Northern Great Plains Research Laboratory

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For environmentally and economically sound agro ecosystems for the northern Great Plains.

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Designing Cropping Systems for Sustainable Bioenergy Production

Biomass for bioenergy production can come from a variety of sources including grain, crop residues, dedicated energy crops, and agricultural processing residues. A challenge in developing sustainable biomass production systems is to produce these materials in a way that does not compromise our ability to meet current and future food, feed, and fiber demands, is economically viable, and protects our natural resource base and the environment.

Crop Residues – Lessons from Our Neighbors to the East

Research was conducted at the Northern Great Plains Research Laboratory (NGPRL) using field research data collected at the ARS-North Central Soil Conservation Research Laboratory (NCSCRL) in Morris, MN on effects of corn stover collection and alternative tillage systems on crop productivity. The field data were used to calibrate the EPIC simulation model, and the simulation model was used to evaluate the economic and environmental impacts of corn stover harvest across a range of soils.

Credit: Kathy Eystad, USDA-ARS

In the short-term, profitable crop residue harvest is determined by: 1) the direct crop residue harvest and handling costs, 2) nutrient replacement costs, and 3) any short-term impacts on crop productivity. When harvesting corn stover by chopping, raking and baling the stalks, initial simulation results showed average breakeven prices ranged from \$25 to \$37 per ton at the edge of the field. Of this amount, \$22-28 per ton was needed to cover direct harvest and handling costs, and \$5-9 per ton was needed for nutrient replacement. For a corn-soybean rotation in a chisel-plow tillage system, corn stover harvest could have a positive or negative impact on short-term crop productivity. Impacts ranged from a *reduction* in crop productivity equivalent to \$2 per ton of stover removed to an *increase* in crop productivity equivalent to \$8 per ton of stover removed. Short-term impacts of stover harvest on crop productivity were likely due to effects on soil moisture and temperature conditions, with positive effects associated with quicker spring soil temperature warming and negative effects associated with reduced soil moisture available later in the season.

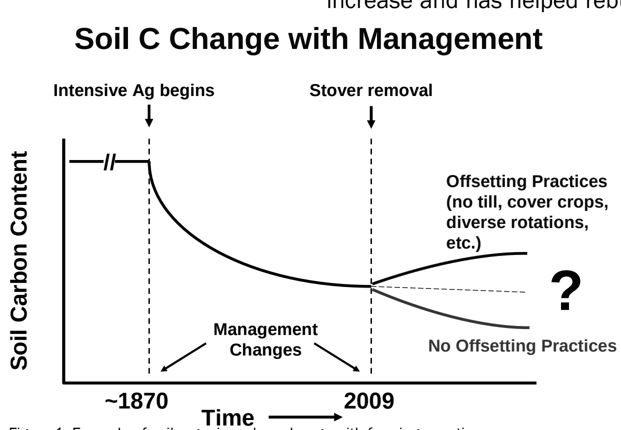

Figure 1. Example of soil organic carbon change with farming over time. Credit: Wally Wilhelm, USDA-ARS, Dec. 2005.

However, harvesting corn stover had a negative effect on soil organic carbon, led to higher erosion levels, and greater loss of phosphorous with sediment. These effects are important from an environmental standpoint since decreased soil organic carbon increases concentrations of greenhouse gases in the atmosphere, and increased erosion and phosphorous loss with sediment decreases water quality. These effects are also important for the farmer, since reductions in soil organic carbon, increases in erosion, and greater loss of soil phosphorous all tend to reduce soil productivity. This can contribute to lower crop yields, which can lead to further declines in soil productivity. The end result is a destructive cycle over time.

The challenge in managing corn stover harvest is to reduce or eliminate these negative effects. Simulation results showed that many of the effects could be offset by changing from a chisel plow tillage system to a strip tillage system. In a forthcoming paper in Agronomy Journal, scientists at the NGPRL and NCSCRL showed that switching from a chisel plow system to a strip tillage system would maintain profitability and would reduce economic risk. Switching to strip tillage has the added benefit of reducing the amount of energy used in crop production. However, reducing tillage is not the only option for making biomass production more sustainable. Figure 1 illustrates the historical declines in soil organic carbon that occurred with intensive tillage over time. Stover harvest has the potential to lead to further declines. However, practices such as no-till, use of cover crops, and diverse rotations could be used to offset further declines and perhaps even rebuild soil carbon levels.

Application to northern Great Plains Conditions

Growing conditions in Minnesota are clearly different from the northern Great Plains, particularly annual precipitation which is about 8 inches higher in Morris than in central North Dakota. Consequently, we would expect the impacts of crop residue removal on soil moisture loss to be a much more important factor in northern Great Plains. Cropping practices also differ between the two regions, with greater crop diversity and greater acceptance of no-till and direct-seeding in the northern Great Plains than in Minnesota. The greater use of no-till in the northern Great Plains has allowed cropping intensity to increase and has helped rebuild soil carbon levels that had been depleted due to intensive tillage and fallow. Without further offsetting practices, harvest of crop residues could potentially reverse these gains. In addition, crop production in the northern Great Plains tends to be more variable than in Minnesota, yet bioenergy producers are going to require a reliable supply of biomass. This means it may be beneficial for at least a portion of agricultural production in the northern Great Plains to include crops that have flexible use that can be diverted to bioenergy if needed.

Sustainable production of biomass in the northern Great Plains will require practices which conserve water, build soil organic matter, and replace nutrients in an economically viable manner. Research is being conducted at the NGPRL on a range of agricultural production systems relevant to bioenergy production: annual crop systems with cover crops, incorporating perennial energy crops into annual crop rotations, dedicated perennial energy crop production, and annual cropping systems designed for multiple-use food, feed, and bioenergy production.

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On-Farm Research Highlights Capacity of Switchgrass to Sequester Soil Carbon

U.S. federal law requires renewable biofuels to meet certain greenhouse gas emission reductions from conventional gasoline using life-cycle assessments (LCAs). Currently, LCAs of switchgrass grown for bioenergy have been mixed, due in large part to the assigned net greenhouse gas emissions associated with switchgrass production. Net greenhouse gas emissions from switchgrass production are closely linked to carbon dioxide uptake and subsequent sequestration in soil, which is reflected by an increase in soil organic carbon (SOC). Unfortunately, nearly all measurements of SOC change under switchgrass have been based on small plot research. While these assessments are useful, it is important to document switchgrass-induced changes in SOC across field-scale, on-farm environments, where conditions are often more variable. To obtain this information, a study was conducted to evaluate changes in SOC in 10 switchgrass fields grown and managed for biomass energy over a five year period. Fields were located in Nebraska, South Dakota, and North Dakota, encompassing an area where previous modeling efforts have shown switchgrass production for biomass energy to be economically feasible. This study was done in conjunction with a large, more inclusive evaluation where net energy and economics of switchgrass production were determined.

Over the five year study period, changes in SOC under switchgrass were highly variable, ranging from a decrease of 540 lbs C/ac/yr at a site near Ethan, SD to an increase of over 3800 lbs C/ac/yr at a site near Bristol, SD. Overall, however, changes in SOC increased across all sites at a rate of 980 lbs C/ac/yr within the 0-12 inch depth. In Nebraska, where four sites were sampled to a 48 inch soil depth, SOC increased at an average rate of 2590 lbs C/ac/yr.

Increases in SOC under switchgrass were likely caused by belowground carbon input from roots. Detailed surveys conducted by researchers at the University of Nebraska in the 1930s indicated switchgrass roots to extend over nine feet into the soil. Furthermore, the researchers observed switchgrass roots to regenerate by replacing dying roots with new, live roots. Such observations support the notion that significant carbon input to the soil is possible under switchgrass.

Accrual rates of SOC observed in this study contribute significantly to the potential of switchgrass to provide a favorable net greenhouse gas balance. As the suitability of bioenergy production systems in the USA are debated in the coming years, data generated in this study should prove useful for scientists and policy makers.

Drs. Mark Liebig and Marty Schmer contributed to this research project. Full results of the project are reported in Liebig, M.A., M.R. Schmer, K.P. Vogel, and R. Mitchell. 2008. Soil carbon storage by switchgrass grown for bioenergy. Bioenergy Research. 1: 215-222.

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Tillage Economics for Irrigated Corn Production: Lessons from Northern Colorado

While no-till is quite often used in Colorado dryland corn production, intensive moldboard plow tillage is still the norm for irrigated corn production. This results in serious wind and water erosion problems in the area.

Producers in the area are concerned about potential yield reductions with no-till and unsure if cost savings would offset any potential yield reductions.

To address these questions, economic analysis was conducted at the Northern Great Plains Research Laboratory using field research data collected by scientists at the ARS-Soil Plant Nutrient Research Unit in Ft. Collins from 2000-2005, comparing the production costs and profitability of conventional tillage (CT) to no-till (NT) irrigated continuous corn.

	CT	NT
Expected Yield at optimum N rate (bu/ac)	189	173
Corn Price ($/bushel)	2.38	2.38
Operating Costs	—— $/ac ——	
Seed	62	62
Pesticides and P&K Fertilizer	62	76
Nitrogen Fertilizer*	55	75
Labor	20	6
Fuel	23	6
Irrigation	88	85
Repairs & Maintenance	32	11
Crop Insurance	24	24
Interest on Operating Capital	9	7
Total Operating Costs	375	352
Machinery Ownership Costs	100	65
Total Costs	475	417
Crop Revenue	451	411
Government Payments	61	61
Gross Returns	512	473
Net Returns to Land and Management	37	56
*Optimum Nitrogen rates (lb/ac):	138	188

Table 1. Average production costs, gross returns, and net returns at the economic optimum nitrogen fertilizer rates averaged over 2000-2005.

While corn yields were 16 bushels per acre lower under NT than for CT, net returns were $19 per acre higher with NT. This was due to reduction in operating costs of $23 per acre and reductions in machinery ownership costs of $35 per acre.

Economic optimum nitrogen rates were higher under NT than under CT, however fuel use was reduced by 75% and labor needs were reduce by 71-72%.

The results showed that, despite yield reductions, no-till could be an economically viable option for replacing conventional tillage in the central Great Plains.

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Farming Practices Influence Mineral Content of Grain and Legume Foods

Farming practices can affect levels of important minerals in common foods.

Scientists at the Northern Great Plains Research Laboratory endeavored to determine if tillage and fertilization influenced mineral content of spring wheat and dry peas.

Mineral deficiencies are common throughout the world's population and often lead to serious health problems. Minerals in foods are ultimately derived from the soil on which they are produced.

Reducing tillage for soil conservation has been critical for increasing food quantity. New evidence from the USDA-ARS Mandan research lab establishes that no-till can also enhance food quality to improve nutrition for a growing human population.

The study found that conventional tillage systems reduced mineral uptake levels in wheat and dry pea compared to no-till or severely reduced soil disturbance systems.

No-till led to significantly higher levels of many important minerals in dry pea. Legumes, like dry pea, have greater mineral uptake with no-till due to their positive symbiotic relationship with mycorrhizal soil fungi. It was also found that increased nitrogen fertilization in dry pea raised manganese and zinc levels, but reduced magnesium levels.

Increased nitrogen fertilization also raised levels of magnesium in spring wheat, but lowered potassium levels.

The no-till production system significantly increased zinc levels in spring wheat. Recent human research has demonstrated that zinc has significant anti-inflammatory actions for the body. Even a mild zinc deficiency has severe negative impacts on immunological and other important bodily functions.

This study was initiated on land previously enrolled in the USDA Conservation Reserve Program (CRP). Non-removal of perennial vegetation at the onset of annual cropping resulted in higher levels of copper and iron in both spring wheat and dry pea, but lower levels of magnesium in spring wheat.

Improved modern farming practices that significantly reduce soil tillage decreases disturbance of soil physical and biological processes. This supports increased uptake of minerals by plants and higher concentrations of minerals in plant and animal derived foods. This provides a win-win-win situation for soil conservation, food production, and human health.

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Feel free to pass on this issue of ***Northern Great Plains Integrator*** to others interested in agricultural research in the northern Great Plains. Northern Great Plains Integrator is published and distributed by the USDA-ARS, Northern Great Plains Research Laboratory, PO Box 459, 1701 10th Avenue S.W., Mandan, ND 58554. Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD). The United States Department of Agriculture prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital and family status. To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence, SW, Washington, DC 20250-9410 or call 202-720-5964 (voice or TDD). USDA is an equal opportunity provider and employer. Mention of trade or manufacturer names is provided for information only and does not constitute endorsement by USDA-ARS. To be added to our mailing list, request a copy through our website or contact editor: Cal Thorson, Technical Information Specialist, USDA-ARS Northern Great Plains Research Laboratory, 1701 10th Ave., S.W., Mandan, ND 58554. Office:701 667-3018 FAX:701 667-3077 Email: cal.thorson@ars.usda.gov

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25th Annual Area 4 SCD Cooperative Research Farm Research Results Conference

USDA Agricultural Research Service scientists will introduce new five-year research plans being initiated at Mandan's Northern Great Plains Research Laboratory at 8 AM on February 24th at the Seven Seas Inn in Mandan. Come join us. You will hear: "Use of Crop Residue for Biofuel: Economics and Sustainability" (Dave Archer), "Biofuel Crops for Northern Great Plains: The Production Challenges" (Qingwu Xue), "Current Research Status of Switchgrass for Bioenergy - What We Know and What We Need to Find Out?" (Marty Schmer), "Cover Crops: Where Do They Fit?" (Don Tanaka), "The Undercover in Cover Crops" (Kris Nichols), "Going From Perennial Crops to Annuals: What Are Your Options?" (John Hendrickson), "Winter Grazing Effects on Soil Quality" (Mark Liebig), "Effects of an Integrated Crop and Livestock System for Fall Forage Production on Beef Cow Growth Performance" (Eric Scholljegerdes), "Integration of Geospatial and Cattle Nutrition Information to Estimate Paddock Grazing Capacity in Northern U.S. Prairie" (Rebecca Phillips), "Adjusting the Composition Beef and Other Foods to Meet the Emerging Market Demand for Healthier Foods (Scott Kronberg), and "A Research Model for the Future" (Jon Hanson).

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Toward a Sustainable Agriculture

Future trends in population growth, energy use, climate change, and globalization will challenge family farmers to develop innovative production systems that are highly productive and environmentally sound. Future farming systems must possess an inherent capacity to adapt to change to be sustainable.

Through a commitment of the U.S. agricultural community, this challenge can be met and family farmers can lead the way toward a sustainable future.

Agriculture Has Been Very Successful in Meeting the Needs of Most of the World's Population.

Today's agriculture feeds a population of six billion people using less than ½ acre of land per person. Despite such impressive achievements, there are concerns about the sustainability of modern agriculture. Intensive agriculture impacts the resource base and potentially reduces both its capacity and its sustainability. In the Great Plains, many cropping systems are characterized by a lack of diversity and declining soil organic carbon.

Sustainable Agricultural Systems

Agricultural systems need to be developed that are sustainable and adaptable to change, yet maintain their productivity. Most family farmers do not develop and use management systems that are designed to be unsustainable. Land managers have difficulty discerning between sustainable systems and those that are not.

Sustainable agriculture balances the need for essential agricultural commodities with the necessity of protecting the physical environment and public health, the foundation of agriculture. Future agricultural sustainability will be impacted by industrialization, global markets, energy supply, and water shortages.

Impact of Industrialization

Industrialization of agriculture leads to increasing farm consolidation and vertical integration in food, bioenergy, and industrial raw material production systems.

To see and understand more fully the intent of industrialized farming, we must examine its philosophies: (1) nature is a resource to be exploited and variation is to be suppressed; (2) natural resources are not valued except when a necessary expense in production is incurred; (3) progress is equivalent to the evolution of larger farms and depopulation of farm communities; (4) progress is measured primarily by increased material consumption; (5) efficiency is measured by looking at the bottom line; and (6) science is an unbiased enterprise driven by natural forces to produce social good.

Three Major Areas of Concern Regarding Industrialization of Agriculture

The first concern is ecological. In the industrial model, declining soil productivity, desertification, water pollution, increasing scarcity of water, increasing pest pressures, and rapid global climate change are viewed as negative impacts only if they have a direct cost to the production system. The second is the socio-economic concern. Issues include increased federal regulation, disparate family farmer incomes, disappearance of the mid-sized farm, and urban sprawl. Once again, without a direct cost to the production system, or an overriding social consequence, the industrial model does not view these changes in agricultural systems as losses or problems. The third is the human health concern. These issues include overuse of antibiotics in animal production, nitrate and pesticide contamination of water and food, and release of toxic residues into our food and fiber supply.

There is an alternative to the industrialization model for family farmers. Many farmers and ranchers are implementing management focused on keeping native grasses abundant and healthy. These managers see themselves as caretakers of the land, thus they value plants, wildlife, and even predators, but they are family farmers first. They tend to think of themselves, not as commodity-producing businessmen, but rather as whole-ecosystem stewards. Livestock are considered tools used to manage the enterprise.

Impact of Global Markets

Family farmers are competing in an increasingly global marketplace. Twenty-first century agriculture is likely to be characterized by: more global competition; expansion of industrialized agriculture; production of differentiated products; precision production; emergence of ecological agriculture; formation of food supply chains; increasing risk and more diversity. In agriculture of the future, successful family farmers will need to be better, faster, and cheaper to have a sustainable competitive advantage. This approach, however, only considers bottom-line economics as the measure for sustainability.

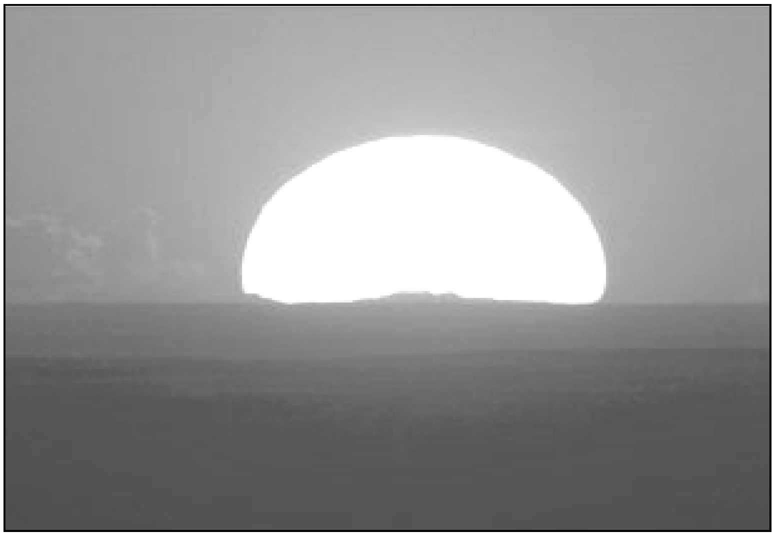
Expansion of trade and faster information flow through the internet are converging to create a new worldwide farm and food system. This new era is being fueled by at least five major issues: (1) finance, technology, and information are being democratized; (2) the internet has empowered global information dissemination and increased the speed of information dissemination; (3) the basic human desire for a better life has emerged at the root of globalization; (4) an increased role of world governments in developing policies that allow their agricultural sectors to become competitive in the global agricultural marketplace by becoming more efficient and offering higher quality service; and (5) opportunities have evolved through international trade to improve consumer health, provide consumer choices, and increase producer income.

Seven outcomes of globalization that will affect family farmers, include: (1) development of domestic policies that directly support international deals are in the best interest of corporate agribusiness; (2) disappearance of middle sized farms and loss of independent ownership; (3) unprecedented mergers, acquisitions, and concentration in all stages of agricultural production, marketing, and retailing; (4) more control of agriculture by fewer representatives; (5) increased agricultural industrialization leading to water, soil, and air pollution and overproduction leading to lower prices for independent producers; (6) a shift in land ownership and land availability, particularly away from minority-owned operations; and (7) the World Trade Organization placing more power and profits into the hands of transnational corporations.

Impact of Fossil-Fuel Energy Use

The use of fossil fuels in agriculture has greatly impacted agriculture. Escalating price of fuel has increased everything from transportation costs to fertilizer costs to feed costs. At the same time, high transportation costs have limited some attributes of industrialization, because high fuel costs mean that large firms can not simply ship either feed or product to areas of low labor costs.

Future family farmers will no longer focus solely on food and feed markets, but will produce for other outlets like energy and industrial uses. Use of a biofuel crop within an integrated system adds not only to farm diversity, but also contributes to the rural community. Selling starch (corn or dry peas) or lignocellulosic material (switchgrass or big bluestem) certainly gives the producer an added economic incentive.



In a base-line project conducted on marginal cropland, switchgrass was found to produce 540% more renewable energy than nonrenewable energy consumed. Managed correctly, average greenhouse gas emissions from cellulosic ethanol derived from switch-grass were 94% lower than estimated emissions from gasoline. Some 83% of the average U.S. household's carbon foot-print for food consumption comes from production, while only 11% and 5% come from transportation and retailing, respectively.

Impact of Water Shortages

Humans use about 26% of terrestrial evapotranspiration and about 54% of available runoff. With increasing global population, water availability is decreasing throughout the world. Such water shortages are leading to vast areas being affected by desertification. Agriculture is the leading source of impairments in U.S. rivers and streams, because of fertilization, pesticide use, sedimentation, and animal activity (through manure impacts on N, P, and pathogen loads). Animal-based production enterprises need to manage for water conservation and healthy vegetation.

A Potential Solution

Full integration of livestock and cropping systems may help in slowing or reversing some of the detrimental environmental and sustainability issues associated with agriculture. Traditionally, family farms with livestock used animal manure in crop production and feed grains in animal production. Integration of livestock and crop-ping systems had benefits of enhancing nutrient cycling efficiency, adding value to grain crops, and providing a use for forages and crop residue. Crop producers with livestock traditionally raised a greater diversity of crops in rotation and livestock could convert low quality crop residues or failed crops into higher value protein. Despite these advantages, many farms in the Great Plains have not achieved integrated land use.

Use of forages and other crops in rotation can reduce energy-intensive inputs required by agriculture, enhance yield of subsequent crops, enhance and intensify nutrient cycling and improve soil quality. Use of legumes in rotation can add significant amounts of organic nitrogen to soil, which can be used by subsequent crops.

One often overlooked aspect of sustainability is the ability of family farmers to adapt to change. Farmers need to respond to rapid changes occurring in the agricultural environment by reducing risk, while retaining management flexibility. Holistic management and integrated agricultural systems are approaches, by which whole-farm strategies and technologies are organized, to help producers manage enterprises in a synergistic manner for greater profitability and natural resource stewardship. In the past, U.S. agriculture was focused solely on its ability to produce sufficient food and fiber to meet national and global demands. Agriculture has been largely successful in meeting these production demands.

What Does the Future Have in Store for U.S. Agriculture?

The driving factors for the near future in agriculture have been put in place. The U.S. Farm Bill has historically dictated the types of crops farmers produce and thereby drives the production practices employed. Despite changes in legislation over the past decade, the Farm Bill will probably maintain its major role to drive agricultural production. Crop insurance appears to stifle diversity, but it has been helpful to stabilize market signal demands for specific crops. Ultimately, this leads to competition between agricultural producers and other programs for federal funds. Increased competition for limited federal funds in combination with international trade issues are likely to result in changes to farm programs.

The majority of the current U.S. population is one or more generations removed from farming. This means the public has less direct connection to issues involved in agricultural production; but they still have a strong demand for perceived benefits from environmental stewardship. Consumers may not be well informed, but they are discerning. This will bring to the forefront such issues as product identity preservation, designer crops (i.e., biotechnological crops developed to meet specific criteria defined by the consumer), improved quality (especially in relation to health issues), and organic production (reduced use of chemical pesticides and fertilizers). These demands for environmental stewardship and food quality characteristics are likely to shape future agricultural policy and to be reflected in the marketplace.

Family farmers are looking for additional economic opportunities and are becoming more market astute. This will result in an increase in multiple farm enterprises within a single farm operation, development of other forms of income-generating operations (i.e., hunting, fishing, site-seeing, etc.), and flexibility to generate an alternative array of products. Changes in agriculture and public demand will benefit grazing and integrated crop livestock operations, in addition to other aspects of sustainable agriculture, by providing an environmentally sustainable agriculture that provides multiple income streams to the producer, while providing socially acceptable land management.

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Sue Mellen Retires

Sue Mellen retired from her secretarial position at the Northern Great Plains Research Laboratory after almost 32 years of dedicated government service. She began her career at the USDA-ARS lab in 1976.

New Faces at the Northern Great Plains Research Laboratory

Dr. Marty Schmer, USDA-ARS Research Agronomist, will focus primarily on cropping systems and biofuels crop development for the northern Great Plains. Marty relocated from Lincoln, Nebraska to Mandan.

Dr. Qingwu (Fred) Xue, NDSU Research Agronomist, is employed by the NDSU BioEPIC bio-energy development center and will office at the Northern Great Plains Research Lab. He will work with the NDSU Research Extension Centers throughout the state and USDA-ARS research staff to support the integration of new biofuels crops into successful cropping systems in North Dakota. Fred relocated from Montana State University to Mandan.

Jack Buckley, USDA-ARS Agricultural Science Research Technician, will be supporting beef and crops research at the Mandan laboratory. Jack, a native of Mandan, is a recent graduate from North Dakota State University with a degree in Animal Science.

Jill Gunderson has joined the USDA-ARS as Office Automation Assistant. Jill, a resident of Baldwin, brings several years of experience in the medical field. She received her degree from North Dakota State College of Science.

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