Expanding horizons of farming with grass

Jean L. Steiner
Director
USDA ARS Grazinglands Research Laboratory
El Reno, Oklahoma

Alan J. Franzluebbers
Soil Ecologist
USDA ARS, J. Phil Campbell Sr., Natural Resource Conservation Center
Watkinsville, Georgia

Constance L. Neely
Vice President
Heifer International
Little Rock, Arkansas

Today's agriculture and food systems are deeply rooted from the era of cheap energy, an assumption of static climate, and the ability of entities to "externalize" environmental and social costs. Recent collapse of global financial systems has led to more openness to discuss rights and responsibilities of individuals and corporations as well as the role of government in economic systems. With growing world population, increased demand on water supplies, increased vulnerability to climate extremes, and low global food stocks, it is time to rethink how to provide secure and resilient food systems and enhanced economic opportunities in rural communities. While the pressures are diverse and great, times of change present opportunities to reassess options and choose new directions. Participants in the *Farming with Grass* conference, held in Oklahoma City, Oklahoma, from October 20 to 22, 2008, set out a vision for agriculture based on sound ecological principles with economic accounting for environmental services and costs. Four grand challenges of agriculture—achieving sustainable bioenergy production, adapting to and mitigating global climate change, improving water quality and availability, and ensuring food security—are interrelated and must be addressed systematically, so that today's solutions do not create tomorrow's problems. Past policies have favored a few commodity crops and have disfavored producers of grasses and other perennial crops. Perennial species, incorporated into diverse agricultural systems, have great potential to enhance resilience against uncertain climate and market conditions. Additionally, by developing on-farm and rural enterprises, agriculture can help revitalize communities and provide healthy, local food options. Addressing these challenges will require a fundamental rethinking of agricultural policy and practice to maintain or increase production, mitigate past environmental damage, protect biological diversity of domesticated and wild species, reduce dependence on fossil fuel, provide healthier foods (particularly to children and the poor), and increase opportunities in rural areas.

Achieving sustainable mixed agricultural landscapes in grassland environments is a broad, perhaps audacious goal, yet the need for change in current agricultural systems is undeniable. As society faces the end of cheap energy and a growing awareness of climate change linked to rising concentrations of greenhouse gases in Earth's atmosphere, additional pressures will come from expanding human population and increasing competition for scarce water supplies. Change in, and uncertainty about, such key drivers of ecological and economic systems requires a fundamental reassessment of agricultural and food systems. Lovins et al. (1999) proposed "natural capitalism" as a business strategy to radically increase productive use of natural resources, solve environmental problems, and provide profit to business. Agriculture, based on primary productivity from sunlight capture through the photosynthetic process, is an excellent sector to explore the potentials of natural capitalism strategies.

Contributors to this book have highlighted significant pressures that face today's agriculture, which must address serious challenges of providing a safe, secure food system and thriving livelihoods for rural areas while addressing issues related to energy sufficiency, global climate, fresh water supply for human consumption and the multitude of other sectors relying on high quality water. Cheap energy (e.g., for cultural operations, fertilization, pest control, equipment, and multitude of other uses) was a key driver for the development of industrial agriculture that prevails today, but we cannot assume energy will be cheap in the future. Instead of being a significant consumer of energy, agriculture is looked to as a future source of bioenergy, at least during the transition from fossil fuels to alternative energy systems. Political and economic principles that have allowed industries, including agriculture, to externalize environmental and other social costs are being revisited. Bennett and Balvanera (2007) identified numerous unintended consequences associated with food and timber production across a range of scales from local to global and from short to long term that have been generally paid for through public funds or through loss of environmental services. Pretty et al. (2000, 2003, 2005) identified substantial environmental, health, and transportation costs of agricultural food production systems borne by taxpayers and consumers. With the dramatic failure of financial markets, society is questioning past economic models that have allowed organizations to grow seemingly "too large to fail," thereby distributing the costs of failure to taxpayers when necessary, while reaping the profits along the way.

With growing world population, increased demand on fresh water supplies, increased vulnerability to climate extremes, and low global food stocks, it is time to rethink how agriculture is performed, so as to provide for more secure and resilient food systems and enhanced economic opportunities in rural communities. Additionally, with agriculture (crop and grasslands) occupying about 43% of the world's ice-free land (Ramankutty et al. 2008), goals for clean water, clean air, and diverse biota cannot be met without good ecological stewardship of agricultural lands. Grasses and other perennials have a major role to play in the more diverse and resilient agricultural systems needed to meet the multitude of ecological functions derived from agricultural lands.

While the pressures are diverse and great, times of change present opportunities to reassess options and choose new directions. *Farming with Grass* conference participants have articulated the need to move to a post-industrial agriculture and set out a vision for agricultural systems that is based on sound ecological principles and with an economic basis that includes full accounting for environmental services and costs. There will be

many challenges in bringing diverse interests together and channeling the strengths of existing agricultural interests toward new approaches to meet emerging challenges. Our objective in this paper is to synthesize the ideas expressed in oral presentations (most of which have been translated into text in the preceding chapters), poster presentations (titles of which appear in Appendix A and some of which are available at http://www.swcs.org/fwg), and facilitated discussions at the conference held in Oklahoma City, Oklahoma, from October 20 to 22, 2008. These ideas are presented to frame the issues and identify strategies of how to move toward more sustainable agricultural systems.

Status and Trends in Types of Agricultural Systems

Agriculture in the United States has undergone significant transformation from the beginning of the 20th century to present (table 1), driven by a combination of historical, technological, and policy changes. Low commodity prices and rural poverty in the 1930s led to development of commodity-based price supports that still influence US farm policy today. Commodity prices rose during World War II, and in the post-war era, very rapid mechanization occurred, leading to increased farm size, reduced farm workforce, and reduced diversity within farms. Starting in the 1970s, export markets became increasingly important. Animal and crop agriculture were increasingly segregated on different farms and production, processing, and retailing were increasingly integrated and consolidated (Dimitri et al. 2005). Toward the end of the 20th century, environmental concerns began to influence agricultural policy, but the agricultural sector has retained special consideration under many environmental and labor laws.

Table 1. Characteristics of US agriculture throughout the 20th century.

Year	US farms (millions)	Average farm size (ha)	Workforce on farms (%)	Commodities per farm (#)	GDP from agriculture (%)	Farms with off-farm income (%)
1900	5.7	59	41.0	5.1	—	—
1930	6.3	61	21.5	4.5	7.7	—
1945	5.9	79	16.0	4.6	6.8	27
1970	2.9	152	4.0	2.7	2.3	54
2000	—	—	1.9	—	—	—
2002	2.1	179	—	1.3	0.7	93

Source: Dimitri et al. (2005)

While much of US farm policy focuses on row crop production, over half of the agricultural land is in grass, and the farm gate receipts from animal agriculture exceed those for crop sales. A primary use of US grasslands is for beef production. The US beef industry consists of five distinct segments: (1) cow/calf production with numerous producers often on small land holdings; (2) stockers with fewer producers who purchase weaned calves from multiple farms and frequently transport animals toward the center of the country; (3) feedlots, in which large numbers of animals are managed within a few operations, predominantly in the High Plains regions of Texas, Kansas, and Colorado; (4) slaughter/packing plants, in which four corporations process over 80% of the beef cattle; and (5) wholesale/retail segment, in which beef products are transported back to the population centers throughout the nation (Phillips et al. 2009). This system developed when energy for transportation and corn for feed were inexpensive, but with extreme

dynamics in energy and commodity markets, beef industry systems face great stresses. As corn is diverted to ethanol plants, transfer of distillers' grain byproducts from the bioenergy sector as an animal feed will become essential for both industries.

Future agricultural production systems must possess an inherent capacity to adapt to change to be sustainable. Trends in population growth, energy use, climate change, and globalization will challenge farmers and ranchers to develop innovative production systems that are highly productive but environmentally sound (Hanson and Hendrickson 2009). Sustainable agricultural systems emphasize the need to mix complementary crops and animals in appropriate times and places, keep the soil covered with growing crops and mulches, and use detailed knowledge of ecological relationships to reduce the use of purchased inputs, such as pesticides and fertilizers, and to solve complex problems.

Core forces driving change in agriculture include growing human population and economic growth in developing countries, which place increasingly greater demands on global energy, soil, water, air, and mineral resources. In the late 20th century, growth of the middle class in Asia greatly influenced demand for and prices of energy and food resources. There is increasing recognition that the demands for food and energy can become competitive, and the moral implications of diverting grain from the food to energy sectors must be addressed.

Dr. Gale Buchanan, USDA Under Secretary for Research, Education, and Economics, identified four grand challenges that agriculture must address during coming decades:

- Achieving sustainable bioenergy production
- Adapting to and mitigating global climate change
- Improving water quality and availability
- Ensuring food security

Themes of energy, climate, water, and food recurred throughout the *Farming with Grass* conference. Additionally, a growing segment of food consumers have been demanding more information about how and where their food is produced, including those who want more local or regional food options.

Kirschenmann (2009) and Ikerd (2009) framed their discussions in terms of paradigm change—the end of cheap energy; the end of the industrial food era. In the face of new or growing constraints, they called for implementation of more sustainable agricultural systems. While industrial agriculture has been held up as a model of efficiency, its efficiency has been assessed from a largely economic perspective that has previously discounted environmental costs associated with ecologically neglecting agricultural practices or systems. Kirschemann (2009) reminded us that while current systems are highly productive, there are also other highly productive models available that are more ecologically sensitive**,** such as poly-culture. Traditional tropical and subtropical agricultural systems were often highly diversified and could provide insights into how to develop systems to meet today's needs. Poly-culture systems must be carefully crafted to meet environmental constraints and to satisfy local preferences for food, but the economic return to innovative managers could be large and environmental and societal impacts could be very positive.

Ikerd (2009) described the approaching end of the industrial food system, driven by changes in consumer demand for locally grown foods that have less impact on Earth's climate and are less reliant on fossil energy and other limited resources. Many view the demand for alternative food systems for the nation as unrealistic and counter to the prevailing model of concentration and globalization in agricultural and food systems. However, prevailing food systems are supported by a vast array of government policies and subsidies that could be redirected toward alternate agricultural and food models. Agricultural markets do not follow classical capitalism because of the concentration of power and manipulation of demand through advertising and marketing. Ikerd (2009) raised two intriguing issues of broad societal significance:

- Once a baseline income is obtained to provide for food and household security, the level of income is really not linked to happiness or quality of life.
- Long-term impacts of decisions are inherently moral and ethical when they impact the interests of future generations; economics is an inherently inappropriate model to address moral or ethical values.

Key issues that were raised during the topic session on status and trends included the following:

1. Agricultural systems will be forced to change as a result of a multitude of ecological, economic, and social stresses.
2. Grass-based agricultural systems can support greater natural resource conservation, improved rural livelihoods, greater diversity of farm income and farm-sector stability, and national security interests.
3. Transition approaches from the current industrial model to more diverse combination of systems (all of which should be ecologically sensitive, economically fair, and ethically based) are in great need.

Environmental, Social, and Economic Benefits of Mixed Grassland Landscapes

Grasslands, and in particular the vast area of the Great Plains of North America, have provided numerous ecosystem services, including hydrological function to provide fresh water in ground and surface reservoirs, high soil quality to maximize nutrient cycling and habitat for soil organisms, sequestration of soil carbon to help maintain the delicate balance of greenhouse gases in the atmosphere, and surface cover to naturally mitigate against erosion. Economically, grasslands provide an abundance of forage available for livestock production and livelihoods of people that value the vast open spaces they occupy. Too often, however, grasslands have been exploited through either (1) excessive cultivation of the deep, rich soils that developed over the millennia (such as in the Great Plains of North America and Pampas of South America), resulting in enormous loss of soil organic matter, native fertility, and soil sediment, or (2) excessive livestock stocking on semi-arid and arid rangelands situated in brittle environments (such as the southwestern United States and Sub-Saharan Africa), resulting in loss of vegetative cover, low resilience, excessive soil erosion, and poor rural livelihoods.

Agricultural lands can be viewed as multifunctional, providing feed, food, and fiber, as well as stable soil and water conservation to protect the environment.

Grasslands, in particular, can provide diverse multifunctional economic and environmental benefits. Sanderson et al. (2009) questioned whether all of these services can be met at the same time, given the increasingly divisive stress between profitability and environmental protection. For example, greenhouse gas emissions may be lower with pasture-based dairy production on a land area basis, but may be higher per unit of milk produced. With optimism that grasslands may be able to produce cellulosic biofuels, land-use may intensify, and the economic, environmental, and social trade-offs will need to be understood to further avoid farm-sector decline, environmental contamination, and unemployment.

Popper and Popper (1987) introduced the idea of the Buffalo Commons–a metaphor intended to generate discussion of alternative futures for the Great Plains that would ultimately return land back to native grasses and focus land use on ecotourism and other extensive rangeland/prairie enterprises. In revisiting the Buffalo Commons, Popper and Popper (2009) noted the evolution of the idea over the past 20 years. Rather than a federally led effort as they originally envisioned, locally led efforts—individuals and community groups—have been building and maintaining a sense of place unique to the Great Plains prairies to create economic opportunities. A mosaic of land uses and management practices—some extensive and some intensive—will likely provide for a wider diversity of opportunities for landowners, entrepreneurs, and communities than any single land use.

Agriculture near large population centers is at great risk of development (American Farmland Trust 2002), but offers the potential to supply local food markets, while protecting the hydrologic and ecologic function of the peri-urban landscape. Grass-fed dairies in Wisconsin provide a model for market development of local food products (Paine 2009). Consumers respond to “narrative” marketing because they are interested in the people and the story behind a food product, as well as the quality of the product. Many consumers respond strongly to nuances of taste or memories associated with a food product. The concept of “terroir” within the oenology industry has demonstrated the potential economic value of associating a particular flavor or aroma derived from unique plant, soil, and climate factors specific to a place. The subtle flavor and compositional differences of local cheeses have similar market potential.

Key issues that were raised during the topic session on benefits of grassland ecosystems included the following:

- A need to make social and policy changes before disaster occurs, such as that which occurred during the Dust Bowl of the 1930s and following excessive pollution of ground and surface waters during the post-World War II agricultural revolution
- Balancing land preservation with land utilization for economic and ecological stability
- Effective technology transfer mechanisms for ecologically based agricultural business models
- Defining the extent of land-use changes in response to sugar and cellulosic biofuel production systems, as well as defining the economic, environmental, and social trade-offs of such changes.

When conference participants were asked "What are the benefits of grasslands from social, economic, and environmental perspectives?" the following responses were obtained:

- Economic—lower input costs, reduced risk with more diverse operations, reduced reliance on government subsidies, and obtaining an economic return adequate to sustain a livelihood
- Environmental—more stable delivery of ecosystem services, reduced soil erosion, water conservation, reduced energy use, improved water quality, enhanced wildlife habitat, greater biodiversity, and reduced greenhouse gas emissions
- Social—healthy foods, reduced health costs, high quality food supply, rural development opportunities, reduced cost for environmental mitigation, and reduced demand for government subsidies
- Who benefits—farmers can realize greater return to labor and management; farm families can realize improved quality of life; rural communities, entrepreneurs, and innovative businesses can have greater economic opportunities; and society as a whole can reap environmental services and improved aesthetics on the landscape
- Who may not benefit—poor are most at risk during any transition, providers of farm inputs to conventional agriculture, concentrated livestock corporations, and commodity groups benefiting from the status quo.

Factors Driving Changes in Grassland Environments

Farming with Grass conference presenters and participants identified many factors that are driving change in grasslands, as well as in other agricultural lands. Greenhouse gas emissions and the threat of global warming have emerged as an underlying force reflecting historically recent, yet widespread fossil fuel combustion pervading the industrial model of agricultural production, as well as the unrestrained energy use and ecological inefficiency of industrial production systems. Water availability and quality have also been factors in the need to redesign agricultural systems, owing to the limited fresh water supply shared between agricultural and metropolitan needs and the recognition of nutrient and bacterial leakages from ecologically inefficient agricultural systems with high synthetic fertilizer and pesticide inputs and concentration of animal feed operations.

Rapidly expanding human population can result in encroachment of people and annual cropping into semi-arid and arid grassland regions. Grasslands and croplands have also been lost at the fringes of towns and metropolitan areas as they expand. Greater demand for food production can lead to irrigation development, which also results in conversion of grasslands to croplands. The Ogallala Aquifer underlies much of the Great Plains in the central United States, and extensive cropping of this former grassland has ensued. The Ogallala Aquifer is being severely depleted, with the prospect of significant disruption of agriculture and other economic activity in the near future. Allen et al. (2009) described the potential for diversifying agricultural systems in the Texas High Plains by incorporating forage grasses and beef cattle grazing into crop rotations. Cotton yield was significantly improved in rotation with forages in addition to mixed crop-

livestock systems having lower irrigation water requirements, being able to maintain net income, reducing water and wind erosion (with associated improvements in air and soil quality), and increasing soil organic carbon and biological activity. Despite these benefits, adoption of mixed grass-crop farming systems faces several impediments, including resistance from traditional land owners, requirements for higher management skills, and a multitude of government policies and public and private infrastructure that favor the status quo.

Resistance to change can be a strong force on an individual, as well as on an institutional level. Arbuckle (2009) described major conceptual barriers to implementation of environmentally and economically based silvo-pasture systems (forest thinning with under-sown pastures) in Missouri that might have been overcome with prior interactive educational and practical experiences. Promotion of significant changes, such as adoption of silvo-pasture or other agroforestry (pastures/crops with trees planted within) systems, requires working in diverse partnerships. To overcome resistance to change, it is essential to be conscious of the social and historical context of the people involved and to address the paradigms and organizational norms of key players.

Policy makers at a national scale also have a need to understand factors influencing change in agriculture. In the prairie provinces of Alberta and Saskatchewan, Census of Agriculture data were evaluated to identify shifts in farm operations and why they might be occurring (Huffman and Saha 2009). Farms that remained in a particular system tended to be larger and more heavily capitalized, but they had lower gross margins and operators tended to be older and did not rely on off-farm work. Farms that significantly changed crop distributions or animal densities tended to be smaller, and their operators were younger and tended to shift away from off-farm work. This evaluation was undertaken to develop better tools to analyze possible impacts of policy options, such as those associated with introduction of bioenergy production into a region.

Key issues that were raised during the topic session on factors driving change included the following:

- Adaptation and adoption of sustainable, mixed grazing, cropping, and forestry systems for different grassland environments
- Assessment of production, ecological, and economic responses to alternative management systems in the short term and the long term
- Development of robust technology transfer protocols to (a) gather key organizations necessary to implement change, (b) educate stakeholders and the public, and (c) promote innovation in solving far-reaching problems faced by individuals and communities within a region

Conference participants were asked “What are the leverage points or incentives to bring about positive change for agriculture?” and “What knowledge gaps do we have to address in grassland management systems?” The following were some of the responses:

- Climate change
    - Quantify and verify soil carbon sequestration in different management systems

  - Support long-term field studies to understand soil carbon and nitrogen dynamics
  - Develop a knowledge base and tools to support carbon credit trading and markets
  - Create adaptation strategies to cope with an uncertain future
- Management practices
  - Establish a long-term research plan to better understand environmental processes
  - Be aware of indicators related to economic sustainability and multidimensional impacts of land management
  - Cultivate better understanding of grazing effects on pollinators, threatened and endangered species, streams and aquatic species, and wildlife
  - Gain better understanding of the fate of organic fertilizers and their impacts on soil fertility
- Integrated farming systems
  - Understand how to manage poly-cultures and develop suitable tools for transfer of knowledge across ecosystem boundaries
  - Improve understanding of how to optimize crop-livestock-grass interactions for social, ecological, and economic outcomes at multiple scales
  - Advance understanding of ecological site descriptions and how to compare across sites
  - Improve energy and water-use efficiency and conservation
- Community and economic impacts
  - Create approaches, resources, and policies to fill skill gaps and rebuild fragmented communities
  - Understand local community impacts of grass-based production, e.g. on reduced purchase of inputs

Assessment Tools for Monitoring and Predicting Changes in Grassland Agricultural Systems

Many tools are available for targeted ecologic-, production-, economic-, policy-, social-, and community-impact assessment, and these tools are critical because "if you can't measure it, you can't manage it." Some tools are applied at field or farm scale, but these tools are often tailored toward conventional systems and may need further development or refinement for more diversified, grass-based systems, including mixed perennial-annual rotations, management intensive grazing, or multiple species grazing within a landscape context. Landscape-level tools are essential for inventory and water quality assessments. There will be an increasing demand for assessment tools—both simple, practical tools for individual decision-making and highly complex tools that incorporate suites of models and databases into a geospatial framework.

Global change is a key issue that requires a sophisticated assessment framework to evaluate scenarios for adaptation and mitigation. Ojima and Corell (2009) sounded the call of urgency regarding climate change, which includes a multitude of issues including global warming, impacts of nitrogen deposition on nonagricultural landscapes, effects of changing land use on ecosystem processes, and altered precipitation patterns within a region. Plant and animal systems are undergoing change, including expansion of weeds,

pests, diseases, and increased pressure from invasive species. With changes in temperature and length of growing season, synchronization across species may be disrupted (e.g., pollinator species or migrating species that no longer are in synchrony with critical plant phenological stages). As temperature increases, evaporation rates increase, changing water availability and use for plants. Management practices that increase soil organic carbon can enhance system resiliency by helping to capture precipitation in soil and increase water-holding capacity in the root zone. In the face of the multiple stressors, agriculture needs better coping strategies to prepare for extreme weather events. An adaptive management approach is needed because of the high level of uncertainty in the driving forces and in the uncertain response of complex systems to those driving factors. In addition, mitigation strategies such as practices that sequester carbon in soils and vegetation, as well as substitution of biofuels for fossil fuels can delay the rate of onset and minimize the magnitude of climate change. Hansen et al. (2008) indicated that if humanity wishes to preserve a planet similar to that on which our civilization and Earth's ecosystems evolved, then we should strive for an atmospheric CO_2 concentration of 350 ppm, which is lower than the current level of 380 ppm.

A tool to bridge the goals of production agriculture and conservation ecology was presented by Quinn et al. (2009). The Healthy Farm Index was developed to assess impacts of organic and sustainable agriculture on ecosystem services, including farm biodiversity. The tool is for farm-scale assessment, tailored to Nebraska sustainable farming systems, but it provides a template and model that could be adapted for production systems in other regions, as well as for grass-based agriculture and complex rotational systems.

Key issues that were raised during the topic session on assessment tools included the following:

1. Adopting and adapting simple and complex assessment tools for promotion of sustainable agricultural systems at field, farm, watershed, landscape, and national levels
2. Including as many key stakeholders as possible in assessment and evaluations so that prompt and robust adaptation and mitigation strategies can be implemented

Conference participants were asked to identify readily known tools that could be used to monitor and predict changes in grassland management. Resources identified include the following:

- Monitoring tools—e.g., rangeland condition, ecological assessment, percent vegetative cover, soil testing laboratories, citizen water quality programs (Alabama Water Watch 2009; Oklahoma Conservation Commission 2009), benchmark sites, soil conditioning index, livestock health rating, rangeland monitoring guidelines (Herrick et al. 2005a, 2005b), holistic management biological monitoring (Holistic Management International 2009). General limitations to monitoring identified include these issues: the fact that while many monitoring tools exist, some may need modification for application at the landscape level; in most environmental projects, funding for monitoring is limited; and soil quality indices are more adapted to cropland than to grasslands.

- Data—e.g., soil surveys, climate records, current weather, remote sensing, census surveys.
- Models—e.g., simulation of production and utilization of rangelands (SPUR 2009), soil carbon (CENTURY 2009), ranch economic models (Rightrisk 2009), and grazing management planning (C-Graz 2009; AFO-Pro 2009).
- Educational tools—e.g., websites, handbooks, visualization tools, field days, and various tools from Agricultural Wildlife Conservation Center (USDA NRCS 2009a).
- Planning tools—e.g., technical guides (USDA NRCS 2009b), one-on-one technical assistance, Holistic Management International (2009), Wild Farm Alliance (2009) guide to biodiversity in organic systems.
- Research—e.g., rangeland carbon flux network (Svjecar et al. 2008), on-farm research active in many locations, rangeland research network (WERA110 2009).
- Networks or groups—e.g., expert farmers as mentors, farmer and grazier groups, community groups, local foods, public participation and facilitation methods, Center for Absentee Landowners (2009).
- Environmental credit markets—e.g., water quality, soil carbon (evolving systems).

Science and Policy Needed to Sustain Agriculture in Mixed Grassland Environments

With the diversity of grassland ecosystems and the multitude of species in mixed crop-grass systems, there are many gaps in our understanding. While some nations have supported very strong research and extension programs in grasslands agriculture for decades, in most countries and on a global scale, research investment for grassland agriculture has drastically lagged behind research investment for commodity crops. Boody et al. (2005, 2009) evaluated multifunctionality of grasslands within watersheds in the upper Midwest and Great Lakes regions. Using scenario analysis, introduction of perennials into a watershed indicated the potential for many environmental benefits. Cellulosic energy buffers could create a large water quality benefit. Rotational grazing could also improve water quality, while providing strong market return at the watershed scale. With such positive impacts indicated by these scenarios, there is a need for field- and watershed-scale research to continue to enhance our understanding of these systems and processes.

Boody et al. (2009) called for a “joined-up” farm policy, in which all components of the farm policy would work toward common goals, rather than having some components work against goals of other components. Desirable farm policy would support public goods from agricultural landscapes and minimize market distortions. Additional policies that could help support grassland farming should address ecolabeling, institutional food purchases, beginning farmer programs, transition support, and institutional support (inspection, food-safety) for small-scale meat packing plants.

The legal system often imposes relatively inflexible requirements for agricultural producers. With a required change in poultry manure management following legal settlement between the City of Tulsa and several poultry integrators operating in the Eucha-Spavinaw watershed of Oklahoma and Arkansas, Sharpley et al. (2009) evaluated

changes in production and environmental outcomes. Traditionally, poultry manure had been applied to pastures for beef-cattle grazing. After the settlement in 2003, about 75% of the waste was transported out of the watershed, exceeding the mandate that 33% be exported. The beef-cattle industry lost an economical source of fertilizer at the same time that the price of commercial fertilizer N-P-K increased more than threefold from 2004 to 2008. Now beef-cattle producers are exploring how to incorporate forage legumes into pastures, use rotational grazing, and adopt other management practices to redistribute nutrients within fields. They need support from the research and education communities to help identify practical alternatives for this transition. There is substantial literature published in the mid 20th century that merits review and updating, since cultural methods during that time were necessary to achieve production and environmental goals without purchased inputs.

French (2009) discussed many unintended consequences of current US farm policy. Poverty is both a metropolitan and rural phenomenon, in the United States and globally, but rural poverty is often less visible. Current US commodity programs distort global markets and make it impossible for farmers in many developing countries to compete in the world marketplace. Global development policy discourages developing countries from subsidizing agriculture. Additionally, commodity subsidies have discouraged US farmers from diversifying their systems to include more grasses and perennial crops because there is a financial incentive to maintain commodity cropland. Hodges (2005) recommended that developing countries be allowed to protect their agriculture as a measure of national security, like developed countries have, and to enhance food security for the world's poorest citizens.

There is a need to confront policies that create barriers to more just agriculture and food systems. United States farm policy has resulted in 2% of farms receiving 30% of payments and crops that produce 30% of farm gate receipts receiving 92% of agricultural payments. Conservation and land stewardship should be at the center, not the periphery, of farm policy, and it should ensure that environmental services and public goods are tied to farm-income support payments (French 2009). However, US farm policy is set in five-year cycles, and legislation passed for 2009 to 2013 maintained the commodity focus. In the near term, proposed carbon cap and trade legislation related to greenhouse gas emissions could help implement more sustainable agricultural systems. In the longer term, French (2009) called for a new alliance in future farm bill debates that would advocate for agriculture, food, and health coalitions. A clear road map of what future agriculture should look like is needed, as well as incremental movement towards that vision in solid, discrete steps. Pollan (2008) suggested that the incoming US president will be the first in decades to face critical issues of global food security, and Pollan proposed that farm and food policy should focus on moving towards a post-oil era, improving the health of American people and mitigating climate change. Refocusing agriculture on the efficient capture of solar energy would "change how things work at every link in the food chain: the farm field, in the way food is processed and sold and even in the American kitchen and at the American dinner table" (Pollan 2008).

Key issues that were raised during the topic session on science and policy needs included the following:

1. Research grass-based livestock production systems to (a) lengthen the growing season with various forages, (b) link forage quality, meat nutritional composition, and human health, (c) identify suitable adaptation and mitigation strategies to combat climate change, such as through greater soil organic carbon sequestration; and (d) develop multiple and mixed livestock grazing systems to increase resilience of a system and reduce grazing system impacts on wildlife and biodiversity
2. Implement farm policies that reverse the trends in the 20th century for increasing farm size, loss of rural population, consolidation and concentration of production and marketing, decline in grasses and perennial crops, separation of crop and livestock production, and greater absentee landownership
2. In the short-term, meld ecologically-based, agricultural-system knowledge, technology, and approaches within existing agricultural policy structure
3. In the longer term, get ecologically-based, grass-root organizations to form wider alliances and positively affect a larger proportion of agricultural stakeholders
5. Develop suitable alternatives to legislation to avoid perverse incentives and target more effectively the goal of sustainable agricultural systems
6. Work toward seamless approaches among business, government, and agricultural sectors to create farming systems that are ecologically pertinent to a region, that utilize nutrient and other natural resources wisely, and that are sustainable into the future

Conference participants were asked, "What should be the priority areas for managing grasslands?" Response included the following:

- Paradigm shift—from an industrial to ecological model of agriculture, full-cost accounting for noneconomic costs and benefits, addressing the energy-climate-water-food nexus
- Need for education—new management ideas and strategies, public awareness of limitations and drawbacks of current practices and potential for increased multifunctional benefits of rural landscapes, best management practices for diversified systems communicated to farmers and land owners, increased awareness of impacts of current agriculture and foods systems on climate change and greenhouse gas emissions, practical approaches to transition to new system, consumer awareness about food products and health impacts of food choices
- Farmer benefits—expand local market systems (local infrastructure), provide appropriate support and incentives for adopting new systems and developing new markets, promote good business practices and local solutions, provide benefit to farmers for environmental services provided, provide clear and consistent signals to producers (policy, incentives, extension, outreach), provide market signals to farmers (fair prices for local foods, income for wildlife enhancement and recreation)
- Comparative analysis—life cycle analyses of economic and environmental costs and benefits, integrated systems research, practical research-based guidelines, funding for research in multifunctional landscapes, improved monitoring of contrasting systems, methods to verify and value environmental services for

evolving markets, understanding and defining ecosystem thresholds and breakpoints

- Land planning and pricing—address development pressures on agriculture, address agricultural policy effects on farmland prices and start-up opportunities for new farmers
- Environment—reduce dependence on fossil fuel for energy independence, network and distribute small-scale energy systems to supply farm and rural community needs, adapt to and mitigate climate change, manage water use and allocation, keep ruminants integral to sustainability of grasslands, alternate nitrogen (nutrient) sources, reduce negative effects of agriculture on environment
- Seamless plan from practice to policy—make policies equally favorable to diversified agriculture (versus current bias toward commodity crops); provide government assistance, research, education; transition from subsidizing industrial agriculture toward investing in more sustainable agriculture; establish policies to manage risks during transition; involve more stakeholders (e.g., industry innovators, community organizers, advocacy groups, food citizens, universities, educators, extension, and researchers)

Moving Forward

The *Farming with Grass* conference convened a diverse group of agricultural researchers, policy advocates, and practitioners to take stock of US agriculture and to articulate a vision for where we want to be, focusing specifically on the role of grasses and perennials in achieving sustainable mixed agriculture landscapes.

Since the early 20th century, US agricultural policy has favored production of selected commodity crops to provide feedstock for industrial agricultural products. Policies have distorted markets and resulted in concentration within the agricultural sector, increasing farm size, reducing rural population, and suppressing rural economic activity. Additionally, a policy system that allowed entities to externalize environmental and social costs has created an agricultural system highly dependent on fossil fuel and purchased inputs, such as fertilizers and pesticides. Agricultural practices have resulted in loss of diversity, soil degradation, atmospheric emissions of greenhouse gases, and water quality problems. Unfortunately, commodities that are subsidized by taxpayers are increasingly processed into foods that are high in sugars and heavy in saturated fats, contributing to a national epidemic of diet-related diseases, such as diabetes, heart disease, and some cancers. Many types of agricultural systems will be required to meet growing human needs in diverse environments. Future agricultural systems will need to capitalize on the considerable technical and economic capacity within existing agricultural organizations and businesses. However, agricultural leaders in the private and public sectors need to develop strategies to operate under policies that create a more even playing field for diversified agricultural systems, increase focus on food quality as well as quantity in anti-hunger programs, ensure open and competitive markets, and enforce environmental standards.

Participants at the *Farming with Grass* conference contributed to a vision for sustainable agriculture and identified key gaps in scientific knowledge, technological capacity, and policy instruments. Conversations culminated in several key messages, which will be useful in supporting “grassroots farmers” who want to incorporate grasses

and perennials into their production systems, who are committed to environmental stewardship of their land, and who depend on the vitality of rural communities in which they live.

Messages to Policy Makers

- Difficult times require broad vision and practical solutions—Investing in land stewardship and rural communities will build social, natural, and financial capital. It is time to begin a national dialog to reform our agricultural economy so that it promotes stewardship of human, natural, and social capital while producing quality food, fiber, fuel.
- Policies should ensure maximum environmental "bang for the buck"—While conservation and good stewardship is desirable on any property, achieving specific environmental goals, such as water quality improvement in a particular water body, improved air quality in a particular city, or protection of a particular at-risk species can best be achieved by targeting the types of conservation practices onto particular land that has the greatest impact on the desired environmental outcome. Targeting is a common-sense approach for public funds to support agricultural conservation. Additionally, other agricultural spending should be re-examined to remove indirect disincentives toward sustainable practices and systems, such as monocultures or concentration of markets that do not provide adequate competition. Farmers who incorporate grasslands and other perennial crops into their rotations and production systems produce many environmental public goods and should have an equal playing field when looking at government support for agriculture.
- Recognize the need for food security—Agriculture and food systems are vulnerable when they rely on imported oil, due to potential price shocks that can disrupt markets. Concentration of food production into a few large corporations increases the vulnerability of consumers to oligopolies. Additionally, large concentrated areas of agricultural processing, such as with beef cattle feeding, slaughter, and packing plants, are vulnerable to intruders disrupting the American food supply.

Message to Conservation Organizations

- Agriculture can deliver environmental services—Agriculture occupies a large portion of the nation's land, and protection of natural resources can only be achieved in partnership with agriculturalists and land owners/managers. Sustainable agricultural systems that maintain a vegetative cover on the soil, use limited external inputs, support healthy soil nutrient cycling, and provide habitat for diverse species can help sustain water, atmospheric, and biologic resources.

Message to Rural Community Leaders

- Sustainable agriculture can enhance economic opportunities—Ecosystem services provided by sustainable agricultural systems are amenities that can attract residents and visitors and offer opportunities to develop recreational and agricultural tourism such as bird watching, boating, fishing, or hunting. Additionally, communities can work with farmers to help develop local food systems, generating jobs along the supply chain and providing affordable and healthy foods to residents. Programs such as Farm-to-School and farmers markets help keep agricultural dollars in the local community.

Messages to Farmers and Farmer Support Organizations

- Gain market access and create economic sustainability—Integrating grasses and perennials into agricultural systems can reduce input costs and enhance profitability. They can also reduce risk by producing more diversified products. Opportunities exist to develop new markets for local food products that can bring added value to the farm and rural communities.
- Work toward freedom from government programs—Current policies do not provide an even playing field for many farmers. Certain crops are favored, and innovation is stifled. Policies support the status quo and do not adequately recognize nor reward farmers who manage their land to produce public goods.

Messages to Consumers and the General Public

- Safe food and good health for families and communities are within reach—Local food products are healthy and secure. You know more about how food was produced and the impacts of the food production on the environment. How food is produced can affect healthfulness, e.g. higher omega-3 (nonsaturated, healthy fatty acids) and lower omega-6 (a saturated, unhealthy fatty acid) in grass-finished beef compared to conventionally produced beef.
- Make a clean and healthy environment a priority—Sustainable agricultural systems can contribute to a healthy environment, and consumers can support sustainable management practices through their purchase choices. Incorporation of more grasses and perennials onto farms will increase biological diversity, provide environmental benefits, and improve the landscape we share.

There are a myriad of challenges ahead in achieving sustainable mixed agricultural landscapes in grassland environments, but the need to do so is undeniable. Four grand challenges of agriculture—achieving sustainable bioenergy production, adapting to and mitigating global climate change, improving water quality and availability, and ensuring food security—are interrelated and must be addressed in a systematic way so that solution of one problem does not create a problem in another. Addressing these challenges will require a fundamental re-thinking of agriculture to maintain or increase production, while mitigating past environmental damage, protecting biological diversity of domesticated and wild species, reducing dependence on fossil fuel, providing healthier foods (particularly to children and the poor), and increasing economic and cultural opportunities in rural areas. Past policies have favored a few commodity crops and have disfavored producers of grasses and other perennial crops. Perennial species, incorporated into diverse agricultural systems, have great potential to enhance agro-ecosystem resilience in the face of uncertain climate and market conditions. In addition, by developing more on-farm and rural enterprises to provide products into local food systems, sustainable mixed agricultural farming systems can help revitalize communities and provide healthy food options to schools, families, and institutions.

References

AFO-Pro. 2009. Natural Resources Conservation Decision Report System. http://www.esri.sc.edu/Projects/usda/application_development/afopro.asp.

Alabama Water Watch. 2009. https://aww.auburn.edu/.

Allen, V.G., T. Sell, R.L. Kellison, P.N. Johnson, and P. Brown. 2009. Grassland environments: Factors driving change. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

American Farmland Trust. 2005. Farming on the Edge: Sprawling Development Threatens America's Best Farmland. Washington, DC: American Farmland Trust. http://www.farmland.org.

Arbuckle, J.G. 2009. Cattle and trees don't mix!?!: Competing agri-environmental paradigms and silvopasture agroforestry in the Missouri Ozarks. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Bennett, E.M., and P. Balvanera. 2007. The future of production systems in a globalize world. Frontiers in Ecology and the Environment 5(4):191-198.

Boody, G., P. Gowda, J. Westra, C. van Schaik, P. Welle, B. Vondracek, and D. Johnson. 2009. Multifunctional grass farming: Science and policy considerations. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

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.

Center for Absentee Landowners. 2009. Center for Absentee Landowners. http://www.absenteelandowners.org/.

CENTURY. 2009. CENTURY Soil Organic Matter Model Version 5. http://www.nrel.colostate.edu/projects/century5/.

C-Graz. 2009. Natural Resources Conservation Decision Support System. http://www.esri.sc.edu/Projects/usda/application_development/cgraz.asp.

Dimitri, C., A. Effland, and N. Conklin. 2005. The 20th Century Transformation of U.S. Agriculture and Farm Policy. Electronic Report from the Economic Research Service. Economic Information Bulletin Number 3.

French, J. 2009. Sustainability in the global perspective: Policy directions for a resilient and conservation-based agriculture. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Hansen, J., M. Sato, P. Kharecha, D. Beerling, R. Berner, V. Masson-Delmotte, M. Pagani, M. Raymo, D.L. Royer, and J.C. Zachos. 2008. Target atmospheric CO_2: Where should humanity aim? The Open Atmospheric Science Journal 2:217-231.

Hanson, J.D., and J.R. Hendrickson. 2009. Toward a sustainable agriculture. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett, and W.G. Whitford. 2005a. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems, Volume I: Quick Start. Tucson, Arizona: The University of Arizona Press.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett, and W.G. Whitford. 2005b. Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems - Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems. Volume II: Design, Supplementary Methods, and Interpretation. Tucson, Arizona: University of Arizona Press.

Hodges, J. 2005. Cheap food and feeding the world sustainably. Livestock Production Science 92(1):1-16.

Holistic Management International. 2009. Holistic Management Works. http://www.holisticmanagement.org/.

Huffman, T., and B. Saha. 2009. Farming system changes in the Prairie Grassland Ecoregions of Canada, 1991 to 2006. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Ikerd, J.E. 2009. Current status and future trends in American agriculture: Farming with grass. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Kirschenmann, F. 2009. Reconsidering grass. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Lovins, A.B., L.H. Lovins, and P. Hawkins. 1999. A road map for natural capitalism. Harvard Business Review 77(3):145-158, 211.

Ojima, D.S., and R.W. Corell. 2009. Managing grassland ecosystems under global environmental change: Developing strategies to meet challenges and opportunities of global change. *In* Farming with Grass, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Oklahoma Conservation Commission. 2009. Quality Water Division Blue Thumb Program. http://www.ok.gov/okcc/Agency_Divisions/Water_Quality_Division/Blue_Thumb/.

Paine, L.K. 2009. Case histories of grass-fed market development in the Upper Midwest. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Phillips, W.A., G.W. Horn, B.K. Northup, and W.S. Damron. 2009. Challenges and opportunities for forage based beef production systems. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Pollan, M. 2008. The Food Issue: Farmer in Chief. New York Times. 12 October 2008.

Popper, D.E., and F.J. Popper. 1987. The Great Plains: From dust to dust. Planning 53(12):12-18.

Popper, D.E., and F.J. Popper. 2009. Looking forward: Adding the Buffalo Commons to the grasslands mix. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Pretty, J.N., A.S. Ball, T. Lang, and J.I.L. Morison. 2005. Farm costs and food miles: An assessment of the full cost of the UK weekly food basket. Food Policy 30(1):1-19.

Pretty, J.N., C. Brett, D. Gee, R.E., Hine, C.F., Mason, J.I.L. Morison, H. Raven, M.D. Rayment, and G.Van der Bijl. 2000. An assessment of the total external costs of UK agriculture. Agricultural Systems 65(2):113-136.

Pretty, J.N., C.F. Mason, D.B. Nedwell, R.E. Hine, S. Leaf, and R. Dils. 2003. Environmental costs of freshwater eutrophication in England and Wales. Environmental Science and Technology 37(2):201-208.

Quinn, J.E., J.R. Brandle, and R.J. Johnson. 2009. Development of a Healthy Farm Index to assess ecological, economic, and social function on organic and sustainable farms in Nebraska's four agroecoregions. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Ramankutty, N., A.T. Evan, C. Monfreda, and J.A. Foley. 2008. Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000. Global Biogeochemical Cycles 22(1), art. no. GB1003. doi: 10.1029/2007GB002952.

Robertson, G.P., V.G. Allen, G. Boody, E.R. Boose, N.G. Creamer, L.E. Drinkwater, J.R. Gosz, L. Lynch, J.L. Havlin, L.E. Jackson, S.T.A. Pickett, L. Pitelka, A. Randall, A.C. Reed, T.R. Seastedt, R.B. Waide, and D.H. Wall. 2008. Long-term agricultural research: A research, education, and extension imperative. BioScience 58(7):640-645.

Rightrisk. 2005. RightRisk. http://www.rightrisk.org/.

Sanderson, M.A., S.C. Goslee, K.J. Soder, R.H. Skinner, and P.R. Adler. 2009. Managing forage and grazing lands for multiple ecosystem services. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

Svejcar, A.J., R.F. Angell, J. Bradford, W. Dugas, W.E. Emmerich, A.B. Frank, T. Gilmanov, M.R. Haferkamp, D.A. Johnson, H.S. Mayeux Jr, P. Mielnick, J.A. Morgan, N. Saliendra, G.E. Schuman, P.L. Sims, and K.A. Snyder. 2008. Carbon fluxes on North American rangelands. Rangeland Ecology and Management 61:465-474.

Sharpley, A., S. Herron, C. West, and T. Daniel. 2009. Outcomes of phosphorus-based nutrient management in the Eucha-Spavinaw watershed. *In* Farming with Grass: Achieving Sustainable Mixed Agricultural Landscapes, ed. A.J. Franzluebbers, __-__. Ankeny, IA: Soil and Water Conservation Society.

SPUR. 2005. General Model Information. http://eco.wiz.uni-kassel.de/model_db/mdb/spur.html.

USDA NRCS (Natural Resources Conservation Service). 2009a. Agricultural Wildlife Conservation Center. http://www.whmi.nrcs.usda.gov/.

USDA NRCS. 2009b. Field Office Technical Guides. http://www.nrcs.usda.gov/technical/efotg/.

WERA110. 2009. WERA110: Improving ruminant use of forages in sustainable production systems for the western U.S. http://nimss.umd.edu/homepages/home.cfm?trackID=6280.

Wild Farm Alliance. 2009. Welcome to the Wild Farm Alliance. http://www.wildfarmalliance.org/.