Potential carbon sequestration and forage gains with management-intensive rotational grazing

cias research brief 95

Center for Integrated Agricultural Systems • UW-Madison College of Agricultural and Life Sciences

September 2015

Do pastures under management-intensive rotational grazing (MIRG) differ from grasslands under other management in terms of forage quality and quantity, carbon sequestration and biological soil activity? Researchers at the University of Wisconsin-Madison set out to answer these questions and discover some of the reasons behind differences in pasture productivity. They compared MIRG to continuous grazing, mechanically harvested forages, and unmanaged grassland similar to land enrolled in the Conservation Reserve Program (CRP). Their findings indicate that MIRG may provide a higher quality and quantity of forage, and more potential for carbon sequestration, compared to the other management systems.

Four treatments

Gary Oates and Randy Jackson from the UW-Madison Agronomy Department conducted this research project at the UW-owned Franbrook Farm near New Glarus. In 2005, they established a randomized complete block field experiment, with three separate replicated blocks of four treatments (MIRG, continuous grazing and two additional forage systems). The study was conducted during the 2006 and 2007 growing seasons. This research was supported by a University of Wisconsin-Madison College of Agricultural and Life Sciences Interdisciplinary USDA Hatch grant and a grant from the Center for Integrated Agricultural Systems (CIAS). Because of the potential benefits of perennial crops, including perennial forages, the perennialization of agriculture is a topic of interest for CIAS.

The grazing season started in May and continued through October, providing six 30-day grazing cycles. During the study, Kentucky bluegrass and orchardgrass were the predominant grasses in all of the treatments. White clover was the dominant legume in the grazed plots, while birdsfoot trefoil was the dominant legume in the non-grazed plots. The researchers applied granular ammonium phosphate (11-44-0) fertilizer at the UW Extension recommended rate (50 lbs. N/acre) in early June of 2005, 2006 and 2007 to all plots except those under no agronomic management (see the description of this treatment on the next page).

Continuous grazing. In this treatment, 25 cow-calf pairs grazed 20 acres for 28 days of every 30-day cycle. For two days of each 30-day cycle, the cattle were shifted to the MIRG plots.

Management intensive rotational grazing (MIRG). The 25 cow-calf pairs from the continuous grazing treatment grazed a 1.5-acre paddock for two days in the MIRG plots, followed by a 28-day rest period. Typically, a six-inch residual was left after grazing. Cattle were returned to the paddocks on a 28-day schedule, rather than according to forage height and maturity, in order to hold the stocking rate constant between the continuous and MIRG grazing treatments.

Cow-calf pairs grazing on a plot at the Franbrook Farm

Researchers compared MIRG to three other forage systems in terms of forage quantity, quality, carbon sequestration potential and microbial activity

Researchers take measurements on continuously grazed pastures

Each cow-calf pair constituted 1.3 animal units (AU, or unit of 1,000 pounds of weight); each acre of rotationally grazed pasture had a stocking rate of 43.7 AU per month and each acre of the continuously grazed pasture had a comparable stocking rate of 45.3 AU per month. Over the course of the growing season, but mainly during the forage slump of summer, the livestock received feed supplements equivalent to 2.7 lb. hay DM (dry matter)/AU/day and 1 lb. cracked corn/AU/day in 2006, and 4.4 lb. hay DM/AU/day and 1.7 lb. cracked corn/AU/day in 2007.

Harvested and unmanaged forage systems. The remaining two treatments were managed without any livestock. One of these forage systems consisted of plots of 0.75 acres each in which the plants were mechanically harvested to a stubble height of 2.5 inches in May, and again when the plants were 12 to 14 inches high. Because of dry conditions in 2006 and 2007, researchers made only two cuttings of hay. Average annual precipitation in this location is 35 inches; in 2006 the annual precipitation was 27 inches, and in 2007 it was 23 inches. The final control treatment consisted of 0.75-acre plots with no agronomic management, similar to land in the Conservation Reserve Program (CRP).

Results

Forage availability. The researchers measured the amount of forage available monthly. In both 2006 and 2007, the potential utilizable forage from the MIRG plots was significantly higher than the other treatments for the growing season as a whole (see Figure 1). The plots with no management had the lowest forage availability in both years. Looking at season-by-season data, the MIRG plots had significantly higher forage availability than all other treatments in spring and summer of 2006, while in 2007 this occurred in spring and fall. There was only one significant change in the makeup of the plant communities in the plots, and that was an increase in cool season grass cover in the harvested treatment.

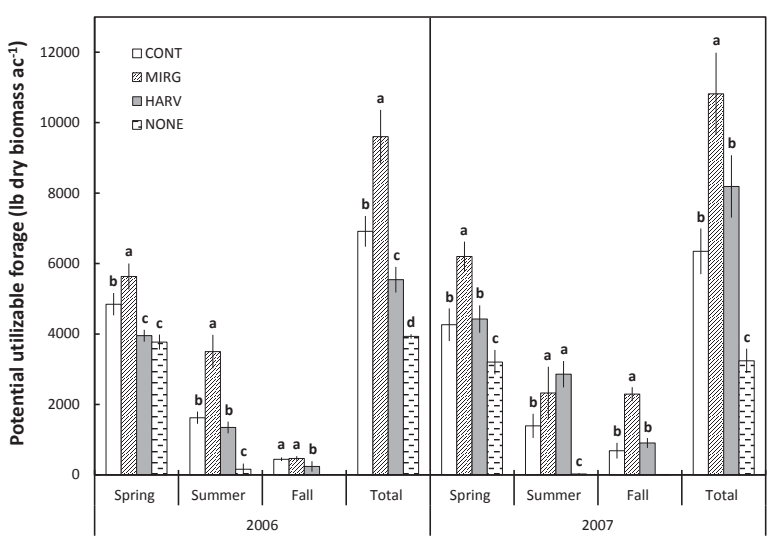

Figure 1. Potential utilizable forage (PUF) in 2006 and 2007.
Error bars show ± SE, n = 3. Means of PUF shown with different letters were determined to be significantly different using ANOVA linear mixed-effects model selection, p<0.05.

Forage quality. The researchers measured the relative forage quality (RFQ) in all treatments. They calculated the RFQ seasonal means by treatment shown in Figure 2 from three samples from each of the three blocks of treatments (or nine samples per treatment per month) during the specified season. RFQ of all treatments in the spring and summer of 2006 was less than 137. At a level of 137, forage is deemed

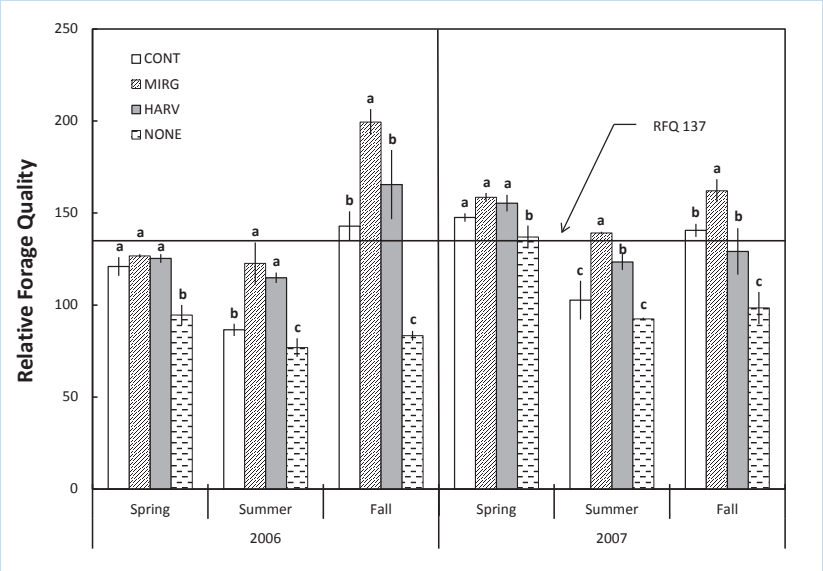

Figure 2. Relative Forage Quality (RFQ) in 2006 and 2007.

Forage at an RFQ level of 137 is considered medium quality. At this level, growing cattle would gain 1.3 pounds/head/day and lactating cows would produce 22 lbs. of milk per day. Error bars show ± SE, n = 3. Bars with different letters within each group were significantly different from each other using ANOVA linear mixed-effects model selection, $p<0.05$.

to be medium quality, providing the necessary nutrition for growing cattle to gain 1.3 pounds per head per day and lactating cows to produce 22 pounds of milk per day. RFQ in MIRG plots was significantly higher than the other treatments in the fall of that year and in summer and fall of 2007. MIRG RFQ was similar to other treatments in the spring of 2007. The plots with no management had the lowest forage quality in both years.

Carbon sequestration. Strategies that increase pasture productivity and improve forage quality are thought to provide opportunities to increase storage of atmospheric carbon, also called carbon sequestration. Carbon that is sequestered offsets carbon that is released to the atmosphere through the burning of fossil fuels, agricultural practices such as tillage, and land clearing activities such as deforestation. The researchers used an ecosystem carbon balance equation to assess whether carbon had accumulated or been lost in each of the treatments. The equation takes into account inputs from above and below ground plant production as well as inputs of imported hay and grain, and outputs of microbial respiration (the use of soil carbon for energy), exports of hay and livestock biomass, livestock rumination and respiration, and soluble carbon loss. Using this formula, the researchers found that the MIRG treatment lost significantly less carbon in 2006 as compared to all other treatments. None of the treatments sequestered carbon that year. In 2007, the MIRG treatment was the only one that sequestered carbon. Oates says, "Perennial pastures have the potential for sequestering carbon, but the import and export of all forms of carbon across the farm boundary need to be considered in order to truly understand the farm's carbon balance."

Microbial communities. While the effects of grazing management on soil microbial life can vary, the researchers sought to understand whether there were any differences in the soil microbial community between grazed and ungrazed treatments, and between the two grazed treatments. The researchers wanted to analyze whether the higher level of plant production in the MIRG treatment was due to direct effects of grazing on plant developmental stage and plant community composition, or indirect effects of

manure deposition and litter quality making nutrients more available to plants through microbial activity. After analyzing microbial populations in the top six inches of soil in the four treatments, the researchers found the different treatments had no effect on total microbial biomass. However, the soil beneath the grazed treatments did have different microbial communities than the ungrazed treatments. The researchers identified litter quality and ease of decomposition—that is, lower carbon to nitrogen ratio in the plant material both above and below ground—as the main reasons for these differences.

When comparing microbial community composition, the researchers found lower fungal-to-bacterial ratios in soils under grazing, irrespective of grazing management. In grazing treatments, less carbon is tied up in plant roots, and the plant litter is more easily decomposed. In addition, in grazed treatments a higher portion of carbon and nitrogen are readily decomposable in the form of manure, stimulating microbial activity and leading to higher bacterial ratios. The higher bacterial ratios mean a faster return of nutrients to a form that is available to plants. In non-grazing treatments, nutrients are made available to plants more slowly because a higher proportion of carbon and nitrogen are bound in organic material and must be broken down by fungi before bacteria can convert it to plant-available nutrients.

While there were differences in microbial community composition between grazed and ungrazed treatments, the makeup of microbial communities was not significantly different between the continuous grazing and MIRG treatments. From this finding, the researchers concluded that higher production levels in the MIRG treatment were not due to soil microbial activity. Instead, greater production likely resulted from the fact that this management strategy periodically resets plant development and maintains a preferred plant community composition because livestock are grazing down all plants in a brief interval as compared to continuous grazing, when they selectively and repeatedly graze down preferred plants.

Conclusion

The results suggest that MIRG offers farmers increased forage quality and quantity when compared to continuous grazing or haying. In addition, MIRG systems have greater potential for carbon sequestration compared to the other systems. Heightened production from the MIRG system compared to continuous grazing most likely results from the unique way that rotational grazing resets plant development and maintains a preferred plant community, rather than from increased nutrient availability through microbial activity. Additional research would be beneficial to determine differences among these treatments on a variety of soil types and farm management approaches, as found on working farms across the state.

For more information, contact: Gary Oates, oates@wisc.edu, 608-265-4022; Randy Jackson, rdjackson@wisc.edu, 608-261-1480.

The Center for Integrated Agricultural Systems (CIAS) brings together university faculty, farmers, policy makers and others to study relationships between farming practices, farm profitability, the environment and rural vitality. Located in the College of Agricultural and Life Sciences at the UW-Madison, it fosters multidisciplinary inquiry and supports a range of research, curriculum development and program development projects. For more information on the Center or on the research in this Brief, contact: CIAS, 1535 Observatory Drive, UW-Madison, Madison, WI 53706 Phone: (608) 262-5200 E-mail: ramcnair@wisc.edu, www.cias.wisc.edu

This Research Brief is part of a series. Contact CIAS for other titles. CIAS staff members are grateful for the reviews of this brief by UW-Madison and UW-Extension faculty and CIAS Citizens Advisory Council members. September, 2015

CIAS

CENTER for INTEGRATED AGRICULTURAL SYSTEMS