Multi-scale ecosystem monitoring: an application of scaling data to answer multiple ecological questions

Sarah E. McCord[1,2], Emily J. Kachergis[3], Jason W. Karl[1,2], Darren James[1,2], Dereck Wilson[3]

[1]USDA-ARS Jornada Experimental Range [2] New Mexico State University [3]Bureau of Land Management

Consistent Multi-scale Monitoring

- Provides a core suite of ecological indicators (Toevs et al. 2011).
- Maximizes data collection efficiency because core ecological indicators are measured at all locations but supplemental indicators may be measured where appropriate.
- Promotes reuse of monitoring datasets to address multiple ecosystem concerns at multiple scales.
- Identifies areas where further study to investigate a specific ecosystem response or ecosystem attribute (e.g., wildlife habitat) will be most impactful.
- Utilizes a probabilistic sample design.
- Key to the Bureau of Land Management Assessment, Inventory, and Monitoring (AIM) Strategy (Toevs et al. 2011).

Table 1. Core indicators in standard ecosystem monitoring (adapted from Toevs et al. 2011.

Method	Indicator
Line-point intercept with height	• Vegetation composition • Amount of bare ground • Vegetation height
Canopy gap	• Proportion of soil surface in larger inter-canopy gaps
Plant species inventory	• Presence of non-native species • Presence of rare plants

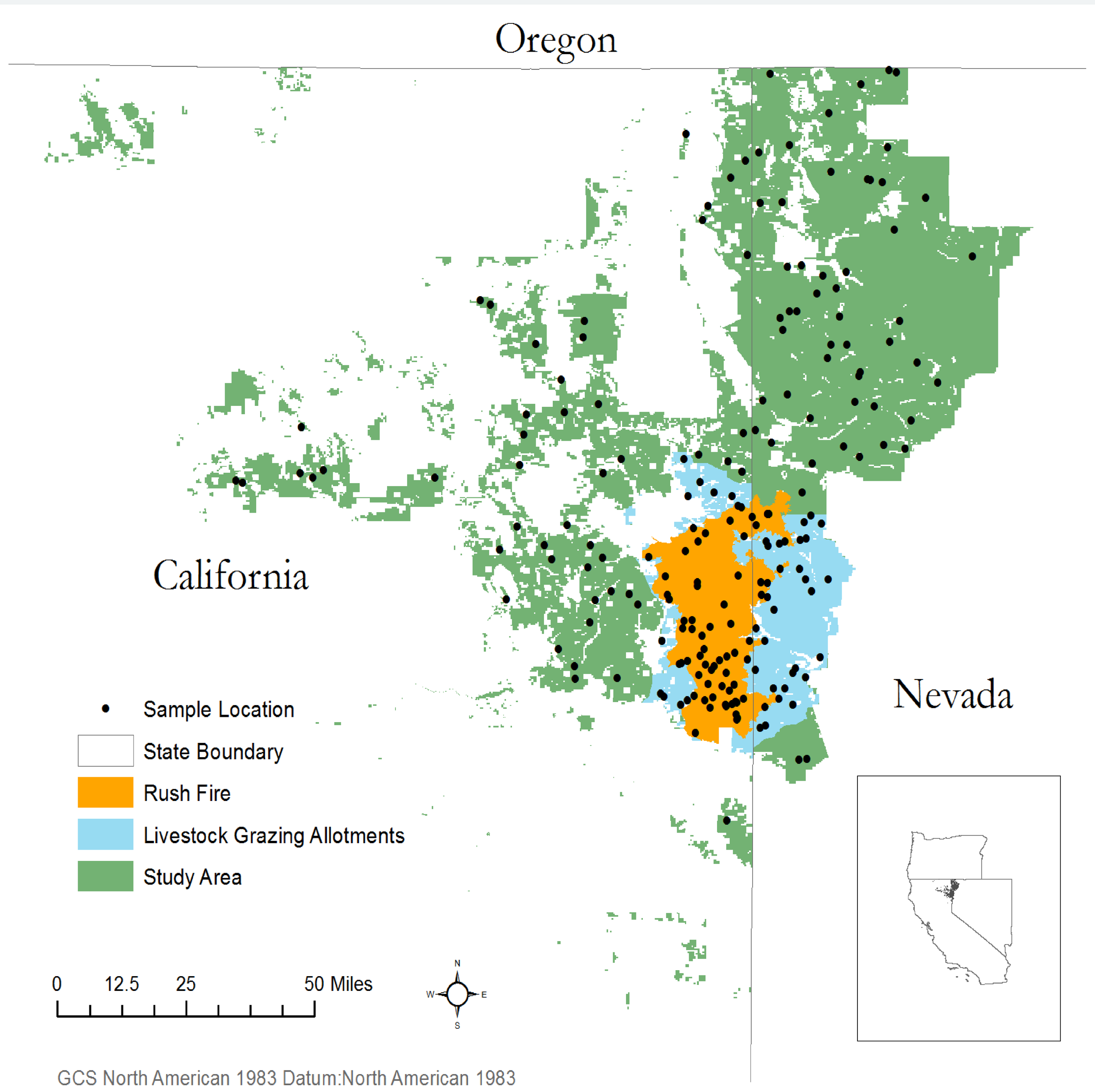

Figure 1. The study area covers Bureau of Land Management lands in northwestern Nevada and northeastern California. In 2012, the Rush Fire burned 315,577 acres in the southeastern corner of the study area. In 2013, a multi-scale ecosystem monitoring effort was implemented in this region to determine the overall ecosystem health of the region as well as the impacts of wildfire restoration treatments in the area affected by the Rush Fire.

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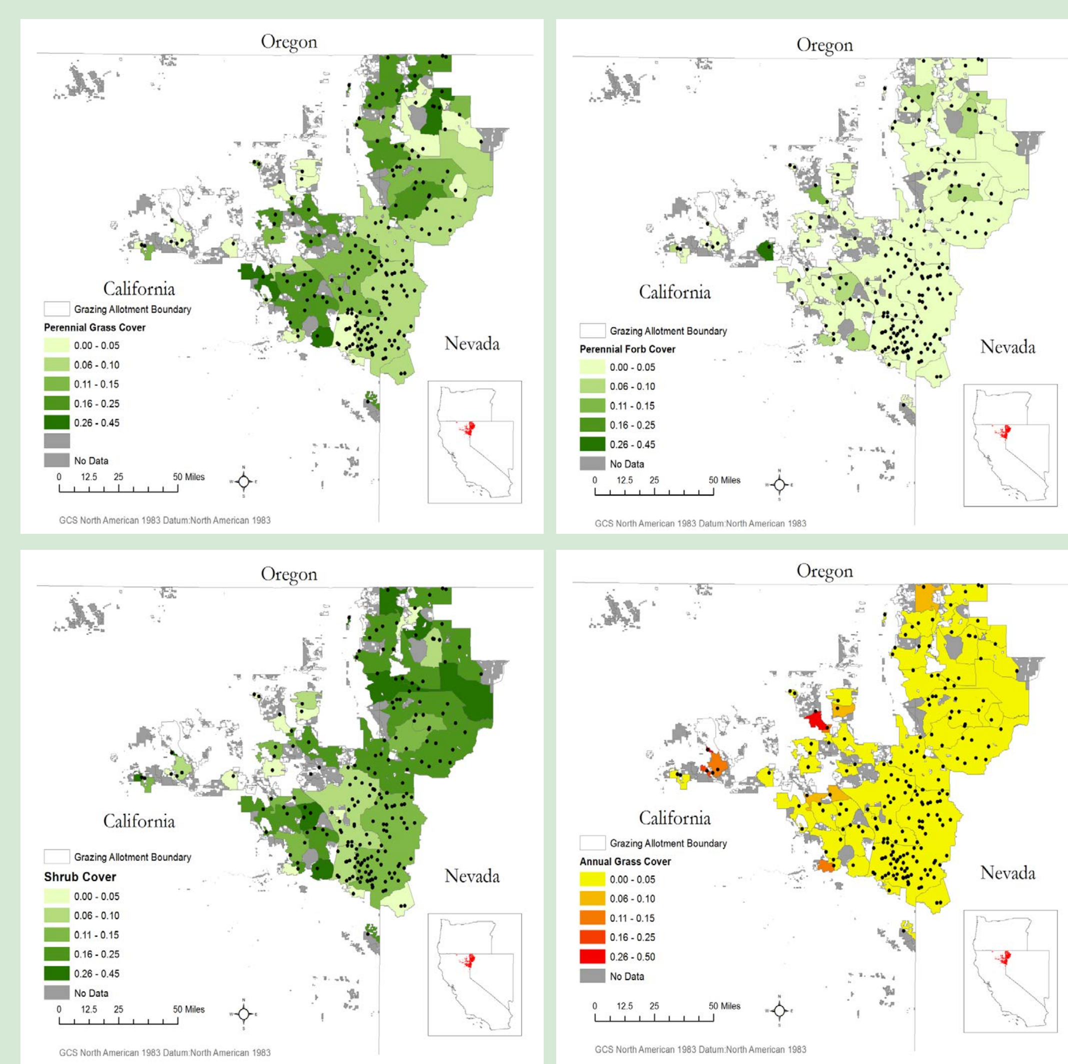
Acknowledgements

We would like to thank the Bureau of Land Management Eagle Lake, Alturas, and Surprise Field Offices for their design, data collection, and data interpretation support. Troy Wirth and David Pyke for their assistance with wildfire restoration and recovery monitoring. Gordon Toevs and Michaela Buenemann for general project support. The data were collected by field crews supplied by the Great Basin Institute. Funding for this project was provided by the Bureau of Land Management.

What is the quality of sage-grouse habitat?



- Potential suitable sage grouse habitat is present in the north and western portions of the study area where perennial grass cover >20% and shrub cover >20% (Figure 3). However, low forb cover throughout the study area may not provide suitable breeding and brood-rearing habitat for sage-grouse (Connelly et al. 2000).
- Annual grass cover is low (<5%) throughout the majority of the study area, which indicates that where site potential will support sage-grouse habitat, invasive species (e.g., *Bromus tectorum*) are significantly impacting sage-grouse habitat (Reisner et al. 2013).
- This extensive survey identifies areas where further studies with additional indicators (e.g., perennial forb density) may be most efficient to best characterize sage-grouse habitat.
- Further stratification of the study area by distance from disturbance, site potential to support sagebrush, and known sage-brush population locations will produce more accurate identification of the quality of sage-grouse habitat.

Figure 3. Four common indicators of sage-grouse habitat quality: perennial grass cover (top left), shrub cover(bottom left), perennial forb cover (top right), and annual grass cover (bottom right). Indicator estimates were stratified by allotment.

Is wildfire recovery sufficient to support livestock grazing?

- In the Observation and Twin Peaks grazing allotments, perennial grass communities are not significantly different from one another in the burned and the unburned areas. However in the Deep Cut allotment perennial grass cover is three times greater in the unburned portions of the allotment than in the burned portions of the allotment.
- Overall site stability between the burned and unburned sections is comparable with estimates of bare ground, soil stability, and the size and proportion of large perennial gaps are similar between burned and unburned portions of the allotment (Table 2, Figure 4).
- These results indicate that post-fire ecosystem recovery may be sufficient to re-introduce livestock grazing to the burned portions of the allotments.
- These comparisons are not the result of a paired design and consequently, the influence of site potential is not included in this analysis.

Table 2. Ecosystem indicator estimates of the burned and unburned portions of three allotments affected by the Rush Fire.

	Deep Cut		Observation		Twin Peaks	
Burned	*N*	*Y*	*N*	*Y*	*N*	*Y*
n	*5*	*3*	*6*	*12*	*25*	*22*
Bare Ground	0.109	0.084	0.126	0.114	0.153	0.164
Total Foliar	0.455	0.407	0.447	0.431	0.398	0.372
Annual Grass	0.001	0.013	0.021	0.006	0.033	0.01
Perennial Grass	0.061	0.029	0.12	0.117	0.07	0.082
Soil Stability	2.44	2.297	2.743	2.143	2.258	1.934
Gaps 101-200 cm	0.202	0.157	0.194	0.200	0.193	0.204
Gaps > 200 cm	0.43	0.628	0.235	0.427	0.447	0.469

Were wildfire restoration and rehabilitation treatments effective?

- After one year of data collection, the efficacy of the fire restoration and rehabilitation efforts was variable (Figure 4). Bare ground cover is significantly greater in drill seeding 1, as compared to the other treatments. Sample plots in drill seeding 1 also had lower annual and perennial plant foliar cover and lower soil stability values than other restoration treatments, the untreated portions of the burn and the unburned portions of the allotments surrounding the Rush Fire. Consequently, drill seeding 1 may have increased the susceptibility of these sites to erosion.
- The aerial seeding and drill seeding 2 treatments did not perform significantly differently from the untreated portions of the Rush Fire or from unburned areas. This indicates that these treatments had a neutral or slightly positive impact in restoring plant communities and decreasing site susceptibility to erosion.
- The unburned portions of the allotments responded similarly to the untreated, burned portions of the Rush Fire. These comparisons are not the result of a paired design and consequently, the influence of ecological site potential is not included in this analysis.

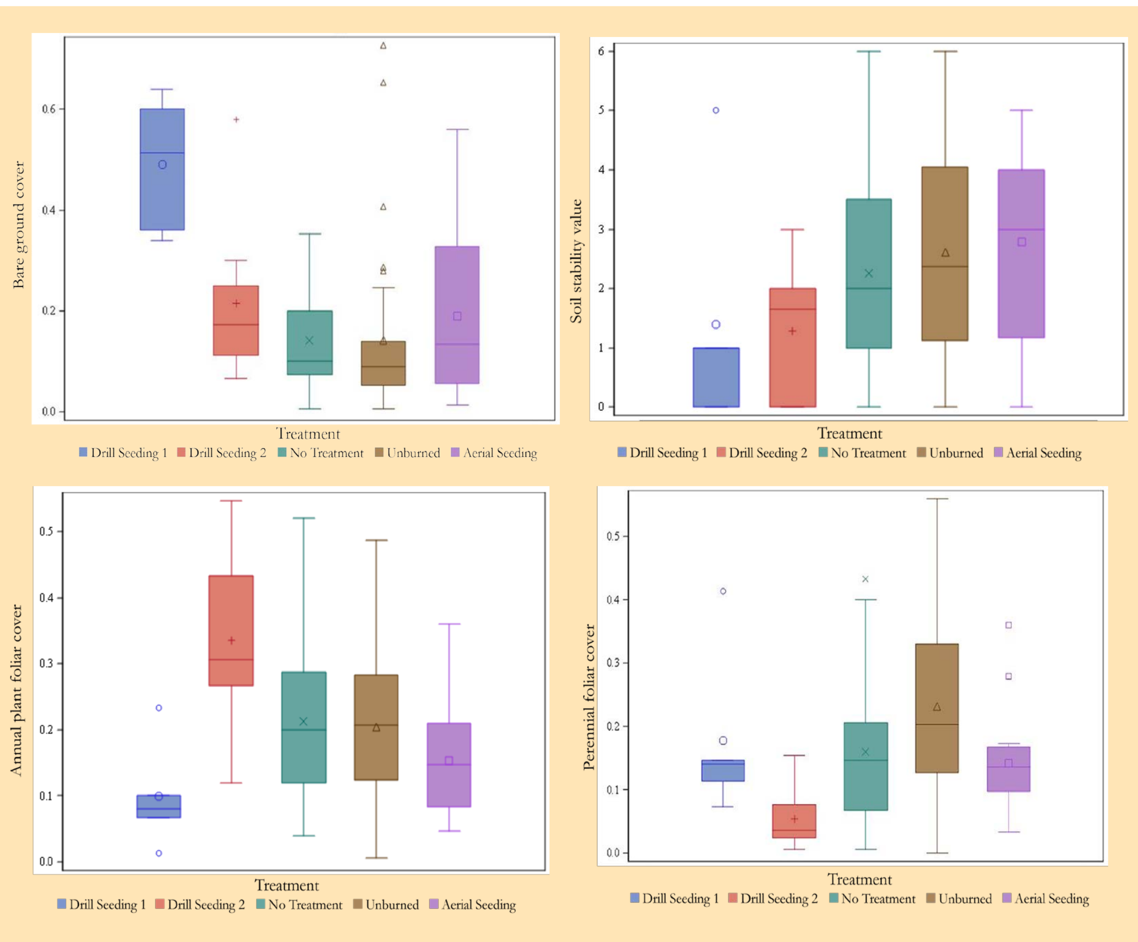


Figure 4. A comparison of vegetation seeding restoration treatments, untreated burned areas, and unburned areas surrounding the Rush Fire

Methods

SAMPLE DESIGN

- Field plots were established according to a probabilistic sample design at three scales (Figure 1).
- At the lowest intensity, sample plots were randomly distributed across the study area stratified by increasing (n=14), decreasing (n=30), and stable (n=58)12-year Landsat TM NDVI trend. This ensured that the heterogeneity of the landscape was sampled.
- At the mid-intensity scale, plots were distributed using a spatially balanced sample design (Stevens and Olsen 2004) throughout the nine allotments which intersected the Rush fire, 36 plots were located within the unburned portions of these allotments, 39 plots were located within the areas of the allotment which burned, .

DATA COLLECTION

- At each 0.7 acre sample location, six core indicators were measured (Table 1).
- These indicators were measured using standard methods: line-point intercept, canopy gap intercept, soil stability test, and a plant species inventory (Herrick et al. 2005; Toevs et al. 2011).

ANALYSIS

- To produce estimates of indicators using plot data at low-intensity, sample weights were applied according to the areal proportion of representation (Table 3).
- Indicator estimates were produced in SAS using the Horvitz-Thompson estimator apply sample weights and produce standard error estimates(Horvitz and Thompson 1952).
- For livestock grazing and sage-grouse analysis questions, the data were post-stratified by grazing allotment because this is a common decision making unit for the BLM.
- To evaluate wildfire restoration treatment effectiveness, Fisher's Least Significant Difference test was used to determine differences between treatments.

Table 3. Sampling intensity, strata if applicable and associated sample weights for the multiple scales of monitoring.

Application	Intensity	Design Stratum	n	Sample Weight
Landscape Scale Sage Grouse	Low-intensity	NDVI Decreasing	30	1.325
	Low-intensity	NDVI Increasing	14	0.391
	Low-intensity	NDVI Stable	58	1.583
Livestock Grazing Allotments	Mid-intensity	N/A	103	0.532
Wildfire Restoration Treatment Effectiveness	High-intensity	Treatment	28	N/A

How does uncertainty change with scale?

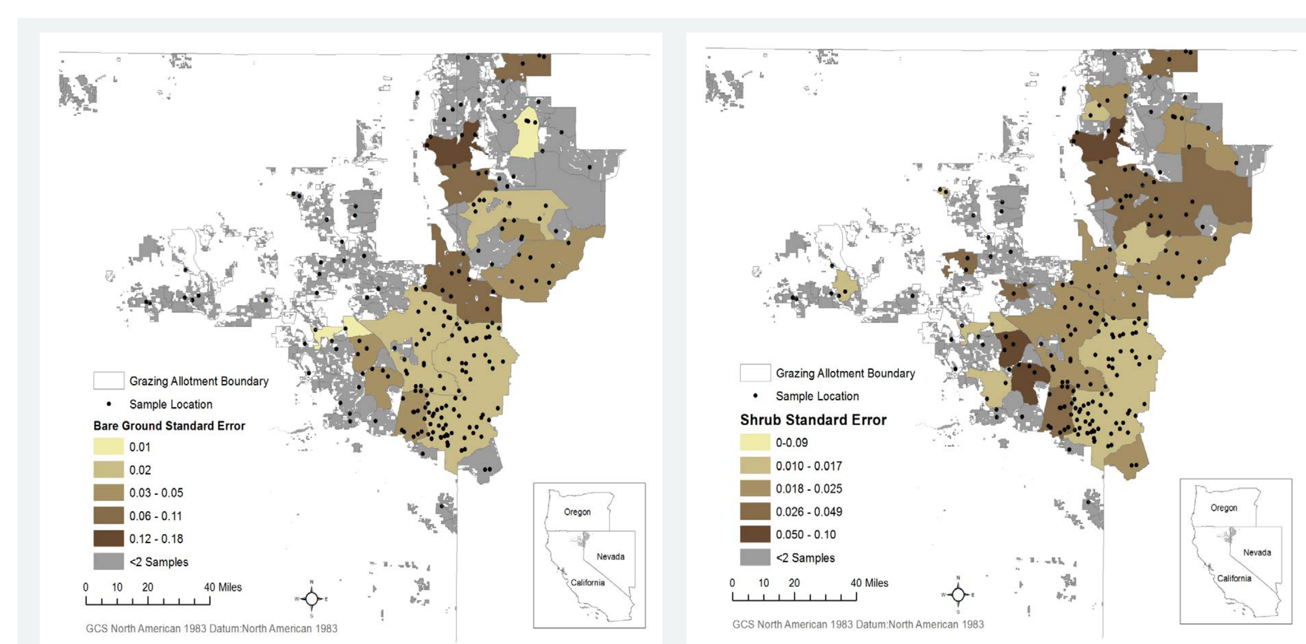


Figure 2. Standard error of bare ground (left) and shrub cover (right) throughout the study area.

- For all indicators, as sampling density increases, uncertainty decreases (Figure 2).
- Applications of the data at larger scales will have larger uncertainty estimates than fine scale applications.
- Changing levels of uncertainty influences the interpretation of the data and adaptive management actions which will result from these interpretations.
- Decision makers and data users should determine the acceptable level of uncertainty for the intended application.