

In-Depth Review Briefing Book of
Long-Term Field Experiment to Evaluate Sustainability of Organic and Conventional
Cropping Systems
(The Beltsville Farming Systems Project; Project Number 1265-21660-002-00D)



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Henry A. Wallace Beltsville Agricultural Research Center
Building 307C, Conference Room
November 17-18, 2005

Agenda for Farming Systems Project External Review
Nov. 17-18, 2005
Building 307C, Auditorium, BARC-East
Beltsville, Maryland

Thursday, Nov. 17, 2005

8:00 Tour of FSP Site

Review Team, Area and Institute Representatives, FSP staff

9:00 Executive Session I.

Review Team, Area and Institute Management Teams

9:30 General Session (open to all)

Welcome and Opening Remarks – Ron Korcak, Associate Area Director, BARC

9:35 Overview, History and Cropping Systems of FSP – Michel Cavigelli

Accomplishments—FSP Objectives 1 and 4 (Agronomic and Economic comparisons)

10:00 Crop yields during ten years of organic and conventional cropping – Anne Conklin

10:15 Economic comparison of FSP cropping systems – Beth Hima

10:30 Weed population dynamics – John Teasdale

10:45 BREAK

Accomplishments—FSP Objective 2 (Soil and Environmental Quality)

11:00 Soil and nutrient erosion potential of organic and conventional cropping systems – Steve Green

11:15 Nitrogen balance and soybean nitrogen fixation in organic and conventional cropping systems – Steve Green

11:30 Greenhouse gas fluxes in organic, no till and chisel till cropping systems – Michel Cavigelli

11:45 LUNCH (Provided)

Accomplishments—FSP Objective 3 (Soil Biological Communities)

12:45 Effects of cropping systems on assemblages of ground beetles (Coleoptera: Carabidae) – Sean Clark

1:00 Soil arthropods in organic and conventional cropping systems: Isopods, diplopods, and earthworms – Katalin Szlavecz

Accomplishments—Spatial Variability

1:15 Landscape level variation in soil resources and microbial properties in a no till corn field – Michel Cavigelli

1:30 Current research on FSP spatial variability – Michel Cavigelli

1:45 Overview of Future Challenges – John Teasdale

2:00 Discussion of Future Challenges
Spatial variability
Changes and inconsistencies in cropping systems
Resources

2:30 Closing Remarks and Adjourn Open Session

2:45 Discussion & Question Session with SYs (timing of this and the next item at the discretion of review team)

4:00 Report Preparation by Review Team

Friday, Nov. 18, 2005

8:30 Refreshments

9:00 Executive Session II.
Review Team, Area and Institute Management Teams

10:00 BREAK

10:15 Review Team Discussion/Feedback – Jeff Steiner presiding

12:00 Adjourn

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1. Beltsville Farming Systems Project (FSP) Overview

The project being reviewed is entirely encompassed within the ARS project, “Long-Term Field Experiment to Evaluate Sustainability of Organic and Conventional Cropping Systems” (Project Number 1265-21660-002-00D), which was recently renewed (2003) with a score of 6 out of a possible 8 (“minor modifications”) as part of the regular Office of Scientific Quality Review (OSQR) process. Therefore, portions of this introduction are summarized from that document.



The FSP is located at the Henry A. Wallace Beltsville Agricultural Research Center (BARC) in Beltsville, Maryland. It is on the east side of BARC, near the BARC dairy, which is south of Powder Mill Road, north of Beaver Dam Road and just east of Edmonston Road. The site had historically been used, as are most fields in that part of the BARC farm, to produce feed for the dairy. The field used for the FSP is 16 ha in size and the plots, in total, comprise 6.8 ha (each plot is 0.1 ha in size). Soils at the site are well-drained, moderately-well drained, and somewhat poorly drained Ultisols. Soils are similar to those found in some areas of the Eastern Shore of Maryland, an area where much of the feed grain for the Delmarva chicken industry is grown. Average rainfall in the area is 1110 mm y⁻¹, evenly distributed over the year, and average temperature is 12.8 °C.

1.1. Project Summary

Conventional field cropping systems have been criticized as being unsustainable because they contribute to environmental degradation (on-farm and off-farm) and are often economically tenuous. Organic farming has been proposed as a means of increasing environmental and economic sustainability of cropping systems. However, we have very little information about the sustainability of organic cropping systems on which to base such an assessment. This project was established at the Beltsville Agricultural Research Center in 1996 to address this need. A long-term cropping systems trial, the Beltsville Farming Systems Project (FSP), was established to evaluate the sustainability of organic, no till, and chisel till cropping systems. The project was designed with the aid of a group of farmers, extension agents, agribusiness professionals, and other agricultural researchers. The FSP is currently comprised of five cropping systems (three organic and two conventional systems) that differ in tillage, nutrient source, weed control method, and crop rotation. All agricultural plots are 0.1 ha in size (9.1 m x 111 m) and all are managed using full-sized farming equipment. The major focus of FSP research is to evaluate the sustainability of the five systems by measuring agronomic performance, soil quality, nutrient dynamics, soil biological activity and community structure, and economic viability of the cropping systems. This research will provide a greater understanding of the relative sustainability of conventional and organic cropping systems, identify key challenges to increased sustainability, and develop a better understanding of mechanisms controlling ecological processes in these diverse cropping systems. Together, these outcomes should help inform policy discussions regarding the

sustainability of organic cropping systems compared to conventional (till and no till) systems. Ecological principles developed through this research can also be used to improve organic production systems.

1.2. Objectives

- Objective 1:* Evaluate crop performance, soil fertility, soil quality, weed population dynamics and other measures of agronomic performance among the five FSP cropping systems.
- Objective 2:* Determine and understand mechanisms controlling carbon (C), nitrogen (N), and phosphorus (P) dynamics, losses, and retention among the five FSP cropping systems.
- Objective 3:* Understand the processes controlling soil biological activity and community structure among the five FSP cropping systems.
- Objective 4:* Predict the long-term sustainability of FSP cropping systems for economic viability and environmental protection under current and future environmental and economic scenarios.

1.3. Funding

In-House Funding

Base funding: \$986,852 annually

External Funding

Headquarters-funded postdoc (Silke Ullrich), “Performance Profiles of Sustainable Cropping Systems from Long-Term Simulations” \$80,000 award to J.R. Teasdale, 2000 (100% on FSP).

National Science Foundation International Supplement, “The effect of past and present human activities on soil biodiversity,” \$35,000 awarded to co-PI K. Szlavecz, 2000-2003 to support collaboration between US and Hungarian soil scientists and ecologists. Grant funded two week visit of Dr. Csaba Csuzdi, Senior Research Scientist (Hungarian Museum of Natural History), to Johns Hopkins University. Dr. Csuzdi, an expert in earthworm taxonomy, who helped in the initial phases of earthworm identification (5% on FSP).

Headquarters-funded postdoc (Steven Green), “Carbon, nitrogen and phosphorus sequestration, retention, and loss in a long-term cropping systems trial”, \$80,000 awarded to M.A. Cavigelli, 2001 (100% on FSP).

National Science Foundation Undergraduate Mentoring in Environmental Sciences (supplement), \$6000 awarded to co-PI K. Szlavecz, 2001-2003 to support summer internships for four minority undergraduates, Larissa Lang, Mary Valentino, Jennifer Stiltz, Janelle Harris, who helped collect FSP invertebrate data (20% on FSP).

JHU School of Public Health, Center for a Livable Future, “Soil food webs in agroecosystems: The effects of different management practices,” \$10,000 awarded to K. Szlavecz, 2001-2003 to support field studies at FSP (100% on FSP).

National Science Foundation Research Experiences for Undergraduate Students, \$6,600 awarded to co-PI K. Szlavecz, 2002 for JHU undergraduate, Sarah Placella, to conduct soil invertebrate studies at FSP (100% on FSP).

Provost Undergraduate Research Award, The Johns Hopkins University, \$3,000 awarded to K. Szlavecz and S. Pitz, 2003 to support senior thesis on earthworms and water infiltration (100% on FSP).

GRACEnet funding, \$12,000 awarded to M.A. Cavigelli, 2005 to support greenhouse gas and soil carbon sequestration work (100% on FSP).

Total external funding 2000 to 2005 = \$194,550

1.4. Personnel

SYs

Michel Cavigelli, Soil Scientist, Project Lead Scientist (1.0 FTE)

Yao-chi Lu, Economist (0.7 FTE)

Ben Coffman, Agronomist (0.25 FTE)

John Teasdale, Plant Physiologist (Weed Science) (0.25 FTE)

Postdocs

Steven Green, Soil Scientist (1.0 FTE), position terminates 9/7/06

Beth Hima, Economist (0.7 FTE), position terminates 7/27/06

Support Staff

Anne Conklin (0.5 FTE; data management and plant sampling)

Mark Davis (0.5 FTE; outreach and crop management)

Linda Jawson (0.5 FTE; greenhouse gas flux), resigning 5/31/06

Ruth Mangum (0.25 FTE; weed research)

2 Students, Cavigelli crew (0.4 FTE each; plant, soil, greenhouse gas sampling)

4 Students, Mangum crew (0.1 FTE each; weed plant, soil sampling)

13 high school interns since fall 2002 (10 hours per week each during school year; greenhouse gas flux)

Current Collaborators, SASL

Jeff Buyer, Research Chemist (soil microbial community structure)

Sara Wright, Soil Scientist (soil glomalin and soil quality)

Current Collaborators, BARC other than SASL

Steve Britz, Plant Physiologist, Phytonutrients Lab, BHNRC (grain phytonutrients)

Thanh Dao, Soil Scientist, EMBUL (soil phosphorus chemistry)

Ray Hunt, Research Physical Scientist, HRSL (remote sensing)

Greg McCarty, Soil Scientist, HRSL (greenhouse gas and soil analyses)

Jack Meisinger, Soil Scientist, EMBUL (soil nitrogen dynamics)
 Jim Reeves, Research Chemist, EMBUL (soil carbon)
 Larry Sikora, Soil Scientist, EMBUL, retired (soil CO₂ flux)
 Bryan Vinyard, Statistician, Biometrical Consulting Service (statistics)

Current Collaborators, other than BARC

Sean Clark, Insect Ecologist, Berea College, Berea, Kentucky (carabid beetles)
 Csada Csuzdi, Biologist, Hungarian Museum of Natural History, Budapest, Hungary
 (earthworm identification)
 Dennis Flanagan, Agricultural Engineer, ARS National Soil Erosion Research
 Laboratory, West Lafayette, Indiana (WEPP model)
 Foster Purrington, Entomologist, Ohio State University, Columbus (carabid
 identification)
 Kathy Szlavecz, Soil Ecologist, Johns Hopkins University, Baltimore, Maryland (soil
 invertebrates)

Past Collaborators

Wayne Dulaney, Remote Sensing Specialist, Hydrology and Remote Sensing
 Laboratory, Beltsville (spatial variability)
 Deborah Fravel, Research Leader, ARS Vegetable Laboratory, Beltsville (soil
 bacteria and fungi)
 Peter Groffman, Microbial Ecologist, Institute of Ecosystem Studies, Millbrook, New
 York (greenhouse gas fluxes)
 Zafar Handoo, Microbiologist, ARS Nematology Laboratory, Beltsville (soil
 nematodes)
 Laura Lengnick, Warren Wilson College, Asheville, North Carolina (initial spatial
 variability and plot work)
 Pat Millner, Microbiologist, ARS Sustainable Agricultural Systems Laboratory,
 Beltsville (soil arbuscular mycorrhizae)
 Martin Rabenhorst, Soil Taxonomist, University of Maryland, College Park, MD (soil
 classification)
 Eric Venteris, GIS Specialist, Environmental Quality Laboratory, Beltsville (spatial
 variability)

1.5. Value of Long-Term Agricultural Research

Long-term agricultural research projects (LTARPs) provide the only means of collecting empirical data on changes in agricultural systems that occur slowly, that have a small signal to noise ratio, and that respond to episodic events such as rainfall (Janzen, 1995). Total soil C levels, for example, change slowly. At the world's longest running LTARP in Rothamsted, England, total soil C levels continue to increase slowly toward an asymptotic maximum in soils more than 150 years after annual farmyard manure applications were initiated (Johnston, 1997). Other variables, such as biogenic greenhouse gas flux from soils, exhibit enormous temporal variability and short-term measurements may not accurately represent treatment effects (Robertson et al., 2000). LTARPs have been essential sources of robust data on cropping system sustainability (Rasmussen et al., 1998), soil C sequestration and dynamics (Paul et al., 1997), soil N

retention (Drinkwater et al., 1998), global warming potential (Robertson et al., 2000), economic performance (Hanson et al., 1997; Clark et al., 1998a), response of agricultural systems to a changing climate and environment (Rasmussen et al., 1998), population dynamics of (some) pest and beneficial species (Menalled et al., 2001; Colunga-Garcia et al., 1997), and on some aspects of soil quality (Doran and Jones, 1996). LTARPs also provide essential data resources for developing and validating crop growth and ecosystem models (Parton et al., 1988; Janzen, 1995; Rasmussen et al., 1998; Grant et al., 2001).

In North America, there are about 50 LTARPs, many of them comparing conventional till and no till systems, crop rotation types and fertility sources and levels (Paul et al., 1997). There is a relative wealth of information on conventional till vs. no till systems due to the large number of LTARPs that include this comparison and investigators have taken advantage of the network of LTARPs to develop a better understanding of C sequestration and dynamics in conventional no till vs. till systems (Paul et al., 1997; Paustian et al., 1998). As a result, discussions regarding government policies to sequester C in agricultural soils tend to be dominated by the benefits of conventional no till vs. conventional till (Flach et al., 1997). Conventional no till systems, of course, rely heavily on herbicides, and herbicide leaching to ground water is generally greater under conventional no till than under conventional till systems (Gish et al., 1998). To ensure that a broader array of potentially sustainable agricultural management options is included in policy debates, it is important to include diverse cropping system options in LTARPs. In response to this need, at least eight LTARPs were initiated in the 1980s and 1990s to fulfill this need by including organic farming options (Liebhardt et al., 1989; Smolik and Dobbs, 1991; Temple et al., 1994; Posner et al., 1995; Robertson et al., 1997; Delate, 2002; Mueller et al., 2002). The Beltsville FSP is one of only two of these LTARPs that includes conventional no till, conventional chisel till and organic systems in the same project. It is also unique in having a comparison of three organic systems with different rotation lengths.

LTARPs may be designed as factorial or systems-level experiments. In systems-level experiments, treatments differ by more than one factor. Systems-level experiments are designed to understand how complex systems function as a whole and to understand how the structure (abiotic and biotic components) of the system affects its function (Drinkwater, 2002). Systems-level research is particularly suited to understanding how organic cropping systems function because many of the management practices used in organic farming are multifunctional (Drinkwater, 2002). For example, cover crops may add biologically-fixed N, decrease N losses (Staver and Brinsfield, 1998), increase soil P availability (Cavigelli and Thien, 2003), decrease soil erosion (Macrae and Mehuys, 1985), suppress weeds (Teasdale, 1998), and provide habitat for beneficial organisms (Altieri, 1994; Lewis et al., 1997). Since incorporating cover crops into a cropping system can affect other aspects of the system, such as planting date and crop rotation, systems level research can provide information not gained using conventional factorial experiments (Drinkwater, 2002). A systems-level experiment can also help identify important ecological characteristics and weaknesses of alternative production systems. The limitation of systems-level research, of course, is that effects cannot be attributed to individual factors. But, systems-level experiments are often used to identify possible

causative factors and to develop hypotheses that can be tested in more traditional factorial experiments. The Beltsville FSP is a systems-level experiment.

1.6. Relevance to ARS National Program Action Plan

ARS research projects are organized into National Programs. This project is in National Program 207: Integrated Agricultural Systems (IAS). The foundation of the IAS NP is using a systems approach in developing sustainable agricultural systems. This project addresses sustainability using a systems-level long-term cropping systems project that emphasizes multidisciplinary agroecological research on a diverse range of cropping systems (no till, chisel till, and organic). The project was designed using input from farmers, extension agents, researchers and agribusiness professionals. The project continues to receive annual input from a focus group of such stakeholders. Most soil and plant samples collected are archived, which facilitates cross-site comparisons and allows questions to be addressed that were not anticipated when samples were originally collected.

1.7. Project History

Origins

This project was initiated in response to a need to develop more research on sustainable agriculture at BARC. The project was modeled on the Rodale Farming Systems Trial in Kutztown, Pennsylvania. The site at which the research is conducted is near the BARC dairy and has a history of having manure applied to portions of the field on a regular basis. Soil P, therefore, tends to be high on the site.

1993-1995: Planning and Site variability assessment

From 1993 to 1995, following eight years of alfalfa, no till corn was grown on the entire site, receiving inputs consistent with local management practices. These three years were used to assess spatial variability of the site. A 25 m x 25 m grid of sampling points was established and plant and soil samples were taken annually to assess uniformity, in large part to aid in selecting areas with reasonable homogeneity in which to establish research blocks. These data have also been used to quantify underlying soil spatial variability.

1996-2005: Cropping systems plots

Seven cropping systems were established in 1996 in accordance with input from a focus group composed of farmers, extension agents, and researchers. Sixty-eight plots (9.1 x 111 m) were established in four separate blocks with all rotation entry points present each year. Plots are large enough to be farmed with full sized farming equipment.

Dr. Laura Lengnick (1993-1997) was the lead scientist and Bob Hoover (1996-1997) was the farm manager during the initial years of the project. Laura and Bob both left ARS at the end of 1997. During 1998 and most of 1999, there was no lead scientist assigned to the project and the project was managed by John Teasdale and Ben Coffman. Since August 1999 Michel Cavigelli has been lead scientist of the project.

2. Cropping Systems

Cropping systems relevant to the mid-Atlantic region were selected with the goal of comparing a conventional no till system to a series of low input and organic alternative treatments. The seven cropping systems that were established are described in brief in the table on p. 8. Changes that have occurred in plot management in later years are also highlighted in the table and described below.

1999-2002: Reduced till organic

During this period, the organic systems were managed using reduced tillage. Instead of chisel-plowing and disking the ground to prepare a seedbed and rotary hoeing and cultivating to control weeds, the existing cover crops were rolled (hairy vetch prior to corn) or mowed (rye prior to soybean) after no till planting, with the intention that the resulting mulch would suppress weed emergence and high-residue cultivation would control weeds that did emerge. This system was effective some years but became less effective with time. Due to a particularly heavy ryegrass infestation in corn, reduced till was abandoned after 2002.

2003-2005: Traditional organic tillage

The organic systems were returned to traditional moldboard plow systems after minimum till proved inconsistently effective in the organic systems. Emerged weeds are now controlled by rotary hoeing and between-row cultivation. A new front-mounted cultivator that permits precision cultivation close to the crop row is used for early cultivations.

2000: Crop rotations improved

In 2000, in consultation with a new focus group, FSP scientists made a number of changes to the cropping systems in accordance with evolving best management practices. 1) Systems 3 and 4 were discontinued since they depended heavily on poultry litter and composted poultry litter to supply N to crops. At the application rates necessary to achieve competitive crop yields, P applications in these systems were much higher than those recommended by the new Maryland P site index. The plots that were previously used for systems 3 and 4 were incorporated into expanded rotations in the NT, CT, and Org4 treatments as follows. 2) Wheat following corn in the NT system was prone to disease so that rotation was expanded to a corn-soybean-wheat/soybean rotation. To maintain the NT and CT systems as direct comparisons, the CT system rotation was expanded to this same 3-year rotation. 3) In the 4-year organic system, establishing a red clover-orchardgrass (RC+OG) hay crop by underseeding in wheat proved challenging. Also, the clover was often outcompeted by the orchardgrass, leaving a poor source of nitrogen for the succeeding corn crop. Therefore, the RC+OG was replaced with alfalfa, expanding the 4-year rotation to a 6-year rotation. These three changes resulted in five cropping systems that used all of the original 68 plots to account for all rotation entry points.

Cropping Systems, 1996-2005, highlighting changes made during this period.

System number	System (and Code)	Years	Crop Rotation*	Management
1	No Till (NT)	1996-1999	C-W/S	Recommended fertilizer and herbicide
		2000-2005	C-r/S-W/S	Same
2	Chisel Till (CT)	1996-1999	C-W/S	Low Input: Reduced fertilizer and herbicide
		2000-2005	C-r/S-W/S	Recommended fertilizer and herbicide
3	Chisel Till with manure	1996-1999	C-W/S	Low Input: Reduced fertilizer and herbicide plus broiler litter
		2000		Discontinued
4	Chisel Till with composted manure	1996-1999	C-W/S	Low Input: Reduced fertilizer and herbicide plus composted broiler litter
		2000		Discontinued
5	Organic (Org2)	1996-1998	v/C-r/S	Chisel and disk for primary tillage
		1999-2002	Same	Reduced tillage: Cover crops rolled or mowed, no tillage before planting
		2003-2005	Same	Traditional tillage: moldboard plow
6	Organic (Org3)	1996-1998	v/C-r/S-W	Chisel and disk for primary tillage
		1999-2002	Same	Reduced tillage: Cover crops rolled or mowed, no tillage before planting
		2003-2005	Same	Traditional tillage: moldboard plow
7	Organic (Org4)	1996-1998	C-r/S-W/RC+OG	Chisel and disk for primary tillage
		1999	Same	Corn: Plow tillage, Soybean: Cover crops rolled or mowed
	Organic (Org6)	2000-2002	C-r/S-W/A	Corn: Plow tillage, Soybean: Cover crops rolled or mowed
		2003-2005	Same	Traditional tillage: moldboard plow

C=corn; S=soybean; W=wheat; RC+OG=red clover + orchardgrass hay; A=alfalfa; r=rye cover crop; v=hairy vetch (or crimson clover in early years) cover crop.

Also in 2000, a hardwood forest on similar soil types was added to the project. The forest is on BARC property and has no known history of tillage. Trees have not been cut for at least 60 years. This site serves to compare the effects of agriculture per se on environmental impacts and soil quality. The site is regularly sampled for greenhouse gas fluxes and has been sampled for soil quality comparisons.



2.1 Focus Group

Farmers, extension agents, agribusiness professionals and other researchers were actively involved in designing the FSP treatments in 1995. A new focus group composed of similar individuals met annually from 2000 to 2003 to discuss management protocols and research direction. Beginning in 2004 we began two separate focus groups, one for the two conventional systems and one for the organic systems. Members of the conventional management team include, from the University of Maryland, Drs. Bob Kratochvil (cropping systems specialist), Ron Ritter (weed science specialist), and Les Vough (alfalfa management) and, from the BARC farm management team, Dan Shirley. Members of the organic management team include Mark Davis (former organic grain farmer) and Ed Fry (Eastern shore organic grain farmer).

3. Annual Data Collection Activities

Feb-Dec	Weekly (April-Oct) or less frequent (Feb, March, Nov, Dec) greenhouse gas sampling
March/April	Weed seedbank sampling
April/May	Cover crop biomass sampling
May	Hay harvest sampling – 1 st cutting
June	Wheat biomass sampling at soft dough stage
June	PSNT soil sampling in corn
June-Sept	Corn phenological stages
June-Sept	Corn and soybean LAI
June	Hay harvest sampling – 2 nd cutting
July	Wheat harvest sampling
August	Soybean (full-season) biomass sampling
August	Hay harvest sampling – 3 rd cutting
September	Weed cover ratings, biomass
September	Corn/soybean grain yield in weedy/weed-free subplots
September	Corn population count, biomass sampling
September	Soybean (double-crop) biomass sampling
October	Full-season soybean grain yield
October	Corn grain yield
October	Hay harvest sampling – 4 th cutting
Oct-Dec	Soil fertility sampling
November	Double-crop soybean grain yield

4. Outreach and Impact

FSP research has been highlighted in several news releases or educational materials:

- FSP research included in “Organic Grows on America!,” Agricultural Research. 2002 v. 50:4-9.
- FSP research highlighted in “An Agricultural Time Machine,” Delmarva Farmer. 2002, April 2, p. 15.
- “Tilling takes toll on soil’s tiny creatures, student finds” The Johns Hopkins University Gazette, 2003, 32:5.
- FSP farming techniques included in “Opportunities in Agriculture: Transitioning to Organic Production” Sustainable Agriculture Network, 2003. 30pp.
- “Navigating new waters: PURA grants launch 41 undergraduates into sea of research projects,” The Johns Hopkins University Gazette, 2004, 33:11-12.
- “Longer crop rotations help organic farmers” in Research Highlights section of CSA News, October, 2004.
- “Weed seedbank dynamics in three organic farming rotations” in USDA-Organic Interest Group Recent Organic News Items, Dec., 2004.
- “Organic farming is a winner for sustainability,” ARS press release about FSP research, published extensively, including in Food Industry Environmental Network (11/27/04); STAT Communication’s AgReport (11/26/04); SeedQuest (11/26/04); CABI’s Organic Update Newsletter (Nov. 2004); USDA-OIG’s Recent Organic News Items (Dec. 2004); The New Farm (12/4/04) and USDA Radio.
- “Weed seedbank dynamics in three organic farming rotations” AgProfessional, 2005, April:56-58.
- Alex Avery, Hudson Institute, cited FSP organic research in letter to the editor of BioScience 55:820, referring in phone conversation to FSP scientists as “the most objective source for organic farming research”, 2005.
- FSP research included in “Banking on BARC,” The New Farm, July, 2005.
- FSP research highlighted in “From the Editor,” Journal of Sustainable Agriculture 2005. 26:1-2.
- FSP scientists interviewed by Dr. Rhonda Janke, Kansas State University, for upcoming book on Sustainable Agriculture, Aug., 2005.
- FSP scientists interviewed by Camille Barchers, Southern SARE Agricultural Systems Research Project Leaders, for upcoming Systems Research Handbook, June, 2005.

FSP scientists have been invited to make presentations about FSP research to scientific and grower audiences:

- USDA-ARS and Center for Rural Affairs Workshop, Salt Lake City, UT, 1999.
- Scientific Congress on Organic Agriculture Research, Pacific Grove, CA, 2001.

- USDA-ARS Agricultural Research Station, Salinas, CA, 2001.
- Applying Pest Ecology Concept Workshop, Michigan State University, 2001.
- USDA Economic Research Service, Washington, DC, 2001.
- BARD 20 Year Planning Workshop, Alexandria, VA, 2002.
- OECD Organic Conference mid-conference tour, BARC, 2002.
- Rural Development Administration, Hunam and Suwon, Republic of South Korea, 2002.
- Keynote speaker, Farmer-Researcher Roundtable, Georgia Southern University, Statesboro, GA, 2003.
- Future Harvest/CASA and Rodale Institute Farm Field Day, April 2003.
- Organic Agriculture Symposium, ASA-CSSA-SSSA Annual Meeting, Denver, CO, 2003.
- ESA Mid-Atlantic Ecology Conference, Lancaster, PA, March 2004.
- Keynote and workshop speaker, Southern Sustainable Agriculture Working Group Annual Meeting, Louisville, KY, 2006.
- The Johns Hopkins University Dept. of Earth and Planetary Sciences, 2006.

Outreach publications

- “Another Way: Organic Grain Production,” video and educational materials produced in collaboration with extension personnel from Maryland, Pennsylvania, New York, New Jersey, 2002.
- “Small Farm Success: Profiles of Sustainable Farming Systems,” Future Harvest-Chesapeake Alliance for Sustainable Agriculture Publication. 2003. 16 p.
- “Characteristics of Sustainable Farmers: Success in the Mid-Atlantic,” Future Harvest-CASA, Stevensville, MD. 2003. 24 pp. In collaboration with University of Maryland Extension, Accokeek Foundation, and Future Harvest, supported by USDA IFAFS grant.
- Book review of “Agriculture and the nitrogen cycle: assessing the impacts of fertilizer use on food production and the environment” Ecology 2005.

Professional Advisory Groups on which FSP Scientists and Staff serve

- SARE Technical Committee, 2001-2004.
- Maryland Organic Certification Advisory Committee, 2001-2005.
- Northeast Region Sustainable Agriculture Research and Education (SARE) Professional Development Program (PDP) winter and summer meetings, 2001-2005.
- Consultation with organic farming methods with the Chesapeake Farms Sustainable Agriculture Project, Chestertown, MD, 2003.
- Co-leader of national effort to develop ARS NP 207 long-term agricultural research projects network, 2003-present.
- Chair, SARE PDP Curriculum Committee, 2004-2005.

Conferences organized by FSP Scientists and Staff

- Farming for Profit and Stewardship (annual meeting), Hagerstown, MD, January, 2000-2006.
- Southern Maryland Small Farmers Seminar, Clinton, MD, 2002.
- Shore Small Farm Forum, Salisbury, MD, 2002.
- Small Farm Family Conference, Virginia State University, Petersburg, VA, Dec., 2003; Nov., 2004; Nov., 2005.

Outreach presentations (1999-present)

At least 60 presentations about FSP research have been given since fall 1999 to diverse groups, including:

- Beef Cattle Field Day, BARC, Oct. 1999.
- BARC Chesapeake Bay Day, Oct. 1999.
- USDA-ARS Integrated Agricultural Systems National Program Workshop, Denver, CO, Dec., 1999.
- Northeast SARE PDP Extension Training Session Workshop, Jan., 2000.
- Romanian National Agency for Agricultural Consulting delegation, BARC, Feb., 2000.
- Eastern Shore Study Circle, Eastern Shore, MD, March, 2000.
- BARC Poster Day, April, 2000.
- New Delhi India delegation, BARC, May, 2000.
- Chinese delegation, BARC, May, 2000.
- Rodale Institute-USDA-ARS Exploring Collaborative Research Opportunities, BARC, 2000.
- BARC Public Field Day, June, 2000.
- West African delegation, BARC, July, 2000.
- Biocontrol of Plant Diseases Laboratory, BARC, Aug., 2000.
- Sustainable Agriculture Field Day, BARC, Aug., 2000, 2001.
- Ohio State University Extension agents, Sept., 2000.
- Board of FONTAGRO (The Regional Fund for Agricultural Technology, Inter-American Development Bank), BARC, Sept., 2000.
- Central Maryland Vegetable Growers Meeting, 2000.
- Northeast SARE Professional Development Coordinators, BARC, 2000.
- Romanian ANCA delegation, ACDI/VOCA (Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance), BARC, March, 2000.
- Farming for Profit and Stewardship Conference, Hagerstown, MD, Jan. 2001.
- FSP Focus Group, BARC, Feb. 2001, March 2002.
- Chinese delegation, BARC, March, 2001.
- USDA Organic Interest Group, BARC, April, 2001.
- Cochran Scholars, BARC, May, 2001.
- Maryland High School Science teachers, BARC, June, 2001.
- Michigan Extension County Director and students, BARC, June, 2001.
- Israeli-Arab Farmers, BARC, Aug., 2001.

- Japanese scientist delegation, BARC, Oct., 2001.
- American scientist delegation, BARC, Nov., 2001.
- Sustainable Agricultural Systems Lab, BARC, Dec., 2001.
- Iowa State University Scientist and Librarian delegation, Dec., 2001.
- Beltsville Area Working Group on Global Change Workshop, BARC, Feb., 2002.
- CASMGS Workshop on Global Climate Change, Michigan State University, Hickory Corners, MI, Feb., 2002.
- Friendly Thyme Herb Club, BARC, 2002.
- Her Highness Sharifa Zein Bint Nasser, Jordanian Princess, BARC, Sept., 2002.
- ATTRA and NAL delegation, BARC, Sept., 2002.
- Society of Environmental Journalists, BARC, Oct., 2002.
- Dr. Adeli Owens, Mississippi State University, BARC, Feb., 2003.
- Dr. Russ Greenberg, Smithsonian Institute, BARC, Feb., 2003.
- Drs. Dave Mortenson and Mary Barbercheck, Pennsylvania State University, BARC, Feb., 2003.
- Rodale Institute and Future Harvest-CASA Farm Field Day, Ingleside, MD, April, 2003.
- Calvert County Farm Bureau, BARC, April, 2003.
- Dr. Hassan Azaizeh, The Galilee Society, Israel, BARC, May, 2003.
- Dr. Sean Clark, Berea College, July, 2003.
- USDA-ARS Integrated Agricultural Systems National Program Workshop, Denver, CO, July, 2003.
- Dr. Chin, Korean scientist, BARC, Aug., 2003.
- Serbian delegation, BARC, Aug., 2003.
- Chinese delegation, BARC, Sept., 2003.
- Vice Director, Agroecology Institute, Zhejiang U., China, BARC, Oct., 2003.
- Organic Farming Research Foundation representatives, BARC, Jan., 2004.
- Spatial Statistics Group, BARC, Feb., 2005.
- Anne Verhallen, Soil Management Specialist, Agriculture and Rural Division, Ontario, March, 2005.
- Seeds of Change Global Management Team Workshop, Mars Inc., Global Headquarters, McLean, VA, April, 2005.
- Johns Hopkins University Soil Ecology Lab Class, BARC, April, 2005.
- Mr. Patrick Mundler, Director, Social Sciences and Management Department, Institute of Agriculture, Rhone-Alps, France, BARC, May, 2005.
- Dr. Vo-Tong Anh, Dean, Faculty of Agriculture and Natural Resources Director, Center for Information and Communication Technology, Vietnam, BARC, May, 2005.
- Chesapeake Bay Day, BARC, Oct., 2005.

5. Accomplishments--Summary

Research conducted on the FSP has shown that:

FSP Objective 1: Agronomic performance—crops

- Organic corn yields over ten years are almost always lower than conventional corn yields, likely due to various combinations of higher weed pressure, later planting date, and challenges with cover crop management in organic compared to conventional corn.
- Corn yields tend to increase with increasing rotation length in organic cropping systems, likely due in part to better weed control and enhanced fertility with increasing rotation length.
- Organic soybean yields over ten years are lower or equal to conventional soybean yields. Lower yields are likely due to greater weed pressure and later planting date in organic compared to conventional systems.
- Organic wheat yields are generally similar to conventional wheat yields.
- Soybean seed α -tocopherol as a proportion of total tocopherols was greater in 3-year organic rotations than in 2-year organic rotations and was greater in no till than in chisel till systems, but this effect was not consistent among years. Results may reflect different levels of plant stress in the different systems.
- Corn and soybean biomass were linearly correlated to a normalized green-red difference index measured using a remote-controlled model aircraft for biomass values between 0 and 120 g m⁻².

FSP Objective 1: Agronomic performance—weeds

- When weather and other factors allow for timely weed control in organic systems, weed control effectiveness increases with crop rotation length such that weed control in organic rotations that include a hay crop is comparable to weed control in conventional systems.
- Weed communities in organic cropping systems are dominated by pigweed and lambsquarters while grasses and perennial species are dominant in no till systems.
- Weed seedbank size is negatively related to crop rotation length among organic cropping systems.
- Weed seedbank size can be reduced by about 50% in one year with good weed control, regardless of organic crop rotation length.
- Crop loss to weeds is greatest in dry years and least in years with adequate rainfall; this effect is similar in all FSP cropping systems.

FSP Objective 2: Soils and environmental quality

- Among systems with three-year crop rotations, no till cropping has the lowest and chisel till has the highest soil and nutrient erosion potential. Organic cropping systems show intermediate soil and nutrient erosion potential. Although soil quality is similar in organic and chisel till systems, organic systems have lower erosion potentials due to having plant cover during a greater proportion of the year than do chisel till systems.
- Bioactive phosphorus increases over time in soil aggregates, suggesting that P release by eroded sediments might increase with time. Dynamics of P release

seem to be biologically controlled and rates seem to differ with aggregate size class.

- Soybean nitrogen fixation is lower in 6-year organic rotations than in shorter organic rotations and conventional systems, likely due to higher soil nitrogen levels in the 6-year organic system soils.
- Cumulative soil CO₂ flux is greater in organic than in no till or chisel till systems (corn phase in 3-year rotations) due mostly to large CO₂ fluxes in the organic system following vetch plow down and manure addition (2004), but not due to rotary hoeing and cultivation. Carbon inputs are also greater in organic than in no till and chisel till systems.
- Maximum CO₂ flux occurred at lower soil moisture content in the organic system than in the no till system [20.0% vs. 27.6% soil volumetric water content (VWC), respectively]. CO₂ flux was greater in the organic system than in the no till system below 29% VWC but greater in the no till system than in the organic system at soil VWC greater than 40%. These differences are likely due to higher dissolved organic carbon and lower porosity in the organic soil than in the no till soil.

FSP Objective 3: Soil biological communities

- Ground beetle assemblages were distinct in organic systems compared to those in the two conventional systems. Carabid biomass is highest in organic systems, likely due to greater ground cover in organic systems than in conventional systems.
- Isopod+diplopod assemblages were often distinct in organic systems compared to those in the two conventional systems.
- Isopod and earthworm biomass are greatest in no till, lowest in chisel till and intermediate in organic systems. Differences are likely due to the detrimental effects of tillage on these soil invertebrates and to the positive effects of increased ground cover in the organic systems compared to the chisel till system.
- Tillage has a greater effect on soil hydraulic conductivity than do earthworms. Areas with earthworm burrows, however, have much higher ponded water infiltration rates than do areas with no burrows.
- Soil survey-defined soil types can be used as an initial predictor of some soil microbiological properties at the landscape level, but soil sampling probably needs to be conducted at a finer scale to adequately predict most soil microbiological properties.

FSP Objective 4: Economic performance

- During the initial transition years, conventional no till cropping systems consistently show greatest economic returns among FSP cropping systems. The 3- and 4-year organic cropping systems had higher returns than conventional no till in some years and some crops. These results do not include organic premiums that can provide substantially higher revenue in some years.

Research results are presented in more detail in the Research Summary section. Accomplishments have been published and presented in the following venues.

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- Cavigelli, M.A., L.L. Lengnick, J.S. Buyer, D. Fravel, Z. Handoo, G. McCarty, P. Millner, L. Sikora, S. Wright, B. Vinyard, and M. Rabenhorst. 2005. Landscape level variation in soil resources and microbial properties in a no-till corn field. *Applied Soil Ecology* 29:99-123.
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- Hima, B.L., M.A. Cavigelli, Y-C. Lu, and J. Teasdale. A comparative economic analysis of the Beltsville Farming Systems Project. *Journal of Sustainable Agriculture*. To be submitted December 2005.
- Green, V.S., M.A. Cavigelli, and J.J. Meisinger. Soybean nitrogen fixation in organic and conventional cropping systems in the mid-Atlantic. *Journal of Sustainable Agriculture*. To be submitted 2006.
- Clark, S., K. Szlavecz, and M. Cavigelli. Ground beetle assemblages in conventional, no till, and organic farming systems of the mid-Atlantic region. *Economic Entomology*. To be submitted 2006.

- Cavigelli, M.A., and J.R. Teasdale. Organic and conventional crop performance during the first ten years of a long-term agricultural research project. *Renewable Agriculture and Food Systems*. To be submitted 2006.
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- Szlavecz, K., C. Csuzdi and M. Cavigelli. Earthworm assemblages in three cropping systems in the Mid Atlantic Region. *Biology and Fertility of Soil*. To be submitted 2006.

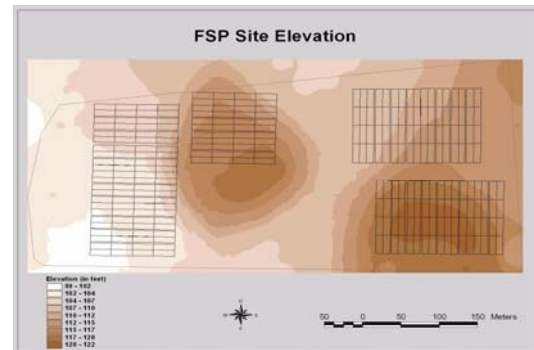
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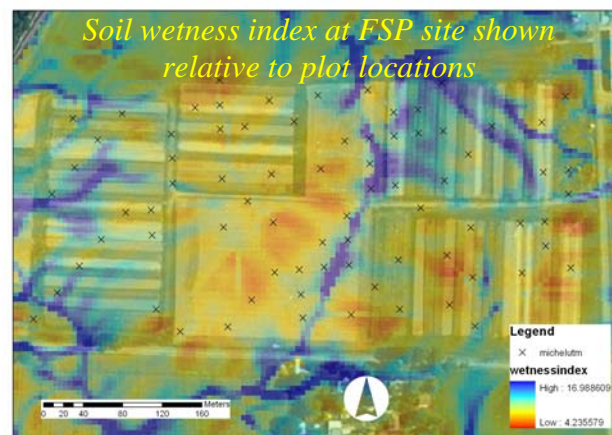
6. Challenges

There are at least three factors that pose significant challenges to conducting research at the FSP site: 1) Underlying soil spatial variability, 2) Changes and inconsistencies in cropping systems management and performance during the first ten years of the project, and 3) Limited funding and personnel. These issues are discussed in some detail here and will be the focus of presentations and discussion during the afternoon of the review session, November 17. The goals of these discussions will be to determine the extent to which these challenges are barriers to meeting the four objectives of the FSP project plan, to explore avenues for surmounting these barriers, and to determine how to proceed with FSP research in light of these challenges.

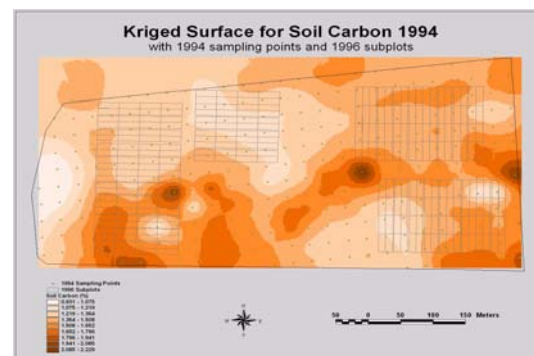


6.1 Spatial variability

All field projects have underlying spatial variability. The question is: how much variability is acceptable in order to conduct publishable research in a randomized complete block design, i.e. to be able to see treatment effects. And, how much underlying variability exists at FSP? While a lot of data has been collected to characterize spatial variability at FSP and a fair amount of SY time has been spent to analyze these data, there are not currently qualified personnel to fully take advantage of this rich data set.



Data collected from 1993 to 1995 were used to establish as uniform a set of replicated field blocks as possible at the site. Nonetheless, among block and within block variability can be high for some variables, including soil wetness and soil carbon, which are illustrated to the right.

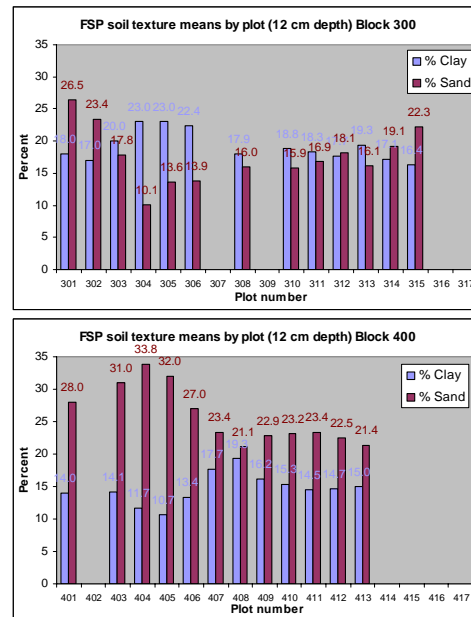


As a result, data collected on soil quality, weed-crop competition and other parameters show high within treatment variability and, at times, strong treatment by block interactions.

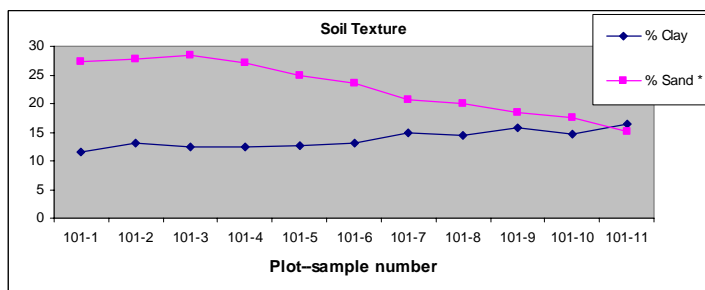
Examples of soil texture variability within and between blocks at FSP site

Research is being conducted to better understand how soil variability may be contributing to within- and among-block variability. Soil texture proved to be an important determinant of a number of soil physical, chemical and microbiological properties in an early assessment of soil spatial variability at the FSP, and crop yield has been shown in other studies to vary with soil texture. Therefore, soils in all 68 plots have been sampled (11 samples per plot to a depth of 12 cm) to characterize soil texture in the top 12 cm across the site (data from 43 plots analyzed to date).

In addition, we have a digital elevation map of the site that together with soil texture data can be used to more fully characterize the spatial variability of the site. The spatial variability at FSP can also be used to study the effect of, for example, terrain attributes (e.g. toeslope, midslope, etc) on soil characteristics, crop yields and other response variables. Compiling these complex data sets, however, requires resources and expertise not currently available among FSP staff or collaborators.



Example of soil texture variability along length of one FSP plot



Questions for discussion:

- What level of among block and within block variability is acceptable?
- How can we use the wealth of spatial variability data at the site to best account for variability in response variables?
- Is the spatial variability at the site too high or too complex to justify certain types of sampling, hypothesis testing?
- How can we take advantage of this variability to understand the impact of soil gradients on various ecosystem processes?
- Is the spatial variability at the site too high or too complex to justify continuing the project?

6.2. Changes and inconsistencies in cropping systems

Various types of changes and inconsistencies have occurred in the first ten years of the FSP.

6.2.1. Changes in crop rotations in 2000

Specific changes are discussed in section 2. Cropping Systems. The implication of these changes is that not all FSP cropping systems are 10 years old. Thus, making some ten-year cropping systems comparisons is limited by these changes. In addition, plots that were taken from systems 3 and 4 and added to systems 1, 2 and 7 do not share the same number of years of management as the original plots in these systems.

Questions for discussion:

- While such changes are perhaps common to LTARPs as managers learn to tweak original systems to reflect best management practices for their location, what are the implications of such changes for detecting treatment differences and for publishing research results?

6.2.2. Management changes within crop rotations

Due to changes in personnel and weather, management within a cropping system has not always been consistent within the general guidelines used for a particular cropping system. For example, the changes in cover crop management and tillage in the three organic systems represent changes made in conjunction with personnel changes. Examples of a weather-related change in management within a cropping system include that wheat was not planted in the fall of 2002, 2003 and 2004 in the organic systems and in 2002 and 2003 in the conventional systems due to wet fall weather. Also, 2003 was so wet (2nd wettest year on record) that established alfalfa stands died in almost all BARC fields, including the FSP plots. These inconsistencies have resulted in incomplete yield records and in less-than-ideal performance of some cropping systems some years. While future weather is certainly beyond our control, the SYs have learned from early management decisions how best to manage the current five systems. An acceptable level of management and good growing conditions during 2004 and 2005 have provided the opportunity to obtain a relatively good assessment of the potential of the five systems in those years.

Questions for discussion:

- While some of these program- and weather-related changes in management probably reflect farmer practices in the region, what are the implications for publishing research results?

6.2.3. Weather-related variability

Since the FSP is not irrigated, crop yields can vary tremendously from year to year. For example, corn and soybean yields were severely reduced in all cropping systems in 4 of 10 years (1997, 1998, 1999, and 2002) due to severe droughts. In addition, the FSP site has many poorly drained areas leading to, at least, spotty areas of poor growth during wet periods and, at worst, complete crop failure (e.g. alfalfa in 2003) or inability to plant or manage crops in a timely manner (e.g. no wheat in some years or poor weed control

because of inability to cultivate). With low corn yields in 2003 due to a very wet year (2nd wettest on record), half of the 10 years have had poor crop yields. In addition, site based measurements of soil parameters or soil populations of various species—especially weeds—can be influenced more by site differences in drainage than by system effects.

Questions for discussion:

- What are the implications of low crop yields in half the years in a LTARP?
- What are the implications of the interactions between site drainage properties and weather on our ability to detect system differences for many soil physical, chemical, and biological parameters?

6.3. Limited funding and personnel

Similar LTARPs often have fewer treatments, larger budgets, and more personnel than does the FSP. The FSP consists of 17 distinct agricultural programs (replicated four times = 68 total agricultural plots) with unique management requirements each year. Coordination of field operations takes a considerable portion of SY time (Cavigelli, Coffman, and Teasdale) from April to July and lesser time through November and in March. It also requires coordination between two farm management units, Farm Operations East and Farm Operations West, to conduct all farming operations. The large number of unique operations required for each plot often competes with requests by other researchers on the West Farm and farm production obligations on the East Farm. Thus, timely farming operations are always a struggle.

This project currently has no full-time support staff member. Duties have been divided up among current staff for managing farm operations, collecting data, supervising students, and managing the ever-growing database. With the limited staff hours available, our budget restricts much of our sampling to a particular subset of plots. For example, soil and nutrient erosion data and soil invertebrates were collected from just 12 of 68 plots, and greenhouse gases are collected weekly from just nine plots. Thus, the FSP involves significant investment of SY time in crop management but the limited budget restricts the number of those plots that can be sampled for a given project.

Our limited budget means that our research relies heavily on effective collaborations, postdocs, and external funding. While collaborations and external funding are essential to the success of any multidisciplinary long-term field project, the proportion of studies at FSP that rely on such arrangements is perhaps disproportionately large. Collaborations leverage outside resources to the benefit of all involved but they also add an additional level of coordination and uncertainty that is not typical for most ARS projects.

Additional funding would allow more complete and timely sampling of existing plots, allowing us to take full advantage of having each rotation entry point present each year in each rotation. However, the funding prospect in the near future seems even more limited than current levels. For example, the current Congressional proposal to cut the ARS budget by 6% would result in a cut of close to half of FSP discretionary funding. Meanwhile, salaries, which constitute 59% of the FSP budget, and indirect research costs, which constitute 26% of the budget, continue to rise.

These cuts come at a time during which FSP research is perhaps more relevant than ever because of its focus on both organic farming and long-term research. For example, organic food sales continue to increase at nearly 20% per year. There is also a growing interest in developing an organic livestock industry in the United States. A major limitation to its development is that there is not sufficient organic grain production in the United States. To remedy this situation, North Carolina State University, for example, recently hired a new faculty member to work on organic grain production exclusively. As organic grain production increases, it will become even more important to understand the impact of organic grain farming on the environment. Since FSP is one of only two sites that include no till, chisel till and organic cropping systems and is perhaps the only site that includes three organic systems with three different crop rotation lengths, the FSP is uniquely poised to serve the growing interest in organic grain production. The quality of FSP research is reflected in a recent comment by Alex Avery of the Hudson Institute who referred to FSP and SASL as the most objective source of organic research. In addition, the wealth of spatial variability data collected at FSP provides a unique data set of special value to researchers working to understand the impact of landscape level variability on crop yields and soil processes, including those working in remote-sensing and in site-specific agriculture.

With respect to FSP and the value of LTARPS, ARS recently initiated a national network of researchers conducting greenhouse gas and carbon sequestration research, much of it on LTARPs. FSP is part of this network. Also, ASA-CSSA-SSSA, USDA-CSREES, NSF, the Ecological Society of America, and economists recently met to begin planning a joint USDA CSREES-NSF Long Term Agroecosystem Research Network. There is clearly broad interest in taking advantage of the unique types of information that can be collected at LTARPs.

All successful very long-term agricultural research projects (e.g. Rothamsted) have been maintained during some very lean financial times. Without the efforts of researchers in charge of those projects, our understanding of, for example, soil carbon dynamics would not be as well developed as it currently is. One practical result of this LTARP-generated knowledge is that carbon credits, including soil carbon sequestration credits, are currently being bought and sold on the Chicago Board of Trade in an attempt to help mitigate global climate change.

Questions for discussion:

- How valuable is the FSP?
- Is the base funding adequate for running the FSP in its current configuration?
- If not, what changes could be made to maintain or enhance the value of this 10-year old project?
- Should the project be altered in any way to make better use of existing funds?

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8. Research Summaries