Trial by Fire: Restoration of Middle Rio Grande Upland Ecosystems

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Abstract—The majority of upland ecosystems (desert scrub, grassland, pinyon-juniper, ponderosa pine and higher elevation conifer forests) in the Middle Rio Grande Basin were historically dependent on periodic fire to maintain their composition, productivity, and distribution. The cultural practices of European man have altered the function, structure, and composition of virtually all Middle Rio Grande Basin ecosystems. Centuries of widespread livestock grazing has altered natural fire frequencies and intensities in upland habitat types. Fire suppression has lead to an increase in woody plant abundance on many upland sites, from grassland to ponderosa pine forests. The negative consequences range from increased surface runoff and soil erosion in grasslands, shrublands and pinyon-juniper woodlands to increased potential for severe wildfire in ponderosa pine forests. The goal of restoration in these systems is to reintroduce fire. Unfortunately, due to varying levels of degradation, it may not be possible, or reasonable, to simply burn areas and expect them to recover their former attributes. Successful restoration requires some knowledge of the extent of degradation and the potential for recovery. I will discuss the process of identifying problems, determining land status, and defining realistic objectives. I will present three case studies as examples of ecosystems in different stages of degradation that required different restoration procedures for reintroduction of fire.

Ecological restoration is defined as the process of assisting the recovery and management of ecological integrity. Ecological integrity includes a critical range of variability in biodiversity, ecological processes and structures, regional and historical context, and sustainable cultural practices (The Society for Ecological Restoration). Restoration of Middle Rio Grande upland ecosystems generally involves reintroduction of fire. Restoration of some systems may begin with a prescribed fire, however, other systems have changed to the point that additional treatments are necessary before fire can be used. An understanding of ecosystem disturbance dynamics and their potential to create problems, as well as the health and status of the system in question, can help to determine appropriate procedures for ecosystem restoration or to prioritize multiple restoration projects given limitations of time and resources. Monitoring programs must be implemented to provide the data necessary to make objective evaluations of the consequences of disturbance and ecosystem status.

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Problem Identification

It is important to understand the difference between disturbances and problems. A disturbance can change any combination of the functional, structural, or compositional components of an ecosystem. The change may be temporary or permanent. The change is not necessarily detrimental to the health of the ecosystem. Certain disturbances, such as fire or flooding, are critical to the long-term maintenance of grassland and riparian ecosystems, respectively.

The changes brought about by disturbance may result in a problem or they may not. From a purely ecological standpoint, this is dependent upon the response (the resistance and resilience) of the ecosystem in question and the magnitude and intensity of the disturbance. But in large part the perception of a problem is dependent upon the values and judgment of the person or persons managing the land. Although the perception of a problem will always be somewhat subjective, it should be possible to identify ecosystem indicators that can be objectively quantified and monitored. Problems could be more objectively defined as one or more indicator values occurring outside of some range of acceptable variation. Possible ecological indicators might include components of ecosystem function (surface runoff, soil erosion, fire/flood occurrence and frequency) and ecosystem composition and structure (invasive native and exotic plants, threatened and endangered species). Social and economic indicators could also be developed and incorporated into the analysis.

Ecosystem Status

Ecosystem status can be conceptualized using a state and transition model (fig. 1) such as the Rangeland Health Model proposed by the National Research Council Committee on Rangeland Classification (Busby and others 1995, CRC 1994). In this model, ecosystems are classified as healthy, at risk, and unhealthy. A healthy ecosystem can sustain the stability of soils, watersheds and ecological processes and the capacity to produce commodities and satisfy values. An ecosystem at-risk shows signs of degradation and has an increased vulnerability to further degradation but ecological processes can still be used to restore the system within a time frame meaningful to humans. An unhealthy ecosystem has been degraded to the point that improvement cannot occur without external inputs such as seeding, soil amendments, thinning, etc. The circles with letters represent a range of ecosystem states within these health classifications. The vertical axis represents biological potential or the capacity to produce commodities and satisfy values (CRC 1994). The vertical dashed lines represent thresholds between ecosystem states. Using

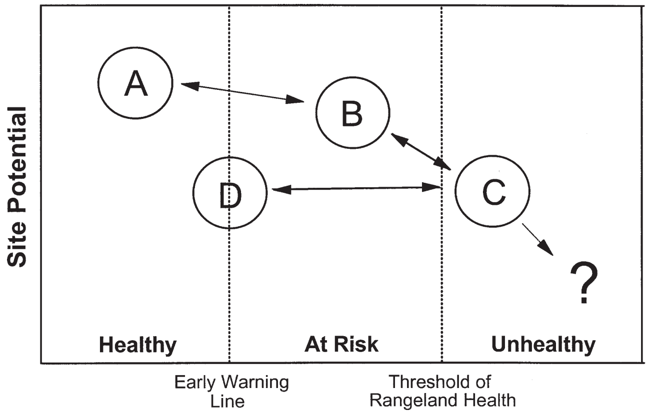

Figure 1—Rangeland health model adapted from a report by the National Research Council Committee on Rangeland Classification (1994) and Busby and others (1995).

a typical grassland degradation scenario, the state represented by circle A would be a healthy, productive grassland or grassland savanna ecosystem. Disturbances such as grazing and fire suppression can lead to problems like woody plant encroachment and a reduction in herbaceous plant abundance which may indicate that the first threshold (early warning line) has been crossed and the original grassland is at risk (circle B). Removal of grazing pressure and reintroduction of fire could halt the degradation process and initiate restoration. Continued disturbance could lead to further reductions in herbaceous ground cover with significant increases in surface runoff and soil erosion which would indicate that the second threshold (threshold of rangeland health) has been crossed. At this point (circle C) a positive feedback cycle of increasing degradation has been initiated and the system is no longer under biological control. Consequently, ecological processes alone cannot be used to restore the system within a time frame meaningful to humans. If no action is taken the system will continue to degrade (?) and/or eventually stabilize as a new vegetation assemblage at a much reduced biological potential (circle D).

Realistic Objectives

The ability to distinguish between disturbances and the problems they create, and determine ecosystem status will provide insight into what types of restoration procedures will be most effective and where limited resources will best be used. Burning an unhealthy degraded woodland is not likely to restore a grassland. Either additional measures must be taken or resources should be used on at-risk sites that have a greater potential for recovery. Conversely, fertilizing and reseeding an at-risk site may be unnecessary if equally beneficial results can be obtained at a much lower cost by burning.

Role of Monitoring

Monitoring is critical to the success of this process. Data from indicators are necessary to quantify the effects of disturbance, objectively identify problems, and determine ecosystem status. All too often, this research included, few to no data are available to make these pretreatment evaluations and we must rely on a subjective evaluation of the site. Once a course of action has been determined, data are critical to objectively evaluate treatment effects and progress toward management objectives.

There are two basic types of monitoring programs. The first, a general or baseline monitoring program, can be used to identify changes in ecosystem indicators but cannot be used to determine the cause of these changes. In order to attempt to determine cause and effect a specialized or research monitoring design must be used which involves monitoring on treated sites as well as untreated control sites.

There are pros and cons to both forms of monitoring. Although cause and effect cannot be determined with a baseline monitoring program, it is a much more cost effective method for monitoring at broad scales. In this age of adaptive management, we should be using an adaptive monitoring approach with baseline monitoring applied at broad scales to detect changes in ecosystem indicators. If a change in an indicator is determined to be a problem, or a potential problem, a specialized monitoring design could be implemented at a finer scale to determine the cause of the problem and help determine the appropriate management response.

Case Studies

The following case studies of restoration of former grassland ecosystems in various stages of degradation are used as examples of the process described above. In each case the treatments and objectives change depending upon the problems and ecosystem status.

The Albuquerque Open Space (AOS) site is a healthy bunchgrass grassland located west of Albuquerque near the Double Eagle Airport. The site is dominated by Indian ricegrass, *Oryzopsis hymenoides* (Roem. & Schult.) Ricker, and needle and thread grass, *Stipa comata* Trin. & Rupr. The potential problem with this site is not that it is being disturbed but that there is a lack of disturbance. The site has not been grazed or burned for over 20 years and there is a large standing dead component in the aboveground biomass pool. The standing dead biomass contains nutrients that are unavailable for plant growth and reproduction and that would normally be recycled through the soil by grazing or fire. Our objectives for this site were to use fire as a nutrient cycling process to stimulate new growth and reproduction.

The Bernalillo Watershed (BW) site is located south of Placitas, NM and is dominated by a mixture of blue grama, *Bouteloua gracilis* (H.B.K.) Lag. ex Steud., and galleta, *Hilaria jamesii* (Torr.) Benth., grasses and broom snakeweed, *Guttierezia sarothrae* (Pursh) Britt. & Rusby, an invasive native shrub. This site was an overgrazed juniper woodland prior to the 1950s when the juniper was removed with heavy equipment and the soils were contoured to hold the runoff. Although there has been no significant livestock grazing on this site for 50 years, the native grasses have not recovered, the shrub component is high, and there is evidence of runoff and soil erosion. This site was classified as at risk because of its degraded state and we believe that it is still possible to restore a grassland using ecological processes with limited outside input. Our objectives for this site are to use prescribed fire to increase the herbaceous plant abundance and subsequently stabilize the soils. We plan to use sequential applications of prescribed fire separated by recovery periods. Our hypothesis is that with each fire the shrub component will decline and the herbaceous vegetation will increase. After three to four restoration fires the herbaceous vegetation should have recovered enough to stabilize the soils and fire can then be used once every 10 years or so for ecosystem maintenance.

The Guaje site is located north of Los Alamos, NM, on the Santa Fe National Forest, Espanola Ranger District. This site is a pinyon, *Pinus edulis* Engelm., - oneseed juniper, *Juniperus monosperma* (Engelm.) Sarg., woodland with a degraded blue grama understory. As with the BW site, the primary disturbance (in this case livestock grazing) has been removed for many years but the grassland community has not recovered on its own. The site was classified as unhealthy because there has been significant runoff and soil erosion with headcutting and arroyo formation evident throughout the study site. Significant outside inputs will be necessary to restore the herbaceous understory and stabilize the soils. We have thinned the trees in an attempt to directly reduce competition for water between the trees and herbaceous vegetation. We used the slash as a surface mulch to indirectly increase water availability to the herbaceous vegetation by reducing evaporative soil water loss and by increasing surface roughness, thereby reducing runoff and increasing infiltration. We plan to reintroduce fire once the herbaceous plant community has recovered to a point that there are sufficient fuels to support a surface fire.

Methods

Vegetation on all study sites was sampled using the Community Structure Analysis (CSA) technique of Pase (1981). The AOS and BW sites both have four, 1 hectare control (unburned) and four, 1 hectare burned plots. Within each plot are three 60 meter CSA transects. The Guaje site has no treatment replication. The thinned and control areas are approximately 20 hectares each and each contains five 100 meter CSA transects.

The AOS site has been burned once in February 1996. Because of adequate fuel quantity and distribution, this site burned well and most of the vegetation was consumed. The BW site was first burned in November 1995 and then again in January 1998. Because of the patchy distribution of the fuels and vegetation and less than optimum conditions, neither fire spread well and both fires left behind substantial patches of unburned vegetation. Fire success might have been greater if we had burned in the late spring, however, due to management concerns and the availability of fire crews, we decided to burn in the fall or winter. The Guaje site was thinned in April 1995. All pinyon less than 20 cm (8 inches) diameter and all juniper were cut by chain saw and the slash was redistributed by hand. Some jackpot burning of large slash accumulations was conducted in the fall of 1996 to reduce the fire hazard. Otherwise no burning has been conducted on the site.

The effect of prescribed fire or thinning treatments was tested by comparing post-treatment conditions on the treated plots to any change on the control plots for comparable time periods. A repeated measures analysis was utilized with treated vs. control included as a treatment factor, post-treatment years as repeated measures, and the pre-treatment sampling period as a covariate. In some instances, the effect of the treatment was not the same for both post-treatment years (i.e., significant interaction between treatment and time). In these instances, significance of the treatment for individual years was assessed by applying a t-test to the change from pre-treatment conditions for each treatment for a particular year. Type I error for these sets of t-tests was maintained by applying a Bonferroni adjustment to significance levels of individual tests (Miller 1981). All analyses were conducted using SPSS 4.0 (SPSS Inc. 1990).

Results

There was a significant decrease in total herbaceous plant cover on the AOS site immediately after the November 1995 fire and all subsequent sampling periods showed no significant treatment effect (fig. 2A). There was no significant treatment effect on total herbaceous cover on the BW site until after the second fire in January 1998 (fig. 2B). All post-treatment sampling periods showed a significant herbaceous plant cover response to tree thinning on the Guaje site (fig. 2C).

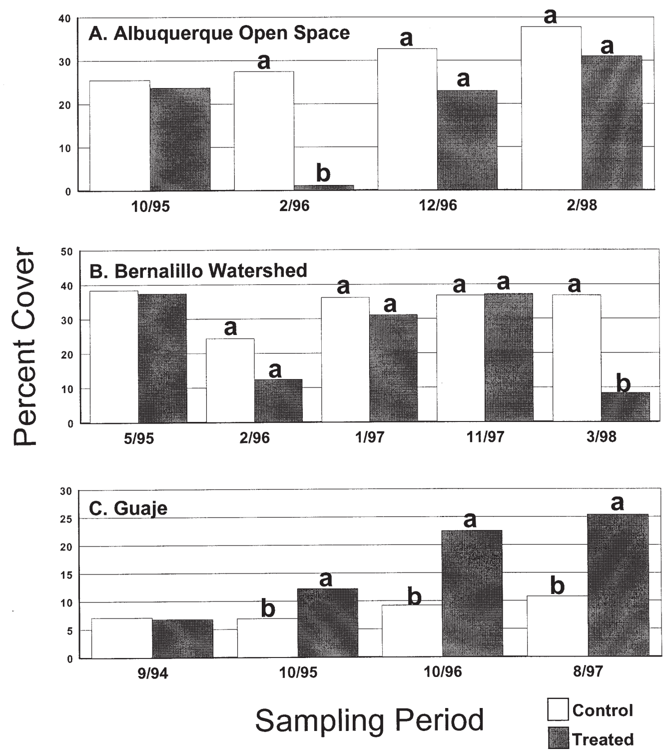

Figure 2—Total herbaceous cover on study sites. Bars with the same letter, within a site and sampling period, are not significantly different (P>0.05). Pretreatment means are displayed for comparison but were used as covariates in the repeated measures analysis and are not included in the multiple t-test evaluation of means.

Discussion

The Rangeland Health Model would predict that natural processes could be used to maintain the functional, compositional, and structural properties of a healthy site, that at-risk sites can be restored using natural processes, and that restoration of unhealthy sites requires outside inputs. Herbaceous plant cover on the healthy AOS site showed a significant response to the first reintroduction of fire. The quantity and homogeneous distribution of herbaceous biomass on the site was sufficient to carry the fire and lead to the desired reduction of herbaceous cover. One growing season following the fire, herbaceous plant cover was not significantly different on the two treatments, indicating a rapid recovery on the burned plots. On this site, fire is easily reintroduced and could be used to increase landscape-scale habitat diversity by creating a mosaic of different successional patches.

The at-risk BW site has not responded as rapidly to prescribed fire treatments. The first fire resulted in a non-significant decline in herbaceous plant cover on the burned plots probably because of the patchy nature of the vegetation/fuels matrix. A substantial portion of the decline in herbaceous plant cover on this site was due to a drought in the winter of 1995/96. Compounding drought stress with fire could have had disastrous results, however, herbaceous cover on both treatments recovered within one growing season which would indicate that this system is very resilient to both drought stress and fire. The second fire, despite the less than optimal burn conditions, resulted in a significant reduction in herbaceous plant cover. We plan to use this 2-3 year cycle of fire and recovery as a test of the restoration potential of the site. However, because this site is not functioning as a healthy grassland, it will take some time for natural processes to affect restoration, if at all.

A good test of the Rangeland Health Model would have been a prescribed burn in untreated pinyon-juniper. Unfortunately, these projects were not originally designed as a test of the Rangeland Health Model, consequently we did not consider using fire as a restoration technique in the unhealthy pinyon-juniper site. Subsequent interpretation of the model indicates that we would have been wasting our time and resources. Although the thinning treatment is more expensive and time consuming the results have been very encouraging. We believe that the herbaceous plant community has recovered to the point where we can now reintroduce fire. The timing for reintroduction of fire can be critical in this system. A window of opportunity exists between burning too soon and burning too late. Burning too soon can result in hot fires that kill herbaceous plants because the slash has not had time to decompose. Burning too late can result in fires that are not hot enough to kill the cohort of seedling and resprouting trees that are released following the thinning treatment. We believe that the appropriate time to burn this site is in the next 1-3 years. Of course this window will be different for different sites and/or environmental conditions.

Conclusions

Middle Rio Grande upland ecosystems evolved with fire. Restoration and maintenance of their function, composition, and structure will require the use of fire. The potential for successful reintroduction of fire back into upland ecosystems depends upon the status of the system and the disturbances acting on it. The process of objectively identifying and distinguishing between disturbances and problems and determining ecosystem status can lead to insights on appropriate management actions. These objective determinations are best made through the use of data derived from monitoring appropriate abiotic, ecological, and social indicators. Appropriate monitoring procedures and programs would provide data for these pretreatment determinations as well as for evaluation of management treatments and progress toward goals.

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