BURNING AND GRAZING COOL-SEASON PASTURES TO PROMOTE PERSISTENCE OF NATIVE, WARM-SEASON GRASSES

by

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ABSTRACT

:: We think it is time to acknowledge the reality of the ecological mosaic. If we do our work with that reality in mind we could be well on our way to solving the problem of agriculture. Now is the time to bring about the merger of agriculture and ecology **::**

– Wes Jackson

In Wisconsin about 850,000 ha of tallgrass prairie existed at the time of European settlement with only less than 1% remaining today. As interest in multifunctional landscapes grows, more emphasis is being placed on the many ecosystem services – provisioning, regulating, cultural, and supporting services – provided by farms. Grass-based farming is one land management approach that may combine both conservation practices and agricultural production. Reintroducing native, warm-season grasses into cool-season dominated pastures offers a compromise between complete restoration and complete eradication, and may have potential ecological, agronomic and social benefits such as improved forage production, restored native species, carbon sequestration, wildlife habitat, and weed exclusion.

The goal of our research was to successfully combine conservation tools (burning) with agricultural management tools (rotational grazing) in order to promote native plant communities and increase forage production (i.e. aboveground and belowground). **Chapter 1** describes the management used to reintroduce native grasses. The contents of **Chapter 2** will be used as a template to create and produce a research brief for outreach and extension that describe the tradeoffs in ecosystem services provided by incorporating native grasses into pasture systems. The target audience of this product is grass-based farmers and land managers interested in grass-based agroecosystems.

CHAPTER 1: BURNING AND GRAZING COOL-SEASON PASTURES TO PROMOTE NATIVE GRASS PERSISTENCE

ABSTRACT

We assisted with a farmer-initiated research project that combined burning and rotational grazing to blend native plant restoration and livestock production by promoting and maintaining native and non-native grass coexistence. The experiment took place on a farm in south central Wisconsin on a cool-season grass pasture that was drill seeded with native, warm-season grasses – big bluestem (*Andropogon gerardii* Vitman), indiangrass (*Sorghastrum nutans* (L.) Nash), and switchgrass (*Panicum virgatum* L.) We used a complete randomized block design to assess native grass persistence under varying disturbance treatments (burned, burned-grazed, and grazed). We used a paired t-test to determine if the difference between 2006 and 2007 native grass density was significantly different from zero. Native grass tiller density increased under the burn (201.72%) and graze (186.09%) treatments, but not the burn-graze (29.52%) treatment. However, the actual native grass tiller numbers in 2007 were much higher in the burn only than the graze only treatment (80 ± 10, 2 ± 1; respectively). We found no loss to native grass tiller density when rotational grazing was applied to plots in the first year after 2 years of grazing exclusion with burning. In addition, we found that native grass cover was greatest in the burn treatment, but not significantly different in the burn-graze and graze treatments. Our results suggest that the use of burning and grazing as a management tool for native grass persistence may be possible with deferred grazing during establishment phase, but alternative timing, intensity, and types of grazing animals should be tested.

INTRODUCTION

The effects of burning on the tallgrass prairie has been widely studied but very little is known about burning and grazing cool-season pasture to promote reintroduced tallgrass prairie species. Prior to European settlement, prairie ecosystems dominated much of the upper Midwest, providing a foundation for efforts to restore patches of the tallgrass prairie in the Midwest (Brye et al. 2002a, Brye et al. 2002b). In Wisconsin about 850,000 ha of prairie existed at the time of European settlement (Curtis 1959) with about 8000 ha (<1%) remaining. While restoration and conservation efforts grow (Hobbs and Norton 1996, Hobbs and Harris 2001, Baer et al. 2003, Camill et al. 2004, Martin and Wilsey 2006), it is infeasible to convert most pastures to fully restored native flora because of their profitability for livestock feed when dominated by introduced, cool-season forage grasses and legumes. Ecological restoration in many ways means "starting over", however, Williams et al. (2007) argue that it may be beneficial to keep the established vegetation and focus on enhancing species composition. We offer a compromise between complete restoration and complete eradication of native prairie by reintroducing native grasses within a cool-season forage matrix.

The coexistence of cool-season and warm-season grass species has been shown to improve the distribution of forage production in pasture systems, especially during the hot, summer months when cool-season grass production is low (Anderson 2000). Belesky and Fedders (1995) found that when management was controlled there was no difference in productivity between warm-season and cool-season grasses. Warm-season grasses possess the C4 photosynthetic pathway, affording them greater water use efficiency (Lambers et al. 1998, Anderson 2000) and therefore less water stress during dry periods. In addition, warm-season grasses may improve supporting, regulating, and cultural ecosystem services. Examples include carbon sequestration, nutrient retention, and wildlife habitat.

Fire management is considered a necessary tool in the establishment and restoration of the tallgrass prairie (Collins and Gibson 1990, Packard and Mutel 1997, Jackson 1999, Brye et al. 2002b, MacDonald et al. 2007). Fire influences both aboveground and belowground net primary productivity via reduced N mineralization and increased root production (Johnson and Matchett 2001) and can also promote plant community heterogeneity (Vermeire et al. 2004). While burning unequivocally favors warm-season grasses (MacDonald et al. 2007), cattle may be useful as a management tool in restoration because of their selective nature (Helzer and Steuter 2005).

The establishment of warm-season grasses into cool-season pastures is difficult, especially when combining grazing and burning (Jackson 1999). Past research has shown that burning alone promoted greater warm-season grass establishment and root production than rotational grazing (Woodis 2008). We addressed the following question: Will warm-season grasses that have recruited into cool-season pastures increase or decrease under burn, burn-graze, or graze treatments? We hypothesized that native grass density would be greater under the burn treatment then the graze treatment, with the burn-graze treatment as an intermediate between burn and graze treatments. Our goal was to successfully combine conservation tools (burning) with agricultural management tools (rotational grazing) in order to promote native plant communities and increase forage production (i.e. aboveground and belowground).

METHODS

This study occurred at the Cates Family Farm in Spring Green, Wisconsin during the 2007 growing season. Soils from the study site are classified as Fayette silt loam (fine-silty, mixed, superactive, mesic Typic Hapludalfs) and have a 12 to 20% slope (USDA-NRCS Web Soil Survey). The study site is of a temperate climate. According to UW Automated Weather Observation Network (AWON) average temperatures in Spring Green, WI during 2007 were -5 °C in January to 22 °C in July.

The farm produces ~50 head of cattle of the Jersey and Angus breeds. The cattle are grazed using a management-intensive rotational grazing system on pastures dominated by introduced, cool-season grasses such as meadow fescue (*Festuca pratensis* Huds.), smooth brome (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), and quackgrass (*Elytrigia repens* (L.) Gould). Dominate forbs are white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.), and common dandelion (*Taraxacum officinale* F.H. Wigg.). Native, warm-season grasses were drill seeded in fall 2003 and spring 2004 at a rate of ~1 g pure live seed m^{-2} and with a mix by weight of 70% big bluestem (*Andropogon gerardii* Vitman), 15% switchgrass (*Panicum virgatum* L.), and 15% indiangrass (*Sorghastrum nutans* (L.) Nash) (Woodis 2008).

Three disturbance treatments – burn, burn-graze, and graze – were applied during 2007 in a complete randomized block design using three 0.5 ha pastures as experimental blocks (Figure 1). Graze only and burn only treatments were randomly chosen within each block while burn-graze treatment was not. The burn treatment was the control in our experiment because we were interested in testing burning and grazing together to promote native grasses of the tallgrass prairie. During the establishment phase of native grasses, burning and grazing disturbances were applied (separately) from 2004 through 2006. In order to combine burning and grazing disturbances, we included grazing on one-half of the previously burned treatments. Burning occurred in April of 2005, 2006, and 2007 and removed 100% of the aboveground biomass. Management-intensive rotational grazing system uses short duration (< 12 h to 3 d) grazing with high stocking densities and 2 to 5 week rest periods (Paine et al. 1999) resulting in 5 to 10 cm residual stubble height. The experiment area has been under this type of grazing for more than 15 years and grazing treatments followed this system. At the request of the farmer, 2007 fall grazing was relaxed in order to accumulate biomass for a spring burn the following year.

Native grass tiller density was estimated in late August of 2006 and 2007. Using a 1-m^2 quadrat we counted native grass tillers every 5 meters along a 50-m transect (Packard and Mutel 1997). We then calculated the average of native grass tillers per plot to estimate native grass density. In addition to native grass density we estimated native grass cover. Species composition was assessed in August 2007 with the line-point method (Heady et al. 1959). Forty-five meter transects were placed in each plot and species were recorded every 10 meters using a 20 x 50-cm quadrat. Native grass cover was then calculated per experimental unit.

Soil temperature, soil moisture, and N availability were collected as ancillary data. Soil temperature was collected monthly on the burn plots and before and after grazing events (June through November 2007). A soil thermometer was inserted into the ground, left until a constant reading was obtained, and then recorded. Gravimetric water content and net N mineralization were measured in June, August, and October of 2007 by taking 12, 10-cm deep soil cores (1.91-cm diameter soil probe) per experimental unit. A portion of the soil samples were used to find gravimetric water content (g water/g dry soil) by recording the soil weight before and after drying at 65 °C for 48 hrs. Another portion of the soil samples were used to find net N mineralization based on 7-day aerobic lab incubation (Rhine et al. 1998).

We used a paired t-test to determine if the difference between 2006 and 2007 native grass tiller density was significantly different from zero. We then used one-way ANOVA to evaluate disturbance treatment effects on these differences in native grass tiller density between 2006 and 2007 and also on native grass cover for 2007. Significance was determined at the $\alpha = 0.05$ level for all tests. Bonferroni's multiple comparison tests were used to separate treatment means after ANOVA. Ancillary data were assessed graphically since we were using them to interpret native grass results rather than to make statistical inferences about these parameters.

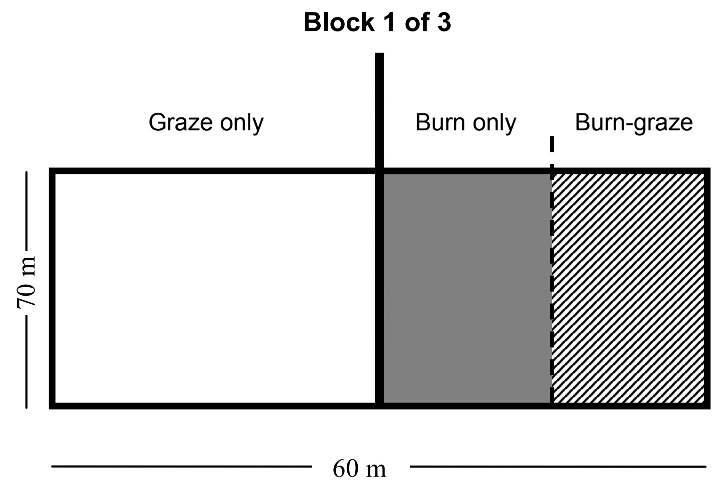

Figure 1. Experimental design showing block 1 of 3. White plots equal graze treatment, grey equals burn treatment and the dashed plots equal burn-graze treatment.

RESULTS

Native grass tiller density increased from 2006 to 2007 under the burn only ($P = 0.006$) and graze only ($P = 0.005$) treatments, but not the burn-graze treatment ($P = 0.18$). While 2 of 3 results were statistically significant, it is important to note the disparity in absolute native grass tiller density. Native grasses in burn plots increased from 19.8 ± 6.5 to 59.6 ± 7.3 while graze was only 1.0 ± 0.24 to 2.8 ± 0.11.

When comparing differences in native grass tiller density between 2006 and 2007, we found that the burn only treatment was significantly greater than the burn-graze and graze only treatments, while there was no significant difference between burn-graze and graze treatments (Figure 2, Table 1).

Native grass cover in the burn treatment was significantly higher than in the burn-graze and graze treatments (Figure 3, Table 2). There was no significant difference in native grass cover between burn-graze and graze treatments.

Visual assessment of ancillary data indicated little variability among treatments in soil temperature or gravimetric water content for 2007. However, net nitrogen mineralization appeared to be lower in the burn only plots than the graze only plots for June and October of 2007 (Figure 4).

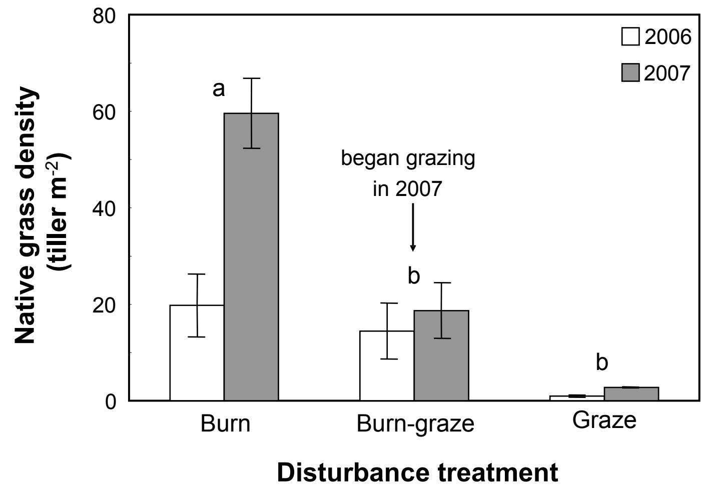

Figure 2. Mean (± standard error, n=6 for 2006 and n=3 for 2007) native grass tiller density for burn, burn-graze, and graze treatments during August 2006 and 2007. In 2007, grazing began on half of the 2006 burn plots to include a new treatment – burn-graze. Means with different lower case letters indicate that differences between 2006 and 2007 were significantly different among treatments as determined with Bonferroni multiple comparison test ($P < 0.05$).

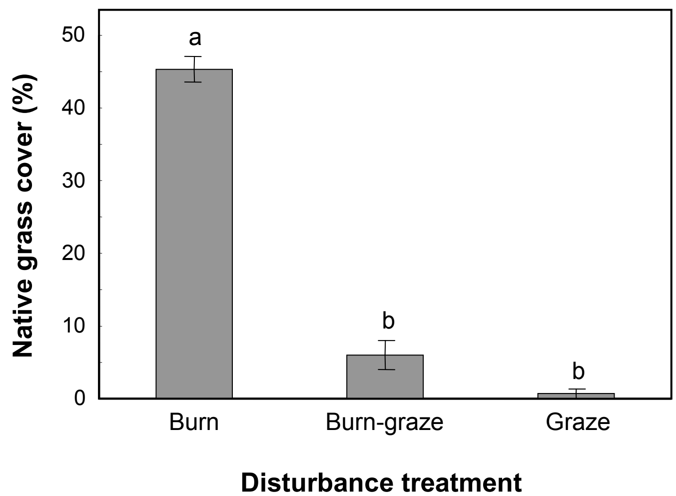

Figure 3. Mean (± standard error, n=3) percent cover of native grass species for burn, burn-graze, and graze treatments during August 2007. Means with different lower case letters were significantly different as determined with Bonferroni multiple comparison test ($P < 0.05$).

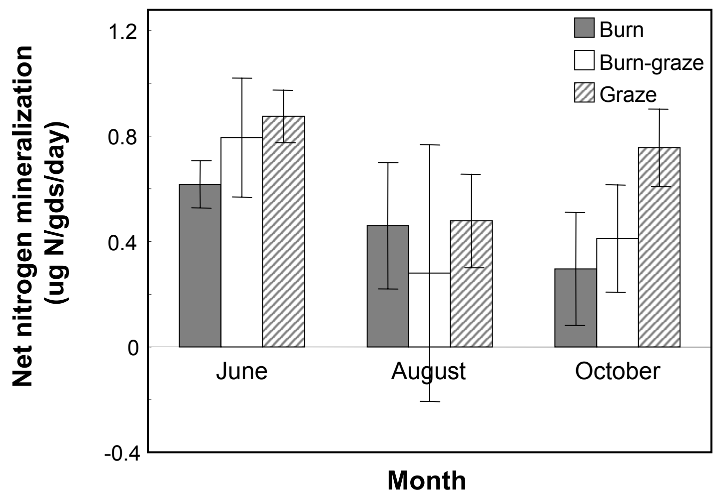

Figure 4. Mean (± standard error, n=3) net N mineralization for burn, burn-graze and graze treatments during June, August, and October 2007.

Table 1. ANOVA output for native grass density difference between 2006 and 2007

Source	df	F-value	P-value
Block	2	3.62	0.13
Disturbance	2	77.75	< 0.001 *
Residuals	4		

Table 2. ANOVA output for native grass cover

Source	df	F-value	P-value
Block	2	< 0.001	1.0
Disturbance	2	157.53	< 0.001 *
Residuals	4		

DISCUSSION

Many studies have examined the effects of burning (Collins et al. 1998a) and grazing (Seastedt et al. 1994, Knapp et al. 1999, Fuhlendorf and Engle 2001, Fuhlendorf and Engle 2004) on native grass establishment in western tallgrass prairie; however, there has been less research on the use of burning and grazing to encourage native grass persistence in the eastern tallgrass prairie. The work described here focused on the first year of combined burning and grazing after a 3-year establishment phase under burning alone and grazing alone. The lesson from the establishment phase was that burning greatly facilitated native grass recruitment into an existing stand of cool-season grasses (Woodis 2008). Grazing during the establishment phase did not preclude recruitment, but neither did it allow native grasses to recruit into the stand in an agronomically significant way.

Studies have shown that fire enhances native grass establishment and abundance and reduces non-native species (Howe 2000, Camill et al. 2004, Prober et al. 2005, MacDonald et al. 2007). Camill et al (2004) found a significant shift to warm-season grasses in prairie ecosystems around year 3 of restoration, and Howe (2000) found that spring burning promoted 5 to 6 times greater warm-season grass production than fall burning and no burning treatments. Burning increases soil temperature and reduces soil moisture and nutrient availability, which allows for greater dominance of native, warm-season grasses (Collins et al. 1998b). However, we observed no consistent effects of management on soil temperature or moisture for 2007. We did observe that nitrogen availability was somewhat lower in the burn treatment during June and October, which may have given the native grasses in the burn plots a competitive advantage.

In the western tallgrass prairie, grazing regimes increase species diversity (Collins et al. 1998a, Knapp et al. 1999) and promote patch diversity (Fuhlendorf and Engle 2001). However, one study examined bison grazing on native, warm-season grasses east of the Mississippi and found that grazing caused a decline in native grass persistence (Jackson et al. in press). Similarly, we found that native grass establishment was limited under the graze treatment. While we found a significant increase in native grass density from 2006 to 2007, the establishment was limited under grazing alone (i.e. an increase of roughly 1 to 3 native grass tillers/m^2 under graze only). Studies have examined that less intense and/or less frequent grazing promotes persistence of big bluestem (Mousel et al. 2003, Mousel et al. 2005). The apical meristem of cool-season grasses is closer to the ground than most native, warm-season grasses, so grazing native grasses too closely to the soil surface could suppress regrowth after defoliation.

Studies have found that combining grazing and burning increases species diversity and heterogeneity (Collins and Gibson 1990), and enhances wildlife habitat (Fuhlendorf and Engle 2001). We found that a combination of burning and grazing in the first year of application resulted in little to no change in native grass density, suggesting that once native grasses are established, rotational grazing regimes may be applied without immediate detriment to native grass persistence. However, these results must be viewed with caution as longer-term rotational grazing may reduce native grass persistence. Jackson et al. (in press) found a precipitous decline of warm-season grasses (though rates of decline were species-specific) under summer rotational bison grazing. While stocking rates were quite high, and the timing of grazing may not have been ideal, native grass cover on their plots decline from

~90% to ~30% over a 6-year period. Hence, more work with other types, intensities, and timings of grazing livestock is needed.

When burning grazed pastures, farmers will need to take into consideration the amount of accumulated biomass remaining from the previous season. We found it difficult to maintain a consistent fire on the graze only plots. Farmers may need to reduce or eliminate grazing in the fall to allow biomass to accumulate for the following spring burn. One alternative is to incorporate "rest paddocks" (Jackson 1999, Hickman et al. 2004, Firn 2007) for 1 to 2 years to facilitate burning and then reintroduce rotational grazing, but with follow-up monitoring that can inform adaptive management.

While combining burning and grazing did not result in native grass loss, there was significantly less native grass cover in these treatments compared to burning alone. This shows how different vegetation metrics might lead to alternate conclusions. Density is calculated as the mean number of individuals per unit area, while species cover reflects how much ground area is covered by the vertical projection of the plant (Packard and Mutel 1997). Native grasses were present in significant numbers (density), but occupying much less space (cover) under the burn-graze treatments. Under both the burn and burn-graze treatments native grasses were present, but when grazing was included, native grasses were not apparent to the observer. The tallgrass prairie species were not allowed to fully express themselves when grazing was applied. This shows the importance of sampling method selection and interpretation of results. Farmers and land managers will need to carefully quantify native grass presence when grazing is applied.

CONCLUSIONS

Our land management approach was to blend biodiversity, conservation efforts with agricultural, pasture production by reintroducing native, warm-season grasses into a cool-season grass pasture. The coexistence of warm-season and cool-season grasses offers many potential ecological, agronomic, and social benefits, including improved forage production, restored native species, carbon sequestration, wildlife habitat, and weed exclusion (Firn 2007). Introducing native grasses as part of the pasture community also offers flexibility to the management system (Moore et al. 2004), especially when production of cool-season grasses are low during hot summer months. One goal in the field of restoration ecology is to enhance conservation values in productive landscapes through integrating production and conservation values (Hobbs and Norton 1996). Combining burning and grazing as a management tool for native grass persistence in the eastern tallgrass prairie region may be difficult to implement initially, but is feasible with deferred grazing during the establishment phase. Further research into “rest paddocks” or rotating paddocks in and out of rotational grazing cycles to allow for spring burning and native grass recruitment is needed.

CHAPTER 2: RESEARCH BREIF FOR OUTREACH AND EXTENSION

SOWING WARM-SEASON GRASSES INTO COOL-SEASON PASTURES:

CONSIDERING TRADEOFFS IN ECOSYSTEM SERVICES

As interest in multifunctional landscapes grows, more emphasis is being placed on the many ecosystem services provided by farms. The ecosystem services framework discussed by the Millennium Ecosystem Assessment (MEA) report classifies the various commodity and non-commodity services provided by agroecosystems (Box 1).

Box 1. Ecosystem services are the benefits provided by ecosystems that promote human well-being. These services fall under four categories:

Provisioning services – products obtained from ecosystems (examples: food, fiber, fuel)

Regulating services – benefits obtained from the regulation of ecosystem processes (examples: flood control, disease control, carbon sequestration)

Cultural services – nonmaterial benefits that people obtain from ecosystems (examples: spiritual, recreational, educational)

Supporting services – phenomena necessary for the production of all other ecosystem services (examples: nutrient cycling, primary production, soil formation)

The ecosystem services framework can be complex but has the potential to clarify which services are or are not being promoted by ecosystems under alternative management scenarios. For example, the increased provision of forage that can result from added nitrogen fertilizer should be analyzed against the altered supporting services (e.g. nutrient cycling) that may take place and affect water quality in a particular region. Grass-based farmers are becoming more interested in non-commodity services (i.e. cultural and supporting services) provided by their farm land.

In addition to provisioning services, we expect farms to sequester carbon, support wildlife, purify water, and beautify the landscape. Grass-based farming is a type of land management that lends itself to both resource conservation and agronomic production, thus many ecosystem services may be simultaneously provided.

More tallgrass prairie has been lost than any other terrestrial ecosystem in North America. In Wisconsin, tallgrass prairie once dominated over 850,000 ha, but <1% of that remains today. Because of this great loss, many are interested in restoring these native species to the landscape. While cool-season grasses are more productive in the spring and fall when climate conditions are cool and wet, they also tend to have higher forage quality than warm-season grasses. Incorporating native, warm-season grasses into grazing systems offers a compromise between complete restoration and no native species in the landscape. Some of the *potential* agronomic, ecological, and social benefits in using native grasses are that they:

- Balance forage production during hot summer months (provisioning service)
- Restore native taxa (cultural service)
- Increase soil carbon sequestration (regulating and supporting services)
- Enhance wildlife habitat (regulating and supporting services)
- Advertise land stewardship (cultural service)

Here we use the results of two studies to examine potential tradeoffs in ecosystem services when considering mixed stands of warm-season and cool-season grasses. Study 1 tested different disturbances in establishing native, warm-season grasses into existing cool-season pastures. Study 2 investigated different mixtures of warm-season and cool-season grasses that had been established for over 10 years.

STUDY 1: MANIPULATING DISTURBANCES TO ESTABLISH WARM-SEASON GRASSES IN A COOL-SEASON SOD

This study took place at the Cates Family Farm, a beef producing farm in Iowa County, Wisconsin from 2004 to 2007. In 2004, three native, warm-season grasses (big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and indiangrass (*Sorghastrum nutans*) were drill-seeded into an existing pasture dominated by non-native, cool-season grasses, legumes, and forbs. Experimental plots were either spring burned or rotationally grazed from 2004 through 2006 in order to promote establishment. Management-intensive rotational grazing was applied monthly (1 d/plot) throughout the growing seasons. In 2007, we included a third treatment of combined burning and grazing. We measured warm-season grass density, as well as pasture production (i.e. forage production, forage quality, and root production) under spring burn, graze, and burn-graze treatments.

Results from the 2007 growing season showed that:

- Burning promoted greater native grass abundance (Figure 1).
- Burning promoted greater root production, while grazing promoted greater forage production (Figure 2).
- As native, warm-season grasses increased there was no change in forage quality in the spring and summer but a slight decrease in the fall (Figure 3).

STUDY 2: FORAGE PRODUCTION UNDER DIFFERENT RATIOS OF COOL-SEASON AND WARM-SEASON GRASSES

This study took place at two locations: Bison Ridge Ranch in Marquette County, Wisconsin and the Wisconsin Integrated Cropping System Trials (WICST) at the Arlington Agricultural Research Station in Columbia County, Wisconsin during 2007. Experimental plots were clipped periodically throughout the growing season (every 4-8 weeks) to mimic management-intensive rotational grazing. Fifteen 50 × 50-cm plots were used at each site to estimate native, warm-season grass abundance and to relate forage production and quality to these gradients. Data from both sites were combined to find forage production and quality. Results from this study showed that as native, warm-season grasses increased, forage production was greater (Figure 4) but forage quality was reduced in August and September (Figure 5).

TRADEOFFS IN ECOSYSTEM SERVICES

The relative importance of various ecosystem services are constantly debated as part of an ongoing societal dialogue about values. Through public policy, society provides incentives to emphasize some services over others. Historically, these incentives have promoted a mentality of "optimizing productivity" among farmers. However, recent emphasis on conservation measures has successfully redirected some farmers' goals and objectives. It is difficult for farmers, indeed any single entity, to decide which services are most important, but many farmers make a conscious decision to manage their land in ways that include other factors beyond economic returns. As more farmers make these decisions, the need for an incentive structure that rewards such behavior becomes more apparent. Just as important is the need for reliable information about the tradeoffs inherent to these decisions so that appropriate weight can be placed on services as they are more or less valued.

FIGURES

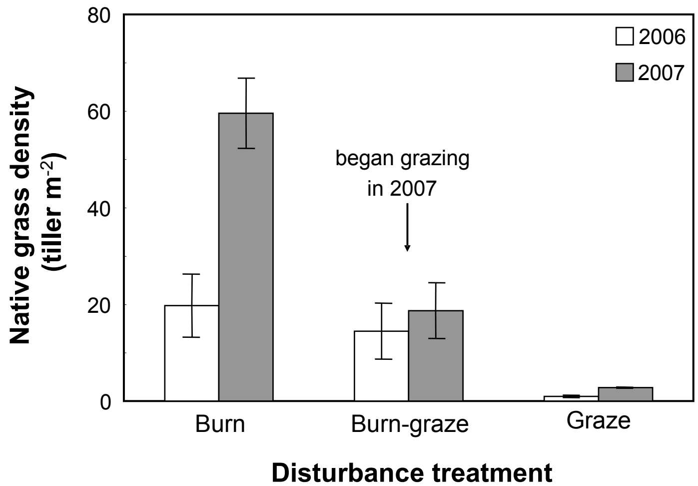

Figure 1. Mean native grass tiller density for burn, burn-graze, and graze treatments during August 2006 and 2007. In 2007, grazing began on half of the 2006 burn plots to include a new treatment – burn-graze.

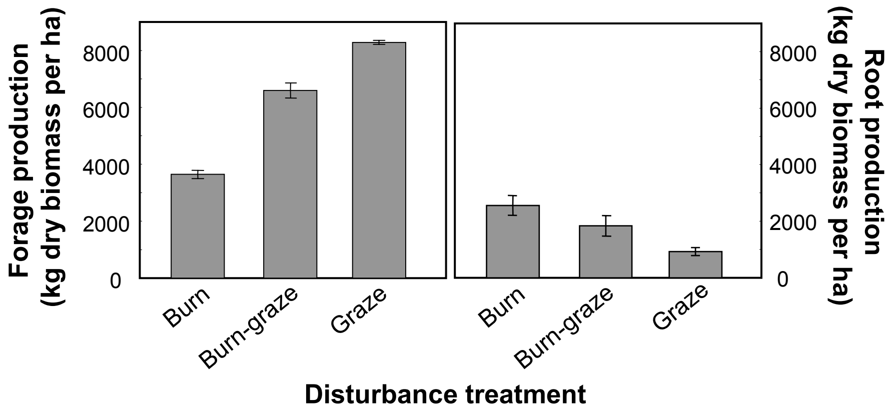

Figure 2. Total forage and root production under burn, burn-graze, and graze treatments during 2007 growing season.

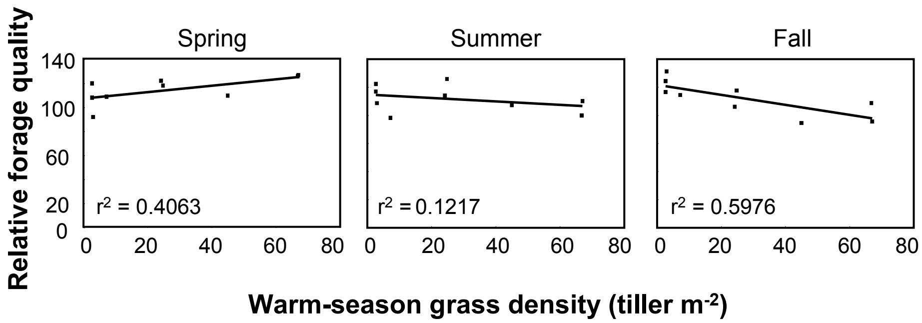

Figure 3. Relative forage quality (RFQ) as a function of warm-season grass density during the spring, summer, and fall of 2007. Full bloom alfalfa has a RFQ value of 100.

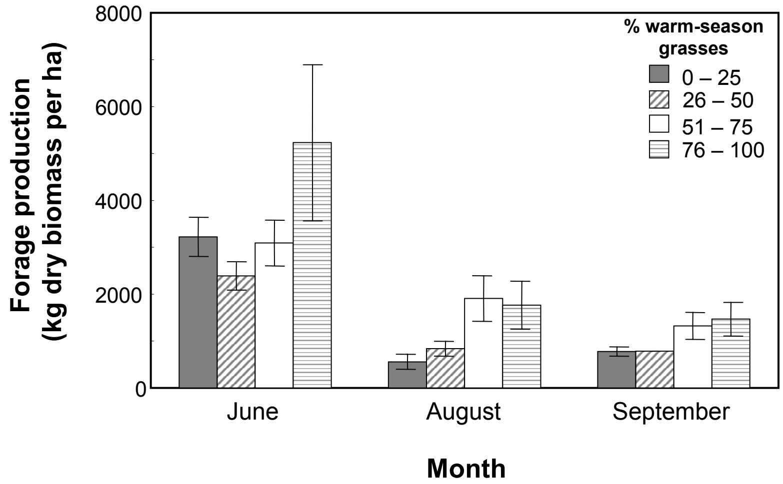

Figure 4. Forage production under different warm-season grass cover classes during June, August and September 2007.

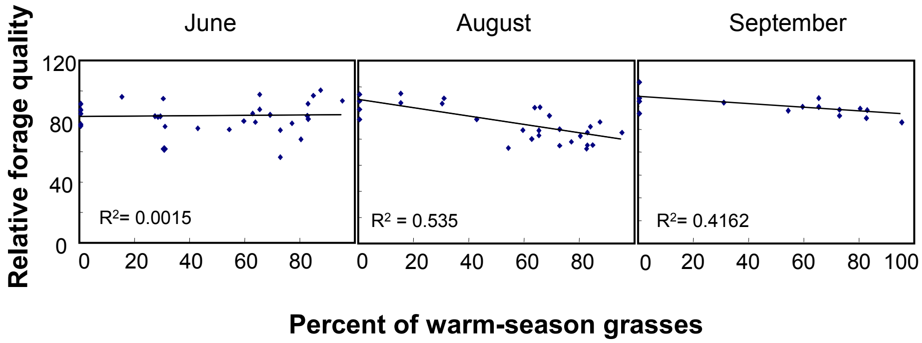

Figure 5. Relative forage quality (RFQ) as a function of warm-season grass cover during June, August, and September of 2007. Full bloom alfalfa has a RFQ value of 100.

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