Bibliography
How does managed grazing affect Wisconsin's environment?
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Introduction

Brummer, E.C. and K.J. Moore. 2000. "Persistence of Perennial Cool-Season Grass and Legume Cultivars under Continuous Grazing by Beef Cattle." *Agronomy Journal* 92:466-471. This Iowa study evaluated cool-season forage species to determine their tolerance to continuous grazing. Twenty kinds of alfalfa, 15 other legumes and 25 cool-season grass species were continuously grazed by beef cattle for four months each of two years. It was concluded that several types of forages were more grazing tolerant than others and could survive when overgrazed. The continuous grazing practiced in this study significantly reduced the stands of many of the cool season grasses and legumes commonly grown in Wisconsin.

DeVore, B. 2001. "Same Storm, Different Outcomes," *Land Stewardship Letter*, Apr/May/Jun 2001. Retrieved 6/3/08 (http://www.landstewardshipproject.org/lsl/lspv19n2.html) Researchers found that after a heavy rain storm in June 1998, a farm under managed grazing lost only 53 pounds of soil per acre compared to 10 tons per acre for crop fields under moldboard plow and 5 tons per acre under chisel plow.

Hensler, A.L., D.J. Barker, R.M. Sulc, S.C. Loerch, and L.B. Owens. 2007." Comparison of management intensive grazing and continuous grazing in beef cattle pasture." In *Proceedings of American Forage and Grassland Conference* 16:48-51. June 24-26, State College, Pennsylvania.. This study compared seasonal forage growth and livestock production between four replicated pastures under either continuous grazing (CG) or management intensive rotational grazing (MIG) at the North Appalachian Experimental Watershed (NAEW) near Coshocton, OH. Beef cows and calves had greater weight gain in the MIG system than the CG system. The cattle in the MIG system were able to graze 17 days longer than the cattle in the CG system, plus hay was harvested in the spring from the MIG system. It was concluded that the MIG system is a viable grazing option for livestock production in Appalachian Ohio.

Kanneganti, V.R. and S. R. Kaffka. 1995. "Forage availability from a temperate pasture managed with intensive rotational grazing." *Grass & Forage Science* 50(1):55-62. The authors sought to match livestock nutritional needs with forage availability to minimize the over-feeding of supplements. From a three-year grazing study in Wisconsin herbage production (including sward heights), species composition and forage quality were determined from April through September. It was concluded that the pastures could provide significant amounts of forage during the growing season, with additional forage necessary for times of water stress.

Taylor, J. and J. Foltz. 2006. *Grazing in the Dairy State*. Madison, WI: UW-Madison Center for Integrated Agricultural Systems. As of 2003, managed grazing was practiced on about 23 percent of Wisconsin dairy farms.

Teague, W.R. and S.L. Dowhower. 2003. “Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks.” *Journal of Arid Environments* 53(2):211-229. From 1995 through 1998, herbaceous basal area and bare ground changes were measured on adjacent heavily and lightly grazed patches in rotationally and continuously grazed paddocks. This study provides evidence that in large paddocks, rotational grazing allows recovery from and reduces degradation caused by patch overgrazing.

USDA NRCS. 2003. *National Resources Inventory, 2003 Annual NRI: State Land Use and Soil Erosion Results Tables*. Retrieved 9/15/08. (http://www.nrcs.usda.gov/technical/NRI/2003/nri03eros-mrb.html) The National Resources Inventory (NRI) is a statistical survey of natural resource conditions and trends on non-Federal land in the United States — non-Federal land includes privately owned lands, tribal and trust lands, and lands controlled by state and local governments. Wisconsin is listed as having 3,081,200 acres of pasture out of a total surface area of 35,920,000 acres. The NRI provides nationally consistent statistical data on erosion resulting from water (sheet & rill) and wind processes on cropland for the period 1982-2003.

1. Does managed grazing promote healthy soils?

Conant, R. T., J. Six, and K. Paustian. 2003. “Land use effects on soil carbon fractions in the southeastern United States. I. Management-intensive versus extensive grazing.” *Biology and Fertility of Soils* 38(6):386-392. A study conducted in Virginia found that rotationally grazed pastures had greater total organic soil carbon content than extensively grazed or hayed pastures in all but one of four sites. The researchers found that grazing treatment with lower root C stocks (managed grazing) had more soil C, suggesting that root turnover and the conversion of litter to soil organic matter was more rapid. The results suggest (as do other studies) that C sequestration rates decrease over time. Treatment duration-weighted estimates of sequestration rates averaged 0.41MgC per ha per year for the four sites. The authors say that implementation of managed grazing appears to lead to significant increases in soil C content and sequestration of atmospheric C in soils.

Dorsey, J., J. Dansingburg, and R. Ness. 1998. “Managed Grazing as an Alternative Manure Management Strategy.” *USDA-ARS Land Stewardship Project.* Presented at the West Central Region of the Soil & Water Conservation Society, Manure Management Conference, February 10-12, Ames, Iowa. It is known that organic matter helps to improve soil aggregate stability. Improved soil aggregate stability allows for air and water penetration into the soil by resisting breakdown from mechanical forces like pressure from raindrops and wind. This ultimately results in less soil erosion and reduced surface runoff which in turn reduces sediment and nutrient inputs into surface waters. Dorsey et al. found that rotationally grazed pastures showed marked increases in organic matter in the top 12” of soil when compared to conventional row crop systems. And they found that earthworm populations were on average 131 percent higher under managed grazing than conventional row crop systems.

Ingram, M. 2007. “An Analysis of Environmental Management approaches with six Midwestern dairy farms: Informing progress toward a sustainable agriculture,” *SARE Research and Education Project LNC04-239, Final Report.* Lincoln, NE: USDA North Central SARE. A comparison of six different agricultural-environmental approaches identified strengths and gaps within each program. Case studies of farmers utilizing each of these programs illustrated how agricultural sustainability is farmer driven, and three practices: commitment to stewardship, transparency of operations and involvement of community, and continual improvement through planning, monitoring, assessment and action—are common among successful managers.

Johnston, A.E. 1986. "Soil organic matter, effects on soils and crops." *Soil Use and Management* 2(3):97-105. Orgnic matter was shown to improve soil moisture holding capacity, increase rainfall infiltration, increase nutrient holding capacity, and promote the stabilization of soil aggregates.

Manley, J.T., G.E. Schuman, J.D. Reeder, and R.H. Hart. 1995. "Rangeland soil carbon and nitrogen responses to grazing." *Journal of Soil and Water Conservation* 50(3):294-298. This research found that nitrogen levels in the upper 30 cm of the soil were similar among all grazing treatments at all stocking rates when compared to a no graze treatment. Another study found soil organic carbon (SOC) to be similar across several grazing treatments and intensities in the upper 30cm of soil. In addition, SOC was significantly higher for all these treatments when compared to a no graze treatment.

Mele, P.M. and M.R. Carter 1999. "Species abundance of earthworms in arable and pasture soils in south-eastern Australia." *Applied Soil Ecology* 12(2):129-137. The abundance and distribution of earthworms was studied in 84 cropping and pasture soils in Australia. An average density of 89 earthworms per square meter was found, with one-third of sites having $>100/m^2$, predominantly in higher rainfall areas. Pasture soils were found to have 3.2 times more earthworms than cropped soils.

Minnich, J. 1977. *The Earthworm Book*. Emmaus, PA: Rodale Press. 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.

USDA NRCS 2008. *Soil Organic Matter.* Retrieved 8/21/08 (http://soils.usda.gov/sqi/concepts/soil_organic_matter/som.html)
To address the environmental goals and maintain the land's productive potential, NRCS advocates going beyond erosion control to manage for soil quality. How soil functions on every inch of a farm—not just in buffers or waterways—affects erosion rates, agricultural productivity, air quality and water quality. The most practical way to enhance soil quality today is to promote better management of soil organic matter or carbon.

2. Does managed grazing reduce erosion/runoff?

Browne, B. and N. Turyk. 2007. "Does managed grazing protect groundwater by denitrification?" Pp. 27-29 in *Managed Grazing Education and Research in Wisconsin,* edited by J. Taylor. Madison, WI: UW-Madison Center for Integrated Agricultural Systems. Denitrification efficiency in soils and groundwater under managed pastures was greater than under cropped ground. Phosphorus levels in groundwater under managed pastures were similar across three-fourths of the sampled locations, and the highest 25 percent of P sampled locations were higher under cropped fields than managed grazing locations.

Daigle, P. 2003. "Grazing Project Exceeds 10,000 Acre Milestone: Economic and Environmental Improvements Easy to Measure." *Agri-View*, July 11, p. C-8. A study conducted by the Central Wisconsin River Graziers Network compared phosphorus losses of managed grazing and conventionally managed farms. It was found that phosphorus losses via soil erosion, barnyard runoff, and fertilizer application were reduced on managed grazing farms by 27 tons in the first year of the study.

Derricks, J. 2008. USDA NRCS Wisconsin State Agronomist. Personal communication, September 15. Madison, Wisconsin. As the Wisconsin NRCS state agronomist and RUSLE2 specialist, Derricks has extensive experience applying this modeling program to various farming systems, climates and soil types in Wisconsin. Derricks explained that while developed for use in estimating soil erosion rates from cropland, RUSLE2 has also been applied to grasslands and pastures and often yields very little to no sheet and rill erosion with dense sods. Pastures with gullies, bare spots or too little residual are not appropriate for the application of the RUSLE2 model and need to be evaluated differently.

DeVore, B. 2001. See listing under Introduction

Dorsey et al 1998. See listing under 1. Healthy Soils

Elmore, W. 1992. "Riparian responses to grazing practices." Pp 442-457 in *Watershed Management: Balancing Sustainability and Environmental Change*, edited by R. J. Naiman. NY: Springer Verlag. Ten grazing strategies used to restore riparian areas were discussed. To ensure that a strategy fits a particular stream and pasture, resource managers and farmers were encouraged to look at the whole watershed. Farmers and ranchers can improve riparian habitat and increase quality forage for their livestock.

Fitch, L. and B. W. Adams. 1998. "Can cows and fish coexist?" *Can J. Plant Sci* 78:191-198. This study found that many streambank erosion problems have been caused by unmanaged grazing that leads to overuse and streambank degradation. Management practices for ranchers to manage grazing for stream health and livestock production are included in this literature review.

Haan, M.M., J.R. Russell, W. Powers, J.L. Kovar, J.L. Boehm, S. Mickelson, and R. Schultz. 2005. "Impacts of Cattle Grazing Management on Sediment and Phosphorus Loads in Surface Waters." *Iowa State University Animal Industry Report 2005*. Ames, Iowa: Iowa State University. A three-year trial conducted at the Iowa State University Rhodes research farm found that both continuously and rotationally grazed pastures with a 2-inch residual sward height had significantly higher pasture runoff than did the ungrazed pastures. However, rotationally grazed pastures with a 4-inch residual sward height had runoff levels that were not significantly different from the ungrazed pastures. Switching from 2-inch continuous to a 4-inch rotational grazing strategy resulted in a 65 percent reduction in total P loss.

Leonard, S., G. Kinch, V. Elsbernd, M. Borman, S. Swanson. 1997. “Riparian area management: Grazing management for riparian-wetland areas.” *Technical Reference 1737-14*. U.S. Department of Interior, Bureau of Land Management, National Applied Resource Sciences Center, Denver, CO. This document functions as a manual for farmers, ranchers and conservationists to apply appropriate grazing management practices to individual watersheds and riparian areas. Various types of grazing strategies and management considerations are cited, along with literature references.

Lyons, J., B.M. Weigel, L.K. Paine, and D.J. Undersander. 2000. “Influence of intensive rotational grazing on bank erosion, fish habitat quality, and fish communities in southwestern Wisconsin trout streams.” *Journal of Soil and Water Conservation* 55(3): 271-276. Because programs implemented in Wisconsin to reduce agricultural impacts on aquatic systems, particularly riparian lands, have shown only minor improvements in stream ecosystems, the authors compared the effects of continuous grazing, intensive rotational grazing, grassy buffers or woody buffers between 23 trout streams in southwestern Wisconsin. This study measured bank erosion, fish habitat characteristics, trout abundance and biotic integrity to evaluate stream quality. The authors found that rotational grazing and grassy buffer treatments had the least bank erosion and fine substrate in the stream channel compared with woody buffers and continuous grazing, while most of the other land use comparisons were not statistically different.

Manley et al. 1995. See listing under 1. Healthy Soils

Mosely, M., R. D. Harmel, R. Blackwell, and T. Bidwell. 1998. “Grazing and riparian area management.” In: M. S. Cooper (ed.) *Riparian area management handbook*. Oklahoma Cooperative Extension Service, Division of Agricultural Services and Natural Resources, Oklahoma State University and the Oklahoma Conservation Commission. p. 47-53. This section of the handbook states that proper livestock grazing management can be consistent with healthy waterways. Recommended methods included setting clear objectives, developing a long-term plan, grazing at the proper times, using fencing to separate management units and control access and providing stable stream crossings and livestock access areas.

Scrimgeour, G. J. and S. Kendall. 2002. “Consequences of Livestock Grazing on Water Quality and Benthic Algal Biomass in a Canadian Natural Grassland Plateau.” *Environmental Management* 29(6): 824-844. Livestock grazing has been shown to have negative effects that contribute to water quality degradation, such as loss of stream bank vegetation. In addition, the soil plays a major role in the cycling of macronutrients such as nitrogen and phosphorus, both of which are elements of concern in terms of agricultural non-point source pollution.

Sovell, L.A., B. Vondracek, J.A. Frost and K.G. Mumford. 2000. “Impacts of Rotational Grazing and Riparian Buffers on Physiochemical and Biological Characteristics of Southeastern Minnesota, USA, Streams.” *Environmental Management* 26(6): 629-641. This report found that the percentage of fine particulate matter, exposed stream bank soil, and turbidity were significantly higher in continuously grazed sites than in those where managed grazing was implemented. They found fecal coliform bacteria levels to be consistently higher in waters adjacent to continuously grazed sites than rotationally grazed ones. Another study conducted in

SE MN found nitrate concentrations to be below EPA limits for all surface waters adjacent to both rotationally and continuously grazed sites.

Stout, W. L., R. R. Schnabel, W. E. Priddy, and G. F. Elwinger. 1997. "Nitrate Leaching from Cattle Urine and Feces in Northeast USA." *Soil Science Society of America* 61: 1787-1794. A study in Pennsylvania on rotationally grazed orchardgrass pastures measured nitrate leaching losses from soil during spring, summer and fall. Applied urine and fecal samples to pastures at sites monitored by in-ground lysimeters showed that an average of 18-31 percent of the applied urine N was lost to groundwater under the pastures.

Stout, W. L., S. L. Fales, L. D. Muller, R. R. Schnabel and S. R. Weaver. 2000. "Water quality implications of nitrate leaching from intensively grazed pasture swards in the northeast US." *Agriculture, Ecosystems & Environment* 77(3): 203-210. Nitrate leaching from six types grass and grass-legume pastures used for managed grazing in Pennsylvania was measured. Nitrate leaching losses were lower on grass and legume pastures than on grass pastures with added N fertilizer during a normal rainfall year. During the second year of the study drought conditions and a different grazing schedule were thought to have caused greater nitrate leaching from the grass-legume pastures than the previous year, comparable with or greater than the nitrate losses measured from the grass pastures with added N.

Trimble, S. W. and A. C. Mendel. 1995. "The cow as a geomorphic agent—a critical review." *Geomorphology* 13:233-253. This study found that livestock grazing of waterways can decrease water quality by causing erosion and sediment loss into the streams.

USDA ARS 2008. Revised Universal Soil Loss Equation, Version 2. Retrieved 9/15/08. (http://fargo.nserl.purdue.edu/rusle2_dataweb/)
RUSLE2 is a computer model containing both empirical and process-based science in a Windows environment that predicts rill and interrill erosion by rainfall and runoff. The USDA-Agricultural Research Service (ARS) is the lead agency for developing the RUSLE2 model. The ARS, through university and private contractors, is responsible for developing the science in the model and the model interface. RUSLE2 was developed primarily to guide conservation planning, inventory erosion rates and estimate sediment delivery. Values computed by RUSLE2 are supported by accepted scientific knowledge and technical judgment, are consistent with sound principles of conservation planning, and are used to make conservation plans.

UW-Discovery Farms Program. 2005. *Heisner Family Dairy – University of Wisconsin Discovery Farms Program Update.* Retrieved 7/31/08 (http://www.uwdiscoveryfarms.org/newpubs/newsletters/dataandfindings/heisnersummary.pdf)
Installation of surface water and in-stream monitors on a rotationally grazed organic family farming operation near Mineral Point, Wisconsin allowed the Discovery Farm researchers to collect runoff water, nutrient and sediment data year round. Preliminary results from the first 10 months of collection were reported, showing 98 percent of field runoff occurred when the ground was frozen and 52.4 lb/ac of sediment was lost from the cropland. Tolerable soil loss for this soil type is 8,000 lbs/ac/year.

Vetrano, D. 2008. “Driftless Waters.” Presented at UW-Madison Farm and Industry Short Course, Pasture-based Dairy/Livestock Business Seminar. February 28, Madison, Wisconsin. Southwest Wisconsin fisheries biologist David Vetrano with the Wisconsin Department of Natural Resources has worked with 1,500 miles of streams and rivers for over 20 years. He reports that 85 percent of sediment in the waterways of the region is due to streambank erosion. Managed grazing along these primary based streams opens the canopy to needed sunlight and fosters lush vegetation along the streambank to retain the soil. Vetrano states, “In well managed grazing systems, soil erosion, manure, pesticide and herbicide runoff is reduced to almost zero.”

3. Do managed grazing farms foster wildlife?

Holechek, J.L., R. Valdez, S. D. Schemnitz, R. D. Pieper, and C. A. Davis. 1982. “Manipulation of Grazing to Improve or Maintain Wildlife Habitat.” *Wildlife Society Bulletin* 10(3):204-210. Rotationally grazed fields generally provided greater amounts of nutritious forage in addition to minimizing wild ungulate contact with grazing cattle. The researchers found that it seems that as far as wildlife is concerned, the grazing strategy can be tailored to suit the type of habitat required for the desired species.

Ignatiuk, J.B. and D.C. Duncan. 2001. “Nest Success of Ducks on Rotational and Season-Long Grazing Systems in Saskatchewan.” *Wildlife Society Bulletin* 29(1):211-217. Ignatiuk and Duncan found no statistically significant differences in nest success between rotationally grazed and continuously grazed pastures although nest success was greater for rotationally grazed pastures during the second year of this trial.

Koper, N. and F. Schimiegelow. 2006. “Effects of Habitat Management for Ducks on Target and Nontarget Species.” *Journal of Wildlife Management* 70(3):823-834. This research showed that the density and richness of ducks, songbirds and shorebirds did not have a consistent response to different habitat characteristics. The research also suggests that in dry mixed-grass prairie, deferring cattle grazing is likely to increase densities of only Lesser Scaup but that grazing, in general, can be used by managers to create a heterogeneous habitat that supports many species.

Paine, L. K., G. A. Bartelt, D.J. Undersander, and S.A. Temple. 1995. “Agricultural Practices for the Birds.” *The Passenger Pigeon* 57(2):77-87. As part of a joint project between the WI DNR, Bureau of Wildlife Management and UW-School of Natural Resources, the Agriculture Ecosystems Project was undertaken to determine how agricultural land could simultaneously be wildlife habitat. Among other projects, livestock rotational grazing systems were evaluated as potential grassland bird nesting habitat. The authors reported that rotationally grazed farms generally contain greater acreage of suitable habitat for grassland birds than do conventionally managed confinement-based farms.

Renfrew, R.B. and C.A. Ribic. 2001. “Grassland birds associated with agricultural riparian practices in southwestern Wisconsin.” *Journal of Range Management* 54:546-552. This study compared the grassland bird community in riparian areas in Wisconsin that were rotationally grazed versus two common land use practices—continuously grazed and row crop fields with ungrazed buffer strips. Bird species richness, species dominance, and density did not differ among the land types. However, both continuous and rotational grazing supported grassland bird species of management concern where they rarely were found on buffer strips. Buffer strips may be unsuitable for management concerned species due to dense, tall vegetation, potential for flooding, steep slopes, location, limited width, etc.

Temple, S. A., B. M. Fevold, L. K. Paine, D. J. Undersander, and D.W. Sample. 1999. "Nesting birds and grazing cattle: accommodating both on Midwestern pastures." *Studies in Avian Biology* 19:196-202. Grassland bird nest success was compared among rotationally grazed, continuously grazed and ungrazed grasslands (refuge areas) in southwest Wisconsin. Diversity, density, nest success and productivity were highest in the refuge areas, while rotationally grazed pastures had intermediate diversity and density but the lowest nest success and productivity. The authors recommended rotationally grazed pastures and refuge areas together for greater avian productivity than either kind of grazed pastures alone or frequently mowed hayfields.

4. Do managed grazing farms sequester carbon?

Allard, V., J. F. Soussana, R. Falcimagne, P. Berbigier, J.M. Bonnefond, E. Ceschia, P. D'hour, C. Hénault, P. Laville, C. Martin, and C. Pinarès-Patino. 2007. "The role of grazing management for the net biome productivity and greenhouse gas budget (CO2, N2O and CH4) of semi-natural grassland." *Agriculture, Ecosystems, and Environment*. 121:47-58. A three-year study in France looking at gas fluxes exchanged with the atmosphere in upland semi-natural grassland, which were divided into two paddocks that were continuously grazed. Researchers compared the annual C and greenhouse gas budgets and both paddocks were (and European temperate grasslands in general are) net sinks for atmospheric CO2.

Amundson R. 2001. "The carbon budget in soils." *Annual Review of Earth and Planetary Sciences* 29:535–562. In this review, Amundson focused on the global-scale aspects of soil C and its dynamics. He stated that there is not, as yet, enough information to predict how the size and residence time of different fractions of SOC vary with climate. However, there are abundant data on the variation of total SOC with climate. Topics include the amount of C stored globally in the soil reservoir, the factors and processes controlling its distribution and the tools and data needed to quantify its dynamics.

Baer, S.G., C.W. Rice, and J.M. Blair. 2000. "Assessment of soil quality in fields with short and long term enrollment in the CRP." *Journal of Soil and Water Conservation* 55(2):142-146. Surface (2 to 4 in) soil quality was examined from fields representing short and long term enrollment in the Conservation Reserve Program (CRP). Total carbon (C) and nitrogen (N) amounts were similar in soil with recent and long term enrollment in the CRP and were lower than a native prairie field. Active pools of C and N, however, increased through the CRP. Soil with long term establishment of native grasses in the CRP exhibited 141 percent and 93 percent greater microbial biomass C and N, respectively, than soil recently enrolled in the CRP.

Bellamy P.H., P.J. Loveland, R.I. Brandley, R.M. Lark and G.J.D. Kirk. 2005. "Carbon losses from all soils across England and Wales 1978-2003." *Nature* 437:245-248. Data from the National Soil Inventory of England and Wales was used to compare soil carbon contents over several decades for arable and rotational grasslands, managed permanent grasslands and nonagricultural sites such as bogs, rough grazing and woodlands. The authors reported an overall loss of soil carbon at a mean rate of 0.6 percent per year between 1978 and 2003. All but 8 percent of the over 5,000 sites sampled showed soil organic carbon losses.

Brye, K.R., S.T. Gower, J.M. Norman, and L.G. Bundy. 2002. “Carbon budgets for a prairie and agroecosystems: effects of land use and interannual variability.” *Ecological Applications* 12(4):962-979. Pastures removed from treatment can be significant sink in the short term but this may be temporary—infiltration rates (bulk density and texture) can affect carbon sequestration

Conant, R. T., J. Six, and K. Paustian. 2003. See listing under 1. Healthy soils

Cox, P M., R.A. Betts, C.D. Jones, S.A. Spall, and I.J. Totterdell. 2000. “Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model.” *Nature* 408: 184-187. Increased carbon dioxide in the atmosphere leads to a positive feedback loop in which heat is trapped in the atmosphere, increasing soil respiration rates which in turn increases carbon losses from the soil into the atmosphere.

Jackson, R. D. and J. Stier. 2008. “Restored cool-season grasslands losing soil C irrespective of management.” *Global Change Biology* (submitted). A study at the University of Wisconsin Madison found that the net ecosystem carbon balance was greater for rotationally grazed pastures when compared to continuously grazed or hayed pastures during the trial. However, all of the cool-season grass pastures studied yielded a net loss of carbon over the three years of data collection.

Kucharik, C.J., J.A. Roth and R.T. Nabielski. 2003. “Statistical assessment of a paired-site approach for verification of carbon and nitrogen sequestration on Wisconsin Conservation Reserve Program land.” *Journal of Soil and Water Conservation*, 58(1): 58-67. The threat of global climate change has provoked policy-makers to consider plausible strategies to slow the accumulation of greenhouse gases—especially carbon dioxide (CO_2)—in the atmosphere. The study showed that silt loam soil types in southern Wisconsin possessed a high degree of spatial variability in C and N storage (CVs > 20 percent). Greater numbers of paired sites need to be identified and sampled to achieve good statistical power to verify that the CRP is contributing to C and N sequestration.

Lal, R. 2006. “Carbon dynamics in agricultural soils.” Pp. 127–147 *Climate change and managed ecosystems* edited by in J.S. Bhatti et al. Boca Raton, FL: CRC Press. In this chapter, Lal focused on the ability of soil to moderate climate, based on its influence on the global C cycle. He discussed the interaction between soil and atmospheric carbon pools, primarily referring to agricultural soil C which is subject to intensive human management for food, animal feed, fuel and fiber production. Lal concludes that sequestering C in agricultural soils is an important strategy to reduce net loss of C to the atmosphere. Methods such as restoring degraded soils, using conservation tillage and managing erosion will provide agronomic and water quality benefits as well.

Potter, K.N., H.A.Torbert, H.B. Johnson, and C.R. Tischler. 1999. “Carbon storage after long-term grass establishment on degraded soils.” *Soil Science* 164:718-725. This study sought to determine the amount of soil organic carbon (SOC) degraded by agricultural practices and the rate of carbon sequestration in soils after restoration of grass for various periods of time. The SOC contents of previously cultivated clay soils in central Texas that were returned to grass 6, 26, and 60 years ago were compared with those of soils in continuous agriculture for more than 100 years and with those of prairie soils that have never been tilled. Surface (0 to 5 cm) SOC concentration ranged from 4.44 to 5.95 percent in the prairie to 1.53 to 1.88 percent in the agricultural sites. Carbon concentration in restored grasslands was generally intermediate to that reported for the native prairie and agricultural sites. The SOC mass in the surface 120 cm of the agricultural soils was 25 to 43 percent less than that of native prairie sites. After the establishment of grasses, SOC mass in the grass sites was greater than at the agricultural sites.

Reeder, J. D. and G. E. Schuman. 2002. "Influence of livestock grazing on C sequestration in semi-arid and mixed-grass and short-grass rangelands." *Environmental Pollution* 116: 457-463. This study evaluated the effects of livestock grazing on C content of the plant-soil system of a mixed-grass prairie (grazed 12 years), and a short-grass steppe (grazed 56 years). Significantly higher soil C (0-30cm) was measured in grazed pastures compared to non-grazed exclosures. The data indicated that higher soil C with grazing was in part the result of more rapid annual shoot turnover, and redistribution of C within the plant-soil system as a result of changes in plant species composition.

Reeder, J. D., G. E. Schuman, and R.A. Bowman. 1998. "Soil C and N changes on conservation reserve program lands in the Central Great Plains." *Soil and Tillage Research* 47:339-349. This research study looked at quantifying changes in soil C and N of marginal croplands seeded to grass, and of native rangeland plowed and cropped to wheat-fallow. This comparison study found that tillage accounted for 40-60 percent of the decrease in surface soil C and N in long-tem cultivated fields, whereas in the short-term cultivated fields tillage may have accounted for 60-75 percent of the decrease in C, and 30-60 percent of the decrease in N. Further research is needed to evaluate C and N in the entire soil solum (i.e. solum = altered layers of soil above the parent material), rather than in just the surface soil.

Schipper, L.A., W.T. Baisden, R.L. Parfitt, C. Ross, J.J. Claydon, and G. Arnold. 2007. "Large losses of soil C and N from soil profiles under pasture in New Zealand during the past 20 years." *Global Change Biology* 13:1138-1144. The authors sampled 31 whole soil profiles in New Zealand pastures for which there was data from between 17 and 30 years previously. They compared soil carbon and nitrogen and found significant losses of both since the original sampling. Carbon losses averaged 2.1 kg/m^2 from the profiles, an estimated 106gC/m^2/year, assuming a continuous linear decline. It was suggested that leaching and erosion alone could not account for these losses and that respiration losses exceeding photosynthetic inputs might account for these changes in the soil profile.

5. Does managed grazing conserve resources?

Kriegl, T. October 2005. *Dairy Grazing Farms Financial Summary: Regional/Multi-State Interpretation of Small Farm Data*. Madison, WI: UW-Madison Center for Dairy Profitability. This report found that on Wisconsin dairy farms over a 10-year time frame, graziers had a $0.51 lower total cost per hundredweight than confinement operators. Graziers' fertilizer and lime costs were $0.05 per hundredweight lower than those on confinement dairy farms, and gasoline, fuel and oil expenses were $0.06 lower for grazing dairy farms than confinement farms.

Kriegl, T., 2008. Unpublished. *A limited comparison of energy costs in Wisconsin Dairy Systems.* Madison, WI: UW-Madison Center for Dairy Profitability. Kriegl used actual farm financial data to analyze energy costs on graziers, organic dairy farmers and conventional dairy farmers. In a comparison of the four easily measured energy cost categories per hundredweight of milk equivalent sold (chemicals, fertilizers and lime, gas and utilities), graziers showed the most advantage. However, these differences may be nullified by differences in the proportion of feed rasied and custom work hired in the various systems. Kriegl states, "Comparing the relative energy efficiency of different Wisconsin dairy systems is challenging. Anything short of a life cycle analysis may omit significant energy costs, such as the energy used to produce purchased grain."

Munsch, Jim. 2008. Wisconsin beef grazier. Personal communication. April 12. Coon Valley, Wisconsin. Munsch cited a National Geographic article that reported that it took 283 gallons of crude oil used in all facets of production of a finished 1250# steer or about 1 ¾ gallons per pound of sellable meat. The input of refined petroleum products used on his beef grazing farm, plus an inferred input equivalent of electricity used, was about ¾ pint. This is driven by no fertilizer derived from petroleum products, low machinery usage because they don't raise row crops, not moving cattle around by truck etc.

Paine. L. 1999. *Managed Intensive Grazing: Promises and Realities.* UW-Extension Columbia County. Retrieved 6/5/08. (http://www.uwex.edu/ces/cty/columbia/ag/grazing/articles/grazing6.pdf) This case study of the Breneman dairy farm in Wisconsin shows the effects on one farm of converting to managed grazing in 1992. Profitability improved and costs decreased since the switch. The Brenemans went from a full set of equipment, including seven tractors, to a fleet including one tractor, a mower and a manure spreader. Fuel use has gone from 8000 gallons per year before grazing to 3200 gallons per year (including fuel used for hired custom work on the farm). The ratio of milk production to fuel usage has gone from 16.5 gallons of milk per gallon of fuel in 1992 to 46 gallons of milk to each gallon of fuel in 1999.

Conclusions

Boody, G., B. Vondracek, D.A. Andow, M. Krinke, J. Westra, J. Zimmerman, and P. Welle. 2005. "Multifunctional Agriculture in the United States." *BioScience* 55(1): 27-38. The researchers evaluated possible changes to current farming practices in two Minnesota watersheds to provide insight into how farm policy might affect environmental, social, and economic outcomes. Watershed residents helped develop four scenarios to evaluate alternative future trends in agricultural management and to project potential economic and environmental outcomes. They found that environmental and economic benefits could be attained through changes in agricultural land management without increasing public costs.

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