Northern Great Plains Research Laboratory

NORTHERN GREAT PLAINS

INTEGRATOR

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

July 2009

Soil and Water Conservation Advances in the Semiarid Northern Great Plains

The Great Plains has often been referred to as the "Great American Desert" with many early maps showing this area similar to the Sahara desert. Not surprisingly then, many dryland agricultural practices for North America originated on these plains by necessity.

In this region, annual precipitation typically peaks in mid- to late-spring, with 70% received in the 6-month period from April to September. Frequency and distribution of precipitation varies considerably from year-to-year and month-to-month in addition to geographical variability. Average annual precipitation ranges from 10 to 15 inches. Snow is intermittent and highly variable, but may account for 20 to 30% of total precipitation.

Historic soil and water conservation

Spurred on by promotion of railroads, early settlers came to the Great Plains from humid places such as Europe and the Midwestern U.S. region. Settlers brought with them the familiar tillage tools, cropping systems, and seeds that emulated the longer growing season and greater precipitation regions from which they came. Early settlers came during a wet cycle from 1895 to 1915, which was characterized by above-average precipitation and successful annual crop production. When weather conditions changed to a dry cycle, annual cropping systems were prone to crop failure. One of the first strategies to help producers stabilize crop yields during drought periods and reduce the risk of crop failure was the crop-fallow system and the use of summer fallow.

Photo 1 –Settlers to the northern Great Plains brought tillage tools used in areas with greater precipitation.

Early tillage techniques during summer fallow used a plow or disk to create a condition known as "dust mulch" fallow. Dust mulch suppressed soil water evaporation and disrupted capillarity that brought stored soil water from below. The number of tillage operations needed to create dust mulch ranged from seven to 15 operations. The fine pulverized soil created by dust mulch during summer fallow was vulnerable to wind and water erosion, which became a severe problem culminating in the "Dust Bowl" era of the 1930's.

During the late 1930s and early 1940s, federal farm programs began to stress resource conservation. Fallow water storage efficiency improved with increased knowledge of residue maintenance and water conservation. Changes since 1916 in fallow tillage systems improved water storage, fallow efficiency, wheat yield, and precipitation-use efficiency (grain per total precipitation during the entire rotation cycle). The number of tillage operations per fallow period decreased from seven to 15 in the dust mulch systems of the early twentieth century to zero to four with modern conservation tillage systems.

Conservation Tillage

Conservation tillage includes reduced or minimum till where the soil surface has 30 to 60% crop residue coverage and no-till where the soil surface has over 60% crop residue coverage.

No-till farming resulted from a desire to produce crops in a way that did not degrade the soil by high wind and water soil erosion. In the early 1950s, research began in Belgium, France, Germany, New Zealand, the U.K, and the USA on the concept of no-till chemical preparation of the seedbed. Evolution of modern no-till systems required research in many disciplines to overcome early obstacles. The first no-till adoption by innovative producers began during the 1970s and gradually became a recognized practice during the 1980s.

Increased Cropping Intensity

In 1968, it was observed that conservation tillage altered the time when water was stored as much as it did total water storage. After eight months of fallow, plow tillage had stored only 16% of precipitation, while the minimum-till and no-till systems had stored 40% and 60%, respectively. For spring wheat-fallow systems, nearly 45% of the precipitation was stored during the first 9 months of fallow with minimal soil water storage the second winter.

As the soil profile begins to fill with water and the surface soil nears field capacity, soil water storage efficiency falls regardless of the tillage system used. When using conservation tillage systems, the fallow period could be terminated at an earlier date to allow the planting of a summer crop. Intensifying the cropping pattern and using the precipitation nearer to the time it is received creates the potential to increase the overall system precipitation-use efficiency and ultimately increase soil productivity.

The elimination of fall tillage, especially when combined with post-harvest herbicides to control weeds that would otherwise regrow in early spring, frequently provided an important water conservation benefit. This practice, originally intended to improve soil and water conservation on fallow, made recropping in the subsequent spring feasable. Leaving tall cereal stubble to hold snow provided another mechanism to increase soil water storage the first winter. This is particularly effective for improving soil water storage on sloping land.

Intensifying cropping systems using no-till and improved understanding of the impact of crop sequences has increased annualized grain yield by more than 75% relative to the yield of the wheat-fallow system.

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What drives Agricultural Systems?

Agriculture has done a great job of addressing the food and fiber needs of today's global population. The amount of calories per person per day has risen from 2400 to 2700 calories, despite an increase in the world's population from 2.5 billion people in 1950 to 6.5 billion in 2005. Agriculture only requires about ½ acre per person to achieve this incredible performance because cereal yield have increased by 150% while the amount of land in agriculture has remained relatively stable.

Despite this productivity, there have been some questions raised regarding the sustainability of modern agricultural production systems. These questions are Important because the U.S. and world populations are becoming more urbanized, which means people have less direct connections to farms and ranches. However, the urban population still has an interest in farming and rural areas.

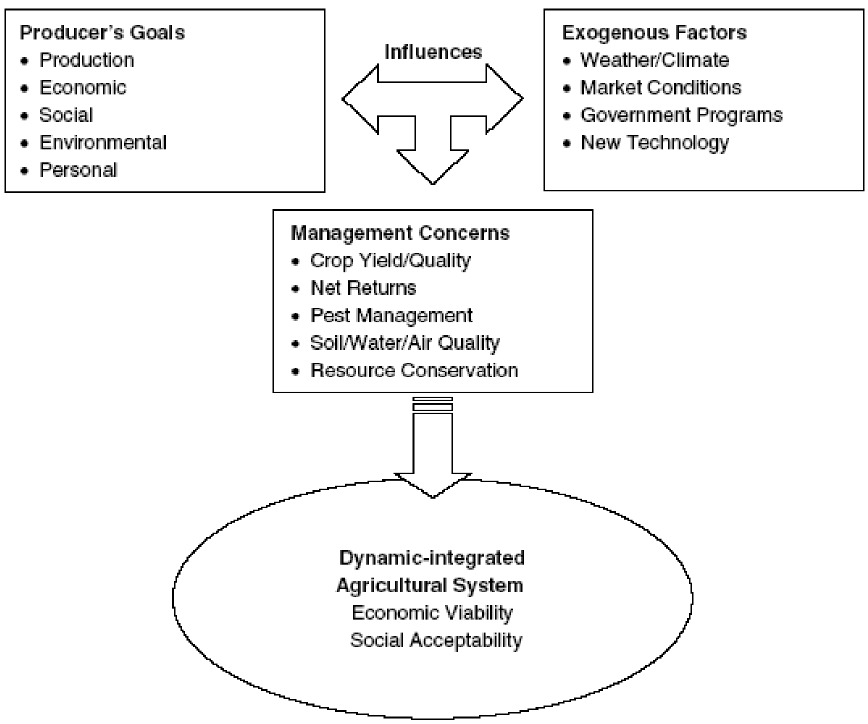

Figure 1. Multiple criteria producers need to consider to make management decisions.

The above factors have resulted in agricultural producers operating in an increasingly complex environment. Farmers must consider multiple objectives when making decisions (Fig. 1) while keeping enough management flexibility to react to changing conditions. An agricultural system that may provide management flexibility while addressing concerns regarding sustainability is integrated agricultural systems. This system is already used by many North Dakota producers who integrate crop and livestock enterprises on their farms.

However, for researchers to help farmers develop management strategies for integrated systems they need to answer certain questions including 1) what is the definition of an integrated agricultural system and 2) what drives agricultural systems? Scientists at the Northern Great Plains Research Laboratory collaborated with ARS scientists in Mississippi and Maine to help answer these questions by holding producer oriented panel discussions in different regions of the U.S. The first meeting was held in November 2004 at Mandan. The result of this meeting was a series of papers that defined integrated agricultural systems, identified factors that influence agricultural systems, looked at how different factors influence each other and identified future challenges in agriculture.

Definitions provide a way for everyone to begin from the same starting point and keep on the same page. Integrated agricultural systems were defined as 'agricultural systems with multiple enterprises that interact in space and/or time and the interactions result in a synergistic resource transfer among enterprises'. Adding management flexibility to integrated systems results in dynamic integrated agricultural systems. These systems provide the benefits of integrated agriculture with a more flexible management paradigm.

The next step in developing management strategies for integrated systems is understanding what factors shape the system. Many factors influence agriculture but we felt they could be placed into Social, Economic, Environmental and Political categories. Each of these categories shapes agriculture both individually and in combination with other factors.

The two major social factors influencing agricultural systems were identified as globalization and low margins requiring increased scale and efficiency. Other major social factors included market consolidation and concentration and the farm bill. Technologies have increased yield and net output which have allowed agriculture to feed the current world population. However, some technologies have also resulted in decreased control by producers, increased intensification, specialization and complexity of production, greater dependence on non-renewable resources, increased production Inputs and hence decreased return, and an enhanced reliance on future technology. Economically there have been dramatic changes in market structure, channels and consumer demand in the past five decades have increased consolidation and specialization in both production and marketing sectors. However, consumers have shown increased diversity in what they want from food products. Increasing consumer interest in where food comes from and how it is produced has also created opportunities for more integrated farm operations.

Integrated agricultural systems, such as those with livestock, may increase soil organic matter, decrease soil erosion, better balance both production and environmental outcomes and improve utilization of natural resources. However, there may be nutrient management issues with crop-livestock systems. Still, integrated systems appear to be better placed to address future environmental challenges.

Understanding factors that shape agricultural systems is important in developing management strategies for future agricultural systems. Dynamic integrated agricultural systems may provide a way to address both current and future problems. However, as agricultural systems become more integrated, the management intensity needed to successfully operate these complex systems increases. This may be a hurdle for future adoption of integrated agricultural systems.

From Renewable Agriculture and Food Systems, Volume 23, Issue 04, December 2008, pp 263-264 doi: 10.1017/S174217050800241X, Published online by Cambridge University Press 31 Oct 2008

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Friends & Neighbors Day

Feeding and Fueling the Future

AREA 4 SCD Cooperative Research Farm

Agricultural Research Service

2 PM CDT
July 16th

Northern Great Plains Research Lab

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No Cost

Free Evening Barbecue Grass-fed Beef

Campus Activities

2 - 5 PM

- ***Presentations:***
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  - **Soil Biology**
  - **Proper Tree Care and Pruning**
  - **Rain Gardens in North Dakota**
  - **Conservation Lawn Care & Watering**
- **Children's Activities**
- **Horse Drawn Wagon Rides**
- **Historical Station Tour**
- **Exhibits**

Research Tours

4 PM

- **Biofuels from Perennial Crops**
- **Biofuels from Annual Crops**
- **Cover Crop Opportunities**
- **Forage Finished Beef**
- **Global Change Science**
- **CCA Continuing Education**

Evening Entertainment by the North Dakota Troubadour **Chuck Suchy**

Soil and Water Conservation Advances in the Semiarid Northern Great Plains

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These yield increases have translated into 25 to 40% gains in net income for Great Plains farmers.

Cropping intensification has had significant positive impacts on soil physical and chemical properties. Cropping system intensification under no-till decreased compaction of surface soil, increased total porosity, and increased effective pore space with the addition of more crop residue biomass to the soil. Coupled with the lack of soil disturbance in a no-till environment, the additional residue carbon has promoted soil aggregation and has increased soil aggregate stability. More intensive agriculture has proven more sustainable than low input agriculture.

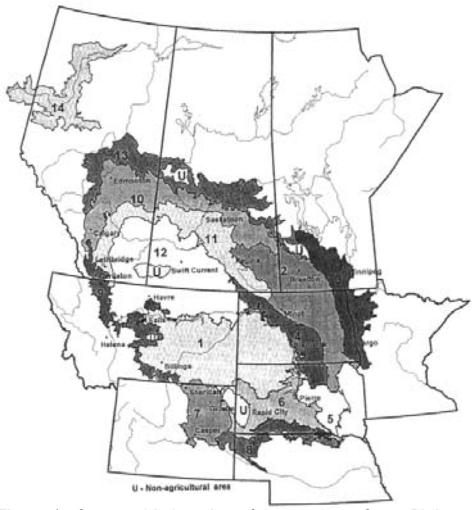

Figure 1. Geographic location of the northern Great Plains as depicted by Padbury et al. (2002) which includes the Canadian Prairie Provinces (Alberta and Saskatchewan) and States in the United States (Montana, North and South Dakota, Wyoming, and Nebraska).

Recent advances

Pulse crops have revolutionized wheat-based cropping systems more than any other class of broadleaf crops. In northern Great Plains states, land seeded to dry peas and other legumes increased ten-fold from 1991 and 2001, and stabilized at greater than five million acres each year between 2005 and 2008. These crops have positive environmental effects on soil nitrogen fertility, soil biology, greenhouse gas emissions, and are important in adaptation of dryland agriculture to climate change.

Expanded use of glyphosate herbicide has resulted in a significant increase in conservation and no-till cropping systems. Farmers now more rapidly cover increased acres by spraying than with mechanical tillage, reducing labor costs and permitting timelier crop management. Glyphosate herbicide currently represents a foundational input for no-till systems.

No-till management is essential for the most efficient use of precipitation. Spring wheat planted into one foot tall stubble increased water use efficiency by 10 to 15% compared to a cultivated seedbed. With the improved microclimate for plant growth in standing stubble, evaporation of water from soil surface was reduced and plant respiration was reduced due to increased plant protection. Increases in water use efficiency were confirmed for pulse and oilseed crops, also. Reduction of wind speeds due to standing stubble was discernable even at full crop canopy. These water use efficiency effects occurred in years with both favorable and unfavorable moisture conditions.

Utilization of diverse crops provides a "rotation effect," where crop yields increase when compared with monoculture systems. This has been especially true when pulse crops such as pea, lentil, or chickpea are sequenced before wheat or barley. Greater crop diversity promotes crop health, reduces weeds and pests, and can reduce production costs. Crop sequence research has shown increased diversity to increase spring wheat seed yield by up to 37%, while pulse crops yields can be improved by at least three-fold through optimal cropping sequencing.

To assist producers in developing maximum crop sequencing benefits, an interactive computer information product (Crop Sequence Calculator; available at http://www.mandan.ars.usda.gov) was developed to assess crop options. Use of the software provides producers options to better manage soil and water resources and provides the tools needed to implement economically viable and environmentally acceptable agricultural systems. The Crop Sequence Calculator is a relatively simple decision support aid. Significant producer interest in this tool shows the need for more extensive development of more robust decision support systems that can optimize economic and environmental outcomes.

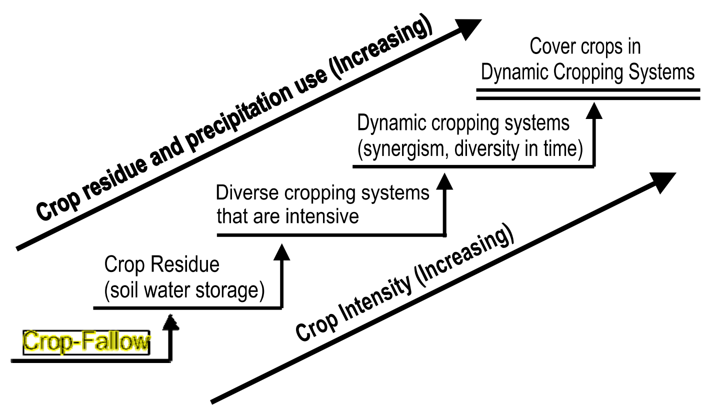

Figure 2. Evolution of soil and water conservation practices in the northern Great Plains as influenced by crop residue, precipitation use, and crop intensity.

The Future

Improved soil and water conservation practices coupled with a better understanding of cropping systems has drastically changed agriculture in the past century, with advent of no-till farming systems and increases in cropping intensity and diversity. Great challenges and opportunities yet lie ahead for agriculture. Today, the role of agriculture has expanded to include a fourth 'F'; that of 'fuel' from a land base already heavily committed to producing food, feed, and fiber.

Economics dominates agricultural science. The major energy input for U.S. wheat production is nitrogen fertilizer, accounting for 47 - 70% of the total energy input. Two significant sources of nitrogen for wheat production are available: application of fossil fuel-derived fertilizer and mineralization of organic matter.

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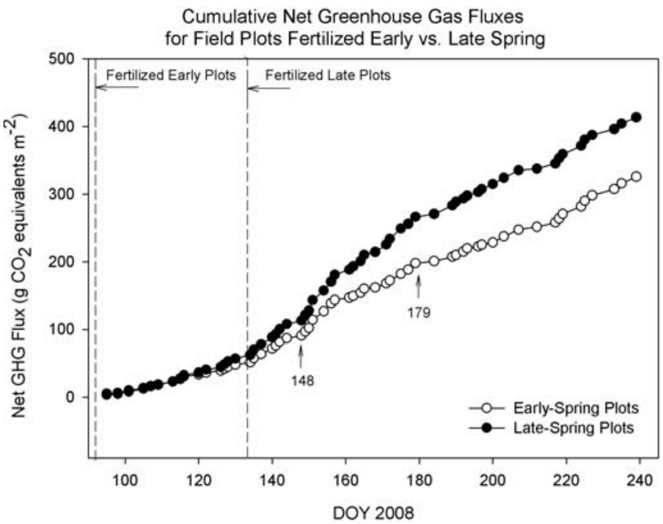
Feel free to pass on this issue of ***Northern Great Plains Integrator*** to others interested in agricultural research in the northern Great Plains. Northern Great Plains Integrator is published and distributed by the USDA-ARS, Northern Great Plains Research Laboratory, PO Box 459, 1701 10th Avenue 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

Fertilizer Application Timing Influences Greenhouse Gas Fluxes Over a Growing Season

Land under cultivation comprises the single largest total land area worldwide. Agricultural practices may contribute significantly to the global increase in atmospheric concentrations of the greenhouse gases methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O).

The effect of fertilization on greenhouse gas fluxes should occur during and shortly after application, yet data indicating how application timing affects both greenhouse gas fluxes and crop yields during a growing season are lacking.



We designed a replicated corn field experiment to determine the short-term effect of fertilizer application timing on fluxes of these gases over a growing season.

Microbial production and consumption of greenhouse gases was found to be influenced by timing of fertilization, with enhanced production of CO_2 for soils fertilized later in the growing season.

Timing of fertilizer application affected net greenhouse emissions for soils planted to corn, with greater emissions for soils fertilized When air and soil temperatures warmed above 50° Fahrenheit in late spring, microbial activity was stimulated by recent additions of urea. Differences between treatments in late spring were most evident when soil moisture rose above 30%.

Carbon dioxide accounted for over 98% of the net greenhouse gas flux measured at the soil surface, while nitrous oxide accounted for less than 2%.

Net greenhouse gas flux calculated for the growing season was 19% lower for soils fertilized in early spring as compared to late spring.

Our results suggest that fertilizer application timing should be considered when evaluating effects of agricultural practices on greenhouse gas emissions. Further, investigation is yet needed to determine how timing of urea application can be used as a management tool to reduce greenhouse gas emissions without sacrificing dryland cropping system yields.

The full article is available in the July-August 2009 issue of the *Journal of Environmental Quality.*

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Control Kentucky Bluegrass and Smooth Bromegrass

Two Mandan ARS scientists are attempting to control Kentucky bluegrass and smooth bromegrass. Range Scientist John Hendrickson and Animal Scientist Eric Scholljegerdes turned cows out May 11th in the first year of a five year experiment.

The first phase involved grazing ten cows on 7½ acres for two weeks. The cows ate Kentucky bluegrass and the smooth bromegrass before they began eating the native grass.

There was a concern that the high stocking rate and the slowness of the grass growth could limit milk production, but it did not show in calf performance.

Once the cows started eating the cool season native grasses the scientists took that as the signal it was time for phase two. Until July 20th five cows will graze another 7 ½ acre pasture. Each fall species composition will be evaluated. They are hoping that grazing earlier will help put more native grasses in the pastures which would be an advantage to producers.

The growth pattern of Kentucky bluegrass means that in typical years production peaks early in the growing season. In pastures with large amounts of Kentucky bluegrass, this may reduce forage production later in the summer. Native grasses, both cool- and warm-season, begin growth later and can be productive later in the growing season.

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Soil organic matter can be augmented by legume crops via biological nitrogen fixation; but knowledge remains surprisingly scant for enhancing soil fertility by legumes. The potential of nitrogen fixation by bacteria with non-legume crops like wheat could fundamentally change the nitrogen fertility situation in the future.

Effective carbon policy will increase attention on land management including decreased nitrogen fertilizer application and promotion of reduced tillage. Increased attention on the environmental footprint of farming will require changes in strategies to positively effect soil carbon storage. Perhaps the biggest transformation in crop production will relate to climate change. There will be direct effects from climate change on crop and livestock production. Our climate is predicted to warm, and increase slightly in precipitation. Agricultural adaptation to an altered climate will be essential. Earlier seeding, increased use of crops with winter growth habits, and using a greater diversity of crops may be crucial. What technology will be required to enable consistently successful crop establishment in more variable soil and air temperatures? What expertise will ensure survival of winter crops with less frequent snow cover? New management practices will focus on soil and water management. As energy constrains wheat production, legumes are likely to occupy more land area. If glyphosate were to become increasingly ineffective under elevated atmospheric CO_2 concentrations, what substitute technology will support no-till crop production?

Agricultural has changed more in the past century than since the dawn of civilization. With increasing opportunities and challenges, positive impact of agricultural research, and the opportunity for agriculture to participate in long-term solutions, we can truly say, “You haven’t seen anything yet!”

Excerpted from upcoming book “Soil and Water Conservation Advances in the U.S.: Past Efforts...Future Outlook.” Don Tanaka, Drew Lyon, Perry Miller, Steve Merrill, and Brian McConkey, Authors; T. M. Zobeck and W. F. Schlesinger, editors

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International Integrated Agriculture Journal Looks to Mandan scientists

Research Scientists from the Northern Great Plains Research Laboratory dominated the December 2008 edition of the international Cambridge University Press, "Renewable Agriculture and Food Systems" journal, which focused on Dynamic Integrated Agricultural Systems.

Research papers by Dr. John Hendrickson ("Principles of integrated agricultural systems: Introduction to processes and definitions", "Environment and integrated agricultural systems", "Interactions in integrated US agricultural systems: The past, present and future"), Dr. Jon Hanson ("Challenges for maintaining sustainable agricultural systems in the United States"), and Dr. Dave Archer ("Social and political influences on agricultural systems") were profiled.

In the editorial to the publication, Dr. Hanson said, "Current American agricultural systems are dramatically different from agricultural systems at the start of the 20th century. Economic, social/political, environmental and technological drivers have all interacted to shape the current agricultural domain. To understand the structure of future agricultural systems, an understanding of how drivers have affected current agricultural systems is needed." Researchers at the Northern Great Plains Research Laboratory are committed to support the future of family farming. A set of robust principles must be defined and subsequently used to design adaptable integrated agricultural systems of the future.

Fulfilling their objective to advancing learning, knowledge and research worldwide, Cambridge University Press has been publishing high quality and technologically innovative scientific journals for 425 years. The international *Renewable Agriculture and Food Systems* focuses on the science that underpins economically, environmentally, and socially sustainable approaches to agriculture and food production. The full edition is available online at: http://journals.cambridge.org/action/displayIssue?jid=RAF&volumeId=23&issueId=04&iid=2522628.

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