A Long-Term Agro-Ecosystem Research (LTAR) Network for Agriculture

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Abstract

As the 21st century unfolds, agriculture will face a series of challenges—in the United States and globally—in providing sufficient food, fiber, and fuel to support a growing global population while our natural resources, environmental health, and available arable land decline and climate changes. The unprecedented nature of these challenges creates a growing sense of urgency for transformative changes in agriculture to accelerate progress towards achieving sustainable agricultural systems that maximize production and economic return for producers, minimize environmental degradation, and adapt to changing climate. Achieving such a transformation requires an improved understanding of the complexities of how agro-ecosystems function at multiple scales (i.e., fields to watersheds or landscapes). Long-term research and data collection are essential to achieving this understanding; at stake are the security and safety of our food production systems, our natural resources, and our environment.

Over the past 10 years, there have been frequent calls for the creation of a 'Long-Term Agro-Ecosystem Research' (LTAR) network, similar to the National Science Foundation's Long–Term Ecological Research (LTER) network, to provide a sophisticated platform for research on the sustainability of U.S. agricultural systems. The U.S. Department of Agriculture's Agricultural Research Service (ARS) currently maintains approximately 23 benchmark experimental watersheds and ranges that collect long-term data on agricultural sustainability, climate change, ecosystem services, and natural resource conservation at the watershed or landscape scale. Some of these sites have been collecting data for nearly a hundred years. Here we present a vision for how a subset of these sites could be used to form the core of an LTAR network. Eventually, such a network would link ARS sites with partner sites operated by universities, other research institutions, and (or) other Federal agencies to support multidisciplinary research and funding efforts addressing regional- and national-scale questions using shared research protocols. Such a long-term agro-ecosystem research network would provide the knowledge to substantially improve both agricultural sustainability and the delivery of ecosystem services to a society that increasingly demands that agriculture be safe, environmentally sound, and socially responsible, in addition to being productive and economically viable.

Keywords: agro-ecosystem, climate change, Long-Term Agro-Ecosystem Research (LTAR) network, sustainability, USDA

Introduction

During the last 30 years, new technologies, changing demographics and social values, and the globalization of markets, cultures, and competition have produced dramatic changes in the world's food and agricultural systems. Agriculture is shifting from a solely commodity-driven system to one at least partly driven by a global consumer population that values the quality, safety, and nutrition of their food and the way it is produced. Today, consumer concerns about food safety, nutrition, animal welfare, and the environmental footprint of agriculture are driving demands for more locally-produced, organic, humane, high quality, and sustainable agricultural products.

More recently, the global economic downturn, rising energy costs, spikes in food prices, and growing food insecurity, particularly in the developing world, have highlighted the challenges that agriculture faces to meet the food, feed, fiber, and biofuel needs of a

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growing global population. These and other factors have shifted public policy towards the creation of more sustainable agricultural systems, as evidenced by a renewed emphasis on the role of rural lands in providing essential ecosystem services and mitigating climate change and by a rededication towards managing natural resources at the landscape scale.

Recent Farm Bills have placed greater emphasis on conservation, organic agriculture, climate change, and sustainability, while the U.S. Department of Agriculture (USDA) has adopted an “all-lands” approach to conservation aimed at bringing public and private landowners together across landscapes and ecosystems to collaboratively address natural resource conservation issues (U.S. Department of Agriculture 2010).

Reflecting a growing sense of urgency, these policy shifts signal a transformative change in agricultural production, accelerating progress towards achieving the four goals of sustainability as defined by the USDA: (1) satisfying human needs; (2) enhancing environmental quality, the resource base, and ecosystem services; (3) sustaining the economic viability of agriculture; and (4) enhancing the quality of life for farmers, ranchers, forest managers, workers, and society as a whole (U.S. Department of Agriculture 2011).

In agricultural ecosystems, physical and biological processes are linked with social and economic processes. To achieve sustainability, it is essential that we understand how these processes interact and their effects on the environment through space and time (National Research Council 2003). Agricultural research must explicitly identify and address these linkages so that progress in one agricultural sector does not inadvertently create or exacerbate problems in another.

Creation of the scientific foundation necessary to transform the Nation’s agricultural production to meet our sustainability goals demands that the agricultural research, education, and extension communities take a strategic, long-term approach to understanding the aggregate effects of farming at the watershed/landscape scale. Such an approach calls for increasing integrative research by bringing together multidisciplinary teams of scientists from government, academic, and private sector research communities to increase synergies, accelerate progress, and improve cost effectiveness.

Long-term research is vital for agriculture to meet its sustainability goals, including profitability, environmental integrity, and the production of ecosystem services beyond food, fuel, and fiber. Building a sustainable agricultural production system requires a comprehensive, systems-level research approach that is both long-term and geographically scalable (Robertson et al. 2008).

Because of its existing infrastructure, the public research sector is uniquely positioned to undertake the long-term, large-scale, risky research necessary to transform agriculture. Conducting such research provides benefits that cannot be appropriated by individual firms. Long-term research often provides new “platforms” of discovery for multiple private and (or) local applications, with broad public benefits that address national needs and that are widely shared throughout the global community.

The Need for a Long-Term Agro-Ecosystem Research Network

Long-term research is essential to understanding how key agricultural system components interact at the whole system level. Environmental field research carried out over decades plays an important role in understanding the physical, chemical, and biological aspects of agro-ecosystems and can yield critical insights for fields such as agronomy, biogeochemistry, ecology, hydrology, and soil science. Long-term field studies are particularly important for anticipating the environmental effects of shifting agricultural practices, improving the effectiveness of conservation programs, and identifying the broader societal benefits of modern agriculture, such as bioenergy production, carbon sequestration, improved water quality and water-use efficiency, and wildlife habitat.

Developing a long-term agro-ecosystem research network

The scientific community has long recognized the value of maintaining long-term research sites focused on natural resources. Experimental watersheds, such as those maintained by the USDA Agricultural Research Service (ARS) and others, have proven essential for understanding regional hydrologic processes in the United States. The long-term data collected and maintained at these sites are critical for effectively managing water availability and water quality for multiple uses, determining flood effects, and developing, calibrating, and validating watershed models and decision support tools. Experimental watersheds also provide key data on sediment transport and flow needed for the optimal design of culverts, bridges, detention basins, and reservoirs. More recently, these sites are also providing data to help improve the effectiveness of USDA's conservation programs.

In addition to supporting high-quality, location-based research, including collaborations with the academic research community and other Federal agencies, long-term research sites provide the opportunity to take the pulse of agricultural ecosystems and the landscapes in which they exist, to help understand how changes in land management practices and the environment affect the status and trends of landscape condition. Long-term research sites allow us to answer important questions that take longer than the normal 2–5 year project cycle to formulate, allow questions to be addressed against a wide range of environmental conditions, allow the inclusion of episodic events, and enable the detection of important but slow-acting phenomena such as changes in soil carbon, climate, and the effect of land use changes. Long-term data collected at these sites also enable the development, calibration, and validation of models used to forecast these changes. It is well-known that diverse, nontraditional research collaborations form more readily around long-term research networks (National Research Council 2000, 2001, 2005; Robertson et al. 2004; Boody et al. 2005).

A network of long-term agro-ecosystem research sites would improve our understanding of agriculture from a systems perspective, facilitating the optimization of multiple management goals. A network would enable greater integration of biophysical and social sciences to provide solutions with acceptable economic and social costs, improve our knowledge of geographic scalability to ensure that solutions developed at one scale are also effective at larger scales, and allow processes that operate at larger scales to contribute to solutions at the field and farm scale. This scalability is critical to improving agricultural productivity for small landholders in the developing world, increasing their food security and improving incomes—both important U.S. foreign policy goals.

A network of long-term agro-ecosystem research sites would also strengthen ties between agricultural research, outreach, and education, helping to improve the relevance of agricultural research to stakeholders. Such a network would increase public understanding and awareness of agricultural ecosystems, including their social, environmental, and management implications.

Proposed criteria for an LTAR network

The critical mass needed to establish an inaugural LTAR program requires a capacity for field-scale experimentation at the site level as well as a capability for stakeholder involvement that exploits existing data sets and regional infrastructure. A reasonable minimum useful duration for an LTAR site is 30 years (Robertson et al. 2008). The Network must include multiple sites that will capture the breadth and diversity of U.S. agricultural production systems. Full value will only be realized when multiple sites function as a network, allowing more robust tests of common hypotheses and comparative analyses in and across different production systems, leading to a comprehensive understanding of agricultural issues.

Key elements for networking include common measurements at multiple sites that provide the foundation for scaling up to regional and national levels. These measurements provide the basis for cross-site syntheses, allowing analyses across gradients of climate change, management intensity, etc. (Robertson et al. 2008).

Criteria for LTAR candidacy could potentially include the length and breadth of existing data records and the availability, accessibility, and organization of datasets (e.g., data in STEWARDS or some other publically-accessible database). A location's infrastructure is also important. Of particular importance is the presence of an instrumented watershed or other long-term research facility (e.g., experimental range) of sufficient size to capture landscape-scale processes and heterogeneity and capable of integrating across small plot, watershed, and landscape scales. The availability of land to support crop and (or) livestock production is critical, as is the site's existing water/energy balance and (or) carbon flux/sequestration research (e.g., Ameriflux, GRACEnet, NEON), with the capacity to integrate across soil, water, and air processes. A formal association with other long term research networks (e.g., Ameriflux, LTER, NEON) is also desirable. Other criteria might include a location's knowledge base, extension capabilities, existing partnerships, and education/outreach potential.

A Proposal for an LTAR Network

As the Federal government's primary intramural agricultural research organization, with significant relevant infrastructure already in place, the Agricultural Research Service (ARS) accepts the challenge of forming an LTAR network for agriculture. Sites for inclusion in the LTAR network will be chosen to represent major U.S. agricultural regions (Northeast; Appalachia; Southeast; Delta States; Corn Belt; Southern Plains; Lake States, Northern Plains; Mountain; Pacific), with attention also paid to major U.S. hydrologic basins at the 2-digit Hydrologic Unit Code scale and National Ecological Observatory Network (NEON) Domains (Figure 1; Table 1).

A steering committee (SC) has already been formed to oversee the site-selection process. Later this year, the SC will solicit "Requests for Information" from the 23 ARS sites that represent candidates for initial inclusion in the emerging LTAR network (Figure 1; Table 1). While site criteria are still being finalized, they will likely include factors such as research productivity, infrastructure capacity, data availability and accessibility, geographic coverage, existing research partnerships, and institutional commitment. Our overall goal is to complete initial selection of ARS LTAR sites by the end of 2011. As we evaluate existing ARS sites for inclusion in the LTAR network, we will begin the process of reaching out to other Federal, academic, and private research organizations, customers, and stakeholders that may have sites suitable for inclusion in the developing LTAR network. Non-ARS sites will be evaluated using the same criteria established for ARS sites, with the overall goal of completing this second phase of LTAR network formation by the end of 2012. When complete, the LTAR network will bring together in a coordinated network experimental watersheds, rangelands, and other sites that address

ARS Benchmark Experimental Watershed and Range Research Sites

Code		Code	
BL	Beasley Lake Watershed	NA	North Appalachian Experimental Watershed
BW	Upper Big Walnut Creek Watershed	NP	Northern Great Plains Research Laboratory
CP	Central Plains Experimental Range	NS	Neil Smith National Wildlife Refuge/Walnut Creek South Watershed
CR	Choptank River Watershed	RC	Reynolds Creek Experimental Watershed
FC	Fort Cobb Reservoir Experimental Watershed	RI	Riesel Experimental Watershed
GCa	Goodwater Creek Experimental Watershed	SF	South Fork of the Iowa River Watershed
GCb	Goodwin Creek Experimental Watershed	SJ	St. Joseph River Watershed
JO	Jornada Experimental Range	US	Upper Snake River/Rock Creek Watershed
LR	Little River Experimental Watershed	WC	Walnut Creek Watershed
LW	Little Washita Experimental Watershed	WG	Walnut Gulch Experimental Watershed
MC	Mahantango Creek Experimental Watershed	YR	Yalobusha River/Topashaw Canal Watershed
MT	Mark Twain Lake Watershed		

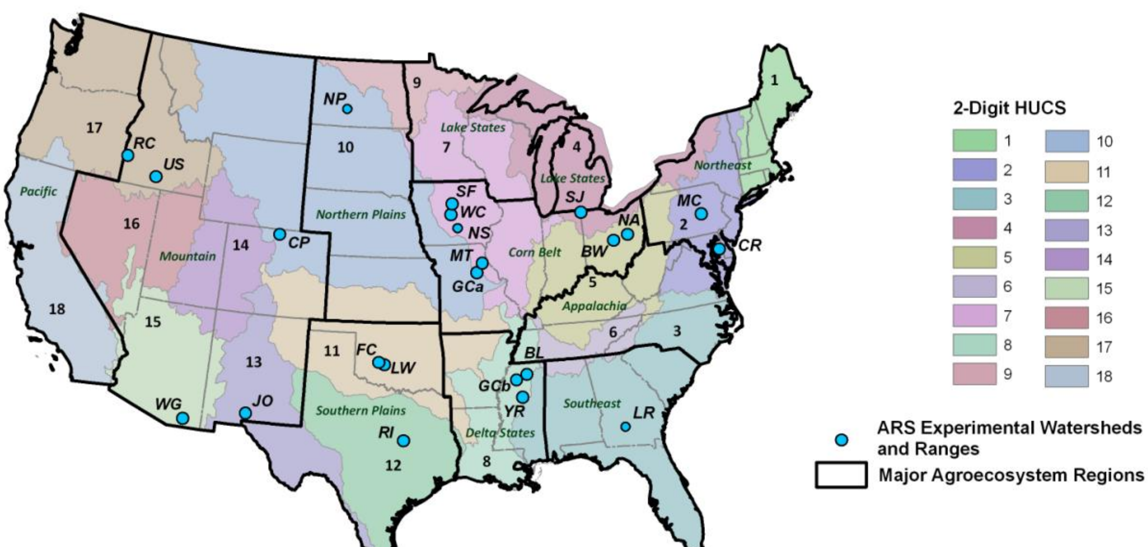

Figure 1. ARS Benchmark Experimental Watershed and Range Research Sites that would be candidates for inclusion in the proposed Long-Term Agro-Ecosystem Research (LTAR) network, plotted vs. 2-digit Hydrologic Unit Code (HUC) watersheds and Major Agro-Ecosystem Regions of the lower 48 United States.

long-term agricultural research at the watershed/landscape scale. The LTAR network will provide an agro-ecosystem complement to the National Science Foundation (NSF) LTER and NEON networks of ecological sites.

Once developed, ARS will offer the LTAR network infrastructure for research and funding partnerships with other Federal agencies, universities, and the private sector. Through these partnerships, funding will be sought from sources such as USDA's National Institute of Food and Agriculture (NIFA) and NSF to develop technologies and processes for standardized data collection, storage, access, and the development of LTAR Network-wide synthesis products to complement other long-term, multidisciplinary, large-scale Federal research investments (e.g., LTER, NEON).

Vision and goals of the LTAR

Our vision for the LTAR network:
Transdisciplinary science conducted over decades on the land in different regions, geographically scalable, enhancing the sustainability of agro-ecosystem goods and services.

Our goal in developing this network:
To sustain a land-based infrastructure for research, environmental management testing, and education that enables understanding and forecasting of the Nation's capacity to provide agricultural commodities and other ecosystem goods and services under changing environmental and resource-use conditions.

Table 1. Potential ARS Experimental Watershed and Range LTAR Sites

Site code*	ARS lab location	Established	Record (years)	Area (km2)	Network affiliations	NEON domain
BL	Oxford, MS	1995	17	9	CEAP	Ozarks Complex
BW	Columbus, OH	2004	8	492 (17)	CEAP	Appalachians/CP**
CP	Cheyenne, WY	1939	73	63	LTER/NEON	Central Plains
CR	Beltsville, MD	1985 (2004)	27 (8)	2057 (395)	CEAP	Mid Atlantic
FC	El Reno, OK	2004	8	786	CEAP	Southern Plains
GCa	Columbia, MO	1971 (1969)	41	73	CEAP	Prairie Peninsula
GCb	Oxford, MS	1981	31	21	CEAP	Ozarks Complex
JO	Las Cruces, NM	1912	100	780	CEAP/LTER/NEON	Desert Southwest
LR	Tifton, GA	1967 (2002)	42 (10)	334 (5208)	CEAP	Southeast
LW	El Reno, OK	1961	51	610	CEAP	Southern Plains
MC	University Park, PA	1967	45	420 (7)	CEAP	Northeast
MT	Columbia, MO	2005	7	6417	CEAP	Prairie Peninsula
NA	Coshocton, OH	1935	77	4		Appalachians/CP**
NP	Mandan, ND	1912	100	800	NEON	Northern Plains
NS	Ames, IA	1996	15	52		Prairie Peninsula
RC	Boise, ID	1960 (1962)	52 (50)	239	CEAP	Great Basin
RI	Temple, TX	1937	75	3	CEAP	Southern Plains
SF	Ames, IA	2002	9	780	CEAP	Prairie Peninsula
SJ	West Lafayette, IN	2002	10	205	CEAP	Great Lakes
US	Kimberly, ID	2005	7	820	CEAP	Great Basin
WC	Ames, IA	1992	19	51	CEAP	Prairie Peninsula
WG	Tucson, AZ	1954	58	150	CEAP	Desert Southwest
YR	Oxford, MS	1999	9	110 (5920)	CEAP	Ozarks Comples

*Site Codes follow Figure 1
**CP, Cumberland Plateau

LTAR network operating principles

- Develop research questions that are shared and coordinated across sites.
- Provide the capacity to address large-scale questions across sites through shared research protocols.
- Collect compatible datasets across sites, and provide the capacity and infrastructure for cross-site data analysis.
- Facilitate and foster shared engagement in thinking and acting like a network.

Conclusion

Globally, agriculture is confronting tremendous challenges in providing for a growing global population under the constraints of dwindling natural resources, environmental degradation, and climate change. If agriculture is to meet the food, feed, fiber, and bioenergy needs of an estimated 9 billion people by 2050, the world's food and agricultural system must become more sustainable.

The National Academy of Science has called for transformative changes to agriculture, including *"…production systems and agricultural landscapes that are a significant departure from the dominant systems of present-day agriculture … that capitalize on synergies, efficiencies, and resilience characteristics associated with complex natural systems and their linked social, economic, and biophysical systems … integrating information about productivity, environmental, economic, and social aspects of farming systems to understand their interactions and address issues of resilience and vulnerability to changing climatic and economic conditions."* (National Research Council 2010, p.525-526.)

Achieving such a transformation requires a better understanding of the complex interactions of the biological, chemical, and physical processes of agro-ecosystems from a long-term systems perspective. The Long-Term Agro-Ecosystem Research network is thus urgently needed to answer some of the important large-scale questions posed by the challenges of the impending effects of climate change and water scarcity, including how episodic events such as floods, drought, and pest and pathogen outbreaks might affect an agro-ecosystem's ability to produce agricultural products or provide valuable ecosystem services. The LTAR network will also be invaluable for detecting important but slow-acting phenomena such as changes in soil carbon, climate, and the effect of land use changes. Such knowledge is vital if we are to achieve our goals for a sustainable agricultural future.

Acknowledgments

The authors thank L. Drew for major editorial contributions and other suggestions for improving this paper. A. Bartuska, M. Smith, C. Walthall, and B. Wee provided helpful comments on an earlier draft of this manuscript. C. Wood provided technical assistance in manuscript preparation.

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