Iterative Model Development for Natural Resource Managers: A Case Example in Utah's Grand Staircase-Escalante National Monument

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Abstract
Non-native plant species, which threaten native plant diversity, are a major concern to managers of Grand Staircase-Escalante National Monument in Utah. Predictive spatial maps with Inverse Distance Weighting provided an effective way to identify "hot spots" of occurrence for three cover types of interest: native species richness, cryptobiotic soil crust cover (lichen, moss, algae, and bacteria), and cover of non-native cheatgrass (*Bromus tectorum*). Maps based on regression tree analysis showed that *B. tectorum* was found throughout the Monument with cover usually < 0.1%, but has heavily invaded mesic sites and areas of disturbance, (cover ranging from 3.4 to 17.8 %). The analysis also showed that *B. tectorum* cover could be predicted by positive correlations with percent soil nitrogen and phosphorous (ppm). We also found a significant inverse relationship between high native plant species cover and cryptobiotic soil crust cover. These methods provide managers with an effective way to concentrate mitigation and conservation programs.

I. INTRODUCTION

The 1996 proclamation and establishment of the Grand Staircase-Escalante National Monument in Utah acknowledged the ecological importance of this scenic, arid ecosystem. The Monument includes an abundance of unique isolated plant communities and is home to 40 of Utah's rare plant species, 163 endemic species, and includes 30% of the state's flora (Shultz, 1998). However, non-native plant species comprise one of the most significant threats to the ecological integrity of the monument (Davidson and Belnap, 1997). Non-native plant species can be toxic to livestock and wildlife and can replace native plant species (Harper et al., 1996).

Invasion of non-native species may alter ecological processes by changing fire regimes and successional stages of affected ecosystems. In some areas of the Monument, non-native species are widely dispersed and in many areas have become locally dominant. Based on earlier data, 79%, of the 367 1000-m^2 plots contained non-native species, and 1688 of 3670, or 46%, of the 1-m^2 subplots contain non-natives. Stohlgren et al. (2001) suggested that given current patterns of invasion, it may be challenging to preserve the native plant species and soil crusts for which the National Monument was established. Non-native species such as cheatgrass (*Bromus tectorum*), have successfully invaded much of the landscape within the Monument (Stohlgren et al., 2001). In particular, cheatgrass can rapidly establish following a fire, causing increased fuel loads and an increase in the fire return interval resulting in a positive feedback cycle (Davidson and Belnap, 1997).

Cryptobiotic soil crusts are formed by living organisms and their byproducts, creating a surface crust of soil particles bound together by organic materials (USDA, 1997). Soil crusts are widespread and play an important ecological role in the functioning of soil stability, atmospheric nitrogen fixation, nutrient contributions to plants, soil-plant-water relations, seedling germination, and plant growth (Grand Staircase-Escalante National Monument Management Plan, 2000). It is believed that the condition and development of soil crusts may serve as an indicator of disturbance from grazing and fire as well as patterns of stability.

The governing agency for the Monument, the Bureau of Land Management, is faced with a variety of management challenges including protecting native plants while providing for recreation, grazing, mineral exploration, and natural fire regimes on the landscape. It is important to quantify patterns of non-native plant species development for land managers using a science-based approach to assist the decision process with regard to treatment and mitigation.

Our goal was to quantify patterns of native plant species cover, cryptobiotic crust cover, and *B. tectorum* cover relative to environmental variables to provide land managers scientific data on which to base wise conservation efforts. Field data on vegetation, soils, and crusts, and a correlative approach were used to examine variables under which non-native plants have successfully established in the Monument. The objectives were to: (1) use a comprehensive geographic information system (GIS) database to evaluate patterns of *B. tectorum* occurrence relative to native species cover and cryptobiotic soil crust cover; (2) create spatial maps showing the estimated percent cover of native plant species,

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cryptobiotic soil crusts, and *B. tectorum*; and (3) use statistical analyses to quantify these patterns and determine which variables are correlated to these patterns.

II. STUDY AREA AND METHODS

The Grand Staircase-Escalante National Monument is located in the south-central portion of Utah, as a part of the Colorado Plateau system (Figure 1). The 769,000-ha Monument primarily consists of an arid landscape with an abundance of variable, isolated habitats, which support a unique array of vegetation communities and biological diversity. The area contains both a high plateau and low canyon-land geography, with elevation ranging from 1160m to 2620m.

Vegetation sampling in the Monument was based on stratified random sampling of rare and common habitats (Stohlgren et al., 2001). There are currently 367 modified-Whittaker plots in the Monument (Figure 1). The modified-Whittaker design is a nested multi-scale vegetation sampling method proven robust for sampling plant species richness in a diversity of environments (Stohlgren et al. 1995, 1997a,b, 1998a,b, 1999, 2000). This design was used to collect species data at multiple spatial scales. Each plot includes ten 1-m2 subplots, two 10-m2 subplots, and a 100-m2 subplot, nested within a 1000-m2 plot. In each of the 1-m2 subplots, we recorded the foliar cover and height by species, the percent cover of bare ground, rock, litter, duff, dung, and cryptobiotic soil crusts by developmental stage. Within each of the 10-m2 subplots, the 100-m2 subplots, and the remaining area of the 1000-m2 plot, we recorded presence of vegetation by species and cryptobiotic crusts by developmental stage. A 2.5cm diameter soil corer was used to take five samples, one at each corner and from the center of each plot at depths of 0-15cm and combined to be representative of the entire modified-Whittaker plot. Ancillary data at each plot includes UTM location, a detailed site description, and still photographs. This information facilitates return visits to the plots for future monitoring, and provides spatial information to be incorporated into a geographic information system.

III. GIS ANALYSES

The GIS database used to develop this project contained several coverages consisting of independent variables thought to influence variability in plant species richness and the cover

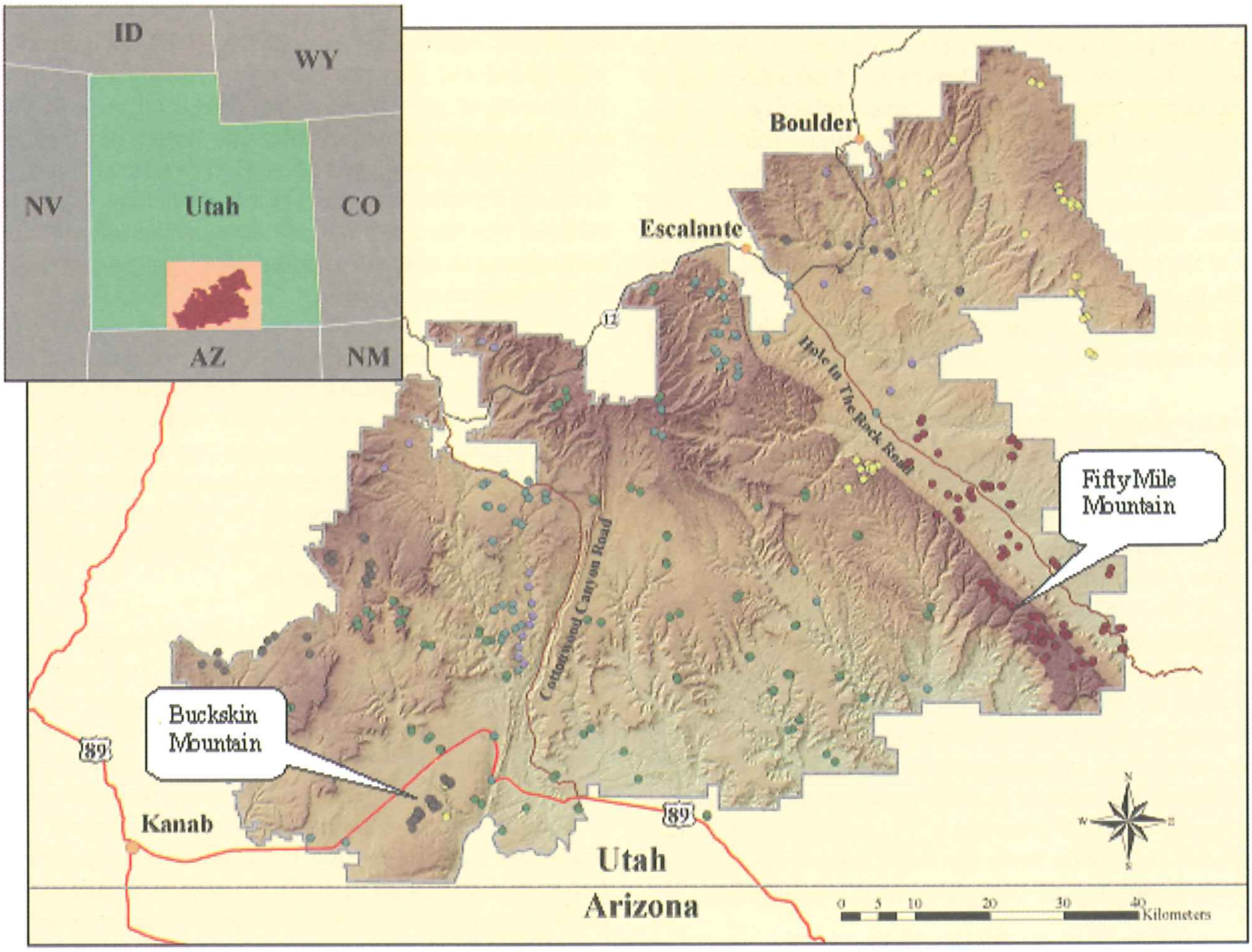

Figure 1. Study area at Grand Staircase-Escalante National Monument, Utah, USA.

of non-native plant species. These layers included a 10m resolution Digital Elevation Model (DEM; Department of Interior; U.S.G.S.), which was used to create a 10m grid of slope and aspect (ARC/INFO©; ESRI 1997). Additional coverages include geologic parent material and soil type. A point shapefile based on the UTM location of 367 modified-Whittaker plots within the monument was generated in ArcView© and then joined to an MS Access© database of field data using an SQL (Structured Query Language) connection.

The ArcView© field calculator was used to map elevation, and derive slope, and aspect for the individual plots, based on the DEM. Using separate coverages for geologic parent material and soil types present in the Monument, the ArcView© geoprocessing wizard was used to spatially join the plot data and then determine the geology type and dominant soil type for each of the points in the Plots coverage. The information derived from these analyses was exported to the project's primary database for statistical analysis (Systat©, 2001, version 10).

IV. STATISTICAL ANALYSES

A trend surface model was developed for each of the cover types of interest: (1) % native plant species cover; (2) % total cryptobiotic crust cover; and (3) % *B. tectorum* cover, based on the field data from the 1-m^2 subplots. This operation was performed using ArcGIS© Version 8.2 with standard software defaults. The output was a series of predictive maps, which estimate the percent cover for each cover type across the Monument using Inverse Distance Weighting. This interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, Inverse Distance Weighting will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, the procedure assumes that each measured point has a local influence that diminishes with distance. It weights the points closer to the prediction location greater than those farther away (ArcGIS© Version 8.2). The purpose of the predictive maps was to identify possible "hot spots" of occurrence in the Monument to help managers target treatment or mitigation efforts. To further examine the variables that influence these hot spots, regression trees were developed as described below.

All variables were assessed for normality and transformed where appropriate (using Systat 2001, version 10). Log transformations were conducted on total crust cover, B. tectorum cover, native cover, inorganic carbon, nitrogen, and phosphorus using $\log_{10}(x+1)$ to account for values that were zero.

Regression tree analyses were then conducted to identify significant independent variables that describe trends of native plant species cover, total cryptobiotic crust cover, and *B. tectorum* cover based on data from the 1-m^2 subplots. Regression tree analysis begins with all cases (subplots) in one cluster and splits the data attribute by attribute into a hierarchical binary tree. The terminus of each branch represents a cluster whose members are more similar to each other than to members of the twin cluster (Systat 2001, version 10). This approach was used for several reasons. First, regression trees are non-parametric models that have a high computational efficiency that easily incorporates categorical variables (e.g., cover type, soil nutrients) and they are well suited to handle non-homogenous datasets (e.g., unbalanced sample sizes, high variability). Second, regression trees are able to identify the relative importance of independent variables and their interactions to the predicted variable in a hierarchical format without inferring cause and effect relationships. Finally, regression tree analyses present resource managers with a comprehensive output that simply describes the relationships of multiple independent variables, thus facilitating the understanding and use of results by a broader array of resource managers and stakeholders (Hansen et al. 1996).

Three separate regression trees were developed, one for native plant species cover, total cryptobiotic cover, and *Bromus tectorum* cover based on eight independent variables: % total crypto cover; % native plant species cover; % *B. tectorum* cover; elevation (m); % sand; % clay; % inorganic carbon; % nitrogen; and phosphorus (ppm). In each of the separate trees, the dependent variable was removed from the list of independent variables. Each loss function is expressed in terms of a goodness-of-fit statistic, the proportion of reduction in error (PRE). Proportion reduced error values are equal to R^2 values, and are used to describe the amount of variation explained by the independent variables in the model (Hansen et al. 1996).

V. RESULTS

Native and non-native plant cover, and cryptobiotic crust cover varied greatly by vegetation type (Table 1.) Average native species in the 19 vegetation types was relatively consistent, ranging from 15.4 % to 42.6 %. Cryptobiotic crust cover was more variable among vegetation types ranging from 11.9 % to 65.4 %. Non-native species cover and *B. tectorum* cover were highly variable among vegetation types (Table 1).

Soil characteristics also varied considerably among vegetation types (Table 2). Percent clay of soils varied by more than a factor of two, which greatly affects water-holding capacity among vegetation types. Equally important, soil nutrients (N, P, and inorganic C) varied by a factor of ten among vegetation types (Table 2). In the predictive spatial maps there was a relatively even distribution of native cover throughout the landscape, typically ranging from 9.1 to 27.6 %. However, a significant area along Fifty-Mile Mountain in the eastern portion of the Monument (Figure 1), was between 27.6 and

Table 1. Basic statistics for regression tree analysis. (Min. & Max values for each variable are in bold and the standard error is in parenthesis.)

CODE	VEGETATION TYPE	n (Veg)	NATIVE COVER %	NON-NATIVE COVER %	Bromus tectorum COVER%	n (Crypto)	TOTAL CRYPTO COVER %
1	*Desert Shrub*	290	16.3 (1.0)	2.0 (0.3)	1.5 (0.3)	290	57.3 (1.7)
2	*Blackbrush*	270	29.2 (1.4)	2.5 (0.4)	2.3 (0.4)	270	50.6 (1.8)
3	*Desert Shrub/Grassland*	160	21.5 (1.6)	2.2 (0.3)	1.7 (0.3)	160	48.1 (2.4)
4	*Sagebrush*	310	24.6 (1.3)	3.1 (0.4)	2.2 (0.4)	310	55.9 (1.7)
5	*Juniper*	220	16.6 (1.6)	0.4 (0.1)	0.4 (0.1)	290	**65.4 (2.1)**
6	*Juniper/Sage*	170	24.7 (1.8)	7.4 (0.9)	6.6 (0.9)	170	36.6 (2.2)
7	*Disturbed PJ/Sage*	280	**15.4 (1.3)**	12.6 (0.9)	7.1 (0.8)	280	38.9 (1.5)
8	*Pinyon-Juniper/Sage*	210	31.2 (2.1)	0.9 (0.2)	0.9 (0.2)	210	54. 4 (2.1)
9	*Pinyon-Juniper*	**880**	24.3 (1.1)	1.4 (0.2)	0.9 (0.1)	**880**	45.2 (1.1)
10	*Pinyon-Juniper/Oak*	180	**42.6 (2.9)**	0.5 (0.1)	0.3 (0.1)	180	38.5 (2.4)
11	*Pinyon-Juniper/Manzanita*	60	35.8 (3.8)	**0.1 (0.0)**	0.1 (0.0)	60	39.1 (4.6)
12	*Pinyon Pine*	40	35.3 (6.2)	1.3 (0.4)	1.3 (0.4)	40	40.1 (6.0)
13	*Mountain Shrub*	110	34.6 (2.9)	1.9 (0.5)	1.4 (0.5)	110	39.3 (2.8)
14	*Ponderosa Pine/Manzanita*	70	37.8 (4.5)	0.8 (0.5)	0.8 (0.5)	70	29.3 (3.8)
15	*Rabbitbrush*	90	29.7 (3.1)	5.5 (1.6)	4.5 (1.5)	90	46.1 (3.1)
16	*Aspen*	60	57.6 (4.4)	8.7 (2.1)	**7.4 (2.1)**	60	**11.9 (2.6)**
17	*Wet Meadow*	30	37.0 (5.2)	**27.5 (5.0)**	2.0 (0.8)	30	16.4 (5.6)
18	*Spring*	**20**	29.9 (7.5)	5.4 (3.4)	**0.0 (0.0)**	**20**	30.3 (7.0)
19	*Perennial Riparian*	220	35.3 (2.6)	12.3 (1.6)	1.6 (0.4)	220	36.4 (2.4)

79.2 % native cover (Figure 2a). In southern portions of the Monument, areas of low native cover (< 9.1%) correspond with areas of high crust cover (> 79.2%; Figure 2b). Patterns across the entire Monument indicate that areas of high cryptobiotic crust cover (> 54.2%) are prevalent in areas containing less native species cover (< 27.6%) and low cover of B. tectorum (< 3.4%). There is a high frequency of B. tectorum across the Monument, but the numbers indicate that the relative cover is generally < 1.0% and most often < 0.1%. Areas of high B. tectorum cover were limited and patchily distributed in the south and east portions of the Monument (Figure 2c).

The first regression tree generated to predict native species cover for the entire Monument identified one significant independent variable, total cryptobiotic cover (Figure 3). The mean native cover for all tested plots was 26.4%. The highest percent native species cover (48.8%) occurs when total cryptobiotic cover is < 8.5%. When total cryptobiotic cover was between 8.5 and 69.0%, native species cover is 27.4%, and when cryptobiotic cover was > 69.0%, the mean native species cover drops to 11.6%. This model accounted for about 19.0% of the variation in native species cover.

The second regression tree generated to predict the total cryptobiotic crust cover for the entire Monument identified two independent variables, native cover, and soil nitrogen (Figure 4). The mean crust cover for the tested plots was 45.7%. The first split stated that average total cryptobiotic cover was higher than average (55.3%) when native cover was < 26.5%. The next split reported that when N was < 0.08%, total cryptobiotic cover was even higher with a mean of 61.9%. This model accounted for about 21.0% of the variation in total cryptobiotic crust cover.

The third regression tree was generated to predict the cover of *B. tectorum* for the entire Monument (Figure 5). The mean cover of cheatgrass for the tested plots was 2.2%. This model had three branches, which include the independent variables phosphorus (P), and nitrogen (N). The first split occurs when P levels were > 48 ppm, where *B. tectorum* cover was much higher than average (41.4%), but this occurred on only 10 of 3440 1-m^2 subplots (i.e., in one 1000-m^2 plot). When P was below 48 ppm, cover was average (2.0%). The next branch was also P driven. When P < 18.0 ppm, the mean cover was below average (1.5%). When P was > 18 ppm and < 48 ppm, the mean cover was to 8.0%. The third split occurs when N was < 1.4 %, average cheatgrass cover was estimated at 5.1%, and when N > 1.4%, the average cover of *B. tectorum* was estimated at 25.1%, again, much higher than the average. This model accounted for 23.0% of the variation.

Table 2. Basic statistics for regression tree analysis, continued.

CODE	VEGETATION TYPE	n (Soil)	%SAND	%CLAY	% INORGANIC CARBON	%N	P (ppm)
1	*Desert Shrub*	280	68.0 (1.5)	**21.4 (1.2)**	0.9 (0.1)	**0.0 (0.0)**	4.7 (0.2)
2	*Blackbrush*	240	80.1 (0.1)	13.9 (0.5)	0.8 (0.0)	0.0 (0.0)	4.8 (0.2)
3	*Desert Shrub/Grassland*	150	69.4 (1.3)	18.7 (1.0)	0.7 (0.1)	0.0 (0.0)	8.9 (0.6)
4	*Sagebrush*	310	69.0 (1.1)	16.0 (0.5)	0.7 (0.0)	0.1 (0.0)	8.5 (0.3)
5	*Juniper*	220	73.2 (1.3)	15.8 (0.7)	0.9 (0.1)	**0.9 (0.0)**	3.5 (0.1)
6	*Juniper/Sage*	150	62.3 (1.2)	20.5 (0.7)	0.7 (0.1)	0.5 (0.1)	13.3 (0.7)
7	*Disturbed PJ/Sage*	280	**62.0 (1.0)**	20.1 (0.4)	0.4 (0.0)	0.7 (0.0)	13.0 (0.5)
8	*Pinyon-Juniper/Sage*	210	78.5 (1.0)	11.5 (0.6)	0.4 (0.1)	0.2 (0.0)	6.5 (0.2)
9	*Pinyon-Juniper*	**870**	69.5 (0.6)	19.0 (0.3)	**1.0 (0.0)**	0.1 (0.0)	6.0 (0.2)
10	*Pinyon-Juniper/Oak*	170	75.2 (1.4)	12.9 (0.5)	0.4 (0.1)	0.4 (0.1)	9.3 (0.5)
11	*Pinyon-Juniper/Manzanita*	60	79.3 (2.6)	11.2 (1.4)	**0.1 (0.0)**	0.1 (0.0)	**2.2 (0.1)**
12	*Pinyon Pine*	40	79.4 (3.5)	14.6 (1.7)	0.2 (0.1)	0.0 (0.0)	6.3 (0.7)
13	*Mountain Shrub*	110	71.8 (1.3)	17.6 (0.7)	0.7 (0.1)	0.1 (0.0)	4.8 (0.3)
14	*Ponderosa Pine/Manzanita*	70	85.9 (1.1)	**8.5 (0.4)**	0.2 (0.0)	0.0 (0.0)	5.9 (0.6)
15	*Rabbitbrush*	90	84.5 (0.6)	9.8 (0.2)	0.7 (0.1)	0.0 (0.0)	6.9 (0.6)
16	*Aspen*	60	80.0 (0.6)	13.3 (0.3)	**0.1 (0.0)**	0.1 (0.0)	**24.4 (0.8)**
17	*Wet Meadow*	30	83.4 (0.0)	9.7 (0.3)	0.2 (0.0)	0.1 (0.0)	17.3 (0.6)
18	*Spring*	**20**	62.0 (3.6)	18.9 (1.9)	**1.0 (0.0)**	0.0 (0.0)	2.9 (0.5)
19	*Perennial Riparian*	190	**86.4 (0.4)**	8.6 (0.3)	0.7 (0.0)	0.2 (0.0)	4.2 (0.2)

VI. DISCUSSION

The predictive spatial maps provided a simple way to identify possible hot spots of occurrence for each of the cover types of interest (Figure 2a, b, c). By examining these maps individually and comparatively, we were able to identify some trends across the landscape that would be useful to land managers. In general, areas containing higher percent cover of native species tend to have less cover of cryptobiotic soil crusts and areas of high crust cover tend to have a lower percentage of native plant cover.

Cryptobiotic crusts have been shown to stabilize soils, improve nutrient status of vascular plants growing in the crust, and improve soil structure (Belnap, 1993). The Monument landscape includes many types of soil crusts including lichens, mosses, green algae, microfungi and bacteria. Soil crusts are also prone to disturbance by such factors as grazing, vehicular activities, recreation, and fire. Therefore, it is important for managers to identify these sites to target management efforts, especially when operating with limited resources. The predictive map for cryptobiotic crust cover (Figure 2b) shows a marked decline in crust cover in the area of Buckskin Mountain, located in the south-central portion of the Monument. This area has experienced recent disturbance by three naturally ignited fires in 1996, 1997, and 1998, and subsequent post-fire treatments (including drill seeding). The predictive maps show a decrease in cryptobiotic crust cover (< 14.7%) particularly compared to surrounding areas where crust cover is > 54.0%. The Buckskin Mountain burn areas also support a much higher percentage of *B. tectorum* (3.4 to 17.8%; Figure 2c). Characterized as opportunistic, *B. tectorum* has proven to be highly successful in reproductive fitness, competition, and resource exploitation (Melgoza 1991, Knapp 1996). These observations are comparable to a study by Evangelista et al. (2002), who found that in general, burned sites had significantly lower native species cover (11.0%) and soil crust cover (4.1%) than adjacent unburned areas. Additionally, this same study found that most of the burned plots had significantly higher non-native species richness and cover and lower native species richness than control sites (Evangelista et al. 2002). Although high concentrations of *B. tectorum* were shown to be patchily distributed throughout the Monument, it was present in 74.0% of the widely distributed sample plots. Despite the low percent cover of cheatgrass, usually < 0.1%, the high frequency and widespread distribution indicates a large potential for increased invasion following fire due to the ubiquitous seed supply. This is particularly important in the southern and eastern portions of the Monument where the percent cover of cheatgrass is very high (0.6 to > 17.8%).

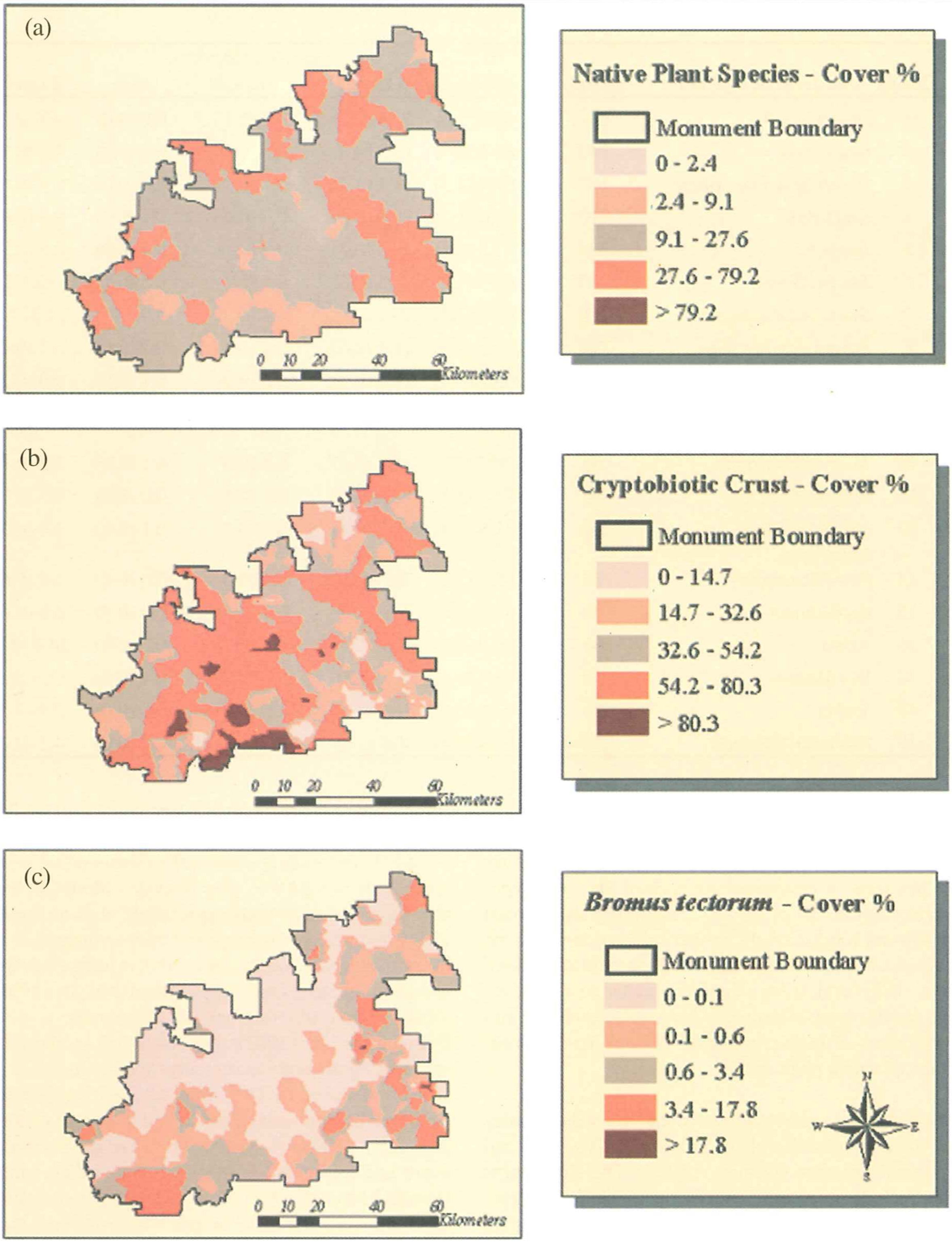

Figure 2. Predictive maps with inverse distance weighting.

Regression trees were used to further identify variables that related to these trends. The regression tree for native cover analysis also indicated that the percent cover was related to the amount of cryptobiotic soil crusts present (Figure 3). This correlation was also present in the regression tree for total cryptobiotic cover (Figure 4), which additionally introduces the presence of soil nitrogen as an independent variable. In areas of < 26.5% native cover, crust cover is shown to be higher when soil nitrogen levels are < 0.08%. Belnap (1996) suggested that soil crusts are a dominant source of nitrogen for semi-desert ecosystems. Our data show that crusts may play an important role in low N areas by filling a niche presented

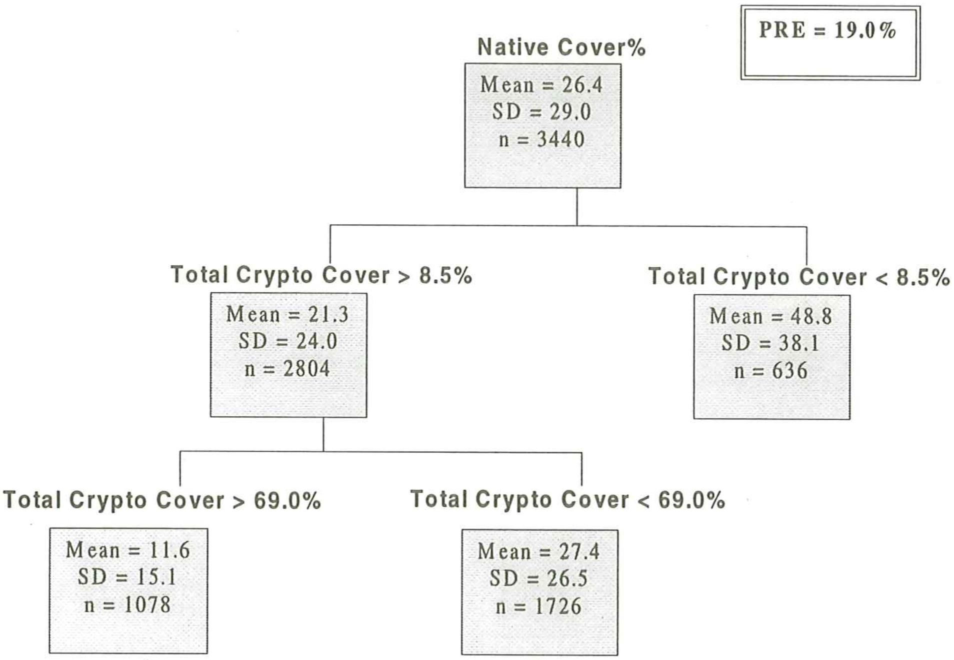

Figure 3. Regression tree - native plant species cover.

by low % native cover.

The regression tree for *B. tectorum* is characterized by phosphorus and nitrogen as the independent variables. In the majority of the subplots tested (91.6%, n = 3,150) the percent cover of *B. tectorum* averaged only 1.5%. Thus, cheatgrass cover was fairly low over very large areas of the Monument (Figures. 2c, 5). Bashkin et al. (2003) suggested that soil P may prove to be a powerful indicator of non-native species establishment and success. Further analysis revealed that some plots had been disturbed by fire, perhaps increasing soil N and P. Additional observations show that areas high in both N and P create islands of high cover of *B. tectorum*. While these islands only make up a small portion of the sample sites (n = 40) they indicate possible hot spots and source populations for future invasions. These sites are primarily areas disturbed by fire or more mesic sites in washes and aspen stands. *Bromus tectorum* was also high in mesic sites, which are also higher in native species richness and therefore may require additional attention from resource managers.

Since management agencies are often operating with limited

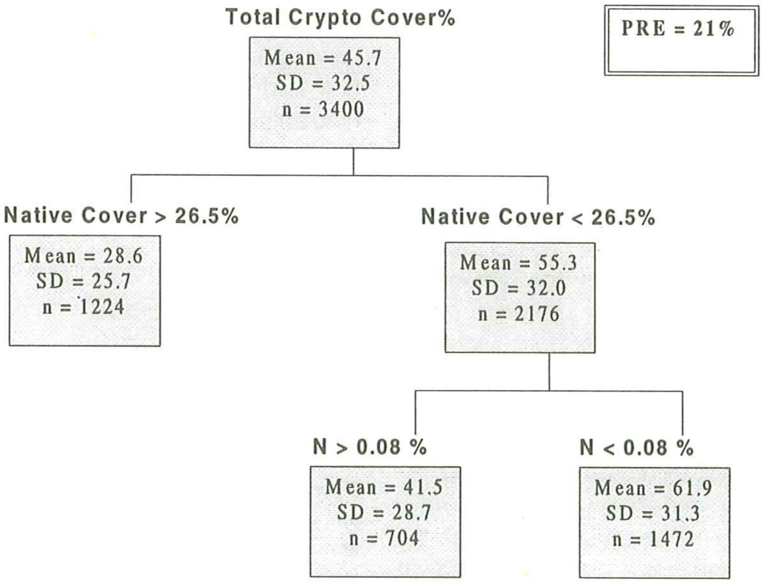

Figure 4. Regression tree - total cryptobiotic crust cover.

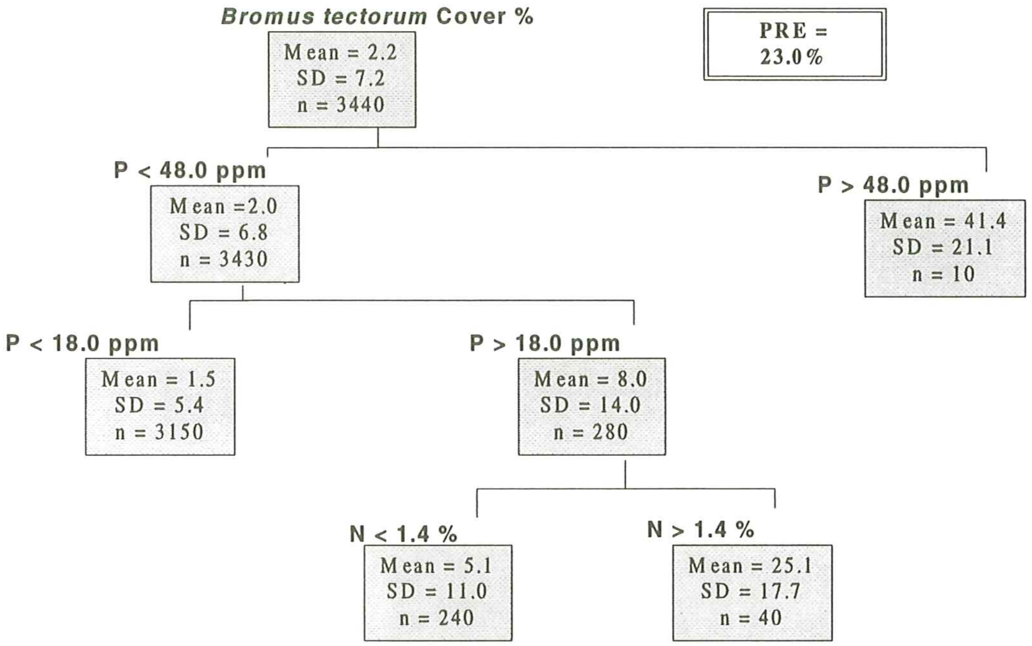

Figure 5. Regression tree – *Bromus tectorum* cover.

resources, iterative modeling can be an important tool in identifying hot spots for a variable of interest. By identifying the independent variables that influence a particular cover type, managers can focus their efforts to curb invasion by non-native species or act to identify and preserve sensitive areas for endemic species, or rare native vegetation types.

This type of modeling can be improved. The predictive spatial maps using IDW do not take into account any independent variables. They are strictly based on the value of a particular cell and its distance to other cells with values > 0. There are a number of alternative methods of interpolation, for example, Kriging, and Cokriging, which could be used to compare the results of Inverse Distance Weighting models (Kalkhan et al. 2001). The methods presented in this paper are intended to provide a rapid assessment of the cover types of interest. More complex methods like unsupervised classification, which examines spectral bandwidth combinations as well as Kriging, improve accuracy, but these methods are computationally intensive, costly, and require extensive expertise in remote sensing and spatial statistics. The regression trees show that certain independent variables influence the distribution of a particular cover type, which is critical for validation of the predictive maps. Other recommendations include additional field sampling in the form of inexpensive cross validation points to record data on the variables of interest, in this case, native species cover, cryptobiotic crust cover, and *B. tectorum* cover. Monument officials are currently working to improve soil and geology type maps, which would be useful for further examination of soil nutrients and their relationship with the cover types. A more detailed soil type map would be useful in identifying soils that are currently under-represented by sample plots. Utilizing additional data should help to improve the amount of variance (PRE values) explained by the regression tree modeling.

In conclusion, we show that predictive modeling using inverse distance weighting can be combined with regression tree analyses to rapidly identify hot spots of a particular cover type. The modified-Whittaker plots only cover a tiny portion of the Monument as a whole (< 0.004%), but this data can be used to get a better understanding of patterns across a broad landscape. Implementation of a GIS database enables managers to incorporate a spatial element that can quickly improve our understanding of where hot spots of occurrence are specifically located without extensive graphs and tables. Under-sampled areas can be identified and additional coverages can be added as needed to determine, for example, how land uses such as grazing and recreation affect an area, or to set priorities for weed control treatments. By examining the multiple variables that influence respective cover types, managers can concentrate their conservation efforts, and develop quantifiable justification for particular treatments.

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