots in which overstory and understory species composition and structure were similar to those in the treatment plots. We did not attempt to standardize variables such as tree density, slope and aspect between treatment and control plots, although these were sometimes similar.

Variables measured

We collected the following data at each plot, using a variable-radius plot (BAF10) for trees and a fixed-radius plot (1/10 acre; 37.2 ft radius) with the same plot center for most other measurements (Figure 1). Most of the variables we measured and the detailed protocols we used followed either the USFS CSE methods (manual and full documentation available at http://fsweb.nris.fs.fed.us/products/FSVeg/documentation.shtml), or were identified in the Monitoring Plan completed in June 2011 for the Roundtable by the Colorado Forest Restoration Institute (CFRI) (see p. 23-31 in plan available at http://www.frontrangeroundtable.org/uploads/Roundtable_CFLRP_Monitoring_Plan_062511.pdf).

1. *Overstory trees.*

a. We measured all trees that were at least 4.5 ft tall and had a diameter at breast height (dbh) of at least 1 inch within a variable-radius plot with a Basal Area Factor (BAF) of 10. For each tree, we recorded species, dbh, health status, height, canopy base height, crown ratio, canopy position, and any signs of physical damage, insect infestation, or wildlife damage. We followed CSE protocols for detailed methods and classification (e.g. descriptions of how to measure canopy base height; codes for health status, codes for decay class of snags or stumps, if present, etc.; CSE manual Chapter 4 and Appendix K).

When we were at a plot location for which CSE data had already been collected by USFS crews, we checked to see whether they had used a BAF 20 rather than 10, and if so we collected data on the additional trees that fell into a variable-radius plot using a BAF 10.

b. We inspected all BAF 10 and BAF 20 trees for indications of wildlife use (e.g. nests, cavities, squirrel feeding sign at base) and recorded these signs if present. CSE crews had sometimes but not always noted this information. We used CSE format to record the type and amount of use (e.g. "woodpecker damage, minor, <20% of tree bole affected"). We noted if nests appeared to be active or inactive. If in doubt about the type of wildlife use, we took photos for later identification by specialists.

c. We noted an estimated age class for each tree (young/transitional/old) based on morphological characteristics described by Huckaby et al (2003) and/or local foresters. CSE crews had done this on the PSI but not the AR.

d. We took a core from one "old"-looking tree of each dominant species present in the plot, and one representative "site" and/or "growth sample" tree per dominant species present, unless these trees had already been cored by CSE crews. (On the PSI treatment plots, crews had followed CSE protocol to core site- and growth sample trees at each plot, count the rings and leave the cores in the field. CSE crews did not take tree cores on the AR.) If we were at a plot where trees had not been cored, we selected trees to core based on the characteristics of site/growth/old trees described in the CSE manual, Huckaby et al. 2003, and/or by local foresters. If no appropriate trees were present within the plot, we chose trees nearby that fit the criteria, up to a distance of about 100 ft from plot center. We recorded all data on cored trees as described above (dbh, height, etc) ; noted distance and bearing to plot center, and gave each a tag. We saved cores for later processing, dating, and analysis in a lab at RMRS.

2. *Saplings and seedlings.*

We counted all seedlings and saplings (less than 4.5 ft tall) present in a 1/200 acre sub-plot (Fig. 1; 8.3-ft radius around plot center; consistent with CSE protocol.) We identified the species of each and classified them into 5 size classes: less than 1 ft tall, 1-2 ft, 2-3 ft, 3-4 ft, 4-4.5 ft. If any small trees were present (height > 4.5 ft but dbh <5 inches) that had not fallen into the BAF 10 overstory plot, we recorded them here also.

3. *Surface fuels.*

We tallied surface fuels on one 50-ft Brown's transect per plot, established along the north bearing from plot center. We followed standard protocols (Brown 1974 and CSE manual) to define and count all downed woody fuels in the 4 standard size classes that were present:

a. 1-hour fuels (up to 0.25 inches diameter) along an 8-ft section of the transect
b. 10-hr fuels (0.25-1 inches diameter) along an 8-ft section of the transect
c. 100-hr fuels (1-3 inches diameter) along a 12-ft section of the transect
d. 1000-hr fuels (more than 3 inches diameter) along the entire 50-ft length of the transect. For each of the 1000-hr fuel pieces, we also recorded the decay class, diameter at the transect tape, diameters at the small and large ends, and length (as specified in Brown 1974 and the CSE manual).

In addition, we measured the depth of the duff layer and of the fuel bed (to the nearest 0.1 inch) at 2 points on the transect. Note: Brown's transect data were collected on CSE plots on the PSI but not on the AR.

4. *Understory plants*.

a. We measured percentage cover of species present in the understory using a point-intercept method. We established 4 transects in the cardinal directions from plot center. Each transect was 30.75 ft long. At 100 evenly spaced points along each of these transects (i.e. every 3 inches between 6' and 30.75'), we recorded any plant present that was up to 4.5' tall. We identified herbaceous, forb, and shrub species present to the species level if possible in the field. If species identification was not possible in the field, we collected a specimen from outside the plot which was pressed for later identification in the lab. We noted substrate type at each point also, i.e. rock, litter, soil, or wood. We noted the size of woody surface fuels (1-hr, 10-hr etc as described above) if present. We noted if portions of trees intersected our sampling points, up to a height of 4.5' off the ground. If more than one substrate and/or species was present at a sampling point, we recorded them all (e.g. litter, kinnickinnick (*Arctostaphylous uva-ursi)*, Douglas-fir (*Pseudotsuga menziesii*) sapling.) The number of occurrences of each plant species and substrate type was tallied to calculate percent cover for each species and substrate.

b. We conducted a complete inventory of all understory species present in a 1/10 acre plot (37.2 ft radius). This entailed systematically searching for any plants that did not intercept the 4 transects surveyed for percent cover, and identifying those additional species either in the field, or from a sample that was removed, pressed, and keyed out in the lab.

Note: On the PSI, CSE crews had conducted a more general understory survey by visually estimating the percent cover of different life form categories (e.g. grass, shrub, etc) and noting the occurrence and percent cover of some individual species of interest. On the AR, no understory data were recorded.

5. *Wildlife use on forest floor*

Note: CSE protocols do not include any of the following methods. Wildlife monitoring options were discussed by the Roundtable monitoring team in 2010-11. Possible focal species/guilds and methods were outlined in more detail by Craig Hansen, USFWS and other Roundtable wildlife biologists, and described in the June 25 CFRI monitoring plan. With additional input and training by Janelle Valladares and Felix Quesada, PSI, the specific methods below were implemented in our pilot study. Some of these methods have been used or are currently used by wildlife biologists on the PSI to monitor certain species.

a. Within the 1/10 acre plot (37.2 ft radius), we searched for and recorded feeding sign of Abert's squirrels and pine squirrels on the forest floor. We counted all chewed cones, middens, branch clippings, etc, that were present, attributing them to either species of squirrel based on descriptions of each species' typical feeding evidence provided by local wildlife biologists. We categorized the cones and clippings as freshly harvested (within the current season) or older (from previous seasons) based on their color. We categorized the middens as active vs. inactive based on the presence of freshly harvested cones or plant material, recent signs of digging, etc.
b. We recorded any scat and tracks present in the 1/10 acre plot. If in doubt as to the species responsible, we took photos or samples for later identification by wildlife specialists. We categorized scat as fresh (from the current spring/summer season) or old (from before the past winter) based on texture, moisture, and other evidence described by local wildlife biologists.
c. If we observed or heard any animals that we could identify to species on or near the plot (within sight from plot center) during the data collection period, we recorded this information. (These data will not be analyzed formally, because we recognize that animals were impacted by our presence and/or by the goshawk calls.)
d. We noted any other signs of animal use, such as game trails, burrows, feathers, bones, etc, and identified the species responsible in the field or from photos whenever possible.

6. Ground-dwelling insects

On most of the plots in the study, we established pitfall traps to capture ground-dwelling insects. Each trap consisted of two16-ounce plastic cups stacked together and buried in the ground so that the lip was level with the forest floor. One trap per plot was set out and left in place for 4-6 weeks. Time of establishment and removal was noted. The insects (and any other organisms) collected in the cups were placed in ziplock bags and frozen to preserve them for later identification by an entomologist at RMRS.

7. Broadcast call surveys for goshawks/raptors

Adjacent to each plot, we performed a brief broadcast call survey for goshawks. These surveys were done before any other activity occurred on the plot. One person stood about 50 ft north of plot center and played a recording of a Northern goshawk alarm call on an iPOD attached to a bullhorn megaphone. The call was played for approx 30 seconds with the bullhorn pointing in each of the 4 cardinal directions (total time 2 minutes.) The presence and/or response of any raptors was noted. This method is used by the PSI NF.

8. Within-stand forest structure ("clumpiness").

At each plot center, we established a sampling transect running 100 m (328ft) north of plot center. Along this transect, we recorded the distances covered by closed-canopy forest vs. openings. In this context, we defined closed-canopy forest as saplings or overstory trees with a dbh of at least 1 inch. If canopies of trees/saplings were less than 5 feet apart, we counted them as part of the same closed-canopy "segment". We defined openings as areas with no saplings/trees present >1 inch dbh. Shrubs could be present in either openings or closed-canopy segments but were not counted/measured. If regeneration (saplings/seedlings with dbh < 1 inch) was present in an opening, we recorded if regeneration covered less than 50% or greater than 50% of the opening's length along the tape. Within the closed-canopy areas, we noted whether the structure was single-story vs. multi-story (canopies of > 1 sapling and/or tree intersecting the tape at the same point). If any snags, middens, or trees with an old-growth appearance were present on these transects, we noted their location (i.e. distance from the start of the 100-m tape) and their dbh/species if applicable. This method is not part of CSE protocols but was developed by co-PI Jonas Feinstein of NRCS as a means of addressing the Roundtable's goal of measuring stand-level forest structure before and after treatments.

9. Plot descriptive data and marking protocols.

At each plot, we followed CSE protocols to record GPS coordinates at plot center (by taking an averaged location from a hand-held GPS unit; stated accuracy usually 5-15 ft), slope (%), slope position, aspect (degrees), elevation (from GPS unit), fuel model (one of the 13 fuel model types described by Anderson 1983), any signs of past disturbance, and the start and end time of the data collection.

We marked plots with a labeled aluminum stake pounded into the ground at plot center. We attached a soft aluminum tag and some colored flagging to the tree closest to the N bearing from plot center, and noted on the tag that tree's bearing and distance from plot center. We also tagged any trees that we had cored and noted their distance and bearing to plot center. We placed additional, labeled aluminum stakes in the ground 37.2 ft N and E from plot center (marking 2 of the 4 radii of the 1/10 acre wildlife use/understory survey plots). Finally, we placed labeled aluminum stakes at 50m and 100m N of plot center to mark the mid-point and end point of the forest structure ("clumpiness") measurement transect. These markers will improve a crew's ability to find the same plot and transect locations to collect data following treatments.

Data collection in 2012 and in future

We will collect the same set of data on all 79 plots in Summer 2012, when treatments have been completed in the treatment units. (Note: we will not re-measure attributes which have not changed, e.g.

forest stand structure on transects in control sites.) If funding and support are available, we intend to repeat these surveys in future also, e.g. at 2, 5, and 10 yrs post-treatment.

Data analysis

To address the study's main questions about the short-term impacts of restoration treatments on ponderosa pine ecosystems, we will use our data to compare the following variables, averaging across plots within each treatment/control unit. Comparisons will be made both between pre- and post-treatment time periods (2011 vs. 2012) and between treatment vs. control areas. Variation among the 3 different agencies' sites (PSIand AR National Forests, and BCPOS) will be evaluated in the analyses.

a. Overstory: Basal area, tree density (stems per acre), species composition, canopy cover, canopy base height, canopy bulk density, proportions of trees of different age classes, age of cored trees
b. Regeneration: Density of seedlings/saplings per acre, species composition
c. Fuels: Total fuel loading, fuel loading of 1, 10, 100, 1000 hr fuels, modeled fire behavior potential
d. Understory: Total species richness and cover; species richness and cover by functional groups (e.g., native/exotic, grass/forb/shrub, annual/biennial/perennial); cover for species of interest (e.g., noxious species, dominant native understory species)
e. Wildlife: Number of species recorded using area; amount of use by individual species/guilds (e.g., squirrels, ungulates, ground-dwelling insects); types of use of area (e.g., foraging, nesting, cover)
f. Within-stand forest structure: Number of openings/clumps; size of openings/clumps; number of single-storied v. multi-storied clumps

References

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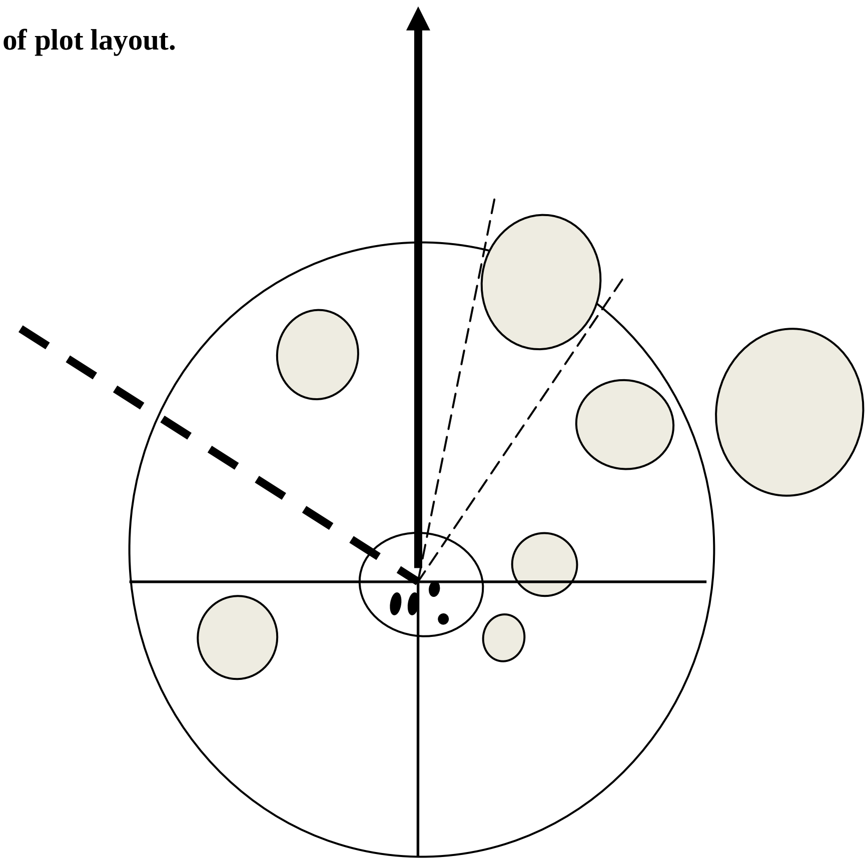
Figure 1. Diagram of plot layout.



Key: (diagram not to scale)

Light dashed lines = Variable-radius plot (BAF 10) to measure overstory trees

Gray filled circles = Overstory trees – all 7 shown here would be counted in for this plot

Large open circle= Fixed-radius 1/10 acre plot (37.2 ft radius) for understory inventory and wildlife use inventory. Point-intersect transects (4, of lengths 30.75 ft) were established on the 4 radii to measure percent cover of plants and substrates.

Small open circle = Fixed-radius 1/200 acre plot (8.3 ft radius) for seedling/sapling survey. Black filled circles indicate 4 saplings present in this illustration.

Heavy dashed line = Brown's surface fuel transect, 50 ft long.

Heavy solid line = Stand "clumpiness" transect, 100 m (approx. 300 ft) long, to measure openings and closed-canopy areas within the stand.

Table 1. Summary: variables measured by our crew and by CSE crews on the PSI and AR National Forests, links to Tier 1 and Tier 2 variables listed in the CFRI Monitoring Plan, and time to collect data.

Variable category	**Specific variables we measured**	**# on CFRI plan list***	**Tier 1 or 2?**	**CSE data-PSI? (yes/no)**	**CSE data-AR? (yes/no)**	**Time it took 2 people to record these data in field****
Overstory - trees	Tree data (dbh, species, health, height, age class)	3,5,6a	1	Y	Y	5-15 min – BAF 20 plot 2-10 min extra – BAF 10 plot
Overstory- trees	Canopy base height, canopy position, snags	6b,7,9	1	Y	Y	Part of CSE methods (included in tree data above)
Overstory – stand data	BA, tree density, species composition, canopy cover, canopy bulk density	1,2, 3,5, 8,9, 10	1	Y	Y	Will be calculated later from field data
Overstory - age	Age of trees-visual estimate of age class	4b	2	Y	N	2 min/plot total
Overstory- age	Age of trees – coring	4a	2	Y (field only)	N	5-15 min/plot; Our methods need later lab time also to cross-date our saved cores
Overstory – health	Presence of insects & disease	24	1	Y	Y	Part of CSE methods
Regeneration	Seedling/sapling density, species, sizes	12	1	Y	Y	2-10 min/plot
Understory – cover	Percent cover by life forms - estimate only	13a	1	Y	N	5-10 min/plot by PSI CSE crew?; some species ID-ed
Understory-cover	Percent cover by species, measured on transects	13c	2	N	N	20-40 min/plot depending on site
Understory – richness and composition	Complete inventory of all species present on 1/10 ac plot	14,15b	2	N	N	20-60 min/plot depending on site; some lab time needed later also for ID
Understory - exotic species	Presence of exotic understory indicators	15a	1	Y?	N	Done as part of our full inventory above
Stand structure	Number& size of openings	16,17	2	N	N	Each “clumpiness” transect took 10-20 min total
Stand structure	Amount of multi- vs. single-story canopy cover	(18)	n/a	N	N	Each “clumpiness” transect took 10-20 min total
Veg. structural stages/classes		18	2	N	N	Calculated/estimated later
Surface fuels	Litter, duff depths	19	1	Y	N?	2-3 min
Woody fuels	1-hr to 1000-hr fuels	20	1	Y	N?	5-10 min
Logs/stumps	number/size/decay class	23	2	Y	Y	Part of CSE overstory and/or fuels methods
Wildife- raptors	Broadcast call survey	21	2	N	N	3 min
Wildlife- tree use	Feeding sign/damage on trees	21	2	Y (some)	N	2-3 min
Wildlife – sign on forest floor	Scat, burrows, feeding sign etc in 1/10 ac plot	21	2	N	N	10-20 min
Wildlife- insects	Ground dwelling insects in pitfall traps	21	2	N	N	2-3 min set-up; 2-3 min collect on 2nd visit; lab time later to ID

Variable category	Specific variables we measured	# on CFRI plan list*	Tier 1 or 2?	CSE data-PSI?	CSE data-AR?	Time it took us to measure these in field**
Stem maps	(for spatial statistics)	11	2	N	N	NOT DONE
Soil characteristics		22	2	N	N	NOT DONE
TOTAL- CSE baseline data tree/veg/ fuels data using BAF 20						15-30 min/plot
TOTAL- Our extra data including BAF 10 trees, coring, wildlife use, stand transects						Varied from 45 min-105 min/plot; average approx. 75 min total with trained crew of 2-3 people
TOTAL – Our complete understory surveys						Varied from 45 -105 min/plot; average 75 min for 1 trained botanist with some help from crew; conducted at same time as our other methods above

Notes:

*See the list, p. 36-37 in the CFRI plan, which identifies Roundtable variables of interest for monitoring and categorizes them as "Tier 1" (top priority for monitoring) vs. "Tier 2" (lower priority) based on team member votes.

**Times to collect data varied among plots depending on how many trees, seedlings, wildlife signs, known vs. unknown plants, animal signs, etc were present to identify, record, measure, sample, core, as applicable. Travel time among plots varied greatly and is not included here. Time to set up plots and markers, tags, etc, and record general plot data (slope, aspect etc) was around 5-10 min per plot. Note that some of these measurements were made simultaneously as the full crew of 3-4 people, including the botanist, worked together on the plot.

Budget and timing

The funds awarded by the SRLCC to this project were $75,861 for July 2011-September 2012. Collecting the full set of data described above on the 79 treatment and control plots in 2011 took approximately 6 weeks of full time work by a trained crew of 4 people (1 GS-7 botanist/field crew leader and 3 GS-3 field technicians.) Based on the crew's salaries and an average rate of progress of 4 plots/day after the crew was trained, this translates to a cost of approx. $150/plot. Additional funds were needed to cover equipment (approx. $2000 plus loaned items), vehicle use ($1200/month), first aid training ($50/person), and per diem costs for the crew when camping ($25/night/person), plus required USGS non-field training as well as in-field training (total 6 days training time for 3 USGS crew members). The total budget needed for the 2011 season was approx $35,000, including overhead taken by USGS/RMRS (35%) and post-season lab time (see below). Matching funds covered time spent by PIs and partners to assemble spatial data and maps, conduct site visits, train and assist the crew, compile and analyze data, etc.

In 2011 the crew surveyed 2-5 plots per day, which included travel time, plot selection, hiking or driving among plots and/or units, some ongoing training of crew members, and equipment set-up/take-down time. We anticipate that some of this time could be considerably reduced in future if plot selection could be done ahead of time by PIs, and if training could be streamlined, etc. However, we also note that considerable time is needed in the lab and office after the field season to 1) identify plant samples 2) identify insects 3) enter data 4) identify some wildlife signs from photos and samples, and 5) process and date the tree cores collected. These steps must be completed before full data analysis can be done.