

Assessing Indicators of Rangeland Health With Remote Sensing in Southeast Arizona

Jared Buono

School of Renewable Natural Resources, University of Arizona, Tucson, AZ

Philip Heilman

Southwest Watershed Research Center, ARS, Tucson, AZ

David Williams

Environmental Sciences Division, Environmental Protection Agency, Las Vegas, NV

Phillip Guertin

School of Renewable Natural Resources, University of Arizona, Tucson, AZ

Abstract—*The goal of this study was to scale up ground-based range assessments to ranch and landscape scales in southeast Arizona using remote sensing and minimum amount of field data collection. Remotely sensed metrics of canopy cover, biomass, and mesquite composition were used to assess soil and site stability and biotic integrity. Ground-based assessments were conducted on 11 field locations and used in conjunction with Natural Resources Conservation Service (NRCS) ecological site descriptions to develop evaluation criteria on two different ecological sites. The data were combined in a GIS and 1,386 km² of rangelands were assessed. A total of 13% of loamy upland range sites were categorized as “None to Slight Departure” from reference conditions for soil and site stability, and 63% were categorized as “Moderate to Extreme Departure” for biotic integrity. The model was sensitive to variation in climate and management. This method is currently being developed as a potential tool for land managers in Madrean Archipelago.*

Introduction

There are approximately 5.6 million acres of semi-desert grassland in USDA-NRCS major land resource area (MLRA) 41-3. Land management in this area relies on a diverse mix of State and Federal agencies as well as private land owners and non-governmental organizations. Rangeland management programs have traditionally relied on data acquired at plot and pasture scales; however, field data collection is time and labor intensive. Land managers are increasingly requiring less expensive and timelier information. The goal of this study was to devise and evaluate a cost effective method of scaling up range assessments from ground-based, pasture-scale assessments to ranch and landscape scales using remote sensing. The development of new remote sensing products under the RANGES program has enabled the measurement of relevant grassland metrics at larger spatial scales (Qi et al. 2002). These new remote sensing products, created specifically to aid rangeland managers, include canopy cover and standing biomass estimates that are sensitive to both green and senescent herbaceous vegetation. By combining these measurements with a limited amount of ground data collection a scaled-up method was developed for Arizona’s semi-desert grasslands.

Procedure

The need for a unified method to assess rangelands has been widely discussed (National Research Council 1994, Society

for Range Management 1995). The approach developed here closely parallels the established ground-based rangeland health assessment method (RLH) adopted by the NRCS and the Bureau of Land Management (BLM) and described by Pellant et al. (2000). This method identifies 17 indicators that are used to assess the ecological attributes of soil and site stability, hydrologic function, and biotic integrity. The result is not an overall determination of health, but a description of departure from ecological reference conditions ranging from “None to Slight Departure” to “Extreme Departure.” Areas are thus evaluated by comparing the indicators to corresponding reference areas and ecological site descriptions. Ultimately, an ecological site-specific evaluation matrix is developed that defines a range of measured values for each indicator. The 17 indicators include bare soil, annual production, invasive species, and functional and structural plant groups. Similarly, this study performed assessments by using satellite derived measurements of herbaceous canopy cover, herbaceous biomass, and mesquite composition as indicators. Canopy cover and biomass (including both green and senescent vegetation) were derived from Landsat ETM+ imagery and empirical factors as described by Qi et al. 2002. Accuracy of these satellite data, as reported by Qi (2002), was determined to have no significant difference between satellite estimates and field observations at the 95% confidence interval. Mesquite canopy composition was derived with ETM+ data by exploiting the phenology of semiarid grasslands after a dry winter when the

majority of photosynthetically active vegetation was mesquite (Marsett 2003).

Eleven study sites were established on two major ecological sites, loamy uplands and sandyloam uplands. These sites are dominated by warm season perennial grasses with an occasional over-story of mesquite and other shrubs. Average annual precipitation in this zone ranges from 12 to 16 inches (NRCS Land Resource Unit 41-3). Ground-based RLH assessments were performed on each site as described by Pellant et al. (2000). An evaluation matrix was then developed for both ecological sites based on ground-based RLH assessments, ecological site descriptions, expert opinion, and reference area conditions. The evaluation matrix defined a range of indicator values for percent canopy cover, biomass in lbs/acre, and percent mesquite composition (see table 1). Herbaceous canopy cover was used as an indicator of soil and site stability, and herbaceous biomass and mesquite composition were used separately as indicators of biotic integrity.

Ecological site maps were derived at the landscape scale from soil surveys. A 10 m digital elevation model (DEM) was used to delineate relevant ecological sites from mapping units whenever possible. The remotely sensed measurements were then applied to the appropriate ecological sites on the landscape using values defined in the evaluation matrix to determine departure categories.

Results

The results were landscape scale assessments for indicators of soil and site stability and biotic integrity. The assessments covered 969 km² of loamy upland and 417 km² of sandyloam upland with a ground resolution of 30 x 30 m. Table 2 details the results of the assessments for each ecological site by departure category. The landscape scale ecological site map

correctly identified all but one of 11 field sites. Results of the biotic integrity assessment based on mesquite composition demonstrated sensitivity to management. Figure 1 compares assessment results to a high resolution ortho-photo. In the photo large tracts of land treated by brush removal can be seen. In the assessment map, treated land was classified as “None to Slight” and untreated land was classified as “Moderate to Extreme” or “Extreme” departure from reference conditions.

Conclusions

Though the initial results are promising, additional studies are needed to quantitatively evaluate the models at landscape scales. Further research is also needed regarding the identification of key indicators, the effects of climate variability, and development of the evaluation matrices. The relationship between remotely sensed and ground-based indicators needs to be determined. This approach used canopy cover, biomass, and mesquite composition as proxy measures of the ground-based indicators of bare soil, annual production, and invasive species, respectively. In addition, because remote sensing may not feasibly measure all 17 ground-based indicators, key indicators will need to be identified for each ecological site.

This study also observed a high degree of variation in cover, biomass, and mesquite composition between sites at the upper and lower ends of the precipitation zone. This may require multiple evaluation matrices within a single precipitation zone. A comprehensive study is being developed for testing in the summer and fall of 2004. Results will be evaluated by range conservationists and land managers. In addition to landscape assessments, the models will be used in an attempt to map states and transitions within ecological sites. Ultimately, this study will identify and evaluate several issues related to scaled-up assessments of grasslands in the Madrean Archipelago.

Table 1—Evaluation matrix.

Indicator	Departure category	Value	
		Loamy Upland	Sandyloam Upland
Mesquite composition	None to Slight	0-2%	0-5%
	Slight to Moderate	2-10%	5-12%
	Moderate	10-15%	12-17%
	Moderate to Extreme	15-20%	17-25%
	Extreme	20-100%	25-100%
Biomass	None to Slight	>1,850 lbs/ac	>1,850 lbs/ac
	Slight to Moderate	1,100-1,850 lbs/ac	1,250-1,850 lbs/ac
	Moderate	600-1,100 lbs/ac	600-1,250 lbs/ac
	Moderate to Extreme	100-600 lbs/ac	100-600 lbs/ac
	Extreme	<100 lbs/ac	<100 lbs/ac
Canopy cover	None to Slight	42-79%	45-78%
	Slight to Moderate	32-42%	36-45%
	Moderate	24-32%	27-36%
	Moderate to Extreme	10-24%	10-27%
	Extreme	0-10%	0-10%

Table 2—Assessment results.

Indicator	Departure category	Loamy Upland		Sandyloam Upland	
		km ²	Percent	km ²	Percent
Mesquite composition					
Biotic integrity	None to Slight	633	65%	320	77
	Slight to Moderate	139	14%	36	9
	Moderate	49	5%	14	3
	Moderate to Extreme	34	3%	14	3
	Extreme	115	12%	33	8
Biomass					
Biotic integrity	None to Slight	3	0.33%	2	0.40
	Slight to Moderate	33	3%	13	3
	Moderate	86	9%	48	12
	Moderate to Extreme	608	63%	223	53
	Extreme	239	25%	131	31
Canopy cover					
Soil and site stability	None to Slight	129	13%	62	15
	Slight to Moderate	365	38%	185	44
	Moderate	215	22%	84	20
	Moderate to Extreme	184	19%	57	14
	Extreme	75	8%	29	7

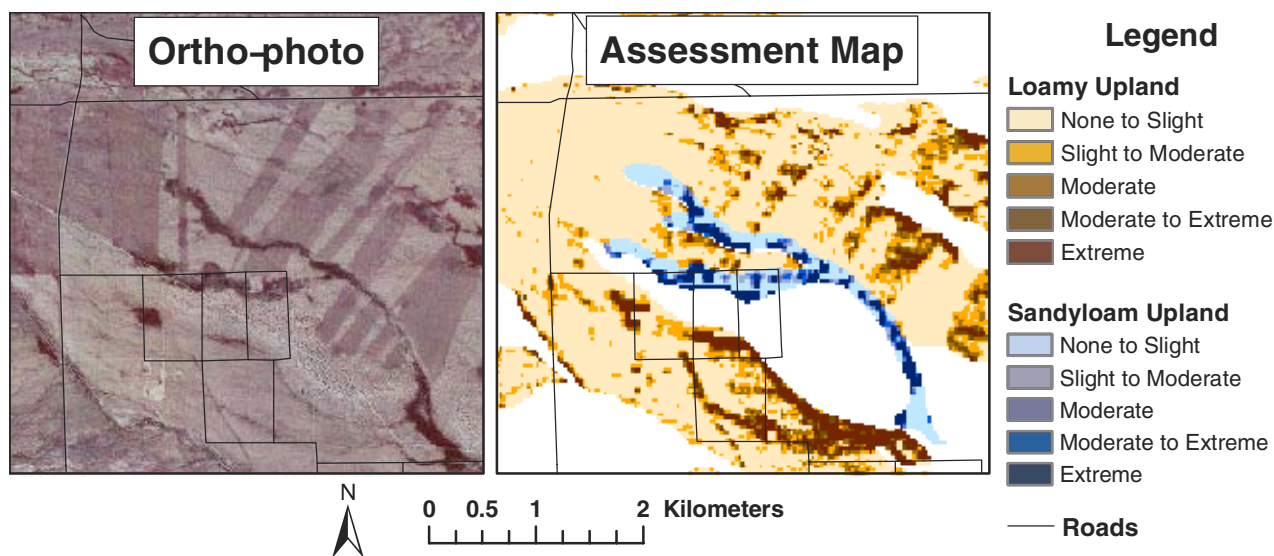


Figure 1—Assessment map, biotic integrity based on mesquite composition.

References

- Marsett, Robin. 2003. Personal Communication. Tucson, AZ.
- National Research Council. 1994. Rangeland health: New methods to classify, inventory, and monitor rangelands. Washington, DC: National Academy Press.
- Pellant, M.; P. Shaver; D.A. Pyke; J. E. Herrick, 2000. Interpreting indicators of rangeland realth (version 3). Tech. Reference 1734-6. Denver, CO: U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center.
- Qi, Jiaguo; R. Marsett; P. Heilman; S. Biedenbender; S. M. Moran; D. Goodrich. 2002. RANGES improves satellite-based information and land cover assessments in the Southwest United States. *Eos Transactions, American Geophysical Union*. 83(51): 601-606.
- SRM (Society of Range Management Task Group on Unity in Concepts and Terminology Committee). 1995. New concepts for assessment of rangeland condition. *Journal of Range Management*. 55: 474-481