Renewable Agriculture and Food Systems: 31(1); 2–8 doi:10.1017/S1742170515000058

The role of portable electric fencing in biodiversity-friendly pasture management

Nickele B. Morgan

Miami University, Oxford, Ohio, USA
Corresponding author: morgannb@miamioh.edu; nickelebmorgan@gmail.com

Accepted 6 February 2015; First published online 8 April 2015 **Commentary**

Abstract

World population is growing, and with it, the demand for food. In order to feed the world and attempt to slow the biodiversity crisis on the planet, farming practices must be altered to preserve species richness and ecological health. The fertile soil found in grassland biomes throughout the world provides a base for rich microorganism biodiversity, carbon sequestration, as well as water and nutrient cycling. Diverse biological communities are found in both natural and semi-natural grasslands; habitat destruction as a result of agricultural practices is a threat to biodiversity in these regions. While critics often blame modernized farming practices for agricultural pollution and habitat fragmentation, 21st century technology will likely be a means for updating farming practices to address both biodiversity conservation and enhanced efficiency for increased food demand. Recently developed portable electric fences, made of plastic netting and stainless steel, have made eco-agricultural practices, such as rotational grazing (RG) and multi-species pasture systems, easier and less expensive for farmers to put into practice than traditional electric fencing. Conflicting literature exists regarding whether or not RG systems outperform continuous grazing systems. Many studies suggest that more research is needed to observe the ecological benefits of RG on active farmland. Portable electric fences could be a valuable tool for completing additional research.

Key words: agroecology, biodiversity, multi-species pasture, pasture, rotational grazing

Introduction

The United Nations[1] expects the world's human population to rise to 9 billion by 2050—and each of these people needs to eat. Currently, agricultural use comprises up to 50% of the world's land and more will surely become subject to conversion[2]. Habitat fragmentation is a primary cause of biodiversity loss at the landscape level, often occurring in conjunction with agricultural use[3]. With more pressure on land resources due to increasing agricultural demand, it is likely that the planet's biodiversity will continue to suffer. Regions where population growth is expected to make the sharpest increases lie in designated biodiversity hotspots, or areas with large concentrations of ecologically threatened species[4,5]. This presents a concern for the preservation of nature and biodiversity in these regions. Without an agricultural system that maximizes productivity while supporting habitat for diverse wildlife, the biodiversity of the planet will continue to decline at an alarming rate[6]. Essentially, the planet is running out of land for food production and humans will be faced with the choice of preserving either food systems or wildlife biodiversity—unless we can choose both.

Farms, often comprised of acres of open fields, have the potential to play a key role in the preservation of grassland ecosystems. Grassland communities, spread across the globe, are increasingly threatened by human development, urban sprawl and even natural succession when farmland is abandoned[7]. Although some environmentalists may consider the semi-natural grassland found on farmland in conflict with native grassland species, preservation of agricultural land is crucial because the current state of biodiversity in these areas has evolved along with the human development of farmland[5,8]. Therefore, proper management of semi-natural pastures on working farms can play an active role in providing habitat to threatened grassland species[7,9].

Despite encompassing such a large portion of inhabitable land, farms (and the farmers who operate them) have been largely absent from the conversation regarding wildlife biodiversity conservation[2,10]. Yet, farmers and ranchers have the opportunity to affect biodiversity preservation, soil conservation and climate change more than any other group[11]. As global demand for agricultural products increases, farmers and environmentalists must collaborate for the benefit of the ecosystems upon which so many organisms rely. Farmers can contribute to the planet's biodiversity by adopting practices designed to preserve the species richness conserved within and surrounding their farmland[12,13].

This commentary explores the basis for portable electric-net fencing as a tool for the implementation of rotational grazing (RG) and multi-species pastures (MSPs) as wildlife-friendly pasture management systems. Utilizing systems like these on semi-natural grassland pastures can promote biodiversity conservation and ecosystem services while maintaining high levels of animal productivity. Despite literature on the topic as early as the mid-20th century[14], the adoption of RG and MSP are far from widespread. The hypothesis is that portable electric plastic net fencing for RG and MSP systems can allow modern pastoralists to assist in the protection of Earth's biodiversity resources.

Dynamics of Grassland Ecosystems within Agricultural Landscapes

Natural grassland ecosystems occur throughout the world and are home to many species[3,7,9]. In the wild, native grasses provide forage for herds of herbivores that move in dense groups across a large area, following desirable plant species throughout each plant's life cycle. This natural movement prevents overgrazing and allows grazed plant species to recover in the absence of their predators. Tall grasses provide shelter for ground-nesting birds that prefer habitats far from trees and buildings; it is also ideal habitat for arthropods and other invertebrates upon which these birds feast. There are instances, as with the cattle egret and domesticated cows, in which natural symbiotic relationships have developed among groups of domesticated herbivores and other grassland species. In general, pastureland research indicates that grazed pastures outperform non-grazed sites in overall species richness[15]. Fertile soil characterizes many grassland environments, and holds rich microorganism biodiversity. Soil microorganisms provide numerous benefits to grassland ecosystems, such as transforming nutrients, breaking down organic matter, pest destruction and building soil aggregation. Agricultural practices, such as tilling, overgrazing and pesticide application have each contributed to the decline of soil microorganisms in agricultural areas[16]. Grassland plants and soil also provide carbon sequestration as well as water and nutrient cycling. Across every region of the world, the biodiversity and ecosystem services provided by grasslands benefit farmers and ranchers as well as the general health of the planet.

Naturally occurring temperate grassland habitat has declined sharply at the hands of agriculture because the characteristics that grasslands possess make them desirable for the cultivation of food products by humans[3,7,17]. Most significant to the decline of wildlife biodiversity is the alteration of species composition and changes to natural patterns of disturbance. Often in cropland systems, wild species are removed and replaced with a single domestic species, sometimes referred to as monoculture. This change in habitat, along with changes to disturbance patterns, can result in local extinction and emigration of native fauna. Developments in nitrogen-based fertilizers led the way for increases in plant productivity, but often at the cost of overall plant-species biodiversity[6,18]. The introduction (both unintentional and intentional through cultivation) of non-native species has, in many cases, resulted in biodiversity losses. Unnatural grazing patterns facilitated by high livestock stocking rates has changed the species composition of grassland plants, necessitating supplemental sowing by ranchers of less diverse or non-native forages. Biodiversity is often used as a barometer for the overall health of an ecosystem, and so this decline would indicate a decrease in grassland health.

Despite all of this, it is worth noting that throughout human history, grassland habitats evolved with varying degrees of human use and often supported a wide range of species uniquely adapted to the semi-natural or agricultural grassland ecosystem[5]. Organisms such as ground-nesting birds, pollinating arthropods, rodents and raptors continue to thrive in grassland environments under agricultural cultivation. Research on farmland in Europe and North America demonstrates a degree of biodiversity increase that has followed the development and maintenance of pastureland[8,19,20]. Although this land has been altered from its natural state, semi-natural grasslands continue to support a wide variety of wildlife and provide essential ecosystem services. In addition to the threat to natural grasslands, increasing human development also threatens semi-natural grasslands and cultivated pastures, thus applying further stresses on grassland species. Additional baseline studies quantifying wildlife biodiversity on agricultural landscapes could benefit future scientific studies of these habitats.

Negative effects of industrial agriculture on grassland ecosystems

Farmers value the health of the land as a matter of their livelihood. However, farmers also value productivity as a result of their efforts. The use of agricultural technologies such as nitrogen-based fertilizers, mechanized implements suited for large fields of single crops and advanced pesticides and herbicides have meant that production per unit of land has increased dramatically in the last century. This has allowed farmers and ranchers to condense livestock into smaller parcels of land and rely on supplements of grain grown from massive single-crop fields to raise meat animals. Unfortunately, these developments toward agricultural simplification have not been beneficial to the surrounding ecosystem[21].

The application of chemical fertilizer changes the soil composition; runoff into local waterways creates a nutrient imbalance that can lead to eutrophication of waterways, which results in the overgrowth of plant-like organisms and oxygen depletion, creating 'dead zones'[17,22]. Additionally, converting natural grassland into cropland drastically and suddenly changes its characteristics as native vegetation is removed and soil is left vulnerable to erosion[6,17]. As a result, cropland is often rendered unfavorable to native fauna that either perish or migrate to a more favorable habitat, thus decreasing local biodiversity. Additionally, high livestock density with uncontrolled, continuous grazing causes the disturbance of plant life without adequate recovery time and produces an overabundance of animal waste[17]. All of these approaches have negatively affected grassland ecosystems and the effects could be alleviated with conversion to biodiversity-friendly pasture systems.

Poorly managed grazing patterns of domesticated ruminants in the late 19th, and much of the 20th centuries resulted in damage to grassland environments. Overgrazing put stress on native grass populations and allowed for the spread of invasive species, either through supplemental sowing by humans or natural means. Bare patches in grasslands due to overgrazing and trampling causes enhanced nutrient runoff, release of greenhouse gasses and unacceptable rates of soil erosion[5]. A reduction in forage height may leave a lack of desirable habitat for ground-nesting bird species and make them susceptible to increased predation. Low forage height can also make it more difficult for grassland plant species to recover, in contrast with forage that is allowed to recover over a period of time[14]. A high stocking rate on managed grassland can result in excessive trampling of nest sites for ground-nesting birds[23]. Although a variety of grazing techniques have allowed some degree of rebound for these ecosystems, an increase in demand for meat may result in the need for more intensively managed pasture and is sure to further stress these ecosystems to a point that is even more ecologically damaging. Further study of the effects of specific agricultural practices on local biodiversity would provide data to better inform interested farmers and conservationists.

Benefits of established pastures on grassland ecosystems

Despite some negative effects to biodiversity with the loss of native grassland, there is evidence that using semi-natural permanent pasture for livestock grazing can positively affect biodiversity. Grazing can have a positive effect on grassland preservation and overall biodiversity within the landscape by allowing field plants to flower and go to seed[5,9,24,25]. This supports biodiversity of native, self-seeding plants and reduces the need for artificial sowing, helping to preserve the most natural state of grassland possible. Permanent pasture preserves species richness to a higher degree than intensively managed livestock operations or monoculture crop fields cultivated to supplement the diet of livestock raised off-pasture, particularly in regard to arthropod species (grasshoppers, butterflies and Heteroptera) studied on active pastures[7,26,27]. A study completed in the plains of central Canada determined that pastures grazed throughout the grazing season may enhance biodiversity over pastures left ungrazed because the grazing behavior of animals creates microhabitats within the pastureland that would not otherwise exist[28]. Herbaceous vegetation in the grassland ecosystem contributes to carbon sequestration, primarily below ground, as grassland plants store a significant amount of carbon in extensive root systems and are not negatively affected by most grazing systems[11,17]. Permanent pasture systems allow the recovery of vegetation, stabilize the soil and do not disrupt the carbon stores in a significant way.

Tools for Pasture Management

Portable electric fences

Electrically charged fences have existed for more than 100 years in one form or another. Mentions of the technology occur in literature as early as 1870 and the first US patent was issued in 1886. Useful practical applications came during World War I and in the 1930s for agricultural uses. Electric fences have come a long way since then. Typical electric fences utilize permanent wood or metal posts with conducting wire wrapped around a plastic or ceramic insulator. Often, permanent electric fences are connected to a power source that ties into the electrical power grid. These fences are beneficial because they are less expensive and can be built to withstand less pressure than non-electric fencing.

A technology for temporary electric fencing developed in the 1990s consists of stainless steel wire woven into a plastic mesh grid that attaches to plastic step-in posts. These fences can be installed, taken down and moved within a matter of minutes. To preserve their portable nature, small solar or battery powered charging units were developed alongside the technology. These units are weatherproof and about the size of a briefcase. This technology is relatively inexpensive (<US$200 for 165′ of fence), and because of its portability, is well suited to rotational pasture systems.

RG and MSPs are among the most popular pasture management systems for the use of portable electric fences. Many farmers choose permanent fence for their property line and use portable electric fence to divide a large pasture into a small paddock as needed. Others, especially those just beginning to raise livestock, are able to rotate stock around a large sward without committing to the expense of permanently fencing an entire pasture. Additionally, subsistence farmers in rural areas or the developing world may take advantage of the solar nature of this fencing system when reliable electric power is not available.

Rotational grazing

RG is one strategy that helps to preserve the health and biodiversity of the grassland ecosystem. In RG, the pasture is separated into at least two, and sometimes up to 100, paddocks and livestock are systematically moved from one paddock to another, allowing the grazed paddock to rest for a sufficient period before being grazed again. Paddock division using permanent fences is often cost prohibitive for small and beginning farmers. Division into temporary paddocks can be accomplished using portable electric fencing with less resource input. Therefore, RG provides benefits to both the ecosystem and the farmer.

RG, when practiced responsibly, can serve as an avenue toward increasing the species richness and ecological health of a managed grassland. This stocking method can result in a 30% advantage in forage production, which could allow for greater carrying capacity of the pasture or greater animal performance[14,15]. Portable electric fencing allows paddocks to be configured in the most flexible manner possible with the least time commitment to the farmer, thus incorporating both efficiency and ease of use.

Species composition

Qualities of RG systems have been shown to positively contribute to increased species richness on the landscapes they occupy. Biodiversity increased when Mediterranean pastures contained grazing-excluded plots, a quality inherent in RG systems[29]. This was true of various species, including density and species richness of bumblebees and butterflies found on sheep pastures in Central France[30]. Two species of ground-nesting birds in Vermont experienced greater reproductive success within RG systems when rest time between grazing periods was extended[31]. When pastures were planted with a greater number of native species at an agricultural research facility in the loess hills region of Iowa, the USA, animal production, plant production, biodiversity and value from ecosystem services were increased[32]. These specific cases suggest that RG systems may benefit biodiversity on a larger scale and further study is warranted.

Wildlife habitat

Wildlife habitat improves when rotational stocking is practiced. Greater connectivity among microhabitats was observed due to seed dispersal by ruminants on RG systems in Bavaria[33]. RG results in decreased soil erosion and less pasture runoff than other forms of high- and medium-density stocking, the results of which contribute to an increase in the health of both the pasture and the surrounding ecosystem[23]. In riparian ecosystems in the USA, RG systems have been shown to positively affect aquatic habitats, resulting in larger substrate size and increased stability of stream banks, all of which have the potential to facilitate greater macro-invertebrate diversity[34]. RG systems have even been suggested to moderately reduce greenhouse gas emissions and increase carbon sequestration[35,36].

Multi-species pasture

As an add-on to the RG philosophy, an MSP system combines the movement of an RG system with multiple domestic species. Designed as a way to mimic symbiotic patterns in natural grasslands, animals are rotationally pastured so that one species is introduced to a paddock after another has been removed. This kind of stacked pasture, specifically when poultry follow ruminants, provides for numerous ecosystem and livestock benefits[37]. First, ruminants decrease forage height as they graze, allowing for ease of movement and foraging by the birds. Secondly, the dung left behind by grazing ruminants attracts insects and consequently their offspring in the form of grubs. Finally, in the process of foraging, the birds scratch through the dung, distributing it over the pasture for optimal absorption of nutrients into the soil and a decrease in the presence of parasites[38]. This method effectively ‘cleans’ the pasture following a grazing episode, increases the production value for a given sward and enhances, rather than harms, the ecological performance of the pasture. Additionally, different species may choose to graze on the specific plants, resulting in greater efficiency for a given pasture space if forages are selected specific to the species present. Diversity in pasture management systems provides benefits in both farm production quantities as well as off-farm factors that positively affect the sustainability of the surrounding ecology[39]. Portable electric fencing can make this type of management system easier on the farmer because the flexibility of a temporary paddock can allow the farmer to make decisions based on changing ecological conditions.

Criticism of RG Systems

The most controversial aspect of this system is a body of evidence that demonstrates little difference between animal performance and plant production in rotational and continuous grazing systems[28,40–42]. All but one of these studies, though, focuses on livestock productivity and/or productivity and biodiversity of forage grass, but not the complete species biodiversity of the pasture and surrounding area, including wildlife. A study in Manitoba, Canada investigated the richness and abundance of songbird species on rangeland and found no difference between the treatments of rotational and continuous grazing[28].

Many of the studies referenced in this paper conclude a need for additional study on the effect of pasture

https://doi.org/10.1017/S1742170515000058 Published online by Cambridge University Press

management systems on wildlife biodiversity. Some criticize highly controlled experiments as poor reflections on the complex nature of ecosystems found on active farmland[2,5,19,28,43,44]. Additionally, many of these studies were conducted on arid ecosystems and expansive ranges[25,41,42]. Considering the vast diversity in grassland climates and the fact that many extension offices are located in more humid temperate climates[23,45–48] and organizations advocating sustainable agriculture[39,47,48] continue to recommend RG and MSP systems, these methods are worth continuing to study as a means to foster biodiversity on active pastures.

Conclusion

Portable electric fencing provides an easy, cost-effective way for farmers to graze single- or multi-species livestock rotationally on permanent pasture. Unfortunately, livestock grazers have not universally adopted this potentially effective system. This could be due to the significant commitment of time and money required for permanent fencing systems, or to contradicting scientific findings regarding the benefits of RG systems on animal productivity. Advances in portable electric fencing have the ability to make adopting RG and MSP systems more attractive to farmers with limited acreage and those entering the livestock business. A growing body of research has suggested RG systems as a way to promote pasture health[5,23,37,38,44], increase species richness within the pasture and throughout the surrounding ecosystem[5,29–32,49], and provide numerous ecosystem services to benefit humans and wildlife[5,32–36]. Additional study of active farmland in a variety of climates is necessary if there is to be increased adoption of RG and MSP systems worldwide, and portable electric fencing is one tool to aid in such research.

Though farmland has not historically been considered a landscape to be preserved for ecological conservation, farmers and conservationists are going to have to find common ground as the amount of land available for each purpose continues to decline. Increasing world populations, and consequently increasing demands on food systems, will require farmers to consider their ecological impact if global biodiversity loss is to be slowed. Popular or not, farmland will become a valuable commodity for conservation; technologies like portable electric fencing will make it easier for more farmers to adopt biodiversity-friendly practices.

Most significant throughout the course of this topical review was the lack of peer-reviewed study directly related to the ecological benefits of RG and MSP conducted in an active and dynamic agricultural setting. If conservationists and agriculturalists alike are to take biodiversity preservation on farmland seriously and invest time and resources into practices that can promote species richness, dedicated and further study of the complex nature of this topic is necessary. The introduction of flexible technologies such as portable electric fencing is likely to make both the practice and research of RG and MSP systems more feasible.

Acknowledgements. Miami University, Oxford, Ohio, USA and the Global Field Program, a graduate program furthering the aims of global conservation and education worldwide, supported this work. The author recognizes assistance from Miami University instructors and colleagues as well as the helpful comments from two anonymous reviewers.

References

1 Department of Economic and Social Affairs, Population Division. 2009. World Population to Exceed 9 billion by 2050: Developing Countries to Add 2.3 billion Inhabitants with 1.1 billion Aged Over 60 and 1.2 billion of Working Age [press release]. United Nations, New York.
2 Scherr, S.J. and McNeely, J.A. 2008. Biodiversity conservation and agricultural sustainability: Towards a new paradigm of ecoagriculture landscapes. Philosophical Transactions of the Royal Society 363:477–494.
3 Primack, R. 2010. Habitat destruction, fragmentation, degradation, and global change. In Essentials of Conservation Biology. 5th ed. Sinauer Associates, Inc., Massachusetts, USA. p. 174–201.
4 Meyers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., and Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858. doi: 10.1038/35002501.
5 Wrage, N., Strodthoff, J., Cuchillo, H.M., Isselstein, J., and Kayser, M. 2011. Phytodiversity of temperate permanent grasslands: Ecosystem services for agriculture and livestock management for diversity conservation. Biodiversity Conservation 20:3317–3339.
6 Aguiar, M.R. 2005. Biodiversity in grasslands: current changes and future scenarios. In S.G. Reynolds and J. Frame (eds). Grasslands: Developments, Opportunities, Perspectives. Science Publishers, Inc., Enfield, New Hampshire. p. 261–280.
7 Watkinson, A.R. and Ormerod, S.J. 2001. Grasslands, grazing and biodiversity: Editors' introduction. Journal of Applied Ecology 38:233–237.
8 Kumm, K. 2003. Sustainable management of Swedish seminatural pastures with high species diversity. Journal for Nature Conservation 11:117–125.
9 Nilsson, F.O.L. 2009. Biodiversity on Swedish pastures: estimating biodiversity production costs. Journal of Environmental Management 90:131–143.
10 Berry, W. 2009. Bringing it to the Table: On Farming and Food. Counterpoint Press, Berkeley, California, USA.
11 Sherr, S.J. 2010. The carbon ranch: using food and stewardship to build soil and fight climate change. Presentation at the Quivira Coalition: 9th Annual Conference, New Mexico. http://youtube.com/watch?v=dF7A0JatBVY& feature=share&list=PL126669E18FC1898A (accessed March 12, 2015).

12 Jackson, L.E., Pascual, U., and Hodgkin, T. 2007. Utilizing and conserving agribiodiversity in agricultural landscapes. Agriculture, Ecosystems, and Environment 121:196–201.

13 Smeding, F.W. and Joenje, W. 1999. Farm-nature plan: Landscape ecology based farm planning. Landscape and Urban Planning 46:109–115.

14 Voisin, A. 1957. Grazing management in northern France. Journal of the British Grassland Society 12(3): 150–154.

15 Sollenberger, L.E., Agouridis, C.T., Vanzant, E.S., Franzluebbers, A.J., and Owens, L.B. 2012. Prescribed grazing on pasturelands. In Conservation Outcomes from Pastureland and Hayland Practices: Assessment, Recommendations, and Knowledge Gaps. Allen Press, Lawrence, KS. p. 111–204.

16 Scherr, S.J. and McNeely, J.A. 2001. Common ground, common future: using ecoagriculture to raise food production and conserve wild biodiversity. Paper presented to the Symposium on Managing Biodiversity in Agricultural Ecosystems; November 8–10.

17 White, R.P., Murray, S., and Rohweder, M. 2000. Pilot Analysis of Global Ecosystems: Grassland Ecosystems. World Resources Institute, Washington, DC.

18 Hopkins, A. and Wilkins, R.J. 2006. Temperate grassland: Key developments in the last century and future perspectives. Journal of Agricultural Science 144: 503–523.

19 Budd, B. and Thorpe, J. 2009. Benefits of managed grazing: A manager's perspective. Society for Range Management 31(5):11–14.

20 Tryjanowski, P., Hartel, T., Baldi, A., Szymanski, P., Tobolka, M., Herzon, I., Golawski, A., Konvicka, M., Hromada, M., Jerzak, L., Kujawa, K., Lenda, M., Orlowski, G., Panek, M., Skorka, P., Sparks, T.H., Tworek, S., Wuczynski, A., and Zmihorski, M. 2011. Conservation of farmland birds faces different challenges in Western and Central-Eastern Europe. Acta Ornithologica 46(1):1–12.

21 Lemaire, G., Franzluebbers, A., de Faccio Carvalho, P.C., and Dedieu, B. 2014. Integrated crop-livestock systems: Strategies to achieve synergy between agricultural production and environmental quality. Agriculture, Ecosystems, and Environment 190:4–8.

22 Kremen, C., Iles, A., and Bacon, C. 2012. Diversified farming systems: An agroecological, systems-based alternative to modern industrial agriculture. Ecology and Society 17(4):44. http://dx.doi.org/10.5751/ES-05103-170444 (accessed March 12, 2015)

23 Undersander, D., Temple, S., Bartlet, J., Sampel, D., and Paine, L. 2000. Grassland Birds: Fostering Habitats using Rotational Grazing. University of Wisconsin Extension, Madison, Wisconsin, USA.

24 Ignatiuk, J.B. and Duncan, D.C. 2001. Nest success of ducks on rotational and season-long grazing systems in Saskatchewan. Wildlife Society Bulletin 29(1):211–217.

25 O'Connor, T.G., Kuyler, P., Kirkman, K.P., and Corcoran, B. 2010. Which grazing management practices are most appropriate for maintaining biodiversity in South African grassland? African Journal of Range and Forage Science 27(2):67–76.

26 Wallis De Vries, M.F., Parkinson, A.E., Dulphy, J.P., Sayer, M., and Diana, E. 2007. Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. Grass and Forage Science 62:185–197.

27 Di Giulio, M., Holderegger, R., and Tobias, S. 2009. Effects of habitat and landscape fragmentation on humans and biodiversity in densely populated landscapes. Journal of Environmental Management 90: 2959–2968.

28 Ranellucci, C.L., Koper, N., and Henderson, D.C. 2012. Twice-over rotational grazing and its impacts on grassland songbird abundance and habitat structure. Rangeland Ecology Management 65:109–118.

29 Bugalho, M.N., Lecomte, X., Goncalves, M., Caldiera, M.C., and Branco, M. 2011. Establishing grazing and grazing-excluded patches increases plant and invertebrate diversity in Mediterranean oak woodland. Forest Ecology and Management 261:2133–2139.

30 Scohier, A., Ouin, A., Farruggia, A., and Dumont, B. 2013. Is there a benefit to excluding sheep from pastures at flowering peak on flower-visiting insect diversity? Journal of Insect Conservation 17:287–294. doi: 10.1007/s10841-012-9509-9.

31 Perlut, N.G. and Strong, A.M. 2011. Grassland birds and rotational-grazing in the northeast: Breeding ecology, survival and management opportunities. The Journal of Wildlife Management 75(3):715–720. doi: 10.1002/jwmg.81.

32 Isbell, F.I. and Wilsey, B.J. 2011. Increasing native, but not exotic, biodiversity increases aboveground productivity in ungrazed and intensely grazed grasslands. Oecologica 165:771–781.

33 Rico, Y., Boehmer, H.J., and Wagner, H.H. 2012. Determinants of actual functional connectivity for calcareous grassland communities linked by rotational sheep grazing. Landscape Ecology 27:199–209. doi: 10.1007/s10980-011-9648-5.

34 Raymond, K.L. and Vondracek, B. 2011. Relationships among rotational and conventional grazing systems, stream channels, and macroinvertebrates. Hydrobiologica 669:105–117. doi: 10.1007/s10750-011-0653-0.

35 Bosch, D.J., Stephenson, K., Groover, G., and Hutchins, B. 2008. Farm returns to carbon credit creation with intensive rotational grazing. Journal of Soil and Water Conservation 63(2):91–98.

36 Manning, R. 2009. The amazing benefits of grass-fed meat. Mother Earth News 223:48–56.

37 Baumann, R. 2009. Multi-species pasture stacking. Organic Broadcaster: Midwest organic and sustainable education service 17(6). Retrieved from http://www.mosesorganic.org/attachments/broadcaster/livestock17.6pasturestacking.html (accessed February 15, 2013).

38 Thomas, H.S. 2010. Multi-species grazing. Beef Magazine August: 30–31.

39 Vandermeer, J., van Noordwijk, M., Anderson, J., Ong, C., and Perfecto, I. 1998. Global change and multi-species agroecosystems: Concepts and issues. Agriculture, Ecosystems and Environment 67:1–22.

40 Bailey, D.W. and Brown, J.R. 2011. Rotational grazing systems and livestock grazing behavior in shrub-

dominated semi-arid and arid rangelands. Rangeland Ecology 64:1–9.

41 Briske, D.D., Derner, J.D., Brown, J.R., Fuhlendorf, S.D., Teague, W.R., Havstad, K.M., Gillen, R.L., Ash, A.J., and Willms, W.D. 2008. Rotational grazing on rangelands: Reconciliation of perception and experimental evidence. Rangeland Ecology Management 61:3–17.

42 Dorrough, J., McIntyre, S., Brown, G., Stol, J., Barrett, G., and Brown, A. 2012. Differential responses of plants, reptiles and birds to grazing management, fertilizer and tree clearing. Austral Ecology 37:569–582.

43 Briske, D.D., Sayre, N.F., Huntsinger, L., Fernandez-Giminez, M., Budd, B., and Derner, J.D. 2011. Origin, persistence and resolution of the rotational grazing debate: Integrating human dimensions into rangeland work. Rangeland Ecology and Management 64:325–334.

44 Teague, W.R., Dowhower, S.L., Baker, S.A., Ansley, R.J., Kreuter, U.P., Conover, D.M., and Waggoner, J.A. 2010. Soil and herbaceous plant responses to summer patch burns under continuous and rotational grazing. Agriculture, Ecosystems, and Environment 137:113–123.

45 Smith, R., Lacefield, G., Burris, R., Ditsch, D., Coleman, B., Lehmkuhler, J., and Henning, J. 2011. Rotational Grazing (ID-143). University of Kentucky Cooperative Extension Service, Lexington, Kentucky, USA.

46 Undersander, D., Albert, B., Cosgrove, D., Johnson, D., and Peterson, P. 2005. Pastures for Profit: A Guide to Rotational Grazing (A3529). University of Wisconsin Extension, Madison, Wisconsin, USA.

47 Russell, J. and Dunn, M. 2011. Cattle grazing for healthier pastures [video file]. Leopold Center for sustainable agriculture. November. Retrieved from http://www.leopold.iastate.edu/news/on-the-ground/cattle-grazing-healthier-pastures (accessed March 12, 2015).

48 Sustainable Agriculture Research and Education. n.d. North central region SARE: advancing the frontier of management-intensive grazing. Retrieved from http://www.sare.org/Learning-Center/SARE-Program-Materials/North-Central-SARE-Program-Materials/NCR-SARE-Brief-Sheets-by-Topic/Management-Intensive-Grazing (accessed March 15, 2015).

49 Cerezo, A., Conde, M.C., and Poggio, S.L. 2011. Pasture area and landscape heterogeneity are key determinants of bird diversity in intensively managed farmland. Biodiversity Conservation 20:2649–2667.