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Rangeland Monitoring and Fire: Wildfires and Prescribed Burning, Nutrient Cycling, and Plant Succession

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Prescribed fires are used to manipulate and manage rangelands, but effective monitoring techniques are needed to ensure that management goals and objectives are being met. The application of an effective fire program on rangelands is not a simple task. Overgrazing by livestock since the early development of the livestock industry has altered the vegetative complex on most rangelands with an increase in woody plants. Because of its relatively low cost, prescribed fire, both cool and warm season, are sustainable practices if proper grazing management is part of the management scheme. Grazing management and prescribed fire have often been treated as separate issues by rangeland managers; however, development and application of an effective prescribed burning program requires an understanding of the relationship between fire and grazing. Ranchers need fuel (grass) to burn and they also need income from livestock, which requires forage (grass, a major part of forage). In the short-term, fire reduces carrying capacity for livestock but, in the long-term, fire increases grass production, resulting in increased carrying capacity. Therefore, some monitoring technique is needed that will allow the manager to budget grass for both fuel and forage. The Grazing Manager (TGM) *is a software program that projects both forage production (expressed as animal unit days) and, animal demand (expressed as animal unit days) for each forage year. TGM has been successfully used on the Texas A&M University Research Station at Sonora as a tool to integrate prescribed fire and grazing management.*

Keywords vegetation management, disturbance, prescribed fire, grazing management, inventory, forage production, animal demand

Western rangelands provide food, fiber, water, wildlife, and other economic and social benefits to mankind. Sustainable production of these products requires cost-effective methods of managing and monitoring the rangeland resource. Since European settlement, rangeland vegetation has been altered, and in some instances, this has had a negative effect on rangeland products as well as the sustainability of the range resource. For example, overgrazing by livestock since the early development of the livestock industry has been a major factor in causing this change (Archer, 1989, 1994). Yearlong, overgrazing reduces the grass component (fine fuel load) and can eventually fireproof the landscape. With a significant reduction in fire frequency and

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intensity, noxious brush species start to dominate the rangeland. For example, ashe juniper (*Juniperus ashei* J.Buchholz) and redberry juniper (*J. pinchotii* Sudw.) infestation of Texas rangelands is an important dilemma because of its impact on forage and livestock production, water yield and quality, wildlife habitats, and rapidly increasing costs of conventional control methods (Thurow & Hester, 1997; Ueckert, 1997).

Other important factors that interact with overgrazing include drought, soil modification, and nutrient cycling. Drought is difficult to define, especially in arid and semiarid regions of the world. Basically, drought refers to a decrease in precipitation, which results in decreased production. Long-term precipitation patterns are naturally erratic on most western rangelands. Therefore, range managers must consider climatic variability and develop a flexible management strategy to cope with normal fluctuations resulting in below average precipitation.

Soil modification can occur when critical amounts of vegetative cover have been removed from the landscape. This condition can actually increase the frequency and intensity of drought. For example, water runoff is the portion of precipitation that leaves the site via overland flow. Runoff is mostly determined by the rate at which water can enter the soil (infiltration rate). Infiltration rate is primarily determined by the size and amount of pores in the soil. Organic matter is vital to formation of stable soil aggregates, which provides for optimal pore space. Organic matter is reduced with overgrazing and/or drought, which can reduce water-holding capacity of the soil.

A reduction in soil organic matter also affects nutrient cycling. Over the long term, excessive levels of grazing and/or drought can potentially reduce nitrogen fixation; increase ammonia volatilization, leaching, and erosional losses; and cause a net loss of nutrients (Archer & Smeins, 1991).

On arid or semiarid rangelands, grazed forage is the primary source of nutrients for livestock enterprises and, for these regions, estimating forage production is difficult due to the variability in precipitation. This problem creates one of the most difficult and important management decisions (i.e., adjusting livestock numbers to match forage demand with a fluctuating forage supply). Also, livestock demand on forage (degree of use) prior to and during drought determines the severity of drought's effect on both livestock and forage production.

As economics of ranching becomes tighter, one of the hardest decisions to make is how to manage the forage resource so the higher successional, more productive grasses, forbs, and browse can be maintained in the vegetative complex. Another important consideration is budgeting the forage resource for either livestock consumption, or fuel for prescribed fire while maintaining adequate soil cover to ensure a healthy soil.

Rangeland Monitoring

The purpose of most monitoring programs is to improve land stewardship by providing a tool to measure the effects of current management objectively. This means that monitoring must provide information that is useful in making management decisions. Management goals and objectives often depend upon the individual owner or manager (i.e., individual management practices that benefit one objective can be detrimental to another). However, regardless of the type of goals and objectives sought by management, some type of monitoring program has to be implemented to measure success or failure.

There are numerous techniques available to monitor rangeland. A review of these techniques is beyond the scope of this discussion; however, Smith (1984) and NRC (1994) provide reviews on this subject. Later, I'll be presenting a specific monitoring technique that provides land managers with timely information that can be used to maintain a proper balance between forage production and animal demand.

Adoption of a grazing strategy that provides a cushion of "reserve forage" allows ranchers some flexibility in the speed and extent to which they must respond to drought as well as provides for the periodic use of prescribed fire to manage noxious brush encroachment (Taylor & Kothmann, 1993). It is the responsibility of the individual rancher or land manager to be aware of how much forage is available and to anticipate current and future animal (livestock and wildlife) demand. Monitoring the extent of use on key vegetation species is a useful indication of grazing pressure. By careful monitoring and control of grazing, the rancher can quickly identify and respond to the beginning of a forage deficit. A user-friendly computer decision aid (*The Grazing Manager*) has been developed to help ranchers estimate seasonal adjustments of livestock stocking rates and test "what if" scenarios regarding forage production (Kothmann & Hinnant, 1994).

Fire

It is well documented that prior to European settlement both prescribed and wild fires were disturbances that played key roles in shaping the different plant communities across the United States (Baker, 1992; Foster, 1917). Historically, fires occurred during all months of the year (Higgins, 1986; Komarek 1968), but summer fires were probably more frequent due to dry conditions combined with increased lightning frequency during the summer (Komarek, 1968; Taylor, 2001).

Fire is a natural disturbance and the fire regime (i.e., frequency, intensity, and size of burns) often is an integral part of ecosystem function (Leitner et al., 1991). As the livestock industry developed across the continent, fire suppression was a major activity of the early European settlers (Scifres & Hamilton, 1993). For example, in 1848, a state law was passed in Texas that made it illegal to fire the prairies between July 1 and February 15. In 1884, another Texas law was passed that made setting fire to any grass a felony. It wasn't until 1999 that a law was passed in Texas that unambiguously stated that a landowner had the right to conduct a prescribed burn on his or her own property.

The increased frequency and intensity of grazing also reduced the grass cover (i.e., fuel load), which helped fireproof a big part of the western rangelands. With the suppression of fire, woody species were able to invade rangelands (Baker, 1992; McPherson, 1997). Intense grazing pressure, which produced gaps in the herbaceous cover, concomitant with increased seed dispersal by herbivores also may have contributed to increased establishment of woody plants (Brown & Archer, 1989).

Ecological theory provides a basis for examining hypotheses about the role of fire in rangeland ecosystems. The intermediate disturbance hypothesis suggests that intermediate disturbance frequencies control competitive dominant species allowing inferior competitors to be maintained in the landscape (Connell, 1978). Only colonizing species are able to establish when disturbance is very frequent, whereas, when disturbance is very rare, succession leads to colonizing species being supplanted by competitive dominant species. If historic rangelands were subjected to periodic wildfires then the historically dominant species should be well adapted to this disturbance regime but not competitively dominant in the absence of the disturbance.

Susceptibility to fire and competitive ability are mainly governed by growth form/life form characteristics (Scifers, 1980). Perennial grasses were historically dominant on many arid and semiarid rangelands (Cory, 1949). The buds of perennial grasses are located at or below the ground making them resistant to fire. Invading woody species are potentially more susceptible to fire because their buds are elevated. However, many shrub and tree species can resprout from the roots or under ground crowns if fires are not intense enough to kill these tissues. Woody plants, once established, are better competitors than grasses because their root systems generally are deeper allowing access to ground water supplies during times of drought. Therefore, the historically dominant grasses generally are better adapted to the disturbance regime than are the invading woody species; however, grasses are less able to compete for required resources once woody plants have become established.

Woody plants also affect nutrient cycling. In general, levels of organic carbon and total nitrogen are greater in soils beneath woody plants than in the grass dominated interspaces (McPherson, 1997). Carbon and nitrogen accumulation under woody canopy cover probably results from increased litter and root biomass.

The reintroduction of fire as a management tool should reestablish the disturbance regime of presettlement times, allowing an optimal balance between the herbaceous and woody plant species. Moreover, diversity should be highest for areas where a fire regime has been reestablished because both inferior and competitive dominant species could be maintained in the landscape (Fuhlendorf & Engle, 2001; Copeland et al., 2002). With the advent of hierarchical analysis of ecosystems and landscapes it is becoming possible to consider the long-term implications of prescribed burning and other management regimes on structure and functioning of rangeland ecosystems (Baker, 1992).

As we enter the twenty-first century, prescribed fire faces an uncertain future. Historic use of prescribed fire by ranchers has never been widespread; however, with the rapid increase in population and increased "urbanization" of rangeland and air quality concerns, the implementation of fire will be even more difficult in the future. However, these problems should not lessen our enthusiasm for prescribed fire. In fact, now is the time to become bold and innovative in the use of prescribed fire, but also be prudent.

Because of its relatively low cost, prescribed fire, both cool and warm season fire (multiseasonal), is viewed as an extremely viable tool (Engle & Bidwell, 2001; Ansley & Taylor, 2000). However, a combination of prescribed fire, coupled with proper grazing management (i.e., proper budgeting of grass to either forage or fuel) should offer the best-case scenario for managing noxious woody plants.

Grazing Management and Prescribed Fire

Grazing management and prescribed fire have often been treated as separate issues by rangeland managers. However, development and application of an effective prescribed burning program requires an understanding of the relationship between fire and grazing. For example, vegetation serves a dual role as forage for grazing animals and as fuel for prescribed burns. The manager must balance the amount of forage that is used by grazing animals and the amount that is used for fuel. The range manager should manage the stocking rate and grazing schedule to allocate enough forage to livestock to provide ranch income and also allocate enough to fuel for effective burning. Land managers can use *The Grazing Manager* (Kothmann & Hinnant, 1994) to determine the most effective stocking rate and grazing schedule to reduce the cost of burning and increase the probability that burning can be implemented as required to manage the range resource.

Where do You Start?

Planning and implementing a successful prescribed burning program to meet long-term goals and objectives requires basic knowledge in the areas of forage and animal production, grazing management, plant ecology, and prescribed fire. Before beginning a burning program, a manager should obtain training in these concepts and techniques. Also, it would be wise to initiate an inventory and monitoring system to measure current conditions and determine if goals and objectives are being met.

Inventory

The first step in planning a prescribed burning program is for the manager to inventory the current condition of both herbaceous and woody vegetation. The current status of the vegetation and the stocking rate will determine the potential for using prescribed fire and what may need to be changed prior to burning, as well as the cost of implementing an initial burn. Also, the current status of the vegetation will determine the kind of plan that should be developed. To make this decision a decision aid would be helpful. Listed in Table 1 is an example of a decision aid that helps determine the status of a problem. This decision aid was developed for Texas rangelands that have the potential to be dominated by juniper. With this aid, pastures can be placed into four different categories and then an evaluation can be determined, based on goals and objectives of the manager.

For example, a target pasture that has been heavily stocked, is in poor range condition, and has dense mature juniper would fit into category 4. Under these conditions there is almost no potential for initiating a cool-season, prescribed burning program until the mature juniper have been mechanically controlled (i.e., chaining, grubbing, roller chopped, etc.) and grazing management is improved. Cost of implementing a burning program under these conditions would be high for winter burning and moderate for summer burning.

Initially the potential for prescribed burning is low for category 3; however, improved grazing management may provide adequate fuel before juniper becomes dense enough to seriously reduce forage production. Initiating a management program before the juniper reaches maturity and begins producing seeds is important. Years of heavy stocking reduces range condition, soil condition, and plant vigor. The pasture may not produce enough fuel to support an effective fire even if it is rested for a year prior to burning. In these cases, stocking rates should be reduced and pastures provided deferment to increase plant vigor and seed production of desirable species prior to burning. Burning prior to correcting grazing management problems will not yield good results. Pastures will need to be monitored to determine when vegetation fuel loads are sufficient for carrying an effective fire. It's obvious that different management plans will have to be initiated for each category. An initial inventory will be required, and then the rangeland will have to be monitored until sufficient kinds and amounts of fine fuel are grown to provide for effective burning.

TABLE 1 A Decision Aid to Help Determine the Status of a Juniper Problem for Texas Rangelands

Categories	1	2	3	4
Stocking rate	Light	Moderate	Heavy	Extreme
Range condition	Good/ Excellent	Good/Fair	Fair/Poor	Poor
Juniper age	Immature	Immature/ Mature 75:25	Immature/ Mature 50:50	Immature/ Mature 25:75
Juniper density	Low	Moderate	Heavy	Extreme
1-hour fine fuel load	Adequate	Marginal	Low	Inadequate
Success of winter burn	High	Moderate	Low (May require mechanical treatment preburn)	Very low (requires mechanical treatment preburn)
Cost of winter burn	Low	Moderate	High	High
Success of summer burn	High	High	Moderate	Low
Cost of summer burn	Low	Low	Moderate	Moderate

Pastures that fit into category 2 have a higher range condition than those in categories 3 and 4; however, 25% of the juniper is mature. For winter burning, a prefire mechanical treatment might be required to kill the mature juniper, which will increase the cost significantly. A reclamation type burn could be initiated with a hot summer fire; however, risks would be greater and this would require a longer post-burn deferment to allow for vegetation recovery. Marginal fuel loads would make it difficult for either summer or winter burns.

Category 1 is the best-case scenario because good to excellent range condition is providing the best kinds of fine fuel (i.e., midgrasses) for hot fires. Also, juniper density is light with immature plants. Winter or summer fires would be very effective and pre- and postburn deferment periods would probably be shorter than other categories.

How do You Graze and Burn?

A rancher acquaintance commented a while back that one can burn too much. He emphasized how difficult it was to make a living from ranching, especially with today's operating costs, and that burning too much would jeopardize income to the ranch enterprise. It was a very honest comment and irrefutably, the ranching industry has fallen on hard times. It's also apparent that burning grass costs money and, in the short-term, may reduce ranch income.

Prescribed fire is a double-edged sword. Ranchers need fuel (grass) to burn and they also need income from livestock, which requires forage (grass, a major part of forage). In the short-term, fire reduces carrying capacity for livestock, but in the long-term, fire increases grass production resulting in increased carrying capacity. Therefore, the answer to the rancher's comment is, "budget your grass for both fuel and forage."

How do You Budget Grass for Fuel and Forage and How Much Will it Cost?

Approximately 10 years ago it was decided to develop an intensive burning plan for the Texas A&M University Research Station at Sonora. The objectives are to compare the effectiveness of warm-season burning and cool-season burning and also the costs associated with not burning (controls). The burning project began with the goal of burning 25% of each grazing system each year, except for the controls. Treatments that represented warm season burning, cool season burning, and control (no burning) were assigned to 36 pastures. All pastures were assigned to *grazing management units* (GMUs). Each GMU is represented by four equal size pastures, which represent one 4-pasture grazing system. Each GMU (grazing system) is assigned its own set of sheep and goats. Initially cattle were removed from grazing to reduce harvest of the fuel load. Once a more favorable balance is achieved through burning and browsing, cattle will be gradually integrated back into the grazing animal mixture. Each treatment is replicated with three GMUs.

In terms of livestock production, the experimental unit is each GMU, which has three replicates (three complete 4-pasture grazing systems per treatment). Management of the grazing systems follow the recommendations of Taylor et al. (1993). Livestock production, including kg of deer harvested, is measured for each year.

Because of the variation within and between pastures due to past grazing and brush control treatments, and differences in soils and topography, three years of base line data were collected. *The Grazing Manager* was used to determine *average* carrying capacity for each pasture and GMU (Figure 1). Also TGM was used to determine seasonality of forage production and monthly forage use ratings for each pasture and GMU, and to provide information for timely stock adjustments in response to forage supply (Kothmann & Hinnant, 1994). Vegetation data is being measured from aerial infrared photographs, permanent line transects for woody plant composition, and quadrats measured along permanent transect lines for her-

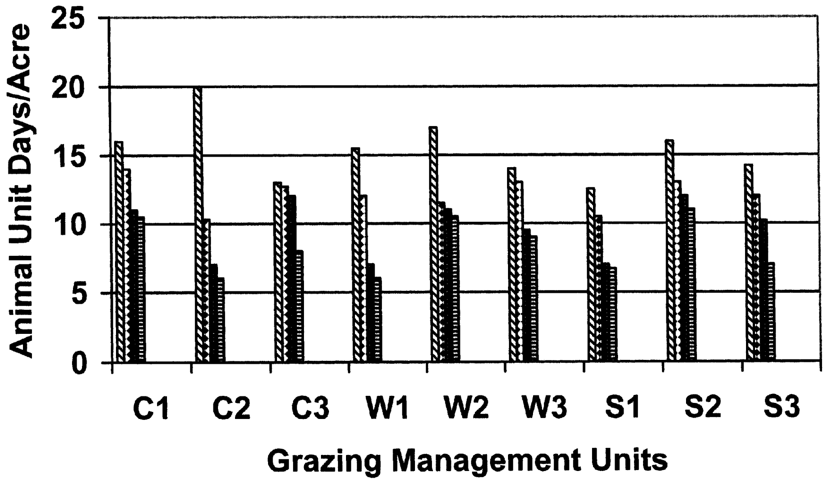

FIGURE 1 Average carrying capacity of pastures on the Texas A&M University Research Station prior to burning treatments. Determined from three years' data by using *The Grazing Manager* software. C = control pastures (no burn), W = winter burn pastures, and S = summer burn pastures. Four pastures represent one grazing management unit.

baceous composition. Individual pastures will be used as experimental units for vegetation analysis.

By using the decision aid (Table 1) pastures can be placed into four different categories and then an evaluation is determined, based on goals and objectives, which pasture to burn first in each GMU. From a personal perspective, pastures that have the greatest and quickest potential to respond to a fire and are cheaply implemented should receive first priority. For example, if 4 pastures are evaluated and two fall into category 1, one in category 2, and one in category 4, I would plan on burning the pastures in categories 1 first. This is not to say that the other pastures would be ignored; in fact, proper grazing management would be required for the other pastures to improve in range condition, which would be part of the process of getting it in condition to eventually burn.

Furthermore, I cannot over-state the value of *The Grazing Manager* (TGM) software as a tool in determining proper stocking rates and also as a monitoring device to determine the increase or decrease in carrying capacity. TGM projects forage production (expressed as animal unit days) and projects animal demand (also expressed as animal unit days), for each forage year (Figure 2). When animal demand is equal to forage production in the TGM program, use on the vegetation is moderate. When forage production values are greater than animal demand, it indicates a surplus of forage. For example, TGM is predicting that approximately 3,500 animal unit days (AUDs) are available for grazing through March for one GMU (Figure 2). Animal demand is approximately 1700 AUDs; therefore, TGM is predicting that we could have increased our stocking rate for the past forage year by 1800 AUDs and still be moderately stocked. However, we could also consider a change in stocking rate at the end of September rather than waiting until the end of the forage year. Approximately 75% of total forage is produced by the end of September for most years for the southwestern region of Texas. Based on this knowledge and the use of the information from TGM, livestock numbers could be increased as early as September. So, it's the manager's decision, does he increase stocking rate to harvest the additional forage or does he burn?

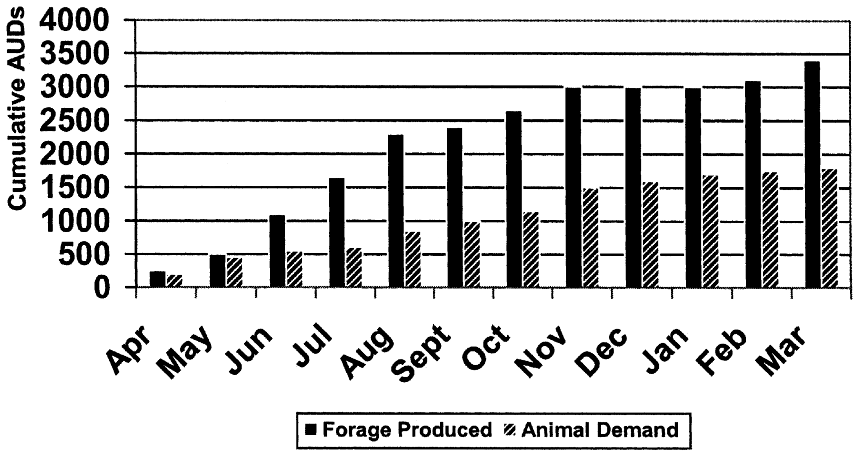

FIGURE 2 Cumulative forage produced and animal demand (expressed in animal unit days) for an actual forage year on the Texas A&M University Research Station at Sonora. Data represents an actual grazing management unit (GMU), which has four separate pastures.

Look at what happens to animal demand if we burn one of the four pastures (Figure 3). TGM is showing us that we can burn one pasture and still have forage for grazing without reducing stocking rate for the total GMU. This data is from an actual forage year on the Texas A&M University Research Station at Sonora. By monitoring forage growth and animal demand, adjustments can be made in animal numbers to balance forage supply with animal demand. TGM assumes a 25% harvest efficiency of the forage by domestic livestock. TGM is an effective tool to allow one to budget grass to either fuel or forage and quantify changes in range productivity.

Sustainable management of most rangelands requires repeated applications of prescribed fire as well proper grazing management. Prescribed fire has the potential to be an effective low cost control method, but it requires greater levels of expertise and management than other control methods. Long-term application of prescribed

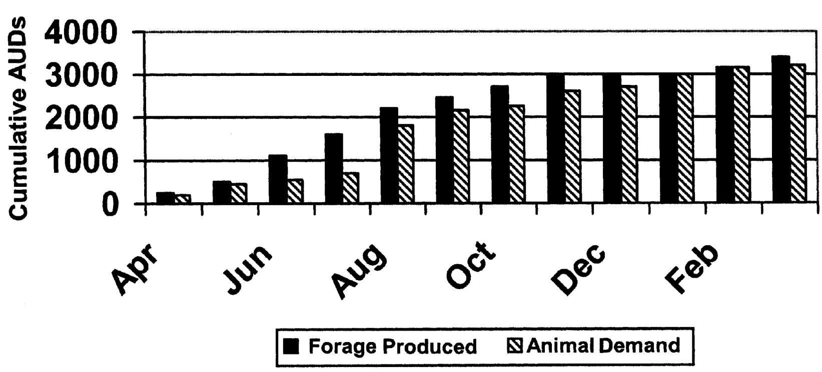

FIGURE 3 Cumulative forage produced and animal demand (expressed in animal unit days) for an actual forage year on the Texas A&M University Research Station at Sonora. Data represents an actual grazing management unit (GMU) in which one of the four pastures is burned.

fire also requires more attention to proper grazing management. Grazing management required for an effective prescribed burning program will also be effective for improving range condition; however, an active monitoring program will have to be initiated to quantify responses of forage growth so that adjustments in management can be done in a timely manner to meet rancher goals and objectives.

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