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A Rapid Forest Assessment Method for Multiparty Monitoring Across Landscapes

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Collaborative natural resource management has emerged as a means to increase the transparency of decisionmaking in public lands management and to promote shared learning among stakeholders. We developed a rapid forest assessment (RFA) approach for monitoring the key characteristics of forests that capitalizes on the growing interest for citizen science monitoring and can be implemented at large extents. The methods were designed for use with minimal training, to maximize field efficiency, and to simplify interpretation of the data. We chose our variables based on the common interests and questions of collaborative groups. We collected data on trees, fuels, woody debris, understory, horizontal cover, weeds, and soil disturbance. We tested the methods with several student groups and quantified the variability of measures within groups. We discuss the benefits of and challenges to engaging citizen scientists in monitoring. The simplicity and efficiency of the RFA make it a useful tool for multiparty monitoring.

Keywords: monitoring, citizen science, forest management, adaptive management, landscape, collaboration

Collaborative natural resource management has emerged as a means to increase the transparency of decisionmaking in public lands management and to promote shared learning among stakeholders (Susskind et al. 2012, Schultz et al. 2013). The Collaborative Forest Landscape Restoration Program (CFLRP) was established in 2009 to bring stakeholders together to collaboratively develop and implement ecological restoration treatments on US Department of Agriculture (USDA) Forest Service lands (16 USC §7303). In addition, the 2012 USDA National Forest Planning Rule (F.R. 77[68] Part 219) emphasizes the importance of the Forest Service incorporating stakeholder perspectives in developing plans for each national forest and the need for more extensive monitoring at multiple scales (Schultz et al. 2013). Together, these new policies rely on increased collaboration to address management challenges at larger, more meaningful spatial scales.

Collaborative adaptive management compels agencies to acknowledge shared learning as a fundamental goal of management actions. Both the CFLRP and the 2012 Planning Rule require the use of multiparty monitoring to assess the effectiveness of management actions, to engage youth groups when possible, and to use the monitoring results to inform future actions in an adaptive management framework. This necessitates stakeholders being involved during all stages of the management process to effectively evaluate the outcomes of management treatments (Larson et al. 2013). However, stakeholders and agency staff may be limited in financial, time, and personnel resources. There exists a tradeoff in any monitoring program between the number of variables measured or the detail of measurements and the number of sites sampled (Figure 1), which requires that monitoring programs consider time and cost when questions and approaches are developed.

Multiparty monitoring using "citizen scientists" can help solve issues of both col-

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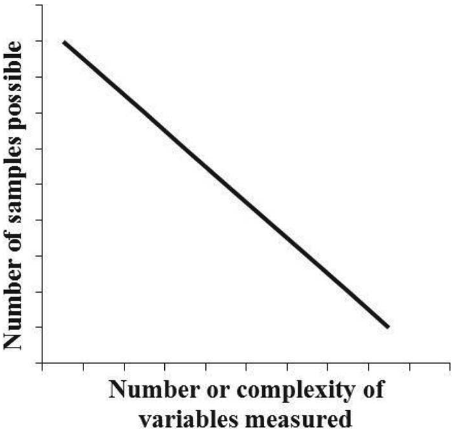

Figure 1. Time and resources to conduct forest monitoring are limited, which creates tradeoffs between the extent and intensity of monitoring efforts.

laboration and limited resources. The Cornell Laboratory of Ornithology, a leader in citizen science, defines citizen science projects as "projects in which volunteers partner with scientists to answer real-world questions."[1] We would add that volunteers, who could include students, collaborative members, or other interested community members, may work not just with scientists, but with land managers. Theoretically, multiparty monitoring may reduce required agency capacity and the costs necessary for monitoring forest management across increasingly larger landscapes. If monitoring protocols are relatively simple, citizen scientist participation could allow for wider geographic and temporal data collection. Citizen scientists are increasingly engaged in many research and monitoring efforts (Cohn 2008), and programs have been successful at involving a wide range of participants and gathering large amounts of data (e.g., National Phenology Network, eBird, and iNaturalist).

There can be difficulties in engaging nonprofessionals in monitoring and evaluation, though. These include hindrances related to insufficient personal time for stakeholders to engage, deficient training or expertise to collect usable data, and lack of funding for equipment or coordination (Fernandez-Gimenez et al. 2008, Conrad and Hilchey 2011). However, there are many benefits to involving stakeholders in project design and monitoring. For example, public awareness about the outcomes of management can increase (Fernandez-Gimenez et al. 2008), and citizens may become better educated about the ecological and social systems in which they live (Evans et al. 2005, Fernandez-Gimenez et al. 2008). Transparency in decisions about natural resource management also increases, leading to improved trust around management activities (Schultz et al. 2014). Finally, data can be collected in a way that results in reliable and repeatable data sets useful to scientists and managers (Au et al. 2000, Cohn 2008). Such outcomes are critical when one is attempting to expand the scale of management.

Common Stand Exams (CSEs) and other existing USDA Forest Service programs, such as Forest Inventory and Analysis (FIA), are important tools for tracking resources and for planning purposes. However, these methods were not originally designed as monitoring tools for use by citizen scientists. They were designed to be a nationally consistent method of vegetation assessment implemented by individuals with considerable training in forest measurements. In addition, data are collected in the field using digital recorders, which may be cost prohibitive (i.e., \$300–\$2,800[2]) and require additional training. Finally, meeting the strict error tolerances of the CSE protocols can often be difficult for volunteers.

We developed a rapid forest assessment (RFA) approach for use by collaborative groups for monitoring key characteristics of conifer-dominated forests that reconciles the tradeoffs between extensive and intensive data collection and capitalizes on the growing interest and support for citizen science-driven monitoring. The RFA favors collecting many samples with coarser measures and addresses several key questions of interest to collaborative groups, especially as they relate to proposed restoration activities. The method simplifies many variables by collecting data into categories. Further, several of the variables can be used as inputs to model important processes in forested ecosystems, such as predicted fire spread or the quality of wildlife habitat.

Here, we describe the RFA method and discuss its use for multiparty monitoring within an adaptive management framework. We end by discussing the benefits of the approach, potential challenges, and integration of RFA with other cross-scale forest monitoring efforts.

Methods

Monitoring metrics should be tightly associated with clear questions concerning natural resource conditions and management actions (Hutto and Belote 2013, Larson et al. 2013). Most vegetation monitoring questions that managers and collaborative members are concerned with relate to fire risk, wildlife habitat conditions, mortality of large old trees, disturbance of soils after treatments, the establishment or spread of invasive plant species, and timber production (e.g., see CFLRP legislation 16 USC §7303). For example, the Southwestern Crown Collaborative in Montana identified five priorities for monitoring: (1) fire and hazardous fuels management in the wildland-urban interface, (2) terrestrial vegetation and wildlife habitat maintenance and restoration, (3) aquatic resources and watershed restoration, (4) economic conditions, and (5) social conditions (see Table 1 for examples of specific questions) (Southwestern Crown Collaborative Monitoring Committee 2012). The RFA could be used to address the first two topics. Similarly, the

Management and Policy Implications

Contemporary forest management in the western United States is endeavoring to match the scale of management with the scale of important ecosystem processes, especially fire. This has resulted in forest management actions that are planned and implemented at increasingly broader spatial extents. Such actions often necessitate both collaboration and adaptive management to address uncertainty and mistrust. Traditional intensive monitoring methods are not designed for use by citizens and are limited in their geographic scope by the costs of data collection. The forest vegetation monitoring method we describe here, the rapid forest assessment, is simple to learn and can be implemented at a low cost. It is designed for use by collaborative groups, citizen scientists, and youth conservation corps, and the data can be used to answer many pertinent management questions. The data can also be used in existing software programs to model forest processes (e.g., fire behavior, forest growth, and wildlife habitat suitability). Involving stakeholders in monitoring can build trust and ultimately improve management efficiency to work at larger scales. Collaborative groups can use these methods to monitor management outcomes at a landscape scale and provide input to forest managers.

Table 1. Data provided by the RFA.

Category	Example question	RFA metric	Modeled or measured
Forest structure, composition, and function	What is the current tree structure of the forest and how does it change with treatments?	Density of trees within diameter classes	Measured
	What is the relative risk of stand-scale crown fire spread and how does the risk change with treatments?	Density of trees within diameter classes used to estimate crown bulk density, input into model to estimate crowning index	Modeled
	How does mortality vary among sites, by species, and size classes of trees?	Live or dead assessment of trees by diameter class and species through time across landscape	Measured
	How does the total cover and relative abundance of life form composition of the understory vary among sites or change with treatments?	Point counts of plant life forms along transects	Measured
	How do surface fuels change with treatments?	Photo load estimates	Measured
	How do probable flame lengths of fire vary among sites and after treatments?	Surface fuel estimates used to model flame lengths	Modeled
Wildlife habitat	How does horizontal hiding cover vary among sites and following treatments?	Horizontal cover board class estimates	Measured
	How does coarse woody debris vary among sites and after treatments?	Transect intercepts of downed logs used to estimate coarse woody debris volume on sites	Measured
Invasive species	Do treatments contribute to invasibility of sites?	Presence and/or frequency of list of key invasive plants	Measured
	What sites or treatments experience invasion by nonnative species and which species invade?	Presence and/or frequency of list of key invasive plants	Measured
Soil disturbance	How do human-caused soil disturbances vary among sites and after treatments?	Presence of soil displacement, compaction, or scorching	Measured

The RFA provides data on a number of important questions associated with forest conditions and responses to management treatments. Colocating various categories of forest monitoring allows stakeholders and managers to better assess tradeoffs and complementarities among forest management actions and their effects on forest values.

Four Forest Restoration Initiative in Arizona identified five indicators for their effectiveness monitoring: (1) invasive plants (metrics: species cover and presence of cheatgrass), (2) diversity of wildlife communities (i.e., wildlife species tracking), (3) diversity of understory communities (metrics: percent cover of native species and percent bare soil, seedlings, and saplings), (4) potential fire behavior (metrics: crowning index, torching index, and rate of spread), and (5) cultural resource conditions (Coconino and Kaibab National Forests 2013). All of the vegetation metrics could be monitored using the RFA, as could the inputs needed to model fire behavior.

We sought to develop field protocols that would allow two people to, on average, complete one RFA plot per hour, excluding travel time. We intentionally developed a datasheet (Supplemental Figure S1[S]) that was limited to 1 page, front and back, to minimize the complexity and time for datasheet management in the field. In addition, we sought methods that could be easily understood by citizens with varying levels of expertise. The methods are flexible and can be tailored to add additional variables of interest. For example, specific wildlife habitat variables or fuel components for input into models might be added. It is worth noting, however, that each additional metric requires both additional time in the field and investment in training.

The RFA field protocols were designed to be efficient and to require modest training. Training was conducted by the lead scientists in the field by establishing plots and walking through each of the variables with the citizen scientists. We provided an introduction explaining the needs and expectations for the monitoring and then spent considerable time reviewing tree species identification. Simple keys to local tree species were provided, emphasizing differences in species and quick identification characteristics (i.e., bark, needles, and cones). Field guides were also provided for common weed species. We recognize that training will take longer in more diverse forests, but that does not preclude the use of this approach. In the case of school groups, we provided introductory material ahead of time for teachers to review with students in the classroom. Most of the variables only require categorization and/or tallying and could be learned relatively quickly. For one variable that required estimating horizontal cover to the nearest 10%, we practiced as a group to ensure consistency (Figure 2a).

Our methods differ from the CSE used by the USDA Forest Service in several ways. We excluded several variables required by the CSE to reduce sampling time; examples include (1) slope and aspect (can be identified from a digital elevation model), (2) vegetation composition type, (3) crown ratio, (4) snag decay class, and (5) duff, litter, and fuel depth. The way in which some variables are estimated is also changed for efficiency. For example, instead of using line-intercept methods for downed woody surface fuel and horizontal understory cover, we use a photo technique and a horizontal cover board, respectively. Finally, we added a variable, soil disturbance, which is not captured by the CSE but is of interest to collaborative groups. We point out these differences only to emphasize the importance of efficiency and simplicity in the design of methods for use by volunteers.

Sampling Approach

As with any monitoring, the sampling scheme should result in reliable estimates of variables at a minimum cost or effort. More specifically, the number of plots should be based on the population of inference, variability in measures, desired change detection, and confidence level in observing a change (Legg and Nagy 2006). Monitoring

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[S] Supplementary data are available with this article at http://dx.doi.org/10.5849/jof.14-118.

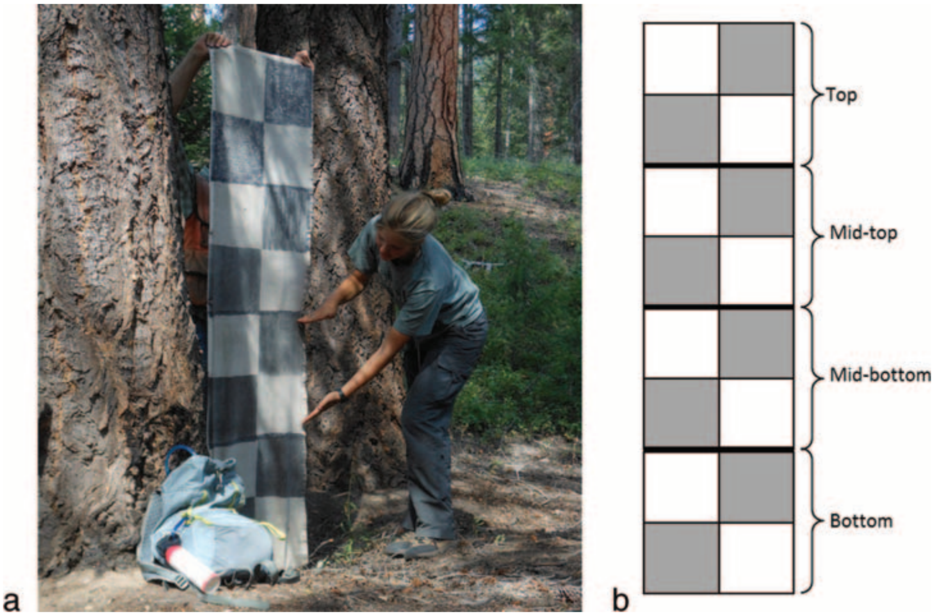

Figure 2. Demonstration of training use of the horizontal cover board (a) and dimensions of the horizontal cover board (b).

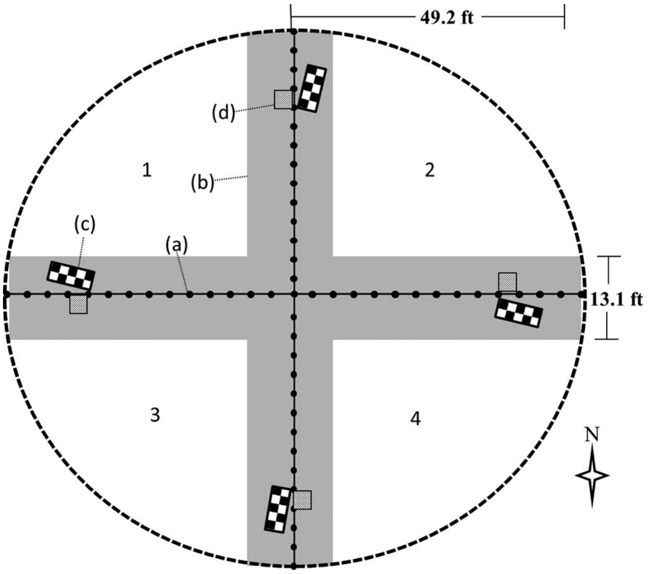

Figure 3. Layout of 98.4-ft (30-m) diameter plot divided into quadrants (1–4): point-intercept transects (a), 6.56-ft (2-m) belt on each side of transect (b), horizontal cover board locations (c), and 3.28-ft (1-m) fuels quadrat locations (d).

partners, hopefully including Forest Service or university experts, should determine this based on local conditions and desired confidence levels. For example, Ray et al. (2012) conducted a power analysis to determine the number of plots necessary to detect a 4% annual change after 10 years of monitoring at 80% power based on the variability of metrics in each vegetation type. The general rule provided by the CSE Users Guide (USDA Forest Service 2014) may also suffice for observing meaningful trends: one plot per 10 acres if the stand is relatively homogeneous and one plot per 5 acres if the stand is not homogeneous.

Plot Layout

Plot locations should be determined before going to the field. We used a circular plot design because they are more efficient to deploy in the field and because circular plots have smaller "edge effects" compared with square or rectangular plots (Bonham 1989). The plot was a 98.4-ft diameter circle (0.175-acre). This plot size was determined based on field testing in northern Arizona and western Montana that a plot of ≤ 0.2 acres could be sampled in <1 hour. Once the center of the plot was determined, two transects (i.e., 100-ft tapes) were laid out perpendicularly in the cardinal directions through the center (Figure 3). Plots may be monumented in the field using permanent markers for more precise remeasurements, if desired. Photos were taken in each cardinal direction from the center of the plot for future qualitative review (e.g., Batchelor et al. 2015).

Variables of Interest

We chose our variables (Table 2) and methods to focus on the questions of interest to maximize field efficiency and to simplify interpretation of the data. Trees are the focus of forest management activities because the resulting structure is important for understanding the potential for wildlife habitat, fire behavior, and timber volume. Ground cover components are also important for many processes including fire behavior and wildlife suitability and can be used as a measure of forest floor disturbance and understory productivity. Woody debris is essential for determining fuel loads of a forest stand (Brown 1971, 1981). Large logs also provide wildlife habitat, soil stability, and seedling establishment sites and play a role in nutrient cycling (Woldendorp et al. 2004). Fine fuels provide key information for predicting fire behavior and effects (Brown 1974). For example, fine fuel loads are combined with fuel moisture estimates in spatial models to predict fire risk (e.g., FIREHARM [Fire Hazard and Risk Model]) (Keane et al. 2010) and fire spread trajectory (e.g., FARSITE/FlamMap; Stratton 2006). Areas of soil disturbance can provide sites for rapid invasion of nonnative species and eventually impair ecosystem function (Symstad et al. 2014).

Trees. Within the entire plot, we tallied all live and dead trees taller than breast height (i.e., 4.5 ft) and ≥4.9 in. dbh by species and size class. The size class was identified using a "go/no-go" gauge, a tool commonly used for fuel measurements, cut to predetermined size classes (Figure 4a). This allows data collectors to quickly determine tree diameter size classes (Figure 4b) while assessing the species and condition (i.e., live or dead) of each tree. A laser rangefinder or an extra tape measure was used to determine whether trees near the circle boundary were within the plot. Because of the clumped nature of young conifers, seedlings and sap-

Table 2. Forest variables obtained within an RFA 98.4-ft (30-m) diameter plot and the equipment needed.

Variable	Where collected	Equipment
Plot coordinates	Center of plot	GPS
Photopoints	(4) at center and one in each direction along transects	Camera
Live and dead trees by dbh class	Full plot	Go/no-go, measuring tape or rangefinder
Saplings and seedlings	6.56-ft belt on each side of transect	6.56-ft stick, go/no-go, transect tapes
Coarse woody debris	Along each transect	Go/no-go
Ground cover	At each 3.28 ft, along transects	Pointer (e.g., chaining pin)
1-,10-, and 100-hour fuel loads	(5) 3.28-ft squares	3.28-ft fuels frame, fuel load photos
Horizontal cover	(4) once in each direction on transect	Cloth cover board
Presence/absence of soil disturbance	Full plot	None
Presence/absence of weeds or species of concern	Full plot	Weed guide

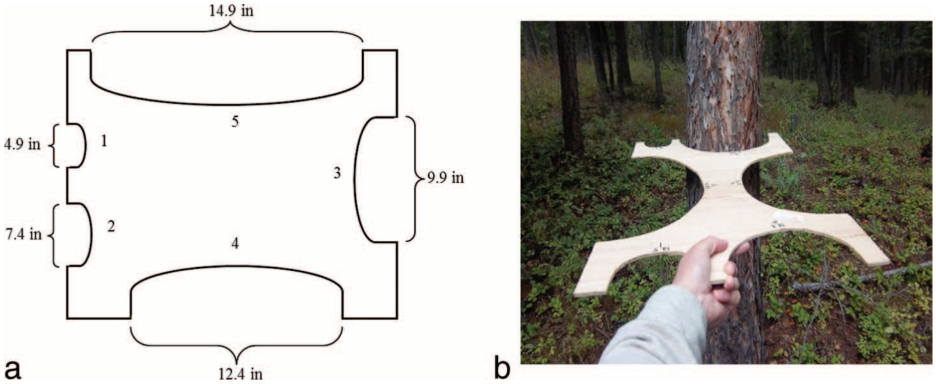

Figure 4. Example of a "go/no-go" board for classifying trees (a) and downed logs (b) and its use in the field. Trees and logs are assigned to the smallest class in which they fit at breast height.

lings were counted, by species, within a 6.56-ft band on each side of both transects. We defined seedlings as all trees under breast height and saplings as all tree species greater than breast height and <4.9 in dbh. The tree size classes chosen can be based on local conditions or available products. For example, the classes we used (Table 3) were based on classes in the Vegetation Mapping Program (VMAP) of the USDA Forest Service's Northern Region (Berglund et al. 2009).

Large diameter trees are often an important focus of collaborative groups and forest management because they strongly influence forest ecosystem functions and services. For example, Sánchez Meador et al. (2015) recently simulated the responses of Arizona ponderosa pine forests to varying tree size diameter caps for retaining large trees in thinning treatments, demonstrating high sensitivity of several forest structure and function (e.g., water yield and scenic beauty) metrics to the level of large tree removal. Collaborative members could help monitor the true responses in these treatments over a large scale. We recorded large trees (e.g., ≥14.9 in. dbh) to the nearest tenth centimeter using a diameter tape. We chose to measure large trees more precisely for two reasons: measuring large trees is fun for citizens and stakeholders may be interested in whether treatments stimulated a growth release in large retained trees. Organizers could decide to record large trees within a larger plot to ensure a sufficient sample, if they are particularly rare in a region.

Horizontal Cover. The quality of habitat for many wildlife species (e.g., snowshoe hare and elk) is often determined by the availability of horizontal hiding cover in the understory (Sullivan and Sullivan 1988). To measure this variable, we chose to use a horizontal cover board (Figure 2b) designed by Nudds (1977). We used a 19.7 × 78.7 in. cover board divided into four 5.4-ft^2 square blocks. One person holds the cover board at 32.8 ft from the plot center in each cardinal direction (Figure 3) while the other person estimates the cover from the plot center. The percentage of each of the main four squares (top to bottom) obscured by vegetation is recorded to the nearest 10%. The mean of the four values is then used as the measurement, and all four measurements are averaged for the plot and used for comparison across plots.

Forest Floor Vegetation and Ground Cover. The cover of plant functional groups or nonvegetative forest floor components was recorded using the point-line intercept method (Elzinga et al. 2001, Herrick et al. 2009) along each transect. Starting at one end of a transect, the first layer of ground cover (i.e., litter, grass, forb, dirt, shrub, tree, woody debris, rock, and moss/lichen) below 19.7 in. intercepted with a pointer (e.g., pin flag or chaining pin) at each 3.28 ft along the transect is recorded. The pointer is placed straight down next to the transect tape to define the point sample. The percent cover of each category can then be calculated for the plot based on the total of 59 points. These data characterize forest floor conditions, including exposed mineral soils, amount of litter, and relative abundance of plant functional types.

Coarse Woody Debris. Coarse woody debris was measured using an adaptation of the line intersect method for forest fuels (Van Wagner 1968) on the two transects. All logs of >6.56 ft long and >3 in diameter that cross the transects were categorized using the go/no-go board. The diameter was measured where the log crossed the transect and recorded within the same size categories as trees. Each log was also assigned a decay class following Brown (1974).

Fine 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. At four locations within each plot (Figure 3), we placed a 10.76-ft^2 square frame (e.g., polyvinyl chloride piping) on the ground (Figure 5a) and compared the dead woody fuels with those in existing photos (Figure 5b) of known fuel quantities from Keane and Dickinson (2007). For each fuel size class, the values are binned further into 5 classes (0, 0–1.8, 1.8–4.5, 4.5–9.0, and >9.0 tons/acre^{-1}). For efficiency, the frames are placed at the 32.8-ft point on each transect, opposite the cover board. A small go/no-go (Figure 4) can be created to help distinguish the size classes.

Soil Disturbance. The number of plot quadrants (i.e., 1–4) with the presence of soil disturbance (e.g., road beds, skid trails, or remnants of burn piles) is recorded to assess the extent of disturbance. Although a more robust quantitative approach is preferred (DeLuca and Archer 2009), our monitoring was intended to assess the presence of significant soil impacts caused by management actions. The presence of such impacts could be used to develop a predictive logistic regression model of soil impacts, but a more thorough quantitative assessment could be easily added to our methods.

Species of Management Concern. Plant species of concern, including invasive weeds, are surveyed for within the entire plot. Users should watch for these species as they record other variables in the plot and then spend only a few additional minutes at the end sweeping the plot for individuals. The number of plot quadrants with the presence of these species is recorded to allow an evaluation of local expansion through time. The number of species to look for should be small and limited to distinctive species that users can be easily trained to identify. Creating a field guide for identifying these species can be very useful when one is working with individuals with limited botanical experience. If there is a question about the identification of a species, it may be collected and identified later by an expert. Our method is intended as a method of early detection, a critical aspect of invasive species management at landscape scales (Simberloff et al. 2013), especially after management activities.

Table 3. Predetermined tree size classes used.

Class	Height (ft)	Dbh (in.)
Seedling	< 4.5	All
1 (sapling)	> 4.5	< 4.9
2	> 4.5	5.0–7.4
3	> 4.5	7.5–9.9
4	> 4.5	10.0–12.4
5	> 4.5	12.5–14.9
6	> 4.5	> 14.9

These classes are based on categories in the VMAP of the USDA Forest Service's Northern Region.

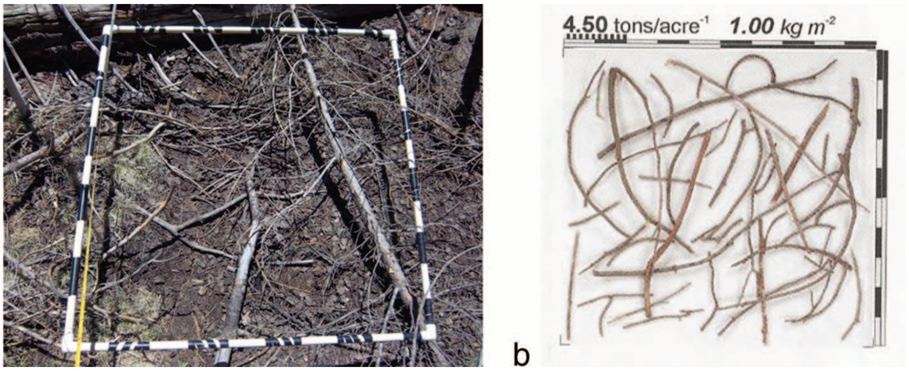

Figure 5. A 3.28-ft (1-m) fuels frame (a) and the corresponding 10-hour photoload (b) from Keane and Dickinson (2007).

Field Evaluation of the RFA with Multiple Groups

We tested the RFA protocol with several groups in the summer of 2013. We hired two undergraduate students to implement the protocols in a wide variety of forest conditions and to train and work with multiple citizen science groups. One such group was the Youth Forest Monitoring Program (YFMP; Figure 6a) of the Helena National Forest, which included a group of students between the ages of 13 and 14. The trainers also worked with two separate crews of the Montana Conservation Corps (MCC; Figure 6b), which typically consist of four to six recent college graduates. Finally, a crew consisting of undergraduates from the University of Montana's College of Forestry and Conservation (Figure 6c) tested the methods in the Bob Marshall Wilderness. In all cases, most individuals reached a level of proficiency to implement the protocols after 1 full day of training. A total of 350 plots were completed over the course of 12 weeks. On average, the crew of two undergraduates completed 6.1 plots per day.

High observer variability is often cited as a shortcoming of citizen science efforts (Dickinson et al. 2010). To determine the ability of different types of observers to consistently measure the variables of interest, we divided the groups described above into three subgroups and asked them to sample three plots each using the RFA protocols. Three plots were laid out and temporarily monumented by leaving the tape measures on site so that plots could be precisely remeasured by each of the three subgroups (i.e., we controlled for spatial error), which resulted in three sets of measurements for three plots. This was repeated for the YFMP, MCC, and university students, while working with them in different locations, and allowed us to assess data consistency for each group. We calculated the margin of error using 90% confidence from the three samples around the means for key variables from each group (Table 4). Most tree and fuel variables showed reasonable margins of error with the exception of 100-hour fuels. Ground cover types were more variable. Error rates could be attributed to the level and extent of training. The YFMP group showed the most consistency; however, they may have received the most thorough training of the groups.

Applications and Conclusions

Benefits of Using RFA Sampling at a Large Scale

The RFA methodology was designed to provide a reasonably quick assessment of forest stand conditions to determine whether additional monitoring or immediate action is needed in an area. Data from this method bridge the gap between qualitative monitoring and more detailed monitoring plots by establishing quantitative bins before field data collection. Because the RFA plots are less intensive, they can be deployed more extensively and with a higher frequency of return visits. They can be used for monitoring across a wider representation of sites for more thorough coverage of a larger landscape. More extensive sampling could also improve the chances of observing rare or uncommon species or processes. Making the data publicly accessible could allow the data to be leveraged across multiple locations. This level of monitoring may further be complemented by additional detail collected at a subsample of more intensive plots and data collected through remote sensing within a nested monitoring framework (Figure 7).

Forest managers, researchers, policymakers, and the public increasingly recognize the importance of landscape-level assessment of forest conditions. Stand-level

Figure 6. Citizen science groups that tested the Rapid Forest Assessment: Youth Forest Monitoring Program of the Helena National Forest (a), Montana Conservation Corps crew (b), and undergraduates from the University of Montana's College of Forestry and Conservation (c).

Table 4. Average relative margins of error under 90% confidence (multiplied by 100 for a percentage) for 11 forest monitoring variables collected among three different groups of observers within three citizen science monitoring crews.

	University wilderness class	MCC	YFMP
	. . . .	.(%).	. . . .
Trees			
Seedlings	7	34	3
Trees per ha	3	4	8
Ground cover			
Litter	12	8	17
Grass	11	28	8
Forb	22	19	10
Bare soil	43	20	10
Shrub	42	4	8
Fuels			
1-hr	7	2	9
10-hr	1	14	11
100-hr	20	55	13
Wildlife habitat			
Horizontal cover	6	5	9

The measured values were not comparable across groups as each group measured a different plot at different times.

approaches to forest management are slowly giving way to landscape-scale approaches. Remotely sensed and spatial data are allowing for forest characteristics to be quantified at landscape and regional spatial scales. However, there remains a need to assess stand-level characteristics across landscapes. These local data are vital for assessing forest conditions at various spatial scales and can be used as inputs to landscape-level models or to validate remotely sensed data. For instance, the FIA program provides small-scale data collected across entire regions. Whereas FIA data provide opportunities to conduct surveillance monitoring, FIA lacks the benefits of a multiparty monitoring program where stakeholders collect data and assess conditions in specific locations of interest.

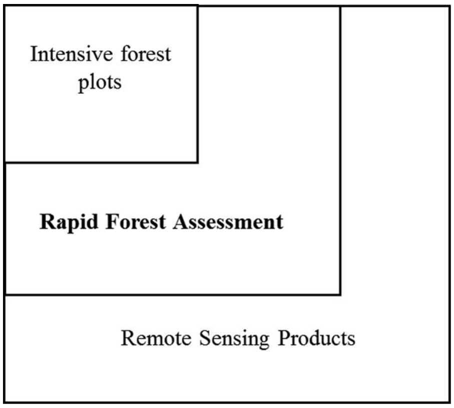

Figure 7. Hierarchy of scales in which the RFA could be deployed.

Collecting data in quantitative bins results in coarse, but still useable and informative, data for many questions relevant to forest structure and processes. Indeed, forest monitoring programs often classify detailed data into quantitative bins for summarizing and presenting to the public. For example, the annual report of the Forest Health Monitoring Program of the USDA Forest Service (USDA Forest Service 2013) summarizes data for live and dead trees using 5-cm dbh classes, although their field protocols measure to the nearest 0.1 in. Our predetermined quantitative bins serve as a shortcut that substantially reduces field time for data collection.

We found that the data from our forests could be used in forest simulation models to provide outputs comparable to more precisely collected data (see supplemental material). Using the midpoints of established class sizes resulted in crown fire modeling results similar to those using individual tree measurements. Similarly, diameter distributions can be used in conjunction with remotely sensed estimates of canopy height (Hampton et al. 2011) and allometric equations of canopy fuel to characterize the effects of forest management on fire behavior attributes (Reinhardt and Scott 2006). Finally, relationships with diameter distribution (e.g., large tree density and snag density) can be used to assess wildlife habitat conditions (e.g., Dickson et al. 2009, Schwartz et al. 2013) for a variety of species including some listed as threatened or endangered.

Multiparty Monitoring and Citizen Scientists

The RFA method can be used for many different objectives by a wide variety of groups. RFA can be used by community forest restoration committees to monitor the effects of collaborative forest treatments. For example, the Lolo Restoration Committee in Missoula, Montana, is currently using RFA to monitor a jointly developed project with the Forest Service using a local high school class. The goal of landscape-level, multiparty monitoring has led the Kaibab National Forest to use a modified RFA to meet some of their Forest Plan monitoring goals (USDA Forest Service, Kaibab National Forest 2014). It could be used by researchers to gain a large sample of forest attributes using citizen scientists or to collect validation data for remotely sensed products. RFA was developed to address questions associated with restoration of fire regimes in the forests of western North America, but the method could easily be adapted to other forest types. Finally, our experience working in a remote location such as the Bob Marshall Wilderness emphasized the utility of a rapid method for being able to collect many samples in a short amount of time and in primitive locations.

The engagement of citizen scientists, in conjunction with land managers, to study and monitor forest attributes can be very effective and beneficial to all involved. We found that students of many ages were able to quickly learn and implement the RFA protocols. Participants learned to identify local tree species and began to recognize differences in forest structure and diversity. Working with scientists, the participants also learned about forest disturbance and management and about careers in natural resource management. In addition, the collected data can be quickly input into a spreadsheet for analysis or for use as a teaching tool. We have developed classroom curriculum materials to further its use as an educational tool.[3]

Multiparty monitoring with citizen scientists can also present many challenges. The capacity for sustained coordination and participation, limits of participants' expertise, and reliability of data are oft-cited challenges when engaging citizen scientists (Cohn 2008, Fernandez-Gimenez et al. 2008). We found that involving citizen scientists takes considerable time in coordination and training. Identifying a single person or organization to lead the coordination is crucial and may require dedicated funding. Sustaining participation from volunteers may always be difficult but could be overcome by using annually available participants such as school groups.

Interested individuals also often have different motivations, strengths, weaknesses, and available time. Consequently, there can be issues in data consistency, accuracy, organization, and use. Measurement consistency can usually be addressed through adequate training, but if volunteer turnover is high, consistency in measuring slow-changing systems through time may be difficult. Studies have shown that volunteers have difficulty with certain types of data collection (e.g., estimating numbers in a group) but can be very accurate in others (Conrad and Hilchey 2011). Our experience suggests that challenges related to expertise and data reliability can be overcome with sufficient training and by designing protocols that are simple and relate directly to the questions to be answered (Cohn 2008). To reduce measurement errors, we have emphasized tallying items into categories.

Finally, if the data are to be used within an adaptive management framework, they need to be trusted by all involved. Not addressing issues regarding sample sizes or training rigor can lead to mistrust by the land management agency or scientists in the credibility of the data collected (Conrad and Hilchey 2011). Conversely, if agency personnel do not acknowledge or use the data and results to review their management actions, participants' trust in the agency can be further eroded. How and where the data are stored and made accessible to all involved can also affect the long-term stability and perceptions of the data. We recommend that collaborative partners work with agency specialists in designing and implementing the RFA.

As land management agency budgets continue to decline, monitoring is often seen as a luxury. Collaborative groups can often help fill some of the capacity needed for monitoring. The simplicity and efficiency of the RFA make it a useful tool for multiparty monitoring across forested landscapes.

Endnotes

1. For more information, see www.birds.cornell.edu/citscitoolkit/about/definition.
2. For more information, see www.fs.fed.us/nrm/fsveg/wince_types.shtml.
3. For more information, see www.swcrown.org/?p=1933.

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