How does managed grazing affect Wisconsin's environment?

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In Wisconsin, the prevalence of dairy and livestock farming has led to questions about how animal agriculture affects the environment. As of 2003, managed grazing was practiced on 23 percent of Wisconsin dairy farms (Taylor and Foltz 2006). Many farmers who practice managed grazing (graziers) have observed environmental benefits resulting from this management system. What have scientific studies shown about the effects of managed grazing on the environment?

Managed grazing refers to a method of feeding livestock by rotating them through subdivided pastures (paddocks) based on the nutritional needs of the animals and forage availability. Under good management, animals typically spend a short duration (several hours to a few days) in each paddock, after which the paddock is allowed to rest and regrow for several weeks. Managed grazing provides continual ground cover and high quality, good-yielding forage for the livestock (Hensler et al. 2007; Kanneganti and Kaffka 1995). In contrast, livestock in a continuous grazing system are left in a single, undivided pasture for weeks or months, often yielding overgrazed, sparse pastures with low persistence (Teague and Dowhower 2003; Brummer and Moore 2000).

Wisconsin graziers have improved poor pastures and converted thousands of acres of cropland to perennial pastures for managed grazing. While there has been little scientific research directly comparing the environmental implications of land in row crops to managed pastures, a study on two farms in Minnesota demonstrated significantly less soil erosion from managed pastures than from row crops after a large rainstorm (DeVore 2001).

We asked Wisconsin farmers who use managed grazing to tell us how their farming systems may benefit the environment. They often compared observations from their current grazing systems to row crop or continuous grazing systems they had used previously or seen on other farms. Their answers encompassed five broad areas: healthy soils, reduced water runoff and soil erosion, wildlife habitat, carbon sequestration and resource conservation. We searched for papers in the peer-reviewed scientific literature relevant to these topics, preferably within agricultural systems similar to those used in dairy and livestock farming in the Upper Midwest. We also consulted with university and agency personnel with expertise in these areas and used other published sources.

In 2003, Wisconsin had about 3.1 million acres of pasture land (USDA NRCS 2003). A great deal of research has been conducted on the agronomic characteristics of pasture. Studies of the environmental effects of intensively grazed pastures are less frequent and extremely varied, however. Many studies of western rangelands, where overgrazing of low-productivity grasslands is the main concern, are not applicable to the high yielding, cool-season grass pastures typically used for dairy and livestock farming in the Upper Midwest and some eastern states.

We present results from papers which are the most relevant to managed grazing systems in Wisconsin and similar regions. This summary is an introduction to these five environmental topic areas as they relate to livestock grazing and is not exhaustive. An annotated bibliography of the references cited in this report is available at www.cias.wisc.edu.

1. Does managed grazing promote healthy soils?

Many farmers who have transitioned land from row crops or continuous grazing to managed grazing say that the soils of the managed pastures have improved. They believe that their soils under managed pasture are healthier due to increased organic matter content, less compaction and more earthworms and insect activity.

Soils rich in organic matter are desirable for their ability to grow crops. Organic matter has been shown to improve soil moisture and nutrient holding capacity, increase rainfall infiltration and promote the stabilization

of soil aggregates (Johnston 1986). Managing for and increasing soil organic matter is now being advocated by the NRCS as the next step beyond erosion control to preserve agricultural productivity, as well as water and air quality (USDA NRCS 2008). Some certification and regulatory programs, such as the National Organic Program, are using organic matter as one of the criteria by which crop management practices are evaluated (Ingram 2007).

Several managed grazing studies have shown that the soils under grazed pastures have more organic matter than soils in other farming systems. A midwestern study found that rotationally grazed pastures had markedly more organic matter in the top 12 inches of soil when compared to conventional row crop systems (Dorsey et al. 1998). A study of farms in Virginia found that rotationally grazed pastures had more total organic soil carbon (a common measure of soil organic matter) than extensively grazed or hayed pastures at all but one of the research sites (Conant et al. 2003). Another researcher found similar levels of soil organic carbon across several grazing treatments and intensities in the upper three inches of soil. Soil organic carbon was significantly higher for all of these treatments when compared to a no-graze treatment (Manley et al. 1995).

Earthworms improve soil by providing tunnels that increase water infiltration, soil aeration and root growth, incorporating organic material into the soil, and increasing the availability of nutrients (Minnich 1977). A Minnesota study found that earthworm populations were, on average, 131 percent higher under managed grazing than conventional row crop systems for nine paired sites (Dorsey et al. 1998). A study of 84 cropped and pastured soils in Australia found that earthworms were three times more numerous under grazed pastures than cropped ground (Mele and Carter 1999).

2. Does managed grazing reduce erosion/runoff?
Farmers who use managed grazing say that their pastures contribute less to soil erosion and runoff of water and nutrients than do continuously grazed pastures or row crops. This is possibly because managed pastures have thick, soil-retaining ground cover year round, require less fertilizer and pesticides than row crops, benefit from evenly distributed manure compared with continuous grazing and have improved soils.

There are also situations on grazing farms which might cause surface runoff or groundwater contamination. In particular, problems can stem from the continuous use of a pasture during winter as a feeding and bedding area for cows, and the deposition of urine by livestock on pastures that cannot fully utilize it, such as under dry or frozen conditions. The UW-Discovery Farms Program has been monitoring water, nutrient and sediment losses from several Wisconsin grazing farms. Preliminary data from one managed grazing farm showed soil loss was well under the tolerable soil loss level established by the USDA and that nearly all surface water runoff occurred when the ground was frozen (UW-Discovery Farms Program 2005).

Another study comparing a managed grazing farm and a corn field in Minnesota's Sand Creek watershed found that after a heavy rain storm in June 1998, the farm under managed pasture, despite its greater steepness, lost much less soil per acre (.0265 tons) than the fields under moldboard plow (10 tons) and chisel plow tillage (5 tons) (DeVore 2001). RUSLE2 modelling predicts a large reduction in soil loss from well-managed pasture compared to most cropped ground (USDA ARS 2008, Derricks 2008 personal communication, Daigle 2003). RUSLE2 (the Revised Universal Soil Loss Equation version 2), a modeling program that predicts long-term average annual erosion by rainfall and runoff, is used by USDA NRCS field offices, researchers and government agencies worldwide.

Runoff of soil nutrients such as phosphorus and nitrogen contributes to agricultural non-point source pollution (Scrimgeour and Kendall 2002). Both grazing management and residual height of the forage after grazing affected water and phosphorus runoff in a three-year grazing trial in Iowa (Haan et al. 2005). There was no difference in phosphorus losses from ungrazed paddocks and rotationally grazed paddocks with a four-inch stubble height; however, when paddocks were grazed to a height of two inches, water and phosphorus runoff were significantly higher. Pastures grazed rotationally to two inches lost less phosphorus than those grazed continuously to the same height.

Several studies in Minnesota compared soil nitrate concentrations on managed grazing and conventional farms. One study found that deep soil nitrate concentrations, which can potentially leach into groundwater, were lower on managed grazing farms with three different soil types (Dorsey et al. 1998). The other studies found nitrate concentrations below EPA limits in all surface water adjacent to both rotationally and continuously grazed sites (Sovell et al. 2000), and similar nitrogen levels in the upper layers of the soil for all grazing treatments (Manley et al. 1995).

It is unclear how managed grazing influences nitrogen loss from pastures. A two-year study conducted on Pennsylvania pastures under managed grazing found that extremely variable amounts of nitrate leached from the pastures, depending on the addition of nitrogen fertilizer and amount of rainfall (Stout 2000). Nitrate losses were higher from nitrogen-fertilized pastures than from grass-legume pastures during a normal rainfall year. During the subsequent drought year, however, the grass-legume pastures had much higher losses from nitrate leaching than the nitrogen-fertilized pastures. Stout et al. (1997) demonstrated high nitrate losses from applied urine in pastures, raising concerns about water quality under livestock grazing systems with a high stocking density.

In addition to variations in nitrate leaching, there may be differences between farming systems in how nitrate is converted to other forms of nitrogen, including nitrogen gas (denitrification). A research project on nine Wisconsin farms found that denitrification efficiency in soils and groundwater under managed pastures was greater (70-90 percent) than under a corn crop (10-15 percent) (Browne and Turyk 2007). This study also found lower amounts of the global warming gas N_2O in the managed grazing systems than in the cropped systems.

Livestock grazing of sensitive waterways has been shown to decrease the quality of these waterways, as the trampling of stream banks causes erosion and sediment loss into the streams (Trimble and Mendel 1995). However, many of these effects have been due to unmanaged grazing that leads to stream bank degradation, primarily in riparian areas (Fitch and Adams 1998). More recently, agencies and conservationists have joined with farmers to promote managed grazing as a way to protect riparian areas (Mosely et al. 1998; Lyons et al. 2000; Leonard et al. 1997; Elmore 1992; D. Vetrano 2008).

3. Do managed grazing farms foster wildlife?

Farmers who switch to managed grazing often comment on the increased animal activity they observe on their farms after making the switch. Wildlife habitat, especially for grassland birds and insects, is affected by grazing management. In addition to the importance of maintaining species diversity, wild animals and insects are vital to

healthy ecosystems because they provide and participate in fundamental processes such as pollination, food chain dynamics and nutrient cycling.

One study found that bird species richness, dominance and density did not differ among rotationally grazed, continuously grazed and row crop fields. However, bird species of management concern were present on the grazed pastures but not on the row crop fields (Renfrew and Ribic 2001). A series of studies in Wisconsin concluded that rotationally grazed farms generally contain more acres of suitable habitat for grassland birds than confinement-based livestock farms (Paine et al. 1995; Temple et al. 1999). The authors recommended that graziers exclude livestock from a section of pasture during nesting season to further increase nest success and bird numbers.

The effects of grazing on wildlife vary between species, given the range of habitat requirements necessary for their survival. With managed grazing, the timing and location of grazing can be chosen to provide habitat for desired wildlife species (Holechek et al. 1982; Koper and Schimiegelow 2006). A Canadian study found that duck nest success was better on pasture, whether rotationally or continuously grazed, than most other habitats of the region (Ignatiuk and Duncan 2001).

4. Do managed grazing farms sequester carbon?

Excessive atmospheric carbon is scientifically linked to global climate change (Cox et al. 2000). As a result, there is increasing interest in sequestering carbon in grassland ecosystems (Kucharik et al. 2003; Lal 2006). Because soils store a large proportion of the world's carbon (Amundson 2001), small changes in soil carbon content can have a large effect on global carbon cycling.

Land set-aside programs in the Conservation Reserve Program have shown that converting tilled soils back to native perennial grasses helps increase soil carbon levels (Reeder et al. 1998; Potter et al. 1999; Baer et al. 2000). Studies conducted in France and southwest Ireland suggest that intensively managed grasslands are net sinks for atmospheric carbon dioxide (Allard et al. 2007).

Grass under grazing can provide higher soil carbon than ungrazed grass, due to more rapid annual turnover of shoot material and changes in species composition (Reeder and Schuman 2002).

A study in the southeastern United States found that rotationally grazed pastures sequestered more soil carbon when compared to continuously grazed or hayed pastures (Conant et al. 2003). Preliminary results from three years of a study at the University of Wisconsin-Madison suggest that the net ecosystem carbon balance is greater for managed grazing pastures than continuously grazed or hayed pastures (Jackson and Stier 2008). However, in the same research project, all of the cool-season grass pastures studied yielded a net loss of carbon over the three years of data collection.

Ecologists are concerned that increased soil respiration rates due to global warming may result in grasslands losing carbon rather than serving as carbon sinks. Evidence for carbon losses from soil on a widespread basis comes from Bellamy et al. (2005), who compared soil inventory data across England and Wales between 1978 and 2003. They found that carbon was lost from all but 8 percent of the sampling sites during this period. Similarly, in New Zealand, which is dominated by livestock grazing, 31 pasture sites were sampled over a span of 17-30 years and had, on average, lost significant amounts of carbon (Schipper et al. 2007).

At this time, it is not known whether managed grazing lands will be able to contribute more to carbon sequestration than other types of agricultural lands. Because changes in soil carbon are extremely small over short time periods, accurate measurement of soil carbon changes is difficult (Kucharik 2003; Brye et al. 2002).

5. Does managed grazing conserve resources?

Measuring resource conservation, particularly energy use, on agricultural operations in the United States is a relatively new field of study. In the case of managed grazing in Wisconsin, farmers' observations about resource conservation include lower production costs resulting from reduced input use; less capital investment resulting from greater use of existing facilities and retrofitting; and lower consumption of fossil fuels due to reduced use of tillage, tractors, machinery and fertilizers and pesticides compared with conventional dairy and livestock farming systems.

To date, the scientific literature has focused on overall farm profitability rather than resource efficiency. Managed grazing operations have shown greater per-cow profits and lower costs per hundredweight of milk produced, though only in part due to lower fuel and fertilizer use (Kriegl 2005). Some Wisconsin graziers have shown, through detailed on-farm record keeping, that managed grazing dramatically reduced their use of fossil fuels (Paine 1999; Munsch 2008 personal communication). But without a full life cycle analysis, it is difficult to assess the true energy costs of different farming systems (Kriegl 2008).

Conclusions

Studying the environmental benefits of managed grazing is challenging and expensive due to the high number of variables and overall complexity of farms, watersheds and habitats. Some researchers have shown improvements over current agricultural practices by modeling land use scenarios which increased the use of managed grazing and other grasslands (Boody et al. 2005). In addition, many farmers and others who observe the agricultural landscape have seen that managed grazing has positive effects on land and livestock; however, the research cited in this report shows mixed results.

Overall, research indicates that careful managed grazing practices benefit the environment. Still, questions remain, particularly about carbon sequestration and resource conservation. As these issues grow in importance to society and funding becomes more widely available, it will be increasingly valuable to research and document whether—and under what conditions—managed grazing can assist in these conservation goals. In so doing, however, there are large differences in management, soil types and slopes, livestock species, stocking density and watershed characteristics that make it hard to generalize about the environmental benefits of managed grazing in Wisconsin and elsewhere.

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This work was supported by a grant from USDA CSREES and Hatch funds.
Editing by Cris Carusi and Ruth McNair. Photos by Claudio Gratton, Lawrence Oates and Ruth McNair.
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1535 Observatory Drive, Madison, WI 53706 • (608)262-5200 • www.cias.wisc.edu • September 2008