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Application of Rangeland Health Indicators on Forested Plots on the Fishlake National Forest, Utah

Maggie G. Toone and Sara Goeking

Abstract—*Typical indicators of rangeland health are used to describe health and functionality of a variety of rangeland ecosystems. Similar indicators may be applied to forested locations to examine ecological health at a local forest level. Four rangeland health indicators were adapted and applied to data compiled by the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station's Forest Inventory and Analysis (FIA) program for research locations on the Fishlake National Forest in central Utah. These data can be used by local forest managers to determine the health status of the local forest and to identify the proportion of sites that may be functioning at risk. Sites considered to be functioning at risk are those in which integrity and stability of site characteristics (soil, vegetation, water, and air) and ecological processes of a balanced ecosystem are threatened. We found the noxious weed and bare ground indicators can be readily used to determine sites at risk. Clear thresholds need to be further defined for application of the species composition and shrub indicators to describe health and functionality of forested sites. With clearly defined thresholds, ecosystem health of forests and rangelands could be monitored with the application of these and other indicators using FIA data.*

Keywords: ecological health, functionality, indicators, bare ground, noxious weeds, species composition

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INTRODUCTION

The national Forest Inventory and Analysis (FIA) program of the Forest Service, U.S. Department of Agriculture has provided a continual forest resource census since the passage of the McSweeny-McNary Forest Research Act of 1928 (DeBlander et al. 2010). The program today conducts comprehensive inventories of all forested land (public and private) in the United States; data collected are intended for large-scale planning and monitoring of the status and trends in renewable forest resources (Bechtold and Patterson 2005). With cooperative agreements with the Forest Service's State and Private Forestry and the National Forest System, the FIA program operates as four regional FIA units (DeBlander et al. 2010).

One of the FIA units, the Interior West FIA program within the Forest Service's Rocky Mountain Research Station, conducted a study between 1998 and 2001 to determine if data collected on all FIA plots—both forest and nonforest—on the Bridger-Teton National Forest (Wyoming) could be used to summarize the health and functionality of its rangelands (O'Brien et al. 2003). That study used indicators of rangeland health developed by the U.S. Department of the Interior's Bureau of Land Management and the Society for Range Management to analyze the utility of FIA data for evaluating the indicators on the Bridger-Teton National Forest. The study verified that the selected indicators were viable means of assessing rangeland health and functionality and demonstrated that the FIA grid and data collection protocol are useful for evaluating and monitoring rangeland health.

One objective of this project was the application of modified versions of rangeland indicators to forested locations on the Fishlake National Forest to gauge whether they could be used to measure forest health and functionality. Ecosystem health is difficult to describe, but generally represents a dynamic system that is resilient, biodiverse, and productive. The components of healthy ecosystems may vary by habitat with some common themes (such as site stability and resistance to invasive plants) that specified indicators could monitor. We sought to determine whether FIA data could be used at the spatial scale of a national forest to evaluate ecosystem health based on the indicators described here.

The Fishlake National Forest encompasses 1,434,592 acres of land in central Utah and does not have any designated wilderness areas (O'Brien and Waters 1998). Forested land makes up 971,500 acres, of which 43 percent is timberland (>5 percent crown cover of timber species) and 57 percent is woodland (>5 percent cover of woodland tree species, or woodland and timber species with timber species making up <5 percent cover) (O'Brien and Waters 1998). Appendix A lists the common and scientific names of timber and woodland tree species found in Utah. The other 463,092 acres are nonforest (<5 percent canopy cover per acre of these timber and woodland species) (O'Brien and Waters 1998).

RANGELAND HEALTH INDICATORS TO BE USED ON FORESTED PLOTS

Four indicators were used by O'Brien et al. (2003) to describe the health and functionality of rangelands: Noxious Weeds, Ground Cover, Species Composition, and Shrub Cover. For this study, the noxious weed indicator and modified versions of the other indicators were measured on FIA plots on the Fishlake National Forest to examine whether the same determinations of health could be made on forested locations.

Noxious Weeds

The presence and extent of noxious weeds indicate ecosystem health. Weed invasions reduce crop yields and wildlife forage; noxious weeds can also cause irreversible environmental damage by degrading watersheds, increasing soil erosion, displacing threatened and endangered species, and reducing the biodiversity of natural plant communities (Westbrooks 1998). Westbrooks (1998) describes several biological characteristics of noxious weeds, such as prolific seed production and rapid growth and maturity, which allow them to spread rapidly and outcompete native vegetation. The Secretary of Agriculture or appropriate State official designates which species are considered noxious (O'Brien et al. 2003). Noxious weeds have enormous economic and ecological impacts. These species are difficult to manage in any landscape, including pristine environments (O'Brien et al. 2003), and will continue to be a threat to the health of public lands until controlled through management practices of prevention, early detection, containment, and eradication (Dewey 1999).

Bare Ground

Bare ground can be used as an indicator to describe how much of a site lacks stabilizing ground cover and thus may be at greater risk of soil loss. Many factors determine a site's ability to resist erosion. Soil characteristics, such as soil composition and moisture content, affect rainfall infiltration (Mein and Larson 1971). Surface cover variables including topographic features and biotic components also influence soil stability (Weltz et al. 1998). Adequate ground cover is needed on all types of soil for watershed protection because it limits the removal of soil resources by wind and water (O'Brien et al. 2003). Standard FIA procedures include collecting estimates of bare ground on every forested subplot.

Species Composition

Describing the vegetative composition requirements for a site to be considered properly functioning is a difficult task due to the variety of environmental dynamics and specific management objectives. Ecosystems are complex, and site potential depends on interactions of soils, climate, and plant adaptability (Roundy 1999). A single species composition list may not suffice to accurately describe the health, ecological projection, or desired community across a given landscape.

The criteria for the species composition indicator could be revised to meet management goals based on specific land management objectives (e.g., fire risk potential, aesthetics, forage production, or wildlife habitat). Therefore, this study reports an overall summary of species composition that can be compared to desired conditions, rather than assessing existing composition relative to a single threshold.

Shrub Cover

Two shrub species are examined in this paper: big sagebrush (*Artemisia tridentata*) and mountain snowberry (*Symphoricarpos oreophilus*). These shrubs were chosen due to the species' importance as wildlife habitat. Additionally, mountain snowberry acts as a component in site stability by binding soil though vegetative propagation and resisting disturbances of low-severity fire and mild browsing (Van Buren et al. 2011). Mountain snowberry is found in a variety of habitats, from sagebrush communities and low foothills to high mountain slopes in elevations ranging from 4,490 to 10,810 feet, so it may be expected to be present in all forest types examined (Van Buren et al. 2011). Big sagebrush and mountain snowberry are described in terms of canopy cover ranges so that land managers can determine if desired proportions of these species are being achieved in different forest compositions.

METHODS

Field data were collected from FIA plots in Utah between 2000 and 2009. These years represent one entire cycle of inventory data, so every FIA plot with at least one forested condition was included in the study. FIA field plots consist of four subplots about 1/24 acre in size with a radius of 24.0 feet. The center subplot is subplot 1. Subplots 2, 3, and 4 are located 120 horizontal feet at azimuths of 360, 120, and 240 degrees, respectively, from the center of subplot 1 (fig. 1). Each subplot also has a microplot with a radius of 6.8 feet, where saplings and seedlings are sampled.

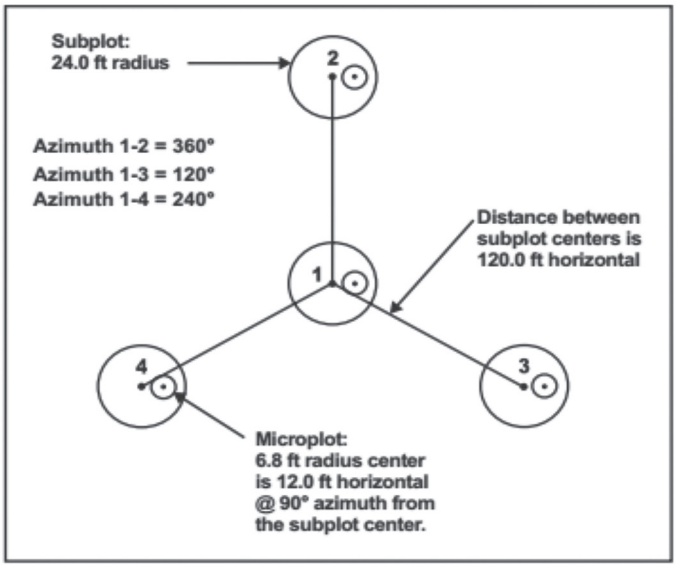

Figure 1—Field plot layout.

The microplot center is located 12 feet directly east of the subplot center. The field plot may be subdivided into different conditions. FIA uses six attributes to define a change in condition within forest land: reserved status, owner group, forest type, stand-size class, regeneration status, and tree density (USFS 2000–2009).

The standard FIA inventory grid has an intensity of one field plot every 6,000 acres. Data are routinely collected on plots that fall on forest land, which was defined during this study as land that is currently or was previously at least 10 percent stocked with specific tree species (termed "tally trees"; refer to Appendix A for a list of tree species in Utah that meet this definition) of any size (USFS 2000–2009). Stocking is determined by using stand factors such as basal area or number of trees by size, as well as spacing relative to a specified level of density (Hansen and Hahn 1992). The FIA field manual further specifies that areas populated by woodland species (where stocking cannot be determined) are considered forested if there is at least 5 percent crown cover per acre by tally trees of any size or the establishment of at least 40 seedlings per acre (USFS 2000–2009). Additionally, land that previously had at least 5 percent crown cover and not subject to treatments that prevent normal regeneration and succession (e.g., mowing or chaining) also meets FIA's definition of forest. The area must also meet minimum size requirements of 120 feet wide and 1 acre in size to qualify as a forested condition (USFS 2000–2009).

There were 261 FIA plots visited on the Fishlake National Forest (including the Teasdale Ranger District of the Dixie National Forest) during the study period. Of these plots, 242 had at least one forested condition. Nineteen plots were nonforest, census water (rivers or streams greater than 200 feet wide and bodies of water greater than 4.5 acres), or hazardous. A variety of forest types were sampled during the study (fig. 2). These forest types were aggregated into similar groups to simplify interpretation of the bare ground and shrub cover indicators. The forest-type groups designated for this study are: (1) mixed pinyon-juniper woodlands, (2) woodland hardwoods (which include Gambel oak, mountain mahogany, and maple), and (3) conifer forests. The aspen and nonstocked forest types were also studied (fig. 3).

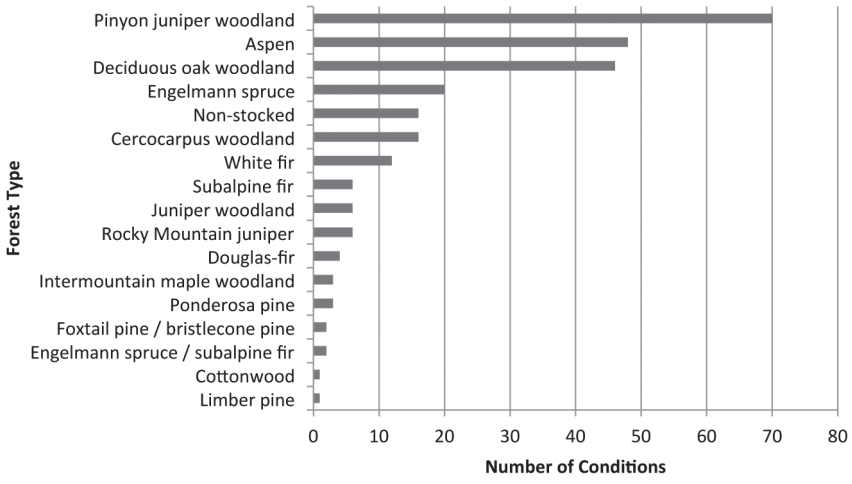

Figure 2—Number of conditions per forest type, Fishlake National Forest, annual inventory years 2000–2009.

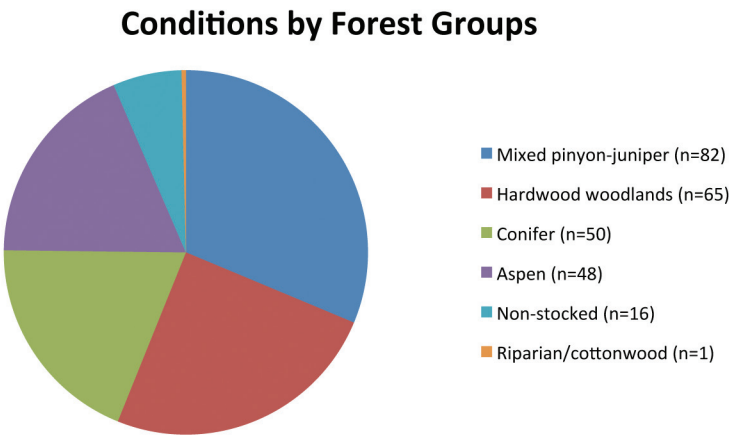

Figure 3—Number of conditions by forest category, Fishlake National Forest, 2000–2009.

Nonstocked plots are those that have less than 5 percent crown cover of trees of any size but meet the definition of accessible forest land by previously meeting this crown cover requirement and not being managed to prevent normal regeneration and succession (USFS 2000–2009). A riparian group was not analyzed because only one cottonwood forest condition was encountered. Although the FIA grid does sample linear features, such as riparian areas, relative to their frequency across the landscape, an intensified survey design is required to adequately describe these features (Gillespie and Smith 1999). The cottonwood site was included in overall calculations for the Fishlake National Forest but not evaluated individually by forest type.

Noxious Weeds

If at least one forested condition was present on the plot, noxious weed information was recorded for all four subplots, regardless of forest or nonforest status. Noxious weed presence was recorded by species and subplot(s) where the plant was found. State and Federally designated noxious weeds for Utah during the period of study are listed in Appendix B (NRCS 2016).

Bare Ground

FIA crews can use either of two methods to sample bare ground: an ocular estimate of the subplot or a line-intersect method. Bare ground can be visually estimated, to the nearest percent, on each subplot by forested condition. The percent bare ground for the condition is then determined by summing the percent bare ground estimates for each subplot and dividing by the number of subplots sampled for each condition on the sample site. Alternatively, the field crew can sample a 25-foot transect along cardinal directions on each subplot and record when bare ground is encountered at each 1-foot mark along the transect. The percentage is calculated by dividing the number of bare ground points by the total number of points in each condition. Bare ground is defined as exposed soil or rocks that are smaller than ¾ inch (longest dimension), or a combination of both (USFS 2000–2009). Bare ground is not recorded when obstacles, such as snow, prevent adequate estimations.

For this study of the Fishlake National Forest, we selected bare ground percentage in lieu of the ground cover thresholds defined in the 1998 Properly Functioning Condition (PFC) Rapid Assessment Process (USFS 1998), where bare ground thresholds are inversely related to ground cover. Thresholds of bare ground or ground cover were not defined for any conifer cover types or nonstocked type in the PFC assessment. Both of these groups have been assigned a threshold comparable to the aspen threshold because conifer forests are more similar to aspen forests than to mixed pinyon-juniper woodlands or woodland hardwoods and the aspen threshold is lower than the thresholds for the other groups (table 1). Nonstocked plots may have a lower threshold of bare ground for properly functioning conditions as they are most often disturbed and therefore are likely to be susceptible to higher rates of erosion. A box plot was created to show the range of bare ground percentages for every condition within each forest category. This range was compared to the PFC threshold for each forest type or forest-type group.

Table 1—Thresholds of bare ground, by forest category, for properly functioning sustainable watersheds on the Fishlake National Forest. Percent bare ground must be less than these threshold values, or the site is considered to be functioning at risk for basic watershed protection.

Fishlake forest type or forest-type group	Percent bare ground
Mixed pinyon-juniper	30
Woodland hardwoods	25
Aspen	15
Conifer	15
Nonstocked	15

The relationship of bare ground to slope and aspect was further examined. For each subplot, FIA crews determine slope, to the nearest 1 percent, by sighting a clinometer along the average incline or decline. For terrain with at least 5-percent slope, aspect, to the nearest degree, is determined along the direction of slope (USFS 2000–2009). The slope and aspect for the overall condition are reported as those variables from the subplot having the greatest area of the condition or those from the subplot with the lowest number in cases where more than one subplot represents equal areas of the condition (Woudenberg et al. 2010). Only a linear relationship was examined between these variables; bare ground for each forest type or forest-type group was plotted as a function of slope and a linear regression was applied. To examine the relationship of bare ground to aspect, degrees were converted to radians. The sine ("east-ness") and cosine ("north-ness") of the radian were then calculated for every condition on the Fishlake National Forest where bare ground was recorded. Bare ground was plotted as a function of each sine and cosine and a linear regression was applied to test the relationship between these variables.

Species Composition and Shrub Cover

FIA records understory vegetation on each subplot within an accessible forest condition. Up to four species that have 5-percent cover or greater are recorded for each life form (tree seedlings/saplings, shrubs, forbs, and graminoids), and percent cover for each species is determined with an ocular estimate. In addition to recording individual species that meet the 5- percent threshold, FIA records understory structure (height class) by life form (trees, shrubs, forbs, and graminoids) on each subplot. The species composition portion of this analysis reports all species recorded at 5 percent or greater by life form. For each species, the number of forested conditions for which the species was recorded is summed by forest type.

Shrub cover is presented as the average percent cover of big sagebrush and mountain snowberry per condition, calculated by adding the cover of the shrub on each subplot and dividing by the number of subplots in that condition, for each plot. By using cover classes defined in the PFC assessment for big sagebrush/grassland sites (USFS 1998), the number of conditions having an average percent cover within each range was calculated and reported for each forest category. The cover classes based on the PFC assessment are as follows: low cover (0–4 percent), medium cover (5–15 percent), and high cover (>15 percent). FIA records only species making up 5 percent or greater cover; thus, the low cover range is represented by conditions in which the species was not recorded. Mean cover of each shrub for all plots within each of the five forest types or forest-type groups was not calculated because the percentage of cover in the low category is essentially unknown.

For the noxious weed, bare ground, and shrub cover indicators, population estimates and sampling errors were calculated by using stratification with known strata weights to form population means. The population means were then expanded by using total land area in the population to produce estimated acres for each forest type or forest-type group and for all forested land on the Fishlake National Forest (Scott et al. 2005). Estimated areas were rounded to the nearest acre.

RESULTS

Noxious Weeds

Noxious weeds were present on 4.1 percent of sampled plot locations (10 of 242 plots) (fig. 4). Only *Cirsium arvense* and *Carduus nutans* were noted, occurring on eight and two locations, respectively. Of the forest types where *Cirsium arvense* was found, four were in deciduous oak woodland, one was in subalpine fir, one was in pinyon-juniper woodland, one was in white fir, and one was in aspen. One site where *Carduus nutans* was found occurred in deciduous oak woodland forest type, and the other was in a nonstocked type. Estimates indicate that 58,230 acres (+/-18,372 acres) of forested land on the Fishlake National Forest have noxious weeds present (fig. 5).

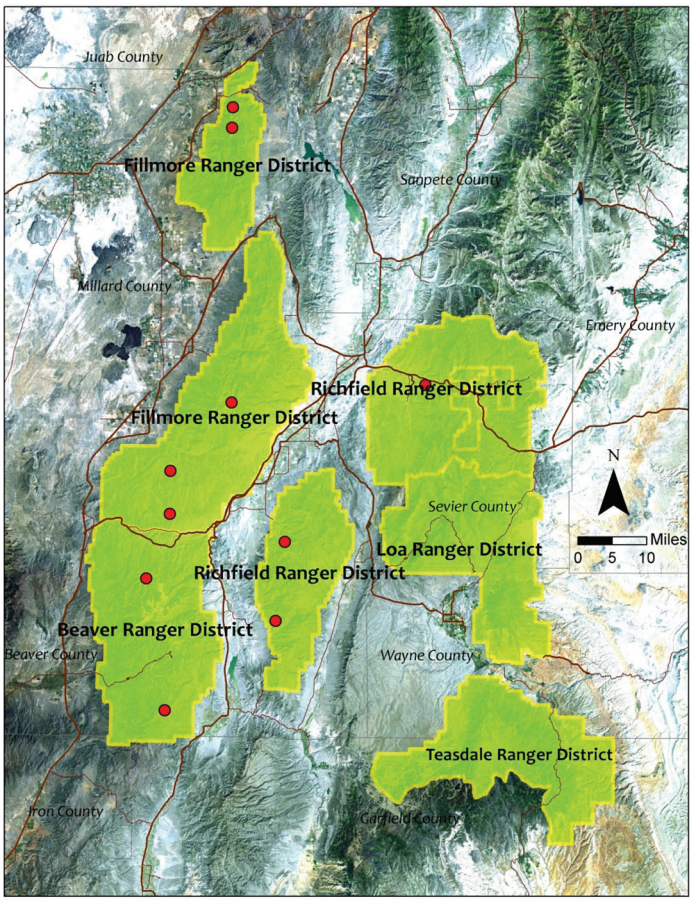

Figure 4—Noxious weeds on FIA sample locations on the Fishlake National Forest.

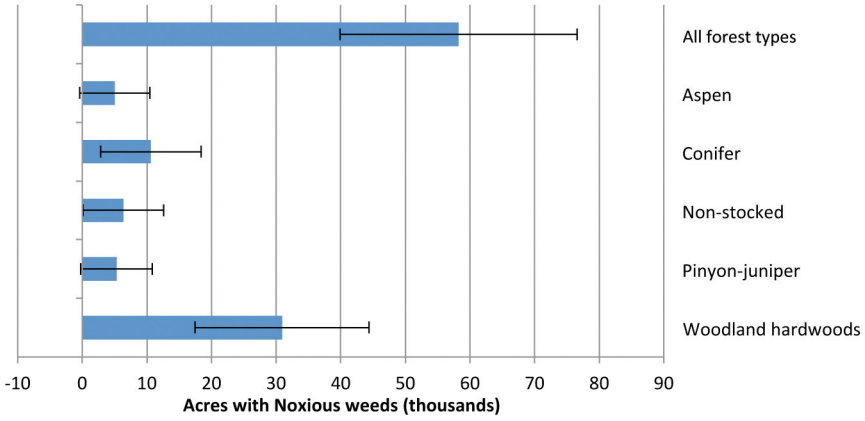

Figure 5—Estimated acres (thousands) containing noxious weeds by forest category on the Fishlake National Forest. Error bars represent plus and minus one standard error.

Bare Ground

All five forest categories had individual conditions that contain bare ground percentages greater than the range of the properly functioning thresholds (fig. 6). Of the 257 conditions (some of the 242 plots had multiple forested conditions) where bare ground was recorded, 22 (8.6 percent) exceeded the threshold considered functioning at risk. The nonstocked type had the largest percentage of conditions (18.8 percent) with bare ground above the designated threshold. The quartile ranges show that the aspen forest type has the least variation in percentages of bare ground recorded, whereas the mixed pinyon-juniper forest-type group has the largest range. Based on the forest conditions where bare ground percentages exceed properly functioning thresholds, we estimate that 110,666 acres (+/-24,856 acres) of forested areas on the Fishlake National Forest may be at risk (fig. 7).

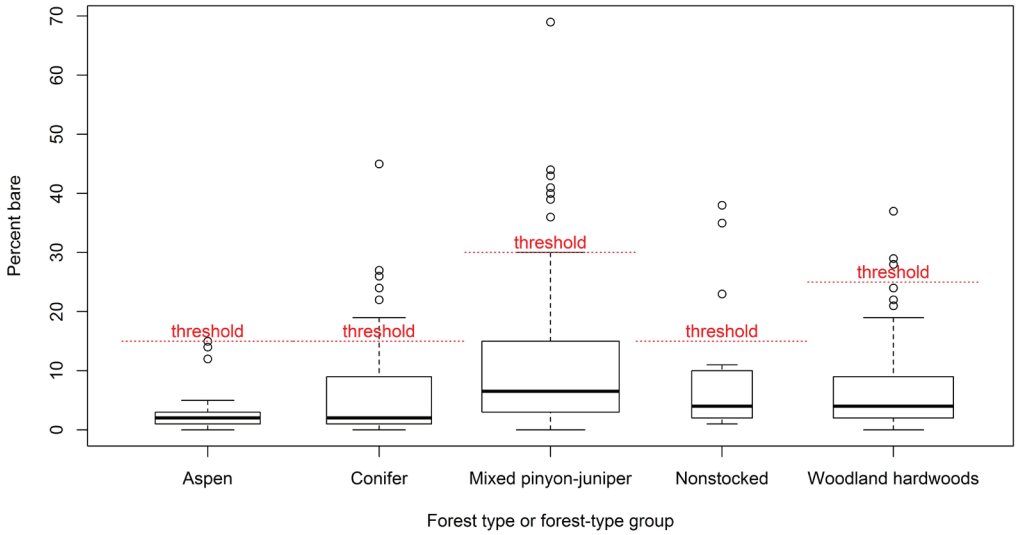

Figure 6—Percent bare ground by forest category on the Fishlake National Forest in relation to properly functioning thresholds, which are represented by horizontal dotted lines. Values (circles) above the threshold lines within each group represent forested conditions that exceed properly functioning thresholds.

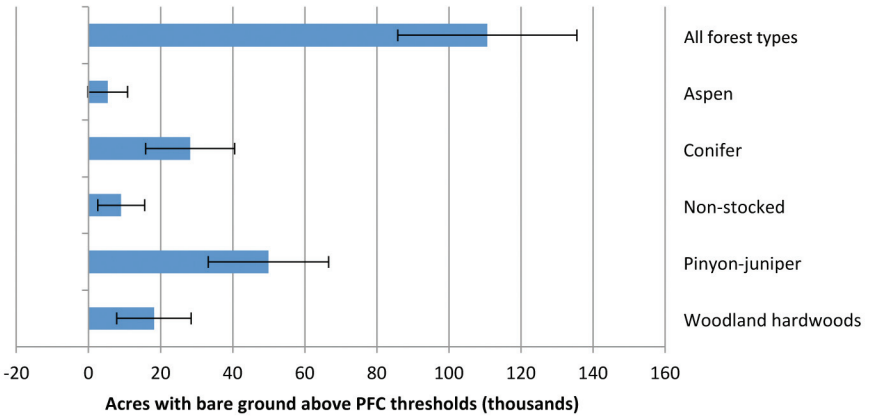

Figure 7—Estimated acres (thousands) with bare ground percent above properly functioning condition thresholds by forest category on the Fishlake National Forest. Error bars represent plus and minus one standard error.

Bare ground percentages show a correlation to percent slope for some of the forest categories (figs. 8 through 12). The slope of the regression lines for the aspen forest type (fig. 8) and conifer forest-type group (fig. 9) is not significantly different from zero ($P = 0.427$ and $P = 0.668$, respectively), but the other two forest-type groups and the nonstocked type show a significant relationship between these variables. The mixed pinyon-juniper (fig. 10) and woodland hardwoods (fig. 11) forest-type groups showed a negative correlation between bare ground and slope ($P = 0.013$ and $P = 0.020$, respectively). One condition in the woodland hardwoods forest-type group reported a slope of 105 percent, which is much steeper than other woodland hardwood locations and may be an outlier. The linear relationship between bare ground and slope may not extend to very steep locations (slopes greater than 100 percent). However, when this outlier is excluded, a significant relationship between bare ground and slope still exists for this forest-type group ($P = 0.032$). For the nonstocked type, bare ground percentage increased with slope (fig. 12).

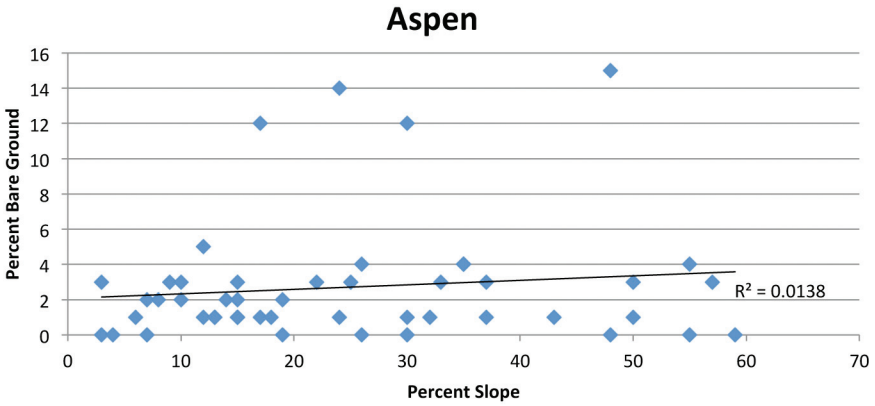

Figure 8—Percent bare ground in relation to slope recorded on conditions in the aspen forest type with a linear regression applied. For $H0:\beta = 0$, $P = 0.427$.

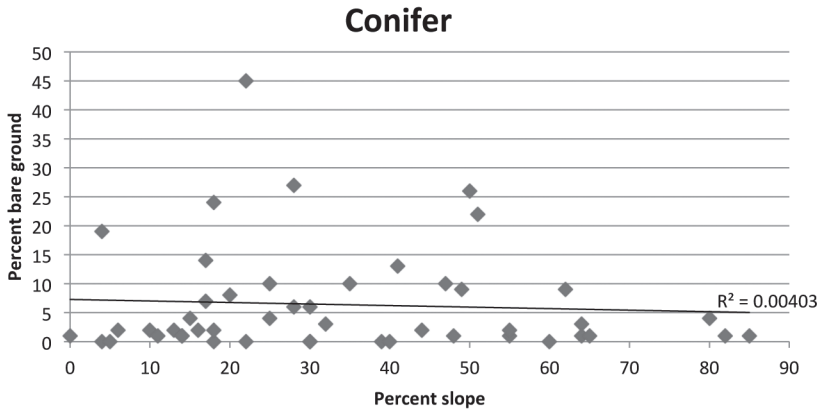

Figure 9—Percent bare ground in relation to slope recorded on conditions in the conifer forest-type group with a linear regression applied. For $H0:\beta = 0$, $P = 0.668$.

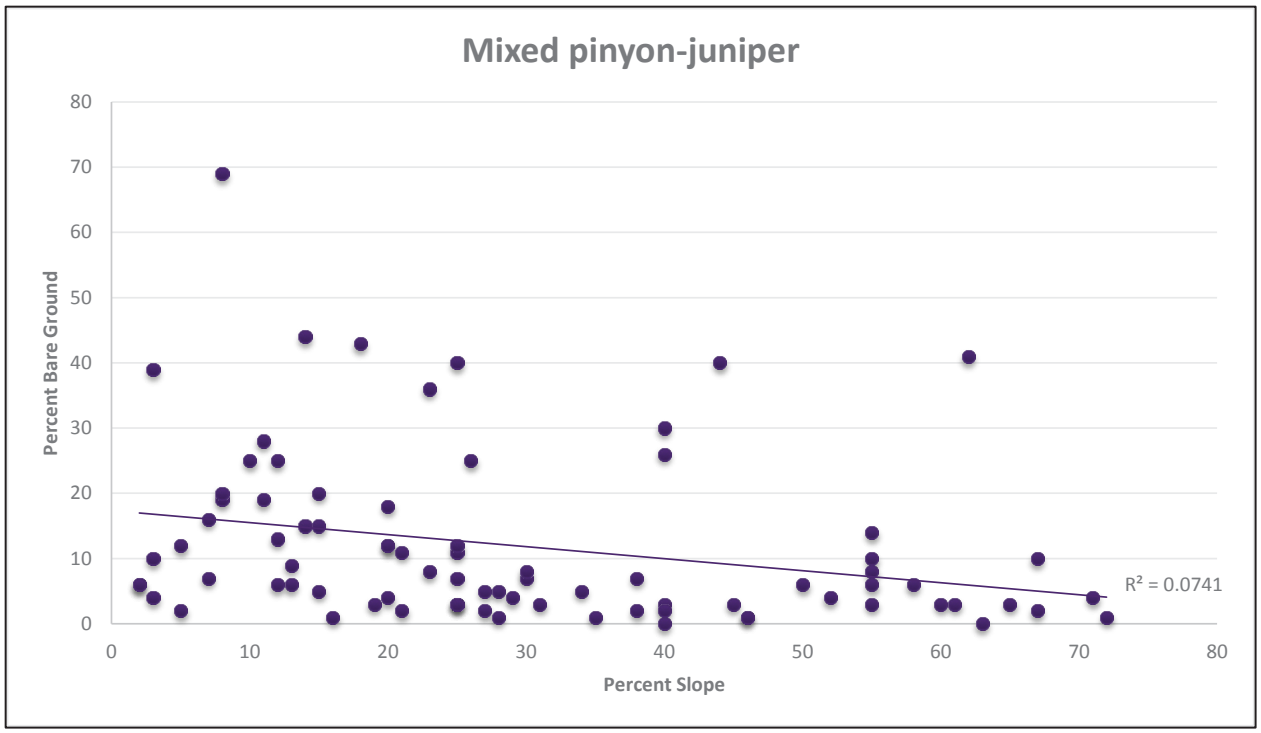

Figure 10—Percent bare ground in relation to slope recorded on conditions in the mixed pinyon-juniper forest group with a linear regression applied. For *H*0:β=0, p=0.013.

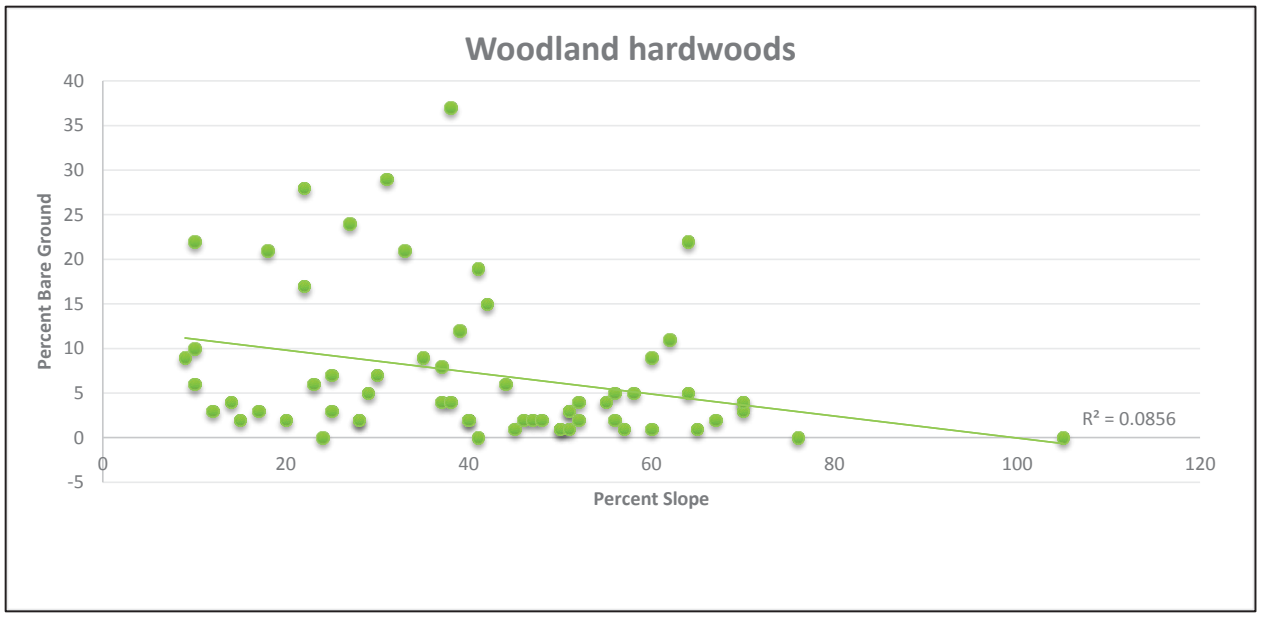

Figure 11—Percent bare ground as a function of slope on conditions in the woodland hardwoods forest group with a linear regression applied. For *H*0:β=0, p=0.020.

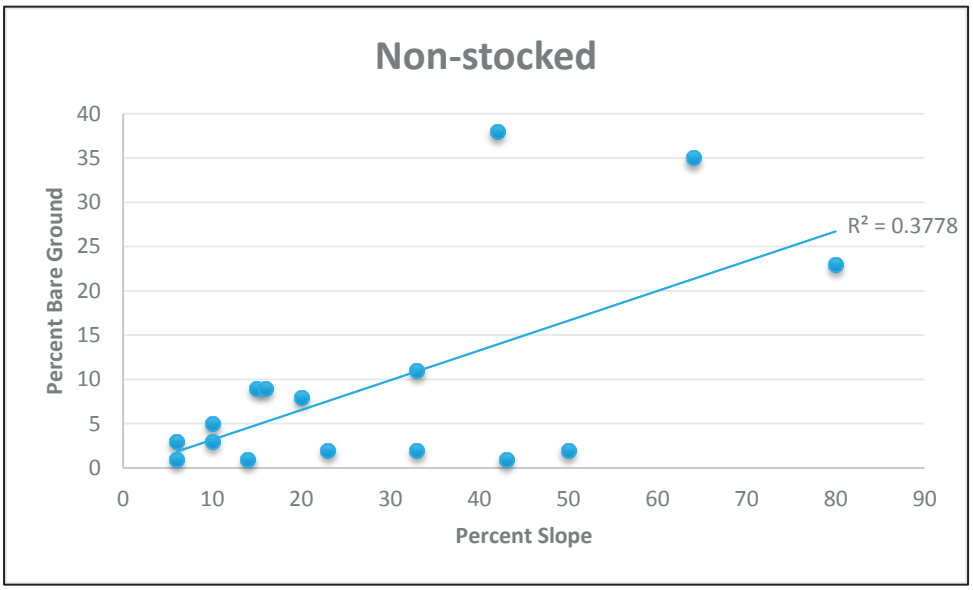

Figure 12—Percent bare ground in relation to slope recorded on conditions in the non-stocked forest type with a linear regression applied. For *H*0:β=0, p=0.011.

To examine the relationship of bare ground to aspect, a linear regression of bare ground versus radians was applied to all forested conditions on the Fishlake National Forest. No significant difference was noted between north- and south-facing slopes ($P = 0.32$), but bare ground did increase with east-facing slopes compared to west-facing slopes ($P = 0.03$). These results may overstate the role that aspect plays in determining whether sites may be at greater risk of erosion because of the many factors that influence soil stability (e.g., soil type, disturbance, and local climate). The small sample size of conditions above the thresholds (22 conditions) must also be considered. These conditions had a range of slopes, forest types, and elevations, indicating that these variables cannot be used reliably to predict amounts of bare ground.

Species Composition

All species recorded at 5 percent or greater cover by life form are displayed in tables 2 through 5. The number of conditions where the species was recorded is tallied by forest type. These tables present the total number of conditions per forest type where species of each life form was recorded, as well as the total number of conditions for all forest types where an individual species was recorded. Of the 23 tree species recorded, Gambel oak met the cover threshold on the most conditions by far: 90 conditions, spanning 10 of the 16 Utah forest types (table 2). The species meeting the cover threshold on the second-highest number of conditions was quaking aspen, with 34 conditions across 5 forest types. Table 3 shows that pinyon-juniper woodlands had the highest variety of shrubs recorded: 18 species found on 78 conditions, or 30 percent of forested conditions. Big sagebrush was the most prevalent species within that forest type. Utah's aspen forest type had by far the largest diversity of both forbs (table 4) and grasses (table 5) with 5-percent cover or greater.

Table 2—Number of conditions where tree species is recorded at 5 percent or greater, by forest type.

Species code:	Aspen	Cercocarpus woodland	Cottonwood	Deciduous oak woodland	Douglas-fir	Engelmann spruce	Engelmann spruce / subalpine fir	Foxtail pine / bristlecone pine	Intermountain maple woodland	Juniper woodland	Nonstocked	Pinyon-juniper woodland	Ponderosa pine	Rocky Mountain juniper	Subalpine fir	White fir	Total
ABCO	2	1		2										1		7	13
ABLA	12				1	6	2								6		27
ACGL		1														2	3
ACGR3	2	1		3					3					1		4	14
ACNE2	1																1
AMAL2	1			8								2					11
AMUT	1			3								6		1			11
BEOC2	1																1
CELE3		8		3								7				1	19
COSE16	1																1
JUOS										3		8					11
JUSC2				1								1					2
PIED		2		2							1	24					29
PIEN	2					16	2	1									21
PIFL2	1					1											2
PIPU	2																2
POTR5	26					4							1		2	1	34
PRVI	4	1		1					1		1	1		1			10
PSME	2				2						1		1			2	8
QUGA	1	10		44	1				2	3	1	20		2		6	90
SAEX			1														1
SARAR3	1																1
TARA												1					1
Total	60	24	1	67	4	27	4	1	6	6	4	70	2	6	8	23	313

Table 3—Number of conditions where shrub species is recorded at 5 percent or greater, by forest type.

Species code	Aspen	Cercocarpus woodland	Deciduous oak woodland	Douglas-fir	Engelmann spruce	Engelmann spruce / subalpine fir	Foxtail pine / bristlecone pine	Intermountain maple woodland	Juniper woodland	Limber pine	Nonstocked	Pinyon-juniper woodland	Ponderosa pine	Rocky Mountain juniper	Subalpine fir	White fir	Total
ARAR8												1					1
ARLU											1						1
ARNO4		1										3		1			5
ARPA6	2	1										5	1		1		10
ARPU5	1	1										2					4
ARTR2	2	4	16						1		7	23		2		2	57
ARTRT												2					2
CEFE													1				1
CEIN7												2					2
CEMO2		1	9				1	1	1			12					25
CHVI8											1						1
CORA												1					1
EPVI												3					3
ERDI14					1												1
ERNA10			1									2					3
ERNAN3												1					1
GUSA2												2					2
HODI		1															1
JUCO6	8	1			2	1	1			1			1		1	1	17
MARE11	7	3	4	2						1	1					2	20
OPPO												1					1
PAMY	2	2	3		1									1		2	11
PHMA5		1															1
PRFA		1															1
PUTR2			3						3		1	7					14
RHTR												3					3
RICE			1												1		2
RIIN2	1																1
RIMO2	1	1			2	1									1	1	7
ROSA5	3		2														5
ROWO	2		1								2						5
SHCA	2																2
SHRO												3					3
SYAL			1														1
SYOC				1													1
SYOR2	17	5	18	2		1	1	1	1		1	5	1	5	1	5	64
UNKN											1						1
Total	48	23	59	5	6	3	3	2	6	2	15	78	4	9	5	13	281

Table 4—Number of conditions where forb species is recorded at 5 percent or greater, by forest type.

Species code	Aspen	Cercocarpus woodland	Deciduous oak woodland	Engelmann spruce	Engelmann spruce / subalpine fir	Intermountain maple woodland	Juniper woodland	Limber pine	Nonstocked	Pinyon-juniper woodland	Ponderosa pine	Rocky Mountain juniper	Subalpine fir	White fir	Total
ACCO4	1														1
ACMI2	2														2
AGUR	1														1
ANRO2									1						1
ARBI2										1					1
ARCO9	2														2
ARLU		1													1
ASTRA	1														1
BASA3			5											2	7
CHFR3	1														1
DEOC	2			2											4
ERIGE2			1												1
FRVI	1														1
GERI	1														1
HEAN3									1						1
HEMA80	1														1
HEMU3	1														1
HEUN							1								1
HEVI4														1	1
HYCA4			2			1									3
LALA3	4		1									1	2		8
LAOC3	1														1
LUAR3	1		1		1										3
LUPIN	2		1	1							2				6
MIGU	2														2
OSBE	1														1
RUOC2	2														2
SAOD2	1														1
TAOF	1								1						2
THFE	1				1			1							3
THMO6	1														1
TRIFO	2														2
UNKN	3														3
VIAM					1										1
VIOLA					1										1
WOOR						1									1
WYAM														1	1
Total	36	1	11	3	4	2	1	1	3	1	2	1	2	4	72

Table 5—Number of conditions where grass species is recorded at 5 percent or greater, by forest type.

Species Code	Aspen	Cercocarpus woodland	Deciduous oak woodland	Douglas-fir	Engelmann spruce	Engelmann spruce / subalpine fir	Foxtail pine / bristlecone pine	Intermountain maple woodland	Juniper woodland	Nonstocked	Pinyon-juniper woodland	Ponderosa pine	Rocky Mountain juniper	White fir	Total
ACHNA	1		1												2
ACHY											1				1
AGCR									1	1	2				4
AGROP2			2							2					4
AGROS2	1													1	2
ARIST										1					1
BOGR2											4				4
BOUTE			1												1
BRCI2	2														2
BRIN2	4									1					5
BRMA4	1														1
BROMU	5					1				1	1				8
BRTE		5	6						3	3	1	1			19
CAGE2	1				1										2
CAHA6	1														1
CAHO5	1														1
CALAM										1					1
CAREX	5	1	2		1					1	1			1	12
CARO5	1														1
ELAL7										1					1
ELGL	2														2
ELTR7	1		1												2
ELYMU	1							1						1	3
FEID											3				3
FEOC	1														1
FESTU		1	3				1								5
FETH	1														1
HECO26	1									1					2
HECOC8											1				1
HESPE11													1	1	2
KOMA										1					1
LESA4	1														1
MUHLE												1			1
PHPR3	1														1
POA	10	1	5	1	1			1	2	3			1	1	26
POCO			1												1
POFE		1													1
POPR	5		1						1		2		1	1	11
POSE											2				2
PSSP6	1	3	1						1	3			1		10
PSSPS			3			1					3			1	8
SCHIZ4														1	1
UNKN	1		1	1						1	2				6
Total	49	12	28	2	3	2	1	2	8	21	23	2	4	8	165

Shrub Cover

Most of the conditions in forest categories have low crown cover (0–4 percent) of both big sagebrush (fig. 13) and mountain snowberry (fig. 14). Because percentages less than the 5-percent cover threshold are not recorded by FIA, actual percentage of cover in the low category is unknown.

Big sagebrush was not recorded in the high cover range (>15 percent) on any sites in the aspen forest type and conifer forest-type group, and most conditions where big sagebrush was reported in medium crown cover range (5–15 percent) generally coincided with forest-type groups of lower elevation (pinyon-juniper and woodland hardwoods) and with nonstocked conditions (fig. 13). Subspecies of big sagebrush are found in a variety of habitats; all but *Artemisia tridentata* ssp. *vaseyana* are typically found below 7,900 ft. (Van Buren et al. 2011). Only 4 of the 51 conifer sites and 1 of the 48 aspen sites sampled during this survey were located below that elevation.

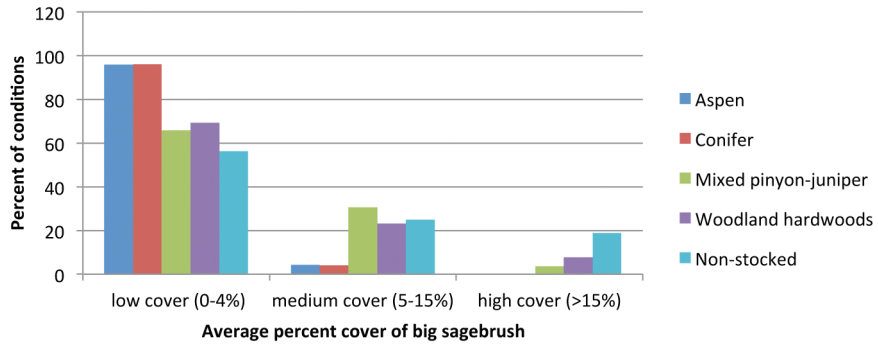

Figure 13—Percentage of conditions in each forest category containing big sagebrush cover ranges of low, medium, and high.

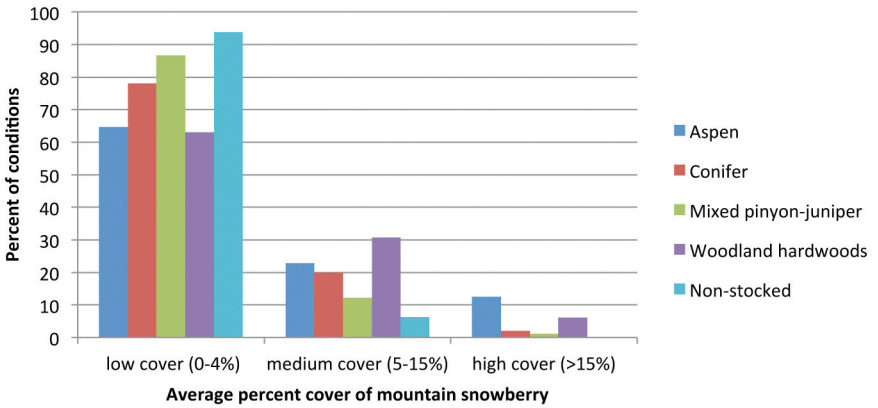

Figure 14—Percentage of conditions in each forest category containing mountain snowberry cover ranges of low, medium, and high.

Big sagebrush was present at the medium cover range on 30 percent of conditions in the pinyon-juniper forest-type group (fig. 13), on an estimated 128,008 acres on the Fishlake National Forest (table 6). An estimated 1,327 acres of nonstocked forest had high cover of big sagebrush; this acreage is substantially smaller than for the pinyon-juniper or woodland hardwoods forest-type group due to the relatively small sample size of nonstocked plots. But the nonstocked type had the largest percentage of conditions (19 percent) with this species in the high cover range, suggesting that as tree cover is removed through disturbance or temporary thinning big sagebrush may thrive and expand.

Few conditions in the forest categories had an average cover of mountain snowberry in the high cover class (>15 percent); the aspen forest type had the largest percentage (13 percent) of conditions containing mountain snowberry in this range (an estimated 30,234 acres; table 7). The woodland hardwoods forest-type group and aspen forest type showed the greatest percentage of conditions containing the shrub in the medium crown cover range (5–15 percent) at 31 and 23 percent, respectively.

Note that the cottonwood condition was included in the estimation for the combined forest categories for the shrub cover indicator. Neither big sagebrush nor mountain snowberry was recorded at 5-percent cover or greater on the cottonwood condition. Calculations for the combined forest categories for both of these shrub species include this condition in the low cover estimate for this shrub.

Table 6—Estimated acres and confidence interval (+/- acres) of area containing *Artemisia tridentata* (ARTR2) in low, medium, and high cover ranges by forest category and for all forest categories on the Fishlake National Forest. Note that the cottonwood condition is included with all forest categories of the Fishlake National Forest and not evaluated individually. Estimated areas are rounded to the nearest acre.

	***Artemisia tridentata* cover range**					
	Low (0–4%)		**Medium (5–15%)**		**High (>15%)**	
Fishlake forest type or forest-type group	**Acres**	**Confidence interval (acres)**	**Acres**	**Confidence interval (acres)**	**Acres**	**Confidence interval (acres)**
Aspen	213,620	32,214	10,143	7,329	0	0
Conifer	231,727	34,504	11,311	8,142	0	0
Nonstocked	24,218	11,007	15,067	9,104	1,327	1,381
Pinyon-juniper	289,809	38,284	128,008	26,421	8,485	6,488
Woodland hardwoods	223,552	32,996	79,119	20,935	22,310	11,302
All forest categories	984,215	61,021	243,648	36,084	32,121	13,032

Table 7—Estimated acres and confidence interval (+/- acres) of area containing *Symphoricarpos oreophilus* (SYOR2) in low, medium, and high cover ranges by forest category and for all forest categories on the Fishlake National Forest. Note that the cottonwood condition is included with all forest categories of the Fishlake National Forest and not evaluated individually. Estimated areas are rounded to the nearest acre.

Fishlake forest type or forest-type group	*Symphoricarpos oreophilus* cover range					
	Low (0–4%)		Medium (5–15%)		High (>15%)	
	Acres	Confidence interval (acres)	Acres	Confidence interval (acres)	Acres	Confidence interval (acres)
Aspen	139,367	26,298	54,161	17,218	30,234	12,849
Conifer	187,364	31,496	50,366	16,601	5,308	5,522
Nonstocked	40,612	14,328	0	0	0	0
Pinyon-juniper	377,965	43,277	43,028	15,271	5,308	5,522
Woodland hardwoods	209,279	32,208	102,827	23,362	12,876	7,558
All forest categories	955,876	62,228	250,382	35,955	53,726	16,639

CONCLUSIONS AND RECOMMENDATIONS

Rangeland health indicators are used by agencies and land managers to monitor the health of rangeland conditions, which include oak and pinyon-juniper woodland FIA forest types, shrublands, alpine communities, marshes, and meadows (Pellant et al. 2005). These (or similar) indicators for rangeland health may have the potential to be expanded to some other forested locations, such as sparsely forested sites.

Management Implications

This study demonstrated that FIA data may be one tool that can be used to analyze ecosystem health for a variety of conditions. The application of modified health indicators can provide land managers the opportunity to examine the current health and functionality status of lands and monitor trends. FIA provides a baseline for detecting changes in ecosystem health. Additionally, FIA data can be used at the spatial scale of a national forest by using current population estimation procedures. Intensified sampling procedures may be required to adequately describe more specific conditions, such as riparian areas, which occur less uniformly through the landscape.

Some of the indicators used by O'Brien et al. (2003) are readily applied to forested conditions and may be useful in determining health and functionality in forests as well as rangelands. Noxious weeds may signal problems where infestations can seriously affect natural communities. The bare ground indicator may also identify sites where erosion is occurring at levels detrimental to forest health.

Although the amount of bare soil is an indication of habitat degradation, Soyza et al. (2000) suggest that bare patch size may be a more reliable indicator of a site's potential for soil and water loss. Revisits by FIA to plots every 10 years provide an opportunity to observe changes in the percentage of bare soil, which could be used to monitor sites where erosion potentially could be a concern. Pellant et al. (2005) note that when evaluating these changes, climatic variables must also be taken into account; the amount of bare ground can vary seasonally and annually with vegetation cover, litter amount, and precipitation patterns in addition to utilization factors such as herbivore browsing and trampling.

This study did not define criteria for properly functioning and nonfunctioning lands on the Fishlake National Forest but left interpretation up to land managers based on the values of these indicators. This paper demonstrates that for any species of interest, crown cover ranges and desired distribution reflecting particular land management objectives could be reported with modification to the shrub cover indicator by using FIA data. Similarly, species compositions by forest type of interest could be evaluated if the desired composition is clearly defined.

Recommendations

Future research should define clear thresholds for species composition and shrub cover indicators to accurately interpret the health and functionality on these lands. Health indicators that are similar to rangeland health indicators could be used once criteria for properly functioning forest conditions are determined. Trace amounts of species are not recorded under FIA protocol (5-percent cover threshold at the time of this study) (USFS 2000–2009) so if mere presence of a species is an important indicator of forest health, data collection methods would have to be refined to meet this requirement.

Pellant et al. (2005) conclude that further research is needed to produce indicators reliant on quantitative measures rather than qualitative estimations and additionally, thresholds need to be clearly defined to determine health of lands in question. O'Brien et al. (2003) similarly note that more work is needed to define nonfunctioning categories to establish ecosystem health measures and thresholds for a variety of cover types and areas. This study suggests that FIA data could be used to monitor health of forests based on these modified indicators assuming that well-defined thresholds can be assigned to forest types or forest-type groups.

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Appendix A—Tally tree species encountered on Utah plots for inventory years 2000–2009. Woodland designation identifies species where d.r.c. is measured instead of d.b.h.

FIA code	Plants code	Common name	Genus	Species	Woodland
15	ABCO	white fir	*Abies*	*concolor*	
19	ABLA	subalpine fir	*Abies*	*lasiocarpa*	
65	JUOS	Utah juniper	*Juniperus*	*osteosperma*	w
66	JUSC2	Rocky Mountain juniper	*Juniperus*	*scopulorum*	w
93	PIEN	Engelmann spruce	*Picea*	*engelmannii*	
96	PIPU	blue spruce	*Picea*	*pungens*	
106	PIED	Common pinyon	*Pinus*	*edulis*	w
108	PICO	lodgepole pine	*Pinus*	*contorta*	
113	PIFL2	limber pine	*Pinus*	flexilis	
122	PIPO	ponderosa pine	*Pinus*	*ponderosa*	
133	PIMO	singleleaf pinyon	*Pinus*	*monophylla*	w
142	PILO	Great Basin bristlecone pine	*Pinus*	*longaeva*	
202	PSME	Douglas-fir	*Pseudotsuga*	*menziesii*	
313	ACNE2	boxelder	*Acer*	*negundo*	
322	ACGR3	bigtooth maple	*Acer*	*grandidentatum*	w
475	CELE3	curlleaf mountain-mahogany	*Cercocarpus*	*ledifolius*	w
746	POTR5	quaking aspen	*Populus*	*tremuloides*	
748	POFR2	Fremont's cottonwood	*Populus*	*fremontii*	
749	POAN3	narrowleaf cottonwood	*Populus*	*angustifolia*	
814	QUGA	Gambel oak	*Quercus*	*gambelii*	w

Appendix B—Plant species designated as noxious weeds in Utah

Scientific name	Common name
Acroptilon repens	Russian knapweed
Cardaria draba	hoary cress
Carduus nutans	musk thistle
Centaurea diffusa	diffuse knapweed
Centaurea solstitialis	yellow starthistle
Centaurea stoebe ssp. micranthos	spotted knapweed
Centaurea virgata ssp. squarrosa	squarrose knapweed
Cirsium arvense	Canada thistle
Convolvulus arvensis	field bindweed
Cynodon dactylon	bermudagrass
Elymus repens	quackgrass
Euphorbia esula	leafy spurge
Isatis tinctoria	dyers woad
Lepidium latifolium	perennial pepperweed
Lythrum salicaria	purple loosestrife
Onopordum acanthium	Scotch thistle
Sorghum almum	perennial sorghum
Sorghum bicolor	perennial sweet sudan
Sorghum halepense	johnsongrass
Taeniatherum caput-medusae	medusahead

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